Feasibility and acceptability of an Internet of Things-enabled sedentary behavior intervention: mixed-methods process evaluation

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Table of Contents

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Abstract

Background: Encouraging office workers to break up prolonged sedentary behavior (SB) at work with regular micro-breaks can be beneficial yet challenging. Internet of Things (IoT) offers great promise for delivering more subtle and hence acceptable behavior change interventions in the workplace. We have previously developed an IoT-enabled SB intervention, called WorkMyWay, by applying a combination of theory-informed and human-centered design approaches. As per the Medical Research Council(MRC)'s framework, for complex interventions like WorkMyWay, process evaluation in the feasibility phase can help establish the viability of novel modes of delivery, to clarify on mechanisms of impacts and to identify contextual factors that affect delivery and interplay with intervention mechanisms.

Objective: To evaluate the feasibility and acceptability of the WorkMyWay intervention and its technological delivery system.

Methods: The study was informed by the MRC guidance on process evaluations of complex interventions. A mixed-methods approach was adopted. A convenience sample of 15 office workers used WorkMyWay during work hours for six weeks. Questionnaires were administered before and after the intervention period to assess psychological variables theoretically aligned with SB. Behavioral and interactional data were obtained through the system database to determine adherence, quality of delivery, compliance, and behavioral outcomes. Semi-structured interviews were conducted at the end of the study and thematic analysis was performed.

Results: All 15 participants completed the study and on average used the system for 25 tracking days (out of a possible 30 days; adherence = 83.3%). For compliance, participants responded to 38.5% of the prompts within 15 minutes. Although no significant changes were observed in either technology-captured or self-reported occupational sitting and physical activity (OSPA) ($p>0.05$), post-intervention improvements were significant in automaticity of regular break behaviors ($t(14)=2.606$, $p=.021$), retrospective memory of breaks ($t(14)=7.926$, $p<.001$) and prospective memory of breaks ($t(14)=-2.661$, $p=.019$). Qualitative data revealed favorable attitudes towards the intervention components despite compromised delivery resulting from data connection problems. A range of intended and unintended mechanisms of action were revealed, suggesting high promise for behavior change.

Conclusions: It is acceptable and feasible to deliver a SB intervention with an IoT system that involves a wearable activity tracking device, an App and a digitally augmented everyday object (eg. cup). The object component is particularly suitable and promising for delivering Behavior Change Techniques (BCTs) like "action planning", "conserve mental resources", "prompts and cues", "add objects to the environment", "habit formation", and potentially "social comparison". More technological development and engineering work on WorkMyWay is warranted to improve delivery before proceeding to the evaluation phase of research.

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Keywords: smart objects; Internet of Things, behavior change; sedentary behavior; workplace; process evaluation, feasibility study

Introduction

In the past decade, ample evidence has accumulated to suggest the unfavorable association between sedentary behavior (SB) and cardiometabolic health, even after adjusting for the amount of exercise [1–3]. Moreover, the amount of sedentary time accumulated in single bouts that last longer than 30 min (i.e. sustained sedentary bouts) and 60 min (i.e. prolonged sedentary bouts) add to the risks, whereas breaks in sedentary time are beneficially associated with metabolic biomarkers [3–5]. With a larger proportion of the workforce employed on sedentary occupations – defined as "jobs involving more than 6 hours of sitting on an 8-hour workday and only occasionally walking, standing and lifting of no more than 10 pounds at a time" [6], occupational sitting has become a public health concern in modern Western societies. Based on studies with office-based workers in Australia and the United Kingdom (UK), occupational sitting contributed more than half of total sedentary time on workdays [7–10]. Self-report and accelerometer studies have consistently demonstrated that office workers spend most (varying from 60% to 82% across studies) of their working hours on sitting [11–14]; moreover, office workers' within-work time is characterized by more sustained (12% -34.8% of total sitting) and prolonged (25% - 49.8% of total sitting) sedentary bouts with fewer breaks than non-work time [8,12]. This makes the office-based workplace a priority setting for interventions targeting SB reduction through the promotion of regular break behaviors.

It is challenging to design an intervention that interrupts users at work at opportune moments and encourages them to move around without causing annoyance. Internet of Things, or IoT technologies, characterized by ubiquitous sensing, context-aware computing, and embedded interfaces, have shown great promise for delivering just-in-time adaptive interventions (JITAI) to improve health behaviors non-intrusively in everyday settings [15], including the workplace [16]. Yet there is a dearth of theoretically driven development and evaluative work on IoT-enabled health behavior change intervention. We have previously reported, in detail, the design and development of an IoT-enabled occupational SB intervention called *WorkMyWay* following the Behavior Change Wheel (BCW) and human-centered design approach [17]. In this paper, we report the next phase of research under the UK Medical Research Council (MRC)'s framework for developing and evaluating complex interventions [18], namely the "feasibility phase", with a focus on process evaluation [19] and an orientation towards theory-based and systems perspectives [18].

Process evaluation in the feasibility phase

Process evaluations investigate questions beyond effectiveness and efficacy and ask broader questions concerning the process through which intervention outcomes are achieved [19]. Although process evaluations can exist at all stages of complex intervention research, when conducted in the feasibility phase, it tends to be more formative and more focused on assessing whether the intervention is implementable, rather than whether it is effective in changing the behavior [20]. Nevertheless, researchers can still explore the promise for behavior change by observing improvements on measures theoretically aligned to the intervention [21].

For research involving automated sensors (eg. accelerometer) for either outcome measurement or for delivering JITAI, the quality of sensor data has bearings on research and intervention feasibility. As demonstrated in [22], whether to adjust for data incompleteness would significantly affect outcome

measures and conclusions about behavior change efficacy. In this regard, the occurrence and severity of data loss caused by technological issues and non-adherence (ie. non-wear time) should be routinely monitored and considered as indicators of feasibility in this phase. Moreover, process evaluation can also explore contexts in which technological failures are more likely to occur, as this will inform the improvement of protocols and development of strategies to minimize the occurrence and adverse impacts of technological failures. Last but not least, considering the potential of analyzing technology-captured data to understand processes of change and identify active intervention ingredients in future larger-scale evaluations [23], it is important to ascertain, at an early stage, whether interactional data of satisfactory quality can be collected and used for analysis.

In addition, acceptability should be another area of focus in process evaluations in the feasibility phase [20]. Indeed, acceptability is integral to feasibility, because interventions disfavored by participants are unlikely to be implementable in subsequent trials [24]. This is especially the case for Digital Behavior Change Interventions (DBCIs), as the quantity and quality of interventions received by a user is dependent on the extent to which the user likes and integrates the intervention delivery technology into everyday routines [25,26]. Hence, it is worth investigating barriers to adoption so that necessary protocol changes can be made and strategies to counter user resistance developed before the pilot and formal effectiveness evaluation trials [20].

Methods

The Study Overview

We undertook a mixed-method process evaluation with a single group pretest-posttest design embedded. The study was approved by the [INSTITUTE NAME REMOVED FOR BLIND REVIEW]. Figure 1 visualizes the study procedure and data collected at each stage. The focus was on assessing feasibility and acceptability of *WorkMyWay* in real-life office settings through reporting the following:

1) Retention, adherence, and compliance of participants
2) Promise for improving behavior and wellbeing demonstrated by trends of changes in occupational sitting and physical activity (OSPA), as well as psychological variables theoretically aligned with the hypothesized mechanisms underpinning the intervention
3) Participants' experiences of *WorkMyWay* including perceived quality and quantity of delivery, mechanisms of impacts and contextual factors.

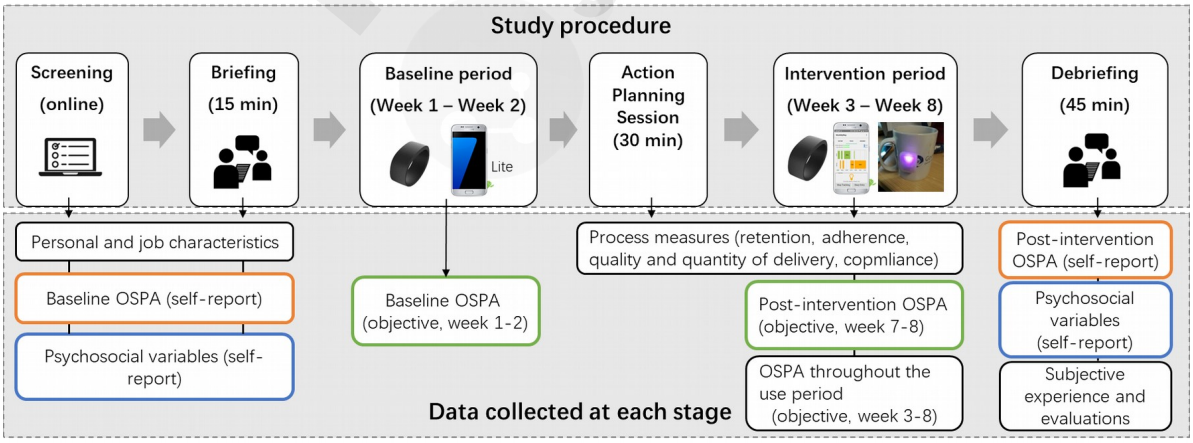


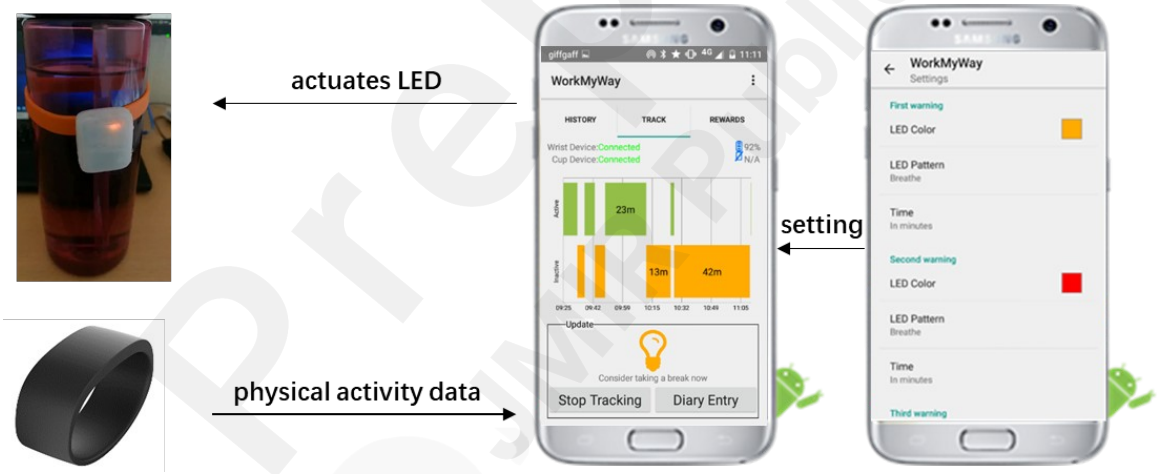
Figure 1. Study procedure and data collected at each stage (OSPA: occupational sitting and physical activity)

The Intervention

The intervention contents and delivery protocol have been detailed elsewhere [17] following the Template for Intervention Description and Replication (TIDieR) [27]. In brief, the intervention is centered on an IoT system also called *WorkMyWay,* which consists of a wrist-worn activity monitor, a light-emitting diode (LED) break reminder attached to a user's own cup or water bottle, and an Android App that communicates with both devices over Bluetooth Low Energy (BLE) connections. The system uses the movement data livestreamed from the wrist device to detect the user's period of inactivity in real time and deliver two major interventional components.

The first interventional component features quick and actionable point-of-behavior prompts delivered during work hours via a digitally augmented vessel (eg. cup or bottle), which is environmentally embedded and well-integrated into an office worker's daily routine. If the user is inactive for 45 to 55 minutes, the cup LED turns into an amber breathing light, meaning "you can consider a break now!"; if the user is inactive for 55 to 60 minutes, it becomes a red breathing light, meaning "you should take a break now!"; if the period of inactivity exceeds 60 minutes, it turns into a red flashing light, warning the user of the emergence of a prolonged stationary period (Figure 2).

The second component features more detailed and in-depth feedback and rewards delivered via a screen-based medium (the App) that the user shall engage with at the end of the workday (Figure 3). To be consistent with the LED color scheme, the App uses amber, red and green bars to signify normal inactive bouts (i.e. bouts shorter than 60 min), prolonged inactive bouts (i.e.. bouts longer than 60 min) and active breaks (i.e. ambulatory bouts) respectively.



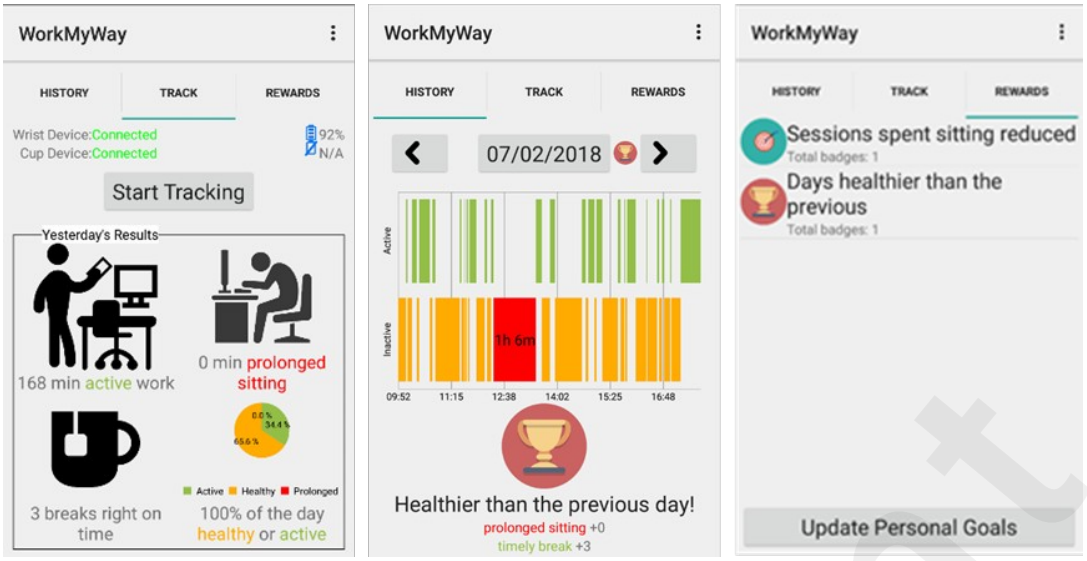


Figure 3. The feedback and reward component

Procedure

To obtain baseline SB, the participant used a Lite version of *WorkMyWay* that only supported tracking while masking all other functionalities from the user for 2 weeks. This was followed by a 30-min action planning session where the participant and the researcher reflected on the baseline data, discussed personal goals, set up action plans, and configured the full *WorkMyWay* system. Afterwards, the participant used the full system for another 6 weeks (intervention period). A weekly reminder email was sent to all participants by the researcher on each Monday morning to enhance adherence.

Sampling and Recruitment

Feasibility studies do not require formal sample size calculation or power calculation [28]. A sample size of 15 is deemed sufficient to uncover most usability and user experience issues [29], which has been used in prior studies to assess feasibility and acceptability of similar eHealth interventions [30–33]. Hence, we recruited a convenience sample of 15 university-employed office workers from two local and geographically adjacent workplaces (a university campus, and an acute teaching hospital campus) via staff mailing lists and on-campus posters. Potential participants were directed to an online sign-up form with screening questions assessing the following eligibility criteria: (1) no physical disability prohibiting engagement in light physical activity; (2) employed full-time on a job that involved significant amounts of desk-based work (3) normally had the discretion over when to take micro-breaks on workdays. Those meeting all the above criteria were contacted by the researcher to schedule a briefing and consent session in their own offices or a nearby meeting room.

Quantitative Data Collection and Analysis

Table 1 Process and outcome measures calculated based on system data

Measures	Calculation
Process measures	
Adherence	tracking days/30
Quality of tracking	valid tracking days/tracking days
Compliance	Prompts with a latency of <=15 min / total prompts triggered * 100%
Outcome measures	

Daily ambulatory time	Accumulated time spent on bouts classified as “active” by the WorkMyWay algorithm
Daily stationary time	Accumulated time spent on bouts classified as “inactive” by the WorkMyWay algorithm
Number of prolonged stationary bouts	Number of stationary bouts that lasted 60 min or above for each day
Duration of prolonged stationary bouts	Accumulated time spent on stationary bouts that lasted 60 min or above for each day

System data were accessed from the server and analyzed using Python, a high-level, general-purpose programming language. Table 1 summarizes key process and outcome measures calculated from the system data. As per the algorithm we had developed and detailed in a previous article [17], whenever the tracking was on, a period with 0 count for 40 or more consecutive 15-second epochs (ie. no data for 10 minutes) would be classified as **“invalid tracking”**, which was likely caused by technological issues or non-wear time; other epochs were all valid tracking time. Tracking days with >3 hours valid tracking time and <3 hours invalid tracking time were regarded as “**valid tracking days**”, whereas the remaining tracking days were classified as **“invalid tracking days”**. We operationalized each participant’s **quality of tracking** as the percentage of tracking days that were valid (ie. valid tracking days/tracking days *100%), which in essence indicated technological reliability, regardless of the participants’ intention to adhere. We also measured each participant’s behavioral compliance with the intervention. For analytic purpose, the onset of the ambulatory or active bout following the prompt event was seen as the response to that prompt, even though the initiation of that break could be irrelevant to the prompts. The time elapsed in between the prompting event and the response was calculated as “**response latency**” and each individual’s **compliance with prompts** was measured as the percentage of prompts the participant responded to with a latency of <=15 minutes.

As for objective OSPA, the following outcome measures were calculated from the tracking data based on the aforementioned algorithm [17]: daily ambulatory time, daily stationary time (ie. any waking behavior done while lying, reclining, sitting, or standing, with no ambulation, irrespective of energy expenditure [34]), quantities and durations of prolonged stationary bouts (ie. periods of uninterrupted stationary time that was 60 min or above).

Participant’s personal and job characteristics, such as age, gender, highest level of education completed, job description, whether they used a sit-stand desk in the office, number of office mates, self-report height and weight were collected with questionnaires during the screening and briefing stage. In addition, a survey (Appendix 1) with the following parts was administered at the briefing and debriefing session to obtain pre- and post-intervention measures respectively:

1) The Occupational Sitting and Physical Activity Questionnaire (OSPAQ) [35] was used to obtain self-report OSPA. For comparison with objective measures, we calculated self-report stationary time by adding up sitting and standing time and calculated ambulatory time by adding up time spent on walking and heavy labor.
2) The 3-Dimensional Work Fatigue Inventory (3D-WFI) [36] was used to assess physical, mental and cognitive work fatigue
3) A 7-point Likert-style (1 - strongly disagree to 7 - strongly agree) scale was used to assess psychosocial variables theoretically aligned with the constructs underlying office workers’ SB [37]. These included automaticity of regular break behaviors (using items from the automaticity subscale from the Self-Report Habit Index (SRHI) [38],), intention (eg. “I intend to break up sitting with regular micro-breaks throughout the day”), perceived behavioral control (eg. “All

things considered, if I wanted to, I could take regular breaks at work"), prospective and retrospective memory of breaks (eg. "I find it difficult to keep track of time when engrossed in work", "At the end of each day, I have an idea of how much time I've spent in prolonged sitting in total", and organizational culture (eg. "The organizational culture and climate here discourages regular breaks and I feel I'm being watched").

Data on process measures were analyzed with descriptive statistics. Objective OSPA and survey data were imported to SPSS 22.0 (IBM Company, Chicago, IL, USA) for inferential statistical analysis. Differences between pre- and post-intervention measures were assessed using paired-samples t-tests, with statistical significance set at .05.

Qualitative Data Collection and Analysis

A semi-structured interview guide (Appendix 2) was developed, informed by the MRC guidance for process evaluation of complex interventions [20], which covered the following topics: participant's perceived quality and quantity of intervention delivery, mechanisms of change and contextual factors (ie. facilitators and barriers) influencing the use and effectiveness of *WorkMyWay*. All interviews were audio recorded with participants' consents and transcribed in verbatim. Data were then analyzed for themes related to feasibility and acceptability of the *WorkMyWay* intervention using a thematic analysis approach [39], which involved familiarization with the data, generating initial codes, searching for themes, reviewing potential themes, defining and naming themes in a code book, final analysis and write-up. Codes were meaningful labels to group and organize data and could be about a certain aspect of the technology (eg. the LED prompts) or experienced change in oneself and the surrounding environment (eg. more awareness of sitting). NVivo version 12 (QRS International Pty Ltd, Doncaster, Australia) was used to facilitate the organization of codes and themes.

Results

The Sample

Table 2 presents the characteristics of the sample.

Table 2 Baseline characteristics of the study sample (n=15)

Characteristic	Value
Age in years, mean (SD), range	40.5 (11.0), 25 – 63
Gender, n (%)	
Male, n (%)	3 (20%)
Female, n (%)	12 (80%)
Highest education level completed, n (%)	
University preparatory degree, n (%)	2 (13%)
Undergraduate degree, n (%)	6 (40%)
Postgraduate degree, n (%)	7 (47%)

Self-reported occupational time spent in	6.2 (1.5), 2.4 – 8.2
sitting (hrs), mean (SD), range	0.9 (1.3), 0 – 4.8
standing (hrs), mean (SD), range	0.8 (0.6), 0.145 – 2
walking (hrs), mean (SD), range	0.1 (0.5), 0 – 1.9
heavy labour (hrs), mean (SD), range	8.0 (0.9), 7.25 – 10
Total office hours	
Height (cm), mean (SD), range	169.3 (7.5), 155 – 180
Weight (kg), mean (SD), range	72.0 (13.6), 49 – 90
BMI (kg/m^2), mean (SD), range	25.0 (4.1), 18.4 – 33.0
Underweight (=<18.5), n (%)	1 (7%)
Normal (18.5 – 24.9), n (%)	5 (33%)
Overweight (25 – 29.9), n (%)	8 (53%)
Obese (>=30), n (%)	1 (7%)
Number of officemates, n (%)	
0	5 (33%)
1	2 (13%)
3	5 (33%)
>3	3 (20%)

Quantitative Results

Adherence and Usage

All participants completed the 8-week study protocol (100% retention), including all measurement and interventional components. Figure 4 provides an overview of the usage data since the installation of *WorkMyWay* full version. Weeks 1 and 2 (ie. baseline period) were excluded from the graph, as Lite version of the App was used during that period.

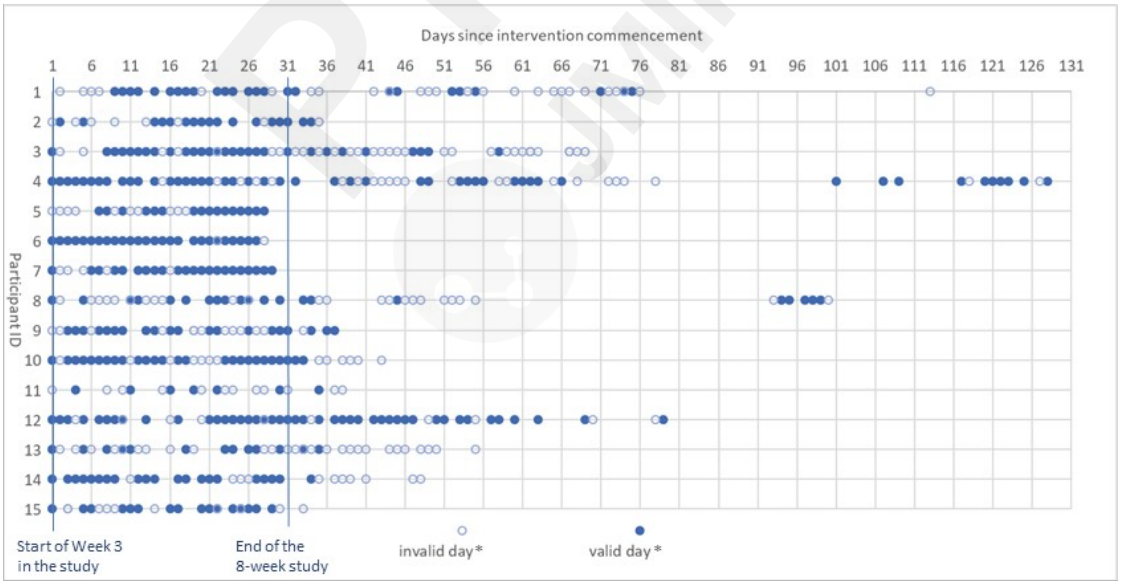


Figure 4 Usage pattern of *WorkMyWay* full version

The number of tracking days over the intervention period ranged from 15 to 30 workdays across

participants, with a mean (SD) of 25(4) days and a median (25^{th}, 75^{th} percentile) of 26 (23, 28) days. This meant the adherence rate ranged from 50% to 100% across participants, with a mean adherence rate (SD) of 83.3% (14.0%) and a median (25^{th}, 75^{th} percentile) of 86.7% (76.7%, 93.3%).

Out of the 375 total tracking days, 262 (70.0%) were valid tracking days. On those valid days, daily valid tracking time ranged from 182.75 minutes to 632.25 minutes, with a mean (SD) of 414.2 (94.6) minutes, or 6.9 (1.6) hours; daily invalid tracking time ranged from 0 minutes to 179.5 minutes, with a mean (SD) of 23.35 (37.6) minutes and a median of 0 minutes. Anecdotal reports suggested that invalid tracking was mostly caused by data loss during Bluetooth disconnection, which will be detailed in sections on qualitative results.

The number of valid days tracked over the intervention period ranged from 6 to 26 days across participants, with a mean (SD) of 17.5(5.3) valid tracking days and a median (25^{th}, 75^{th} percentile) of 16 (14.5, 21.5) days. This yielded a mean (SD) quality of tracking of 68.6% (14.9%), with a median (25^{th}, 75^{th} percentile) of 71.4% (59.3%,81.1%).

After the 6-week intervention was completed, we offered the option for participants to keep using *WorkMyWay*; 11 (73%) participants opted in to continue using the devices in their own interests, but 2 of them (P6 and P9) had to stop earlier than they would like to because we ran out of devices for new participants. The main reasons for not opting in (P2, P5, P7 and P15) to continued use were (i). leaving the university for a new job (n=1), (ii). having technical difficulties setting up (n=2), (iii). physical discomfort wearing the wristband (n=2).

Among the remaining 9 participants (P1, P3, P4, P8, P10-P14) who could use the devices freely for as long as they wanted, the last of day of use (number of days since study end) ranged from 8 (P11) to 98 (P4), with a median of 39 and a mean (SD) of 44.8 (32.5). Self-directed use after the 6-week intervention generated a further 211 days of tracking and usage data, out of which 91 days were valid. As expected, post-study adherence (M=55.8%, SD=19.3%) and quality of tracking (M=35.7%, SD=5.4%) during self-directed use were significantly lower than within-study adherence (M=81.5%, SD=15.3%) and quality (M=67.3%, SD=5.4%), confirmed by paired-samples t-tests ($t(8)$=3.619, p=.007 for adherence; $t(8)$=4.3, p= 0.003 for quality of tracking).

Prompts Delivery and Compliance

A total of 698 timestamped prompting events were recorded. This meant each participant would have received 1.8 (SD=1.1) prompts on a typical tracking day. The number of prompts received by each participant over the study period ranged from 13 (P11) to 116 (P3), with a median of 37.

As Figure 5 shows, slightly over a third of the prompts (269 (38.5%)) were responded to within 15 minutes. Within this category, the majority were responded within 5 minutes (113 (16.2%), followed by 5-10 min (85 (12.2%)) and 10-15 min (71 (10.2%).

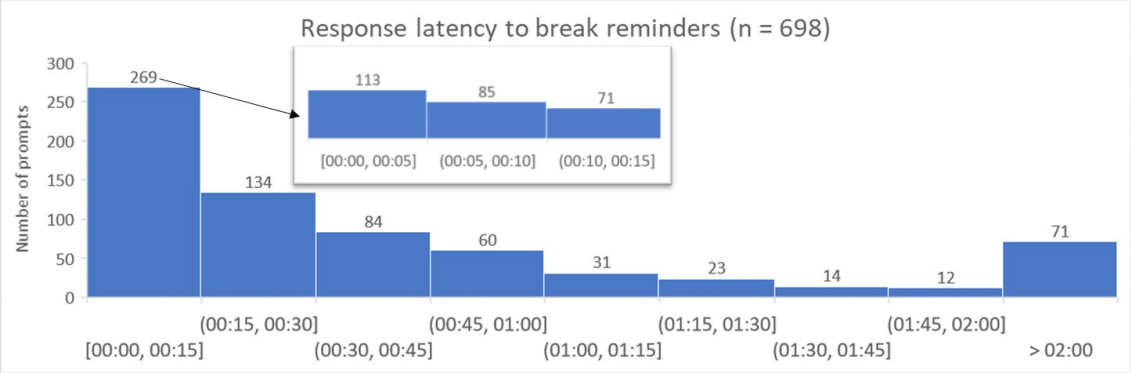


Figure 5 Latency of responses to LED prompts

Promise for Change

As Table 3 shows, paired-samples t-tests on pre-post OSPA differences did not yield statistically significant results. However, post-intervention improvements were significant in several psychosocial variables theoretically aligned with the target behavior, namely automaticity of micro-break behaviors ($t(14)=2.606$, $p=.021$), retrospective memory of breaks ($t(14)=7.926$, $p<.001$) and prospective memory of breaks ($t(14)=-2.661$, $p=.019$).

Table 3. Behavioural and psychological measures at baseline and post-intervention (n=15)

	Pre-intervention, mean (SD)	Post-intervention, mean (SD)	Trend (mean difference)	*t (p)* value
Objective OSPA based on tracking data (based on valid days)				
Valid tracking time, min/workday	430.4 (45.2)	419.7 (51.4)	-10.7	-.627 (.541)
Stationary*, min/workday	355.0 (57.3)	356.7 (56.3)	1.7	.115 (.91)
Ambulatory#, min/workday	75.4 (45.9)	63.0 (28.7)	-12.4	-1.288 (.219)
Duration of prolonged stationary bouts, min/workday	176.1 (78.7)	188.3 (95.3)	12.1	.591 (.564)
Number of prolonged stationary bouts, n/workday	1.8 (.8)	1.8 (.7)	-.05	-.252 (.804)
Self-report OSPA				
Work time, min/day	482.5 (55.7)	492.5 (77.5)	10.1	.569 (.579)
Siting, min/day	369.0 (91.1)	373.3 (78.8)	4.3	.209 (.838)
Standing, min/day	56.0 (77.9)	58.6 (61.2)	2.6	.138(.892)
Walking, min/day	49.5 (38.7)	60.3 (50.6)	10.8	1.131 (.277)

Heavy labor, min/day	7.9 (29.4)	.29 (1.1)	-7.6	-.998 (.335)
Stationary*, min/day	425.0 (60.9)	431.9 (46.3)	6.9	.379 (.710)
Ambulatory#, min/day	57.4 (58.2)	60.6 (50.4)	3.2	.289 (.777)
Determinants of breaks				
Intention to take regular work breaks	6.07 (.89)	6.20 (.86)	.13	.695 (.499)
Positive outcome expectancy	6.18 (.75)	6.27 (.63)	.08	.673 (.512)
Perceived behavioral control	6.20 (.78)	6.33 (.82)	.13	.487 (.634)
Perceived barrier: heavy workload (-)	5.07 (1.9)	5.00 (1.91)	-.07	-.163 (.872)
Perceived barrier: discouraging organizational culture (-)	1.80 (.561)	1.80 (.941)	.00	.000 (1.000)
organizational culture encouraging breaks	6.00(1.00)	6.07(.80)	.07	.202 (.843)
Regular micro-break habit (automaticity subscale)	4.41 (.71)	4.85(.44)	.43	2.606 (.021*)
Retrospective memory of breaks	3.47 (1.47)	6.30 (.80)	2.83	7.926 (<.001***)
Difficulty with remembering to take breaks (prospective memory) (-)	5.70 (1.07)	4.93 (.92)	-.77	-2.661 (.019*)
Work fatigue				
Physical fatigue	2.14 (.64)	2.05 (.60)	-.08	-.807(.433)
Mental fatigue	2.69 (.96)	2.61 (.86)	-.07	-.504 (.622)
Cognitive fatigue	1.57 (.54)	1.78 (.52)	.21	1.809 (.092)

*Stationary time: measured as the sum of sitting and standing time in OSPAQ and as ‘inactive’ time based on the classification algorithm defined in *WorkMyWay*

#Ambulatory time: measured as the sum of walking and heavy labor in OSPAQ, and as ‘active’ time based on the classification algorithm defined in *WorkMyWay*

(-): Factors with supposedly adverse impacts on regular break behaviors

Qualitative Results

A total of 9 subthemes on participants’ experience of *WorkMyWay* were identified, pertaining to the delivery and mechanisms of individual components as well as facilitators and barriers to integrating the overall intervention into everyday routines.

The tracking component

Theme 1 – ease of integrating tracking into everyday routines

Participants reported using the system on most workdays, except for two circumstances - being out of office and encountering technical issues. For the former situations, participants were instructed not to use *WorkMyWay* on ad-hoc out-of-office working days and sick leaves, as they were atypical in their day-to-day work and would distort data.

> *"because often I'm out of the office, like going around the country… coz I'm delivering training at the moment, that wasn't like a typical workday, so I'd leave it behind." - P11, 50% adherence (lowest in the sample)*

The remaining days of nonadherence were due to technical issues, especially problems with syncing data between the tracking devices and the smartphone over Bluetooth connection. If it were not for the connection problems, most participants, even including those with below-average adherence in the study, found it easy to integrate the behavioral tracking into everyday routine.

> *"If everything is running smoothly, it was absolutely fine. So, like the last couple of days, it's been perfect." - P11, 50% adherence*

> *"I think it's really quite simple to use. You just start and stop. That's how it's supposed work, start tracking and stop tracking." – P2, 70.0% adherence*

> *"(It was) pretty easy (to embed the tech use into everyday routine). I guess I have a set-up routine when I get into my office anyway, get my laptop out, set up."*
>
> *– P4, 93.33 % adherence*

The email sent by the researcher at the beginning of every workweek was deemed a helpful reminder to recontinue tracking, especially after holidays. Participants found it more difficult to remember to stop tracking at the end of each workday than to start tracking in the morning, because the automated tracking worked non-intrusively at the background throughout the day. However, forgetting to stop tracking had consequences on the quality of tracking the following day, because with the wrist device logging data in standalone mode for long periods of time, the microcontroller could be easily overloaded and crashed due to a flaw in the hardware design.

> *"I had no trouble coming in every day and turning it on, but I had a couple of days on which, I went back home with my wrist on me. I was like 'no!' …Once you clicked 'tracking' you forget about it" – P8*

Similarly, participants found it difficult to remember to take the study phone with them during short breaks. As the *MetaWear* hardware used for the wrist and cup device were configured to cache data temporarily during short periods of disconnection and resend data to the App upon reconnection, the researcher instructed participants to take the phone with them only if they were out of the office for 15 minutes or longer. However, the devices turned out not to reconnect always as reliably as expected, even after just brief disconnections:

> *"What was hard was remembering to take everything with me. Obviously this is on my arm. But if I had the phone on my desk and somebody'd be like, 'I need you really quickly'. I would been up and walking about but the phone would haven't been with me." -P10*

"I don't know if it would be out of range, so I take my phone when I'm out of the office. But if we just went to the corridor, it was okay to just leave the phone in the office (according to the instruction). Sometimes I don't think it's recorded things like going to the printer and back from the printer for like 10 or 11 times. I don't think it had because it kept saying 'not connected'." – P13

"Most of the time I'd say, when it reconnected, it would just refill the graph. But obviously it's better if you remember to take the phone with you, it would just continuously work, which would be better." - P14

In addition to unreliable connection, the discomfort of wearing the wristband (e.g., "too tight", "sweaty in summer") was identified as another barrier to acceptance by 5 participants (P5, P12-P15). As a result, participants invented news ways of wearing the "wrist' device. For instance, P12, P13 and P14 showed to the researcher how they planned to wear the "wrist" device using clips, pins and sellotapes as shown in Figure 6 for post-study use where more flexibility was allowed in the placement of sensors.

Figure 1 An alternative way of wearing the tracking device suggested by participants

Theme 2 – perceived accuracy of tracking

Despite technical issues, most participants thought the algorithm was accurate in differentiating activity (ambulatory behavior) and inactivity (stationary behavior).

"It's quite interesting most of the time it was accurate. You are like, oh my god I've been sat – you got a red bar - I've been sat for this long already! …so as long as it was working fine, and I trusted the data." – P1

"In the mornings I sit down for longer periods of time. I can corroborate that by looking at my data. It's not good." – P3

"I think like 90% of the time (it was accurate in telling whether I'm active or not)." – P10

"They seem really accurate, especially after one update, I can't remember when it was I updated it. After then it felt really was picking up everything. So I felt like it was quite accurate." – P15

Combining participants' reports with system logs, perceived inaccuracy occurred mostly during periods of device disconnection when no data was recorded at all, and only occasionally during periods when the data connection was intact. In the latter case, the detection algorithm could either be too sensitive in picking up movements that participants would not consider as breaks (eg. opening the window blind, sitting and talking with hand gesturing) (P4, P7, P8), or not sensitive enough in detecting breaks (P1, P2, P3, P11, P14).

"That's why I realized it was quite sensitive because a lot of the stripes were just 1 min. Initially I sat there and thought I haven't been out of the office. What is it recording? Then I thought, oh, I've opened the blind, I've got up and put

something in the bin. Maybe actually I haven't physically moved." – P7

"It (feedback) made me feel really guilty. when you looked at it, obviously it only records if the time you stand up and you are up walking around is more than a minute. So, there would be times where I just quickly buzzed across the hall, or more than a few minutes, oh I'd be like 'oh, that was counted for something.' Then it wasn't counted for anything. Because I have literally gotten up and gone next door" – P11

The issue was rectified by adjusting the detection thresholds upon individual requests. As it was made clear to the participant that the researcher could help make the break detection more, or less, sensitive based on each individual's experience and preference, three participants (P4, P7, P8) requested to have the threshold raised so that the break detection became less sensitive.

"They got more accurate when you gave me new settings toward the end. Because sometimes it would say I was active, but I was just in a meeting. I think I moved my arms too much. but if I walked around the building, it was always accurate to catch that." – P4

"Right at the beginning, it was too sensitive. I was just articulating with gesture, but it would record it as a break. then I talked to you...if you remember, I had problems with the data not being sent, you restarted it and did something, you also changed the parameters the last time. After that, it was no longer doing that." – P8

The prompts component

Theme 3 – fidelity of delivery of the embedded prompts

Interviews suggested the prompts component delivered with the embedded LED (variably called "cup device", "light" in interviews) were not always received by participants exactly the way as intended. The fidelity of delivery was dependent on three factors, the visibility of the LED reminder, the portability and placement of the reminder device, and the reliability of Bluetooth connection.

First, a lack of attentional resources at work to notice the subtle reminder was identified as a barrier by about half of the participants. In addition, several participants (P4, P6, P14, P15) reported accidentally putting down the vessel with the LED facing away from themselves.

"Sometimes the mug was on my desk facing away like that, I would be working. and suddenly I sort of thought, ah, I've been here a long time, I looked at the phone and it had been 75 minutes. then I looked around on the phone and the light on the mug was flashing over here, coz I just didn't have it faced the right way" – P4

"Occasionally I would turn around to look at my bottle and found that I had turned it away from me unconsciously. Then I'll turn it around and find it flashing." – P6

For others, even if the reminders were positioned within the field of vision or in the periphery of attention, they might not notice it if they were concentrating on work.

"But even if I'm working like that, I'm right now not looking at the light. It's below (the screen). Maybe if it was stuck in my screen, it would be different." – P8

"I think I had it too high on the glass...If I'm typing, I'm looking down, I don't

look at the screen, I can't touch-type…I think if I would do it again, I would have the notification thing more to what I'm doing." - P12

Secondly, although the intention was to have prompts and cues delivered with an interface attached to an everyday vessel (eg. cup, bottle, or glass) that plays an important role in many office break activities, not all participants followed the instruction to attach the LED reminder to vessels that they would use for everyday hydration needs. For example, P5, P7 and P9 normally placed the reminder to one vessel while using another vessel for everyday hydration, because the device was too "chunky".

"But it's not in a good place on a cup really. It gets in the way. So, I tended to use a different cup." – P5

"But as I go to other campuses, then I wouldn't take the cup. Although I started taking the LED, but to be honest, sometimes it was in the bottom of the bag." – P9

Finally, the unreliable connection between the devices badly compromised the fidelity of prompt delivery, which even caused potential adverse impacts on behaviors.

"There were a couple of days where I didn't realize and I probably went through sitting, because it wasn't showing…" – P9

"It's only at times when the light didn't come on and the phone didn't buzz, I checked the phone and swiped to see what the time was and I realized I hadn't been up for last hour." – P12

Ironically, in order to be prompted, participants had to proactively check the App from time to time to make sure the cup device was connected. As a result, some reverted to the App for real-time information about inactive time directly.

"Coz I think there were a few little glitches... I didn't realize it wasn't working until I had a look... which is why I then moved to checking on the phone, coz you can't always tell with just the glowing. The light was useful, but actually sometimes I found it's quicker just to see on the App." – P9

Theme 4 – mixed attitudes toward the embedded medium for delivering prompts

Individual differences existed with respect to the preferred modality and medium of prompting. Some preferred the current visual one delivered with the cup device; some suggested it would be more noticeable if the system could deliver a vibratory or audible reminder; others were unsure:

"I got a Garmin that buzzes every time I need to get up and move, but when I'm at work, I'll have my watch on 'do not disturb', which kinds of defeats the purpose. …This (cup device) was a more subtle way of saying, 'you need to get up', as opposed to go out buzzing that's really disturbing to your surroundings. I really like having the visual cue because I feel like it kind of took my attention away from what I was doing and made me physically look away from what I was doing." – P11

"I like the wrist band, because it's more autonomous and if there was a way that could buzz say vibrate to have a break." -P1

"I'm not sure. I'm in two minds. Coz I was gonna say that it would be useful for me to (have) kind of noise, almost vibrate or buzz or something like that. if it is 2-hour meeting, and I forget to turn it off…if you forget, then an hour in, it starts making some annoying noise." - P15

The idea of integrating prompts and cues for breaks with an everyday object related to break activities was evaluated differently across participants. For some participants, this approach made a lot of sense and worked well to prompt and facilitate breaks. As a positive side effect of this medium of delivery, some participants (P1, P2, P3, P12, P14) also reported drinking more liquid:

"Because it reminds you to do something. You can very well take it as an excuse to fill up your water bottle or take it and drink it and then fill it up again. It worked for me in that way." – P3

"I did find actually that it made me probably have more drinks and water than I would have done normally. It's been good in that way…" -p1

"It was good to make me drink more rather than just get up, coz it gets me a reason to go to the kitchen and fill my bottle. If it wasn't attached to a bottle, I might not have taken that with me. I'd just go for a wander. So that was good." - P14

When prompted in interviews, most participants expressed positive attitudes towards the addition of technological features to the cup device for tracking, visualizing, and prompting hydration behaviors.

"That's a good thing to incorporate, especially with it being on a cup because it's important to stay hydrated throughout the day. That's a nice thing to have." -P2

"I think that's interesting for me, just because I know that I didn't drink enough water. So, it was a nice little extra thing to make sure I did drank." – P14

However, a few participants held less favorable attitudes towards this embedded medium for delivering prompts:

"For me even though the glass is there, I will use it in the break, it's not the thing that reminds me of a break. Before having used it, I didn't realize. I really thought the glass would remind me to take a break. (But) it's actually the device with the light that would remind me to get up...I would have to have it close to what I was doing, as I don't touch-type…" – P12

Quite a few participants suggested combining the wrist and cup device into one, or even eliminating both devices and using the smartphone for both tracking and prompting, so as to make the setup routine easier. Participants felt tired of managing multiple devices, partly because of the unreliable connection between the three devices.

"Maybe just having one device or one thing embedded in an object that just all works together as one. That'll be much better than having all the individual things." – P2

"Maybe it would be better if the reminder was somehow in the device you wear on your wrist. That would be less thing to worry about." – P5

Theme 5 – mechanisms of impacts of prompts

Despite various factors compromising the fidelity of delivery, participants reported the LED break reminders did change their behaviors in several ways. For some, the lights served to direct their attention from work to the need for breaks, and bring awareness to sitting time, echoing questionnaire findings that suggested improved prospective memory.

"So, the reminder - that 45 minutes actually feels like a very short amount of time, but when you are sitting for 45 minutes, for your body that's a quite long time - makes me aware of the amount of time I've spent sitting where I could possibly get lost in tasks and quite happily sit for 90 minutes, which is really bad." – P6

"For me it was like when the light came up, I think 'ok I need to take break'. If I was in the middle of something, I tried to finish it, and then go and take a break." - P15

Furthermore, some participants (P3, P6, P12-P15) actively used the LED to support their action plans or implementation intention, which was an intended mechanism of action supported by *WorkMyWay*:

"When the yellow one comes on, I would be more in the frame of mind of 'I'll just finish this sentence' or 'I'll just send this email and then go' or 'I'll just finish this one little job and then go get a drink'. and then with the red one, when I saw it, I tended to just stop what I was doing and just saying, 'just put stuff down' and pick up my mug and go get some water or coffee." – P4

"If I was stuck in a task, the amber light, I would just let it go, til the red, more insistent, and the final stage, the flashing red came on. If I did have the time, if I was in between tasks, I would make an effort to go and fill my water bottle, just go for a walk to the atrium and back, just to get up and about." - P6

We expected participants to develop a somehow automatic response to the LED reminders if they repeatedly take breaks as soon as the LED was on. Therefore, the post-intervention questionnaire assessed the habit strength, or automaticity, of "taking a micro-break whenever the LED is glowing", in addition to "taking regular micro-breaks throughout workdays". However, score on the former (mean=3.4, SD=1.238) was significantly lower than the latter (mean=4.85, SD=.441), based on paired-samples t-test (t=-4.794, p<.001). This was corroborated by the interview finding that most participants tended to think their current responses to the LED were still driven by Type 1 conscious decisions rather than Type 2 automatic processes. However, there were quotes suggesting that the LED did seem to exert a Type 2 influence in terms of heightening the cognitive accessibility of the goal to break regularly and instigating actions smoothly without the need for deliberation.

"On some days I'm really busy, and I would wait. But my first instinct would have been to remind myself, 'oh I have to get up and I have to do something'." – P3

"There was one or two cases where I was in a meeting, and I couldn't get up. But (otherwise) if it flashed, I would do it. I found that quite difficult not to." -P12

"If I see the light, I would be straight up" – P14

Interviews also suggested that if participants used the technology for longer, they would likely develop stronger impulses to react to the LED:

"…this isn't automatic for me yet, but it's a nice reminder…it could be, If I keep using it, I guess, as soon as it goes, you could be like, 'ok' straight away. But at the moment, it feels a bit more like a reminder.'" – P15

There was also suggestive evidence for participants' evaluative learning of the color-coded LED and on-screen feedback, as participants came to like "yellow" and "green" and dislike the "red" colors in the system, potentially because these colors were repeatedly associated with healthy and unhealthy behaviors in the system.

> *"Obviously you don't want any red, do you? I like the yellow and green. If I see a day that's like yellow and green, I know it's been a good day. It sets me up for my mood at the end of the day." -P11*

Therefore, it seemed to be those immediate affective responses toward these colors rather than the deliberation on long-term health benefits, that had driven and energized break actions at points-of-behavior:

> *"We had different stages of flash…So before the flashing, I was trying the 'beat' it really. Yes. I set myself a little challenge to have a micro-break before that stage." - P2*

> *"When you got oranges, you sitting down more, it can't be avoided, but I was consciously thinking I need to get up and move about. I started to get a bit jittery." -P13*

In addition, because of the technological problems that comprised the delivery of prompts, an unintended mechanism of impacts seemed to occur – instead of waiting to be prompted after 45 minutes, participants internalized the rhythms and proactively checked sitting time periodically.

> *"Something in me that just said, you've been sitting a while, let's see if it's blinking and I turn it around, and it was." – P6*

> *"We were quite aware that we haven't moved for a while before the reminder went off. We would check the phone, and say, 'ops, I've been sat for 30 min. Shall we go and have a walk there?' And then we would. So, it wouldn't have the chance to go off." – P14*

Participants also discussed potential carryover effects of the LED reminder after it was removed at the end of the study:

> *"I think once you get into the routine of looking up every hour, and go 'ops, it's time to get up and move', then you almost don't need it. But it's a nice reminder. If I had that for a couple of months, and then do without it and see if continue that behavior, or if I go back to normal." – P11*

The on-screen components

Theme 6 – delivery of the on-screen components

The *WorkMyWay* App visualized stationary and ambulatory time along a color-coded timeline, both in real time and retrospectively in the "history" section. Although it was intended participants left the App running at the background throughout the day, some participants frequently checked the App for actionable information throughout the day, as a complement to the embedded prompts. Indeed, the real-time on-screen visualization was mentioned as the most interesting and valuable feature by all participants.

When asked about their opinions on the "history" section (as opposed to real-time visual feedback)

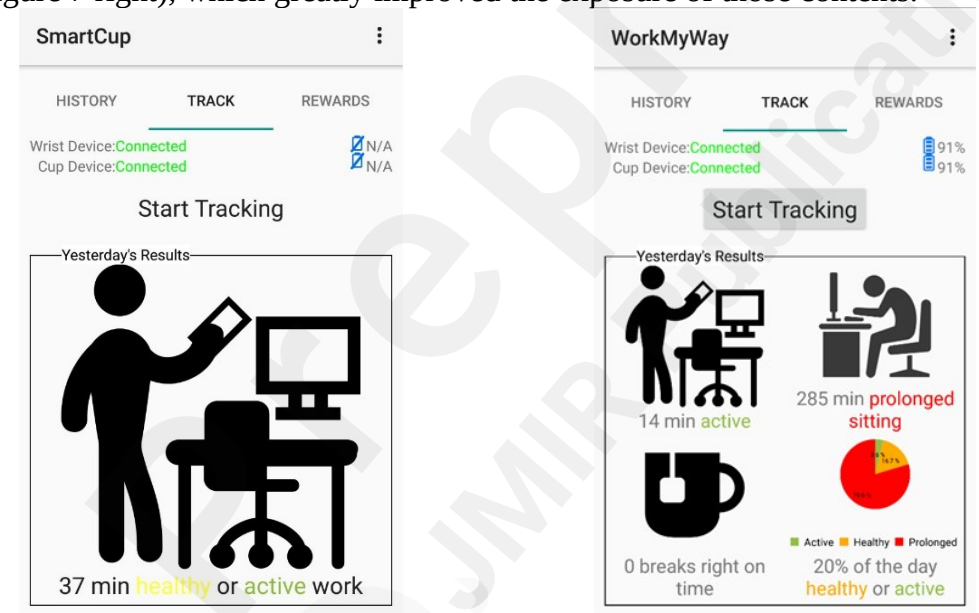
in interviews, participants said it was useful to have the "history" that allowed them to review and compare data on different days, but the frequency and depth of engagement with the historical data differed across participants.

"From time to time, I swiped to review different days, which was interesting." -P4

"I looked at it, but I might not have taken it in so much. It's nice to see it, like compare it to yesterday, how have you done. But I don't really take it massively in, unless you finished, and you went 'that wasn't a very good day'." -P14

"I didn't (review it). I just didn't have enough data or figured out I did have that…I just used it in real time, rather than thinking how did I do. It had passed, I couldn't change it. I don't think it's my interest to look at that either." – P12

Moreover, some features in the "history" section had a limited exposure at the early stage of the study. Although most participants took a glimpse at the summary box that was displayed below the 'start tracking' button each morning (Figure 7 left), not all participants were aware that they could swipe the box to view different metrics. Therefore, an interface update was implemented halfway through the study to make all the summative metrics displayed on one screen without the need to swipe (Figure 7 right), which greatly improved the exposure of those contents.



Original design Revised design

Figure 7. Changes to the layout of the summative feedback in the App

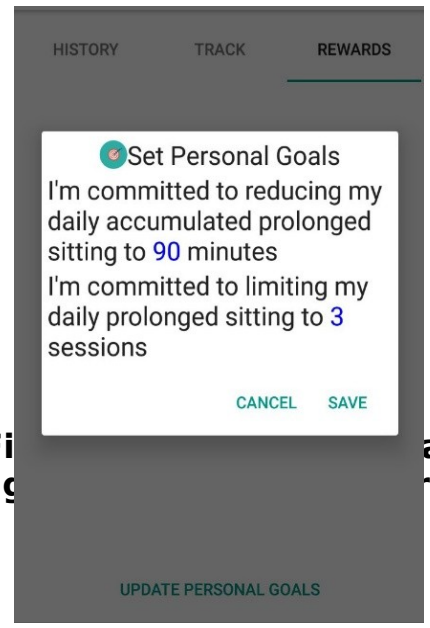
The least used function in the App was 'goal setting', as 9 (60%) participants did not update their goals at all throughout the intervention period, 4 (26.7%) updated it only once and 2 (13.3%) updated it twice.

"I did update it at one point…But actually I don't think I looked at this tab for 3 weeks. It's interesting I looked at all of these data with the number of red blocks in it and yellow and green. but I didn't spend much time looking at the trophies or goals." – P4

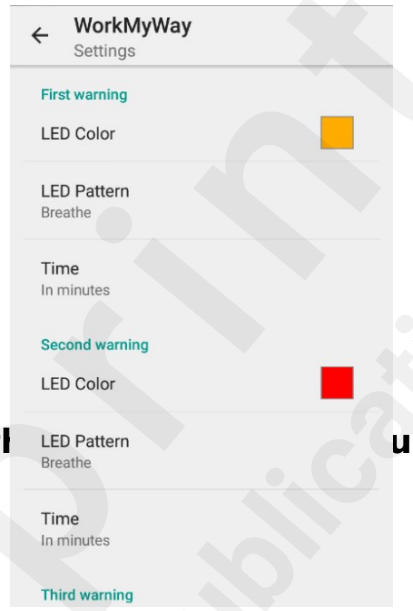
The interview responses suggested a potential reason for low engagement with goal achievement was

that the goal defined in terms of daily cap on accumulative prolonged SB was way too complex to be remembered. There was incongruency between the goal framed in the intervention and the goal perceived by participants, as when prompted with the question *"how often did you update your goals?"*, most participants' immediate responses were about how often they updated the reminder intervals (Figure 8 right), instead of what was set up as goals at the briefing session and in the App (Figure 8 left):

> *"I think I did (change the goal setting) at one point. No, I didn't. I forgot about that...I changed the warning. I kind of saw that as like a goal." -P4*



Intended "goal setting"



Perceived "goal setting"

Fi amed in th us the "g rticipants

Theme 7 –

mechanisms of impacts of on-screen components

Interview responses suggested a variety of potential mechanisms of impacts of the on-screen feedback. Some used the daily feedback merely as a tool for self-reflection, without an explicit intention to use the feedback to change behaviors. They enjoyed using it because they could relate to the data and link the feedback with personal experiences on different days.

> *"In the mornings I sit down for longer periods of time. I can corroborate that by looking at my data." –P3*

> *"Sometimes when it reaches 5 pm. you are drained, mentally. you are like, 'why am I so tired?'…then when I went back to the App and I saw that 'yeah, you've done everything, but it took you 2.5 hours sitting down, which has consequences later on'. It's gonna drain me. For me, I used it as a proof you weren't taking care of yourself." - P8*

Some participants reported the feedback on behaviors enhanced their retrospective memory of daily sitting patterns, which made them come to consider prolonged sitting as a significant health issue:

> *"I think it just made me more aware that I was not getting up, not go to exercise, go all day without a drink. Even knowing how many times you are getting up, being more aware. I could have gone up and gone to the printer and not being aware of how many times I was doing it. But now I've got an awareness." – P13*

Other participants took a further step to use the feedback as a motivational tool to purposefully regulate behaviors and pursue goals.

> *"I think I tried to be better because of the feedback. It's kind of concerning to see the red. I think the colors specifically. You see a lot of reds and you are like, 'em, I don't want that. I want green and yellow.' I looked at my feedback right before I came here as well, so I was like, 'oh it's been a good day today. I've been really good about getting up and taking my breaks.' It has made me better." -P11*

> *"So, if I saw a day like this (with only green/yellow blocks), I'd be very happy, because this would make me feel like I've had a good amount of breaks. I felt like this was a productive day, whereas …even this day looks quite good. I know it's red. It's probably not that long…I tried to avoid red." – P15*

Participants essentially administered to themselves the additional Behavior Change Techniques (BCTs) of "self-reward" and "negative reinforcement (reinforce a behavior by removal of an unpleasant consequence contingent on performance of the behavior)" by utilizing the color-coded feedback, which seemed to be even more motivating than the rewards we had explicitly designed to be delivered by *WorkMyWay* App in the form of "trophies" and "badges".

> *"I spent most time just looking at the blocks of bright red more than I looked at trophies." – P4*

> *"Then you could easily base it on, okay, I did this yesterday, I will do more... Really, I think for me the visual impact was the thing, seeing that you got all greens." – P13*

Participants also discussed how the framing of feedback in the App shaped their thinking with respect to what constituted good versus bad behaviors. For instance, the fact that any interruption of one minute or longer in stationary time was captured and colored "green" in the visual feedback

changed people's perception of what counted as a physical activity break in the workplace, and in turn enhanced people's self-efficacy for reducing and eliminating prolonged stationary bouts.

> *"It actually showed me how much I was moving. So, my perception was that I sat here for hours, coz some days it feels like that. But actually, the green bar shows you I'm physically moving more than I thought." - P7*

> *"Also, the other thing has been actually to recognize I do naturally take breaks just by moving between activities. So, it is a part of my normal day anyway, when I have to move between meetings anyway." – P9*

Similarly, given the way the metrics were calculated and presented in feedback, the system seemed to penalize sitting bouts that exceeded 60 minutes, but not total sitting, and reward timely breaks that were taken after 45-60 minutes of sitting, but not breaks taken at other times, which had potential implications for behavior:

> *"That was a shame. 1 hour and 1 minute, I almost did that one. I could have got an extra trophy…but again see I was only naughty for 6 minutes. but that's producing 30% of the pie chart from going 6 minutes over. Seems a bit unfair…It says, 'breaks on time'. So, I shouldn't take a break every 20 minutes. That's a good question. is it better for you to not take too many breaks?" – P4*

External factors influencing the delivery and effectiveness

Theme 8 – organizational climate and job constraints

Organizational culture was identified as the main contextual factor affecting the uptake of *WorkMyWay*. All participants in the study thought their employer were happy with the behavioral target (ie. hourly break) promoted by the intervention and permissive of employees' personal use of technologies as such, which was also why they could participate in the study in the first place.

> *"I think this workplace will be happy with it, it's a very flexible department…there is a lot of trust and independent work in timing. I don't think people mind if you get up to go to the bathroom in the middle of a meeting, and things like that." – P4*

However, there were some constraints on break behaviors placed by the nature of the work and the relationships with others involved in the job role:

> *"But because of the nature of roles, the period of breaks may have to be a bit more controlled. So like student-facing, student services, they have to be there for particular times, so the breaks are gonna be structured around of their availability and around other's availability. So, the implementation should be quite carefully thought about." – P9*

Different views existed regarding who should be held accountable for employees' behaviors that occurred in the workplace and that had consequences for personal health. Some thought the organizational and management had an important role to play:

> *"I think it should be encouraged. I think it really would rely on who's head in the department as to how encouraged it would be. I think it's something that we should all be doing within the university. Because we should be doing exercises. We should have lunch time exercise session. Because you get very sluggish, when you've done half day work. It's quite tiring. In the afternoon, if you miss your lunch break, you do get very tired...It would be good to bring it on the department's head,*

if you could encourage them to do it, take it on board"- P13

Though the majority held the view that it should be down to the individual to take care of themselves and to choose the appropriate tools, but it would be nice if the organization could offer some options.

"That's interesting. I mean it's everybody's own responsibility, isn't it, to make sure they are taking enough breaks? But it's not always possible. I mean if you are in a meeting, there is a lively discussion going on, you probably wouldn't be able to get up and walk around. I wouldn't take on the responsibility of anybody else's device flashing and say (you) ought to move. I think everybody got to do that for themselves." – P5

"I think the organization doesn't really mind, care either way. They really leave it up to the individuals. So, they don't mind if I would want to put something in place to help me. But they also don't care in making it different for people. It would be nice if they would have some options that we could use. I don't know whether that's where this could go. Then that would be nice to use." -P12

Encouragingly, one of the participants who was a senior manager participated in the study with the interest to source an intervention that could be taken on board and scaled up at the university to improve staff wellbeing:

"As I'm the wellbeing lead, anything that encourages staff to take a practice at work, I'm keen on understanding…(if) you got some summaries of if people actually found it helpful, I'd be quite keen to promote it to university." – P9

Theme 9 - interpersonal influences on adherence and compliance

The subjective norm, or the perception that a majority in the workplace are trying to take regular breaks, was identified as another facilitator to both using *WorkMyWay* and improving behavior.

"It's a nice environment in that. People are often going out to make a cuppa or asking somebody. Yeah. I think we are all very aware of sitting down all day. I think generally people encourage everyone in there anyway, which is good." -P10

"My department is very… they are all occupational therapists and physiotherapists. They are all 'get up and move'. It's welcoming environment for that kind of thing. Everyone is very conscious of that. Like if we've just had an hour of long meeting, let's have a comfort break, get out, stretch your legs, and come back. So that's quite good. -P11

Direct social interactions both facilitated and hindered use of *WorkMyWay* in different contexts. On one hand, most participants had to stop using the reminder device in formal meetings where breaks were not always possible.

"When I was in a formal meeting, it was more embarrassing then because I didn't know how to stop it flashing apart from taking it off and putting it in my pocket… But it could be a social reminder. But it depends what people think is an acceptable meeting. Some people think 2-hour is a perfect thing, I don't think any meeting should be longer than 30 min."

On the other, when a participant did not notice the LED reminder, there was the chance that co-workers who happened to see the LED flashes could remind him or her:

"Some of them that didn't know would come past and say, 'oh, what's that thing flashing?' and then I explained. And then they'd know. Next time, they'd be like, 'hmm, it's gone amber or whatever', coz sometimes I was so focused on the task in hand that I hadn't noticed that…Yeah I think it was really good how everybody else kind of gets involved in an office environment." -P10

The physical artefact of the technology also turned out to be a conversation piece to get people talking about wellbeing in the workplace and sometimes prompt them to take a break together.

"They would go, 'oh what's on your water bottle?' 'Oh, I'm part of a study'. So, they were interested, and it got them talking. So that's quite good. But then someone I work with in office could sometimes see the light when she was over at my desk asking me a question or anything, she pointed it out, and we'd be like, 'oh, maybe we should go get up!' so it prompted both of us to go, get up and make some tea, or do something. So that was quite nice." – P11

For P12, P13 and P14, participation as an office team enabled so much fun in the process and potentially enhanced the usage and effectiveness of the intervention.

"Because we were all in it together. We all had issue. We would sort it out. If xxx(P14)'s is flashing, she wants to get up, and we all go together for a drink or whatever." -P12

"It was a reward to think, 'oh yeah, look, I've done this this. I showed my colleagues. Have you done this?' and we compared it." – P13

"They would check the phone, and say, 'ops, I've been sat for 30 min. Shall we go and have a walk there?' And then we would."– P14

Discussion

Principal Findings

This study provides a detailed evaluation of the process of delivering an IoT-enabled intervention designed to reduce office workers' sedentary behavior. We found a mean adherence rate of 83% and 0% attrition in our sample. Despite some technical issues with *WorkMyWay*, 11 (73%) participants opted to keep the devices and continue using *WorkMyWay* after completion of the study, and 5 of them did not stop using the technology until 3 months later. Compared with previous studies [30,40], those results suggested *WorkMyWay* had a medium to high level of adherence and potential for long-term adoption. This was corroborated by qualitative results that revealed participants' overall favorable attitudes towards *WorkMyWay.* They considered the use of *WorkMyWay* manageable in their office settings and most of the contents valuable and engaging. Though diverse attitudes existed towards the combined modes of delivery – some found the environmentally-embedded prompts particularly interesting and useful for creating awareness of prolonged sitting without being intrusive, whereas others disfavored the mode for delivering prompts because of the system complexity induced by multiple devices. As for behavior change outcomes, no significant changes were observed in either technology-captured or self-reported OSPA, potentially due to a relatively short intervention period. However, promise for behavior change was demonstrated by significant improvements in several psychological variables (eg. retrospective, prospective memory and automaticity of micro-break behavior) theoretically aligned with the mechanisms underlying workplace sitting reduction according to a previous behavioral diagnostic study [37].

To our knowledge, despite the proliferation of wearables and IoT technologies, *WorkMyWay* is the

first theory-informed IoT-enabled SB interventions systematically developed using the BCW guide. Another theory-informed intervention most similar to ours is the *Stand More At Work* (*SMArt Work*) intervention [41]. Both interventions feature BCTs like information about health consequences, prompts and cues, self-monitoring, goal setting, action planning, feedback on behaviors. The *SMArt Work*, has been evaluated in a cluster randomized controlled trial (RCT) (n=146 participants) intervention and showed to be effective in reducing sitting and improving job performance and psychological health at 12 months [42]; this provides further evidence to corroborate the common BCTs used in *WorkMyWay*. While we did not intend to prove effectiveness of *WorkMyWay* in the current study, the results on psychosocial variables did contribute to a better theoretical understanding of SB interventions as strong and weak mechanisms of action could be identified. Moreover, our study demonstrated the feasibility of alternative modes of delivery (e.g wearables, digitally augmented cup, App) to those used in *SMArt Work (Darma* cushion*)*, which echoed the call for a greater choice of devices and tools for self-monitoring and prompting tailored to individual needs resulting from the process evaluation on *SMArt Work* [43].

Revisiting the Intervention Mapping Table

The intervention mapping table (presented as leftmost column 1-4 in Table 4) we created during the intervention development stage [17] can be used to collate qualitative and quantitative results from this study to assess the implementation and promise of individual components (Column 5 and 6). For instance, as Table 4 shows, the 2nd intervention component was intended to target the constructs of retrospective memory, cognitive overload, and behavioral regulation. The fact that participants perceived the activity tracking and feedback as accurate and valuable suggested the acceptability and feasibility of intervention components integrating BCTs like “conserve mental resources”, “feedback on behaviors” and “self-monitoring”; the significant difference in retrospective memory between pre- and post-intervention surveys further supported the high promise of this component for supporting behavior change.

Table 4 can also be used to gain insights into the applicability of specific modes of delivery. For instance, an everyday object augmented with embedded electronics like the cup device in our study seemed particularly suitable for delivering or supporting the delivery of BCTs like “action planning”, “conserve mental resources”, “prompts and cues”, “add objects to the environment”, “habit formation”, and potentially “social comparison”. The mechanisms through which they can change office workers’ SB include improving “prospective memory”, heightening situational “cognitive accessibility of goal”, breaking “habits” and forming new “contingencies”, and restructuring the physical and social environment.

Table4 □ Structured process evaluation guided by intervention mapping

Constructs/Mechanisms of action targeted	COM-B	BCTs	Intervention components and mode of delivery	Evaluation of implementation	Implications for future practice
Knowledge, beliefs about consequences, behavioural intention	Psychological Capability, Reflective Motivation	Information about health consequences, credible source	1. App provides recommendations on healthy break intervals with explanation of scientific rationale and emphasize that the information is from credible sources	Majority did not recall the App screen with the "information".	The promise is unknown given low fidelity and exposure of the BCT. But it doesn't hurt for a human coach to point out where the info is in the App at the face-to-face sessions.
Retrospective memory, cognitive overload, behavioural regulation	Psychological Capability	Conserve mental resources, feedback on behaviours, self-monitoring	2. Use wearable trackers to automatically monitors sitting time and App provides daily feedback to enable user to self-monitor day-to-day changes in break patterns.	When the Bluetooth connection was intact, P's perceived the tracking and break detection to be accurate and valuable; questionnaire indicates increased retrospective memory of break patterns.	High promise via supporting both prospective and retrospective memory. Need to improve reliability of data connection; notify the user of disconnection to avoid adverse impacts; send reminders in advance to give the user a time window to act on the reminder to reduce dependency.
Belief about capabilities	Reflective Motivation	Feedback on behaviours	3. App presents daily summary of and feedback on break pattern.	Some did not fully discover the information; some glanced at it the next morning; some engaged with it extensively.	Display all the useful feedback on one screen without the need for user to swipe to view different metrics.
Belief about capabilities, positive / negative affect	Automatic + Reflective Motivation	Focus on past success	4. The App prompts the participant, at the end of each day, to look at the App feedback on break pattern and to verbally list moments s/he has managed to take timely breaks.	Even though the instruction was not explicit, P's reported praising themselves and feeling good about themselves while viewing the feedback.	High promise despite low fidelity of delivery. In future work, the instruction to self-reflect on successful moments should be more explicitly given and explained by the human coach or /and the tech.
Goal (distal / proximal), beliefs about capabilities	Reflective Motivation	Goal setting (behaviour), discrepancy between current behaviour and goal, review behaviour goals	5. Researcher prompts the person to set goals (e.g. "I want to limit my prolonged sitting within 3 episodes per day) in the App and to review and adjust goals from time to time.	The goal was seldom viewed or updated. Because the framing was too complex to be understood or embraced by the P's	The promise is unknown given low fidelity and usage of the BCT /feature. Future work should identify more meaningful metrics or wordings/framings of goals for SB reduction.
Intention	Reflective Motivation	Commitment	6. Researcher ask the person to use an "I will" statement to affirm or reaffirm a strong commitment to change the behaviour.	The researcher is confident that this has been delivered as intended by strictly following the action planning protocol	High promise as proved extensively in previous research, but not specifically evaluated in this research.
Rewards (distal / proximal), goal (distal / proximal) reinforcement, positive affect	Automatic + Reflective Motivation	Social incentive, social rewards, reward approximation	7. The researcher informs the person that the App will congratulate him /her for achieving any reduction in prolonged sitting, reward is delivered by the App.	Some were really incentivised by the badges and congratulations, whereas others did not care much about the badges. Unexpectedly, the colour-coded timeline and pie chart work as powerful reinforcers and punishments for most P's	High promise. Use of colours with pre-existing associations could help. Formats and aesthetics of reward presentation, gamification,and credibility of the reward rule matter a lot. Their design needs to be informed by research with end users and pre-tested in prototypes in future research. Also important to consider individual differences and personalisation.
Breaking habit, self-efficacy, implementation intention (goal accessibility)	Reflective Motivation	Action Planning	8. Researcher suggests the person plan taking breaks by specifying the frequency, duration and context, including developing "if-then" rules making use of the object-based prompts.	The researcher is confident that this has been delivered as intended by strictly following the action planning protocol; questionnaire indicates increased break automaticity	High promise to break the prolonged sitting habit and form new habit, both based on this study and the literature. Can be supported by object-based prompts /cues.
Prospective memory, cognitive overload/, "goal priming, contingencies, resources	Psychological capability, automatic motivation, physical opportunity	Conserve mental resources, prompts / cues, add objects to environment	9. Add objects that facilitate the performance of breaks to the environment; use the object simultaneously to cue the prospective memory task naturally associated with the object (e.g. cup-cued tea breaks)	Unreliable data connection and delivery of object-based prompts /cues made P's revert to the on-screen real-time visualisation. Questionnaire data show decreased difficulty with remembering to take breaks (better prospective memory)	Despite low fidelity of delivery, based on theory, prior empirical evidence and data from our questionnaires, these BCTs can be promising and worth re-evaluation using a redeveloped system where the reliability and visibility of prompts is improved.
Habits, contingencies	Automatic Motivation	Habit formation	10. Researcher trains the participant to develop new responses to the introduced stimuli through repetitions.	P's reported trying to follow although it was constrained by the context (e.g. in meeting); increased automaticity indicated by questionnaire but not by interviews.	High promise for change but inevitably medium fidelity of delivery because of practical constraints. Technology can be improved to incorporate more data sources, detect contexts and deliver prompts only when it is possible to act on them.
Social support, group conformity, organisational culture /climate	Social opportunity, physical opportunity	Social support (practical and general)	# 11. P's could form teams and foster peer support to promote engagement with the intervention (not intentionally incorporated as part of the intervention)	As a contextual factor, P's joined the study together with officemates were more motivated and able to engage with the intervention and troubleshoot the system.	Despite it being unintended, group participation shows great promise to enable change via peer supports, group conformity and shaping the culture. Can be encouraged explicitly in future.
Social comparison, group norm, modelling, social support, negative affect	multiple	Demonstration of the behaviour, social comparison, information about other's approval	# 12. P's could see other's sitting patterns and share strategies (not implemented in WorkMyWay technology but could happen spontaneously and voluntarily between P's offline)	Some P's shared data with each other and reminded each other of the light on the object. Conversations between co-workers (including non-participants) about SB were triggered by the technology, which changed subjective norms of the behaviour.	Despite it being unintended, comparison, sharing of individual data and opinions on the issue triggered by the technology have promise to influence intention via shaping subjective norms. But those elements need to be designed and delivered with cautions to not introduce surveillance or other misinterpretation.

Strategies to Improve Acceptance and Delivery

The study identified the following main barriers to accepting and using *WorkMyWay*: (a) technical issues with Bluetooth connection and data synchronization (b) the discomfort of wearing the wristband (c) constraints of job and certain work contexts where breaks were unfeasible.

Main motivators and facilitators to ongoing use were identified as (a) perceived gains in cognitions and behaviors enabled by the embedded prompts and on-screen feedback (b) clarity of technology instructions and simplicity of the tracking protocol (c) ongoing improvements to the system design in response to participants' feedback over the study (d) social norms and organizational culture supporting break-taking behaviors.

These findings point to several strategies to enhance acceptance and delivery of interventions similar to *WorkMyWay* (a) Make the data syncing between different devices reliable and effortless for the participant (b) Improve the physical design of the cup device, possibly by making it an LED ring surrounding a vessel visible from all direction (c) Improve the physical design of wearable activity tracker and allow flexible way of wearing (d) Harness social influences and solicit organizational support for implementation.

Strengths, Limitations and Future Work

A main strength of our study is the mixed-method approach that combined system logs, activity tracking data, questionnaires, and interviews to shed light onto multiple aspects of the process of delivering *WorkMyWay* to a group of office workers in the workplace. We demonstrated the feasibility of utilizing technology-captured data to monitor user adherence, density of use and latencies in responding to prompts etc. This approach is advantageous as it allows implementation issues to be considered in relation to the fidelity of individual component delivery in feasibility studies and causal pathways to be potentially modelled in future larger-scale evaluation. Another advantage of the *WorkMyWay* study is the use of the intervention mapping table as the basis for process evaluation, which allows the BCTs and mechanisms of action underlying each intervention component to be scrutinized and direct implications for work on individual components to be drawn.

Nevertheless, this study has several limitations that should be noted. First, the intervention did not sufficiently target the constructs of knowledge and intentions, even though they were considered important determinants of the target behavior [37]. Instead, we decided to place more focus on the constructs less explored in previous research (eg. habit, goal accessibility, memory) and target those with sufficient intention concern about the issue in the first place by employing self-selection sampling. Therefore, the demographics of the study sample was very different from that of the general population – only 30% of the study participants were overweight or obese, compared with 61% of general adult population in England [44]; 100% of the participants had obtained higher education qualifications, compared with 42% of the UK working population [45]. The

demographics of this sample pointed to the possibility of better health-related knowledge and compliance to healthy lifestyle advice than the average population as indicated in previous research [46]. In addition, recruited from higher-education workplace settings, the participants were very supportive of research and tolerant of technological issues, which might not be the case for average office workers employed by other organizations with very different priorities on their agendas (eg. employer targets and financial profit). Therefore, future studies with more representative samples of office workers from a more diverse range of job roles and organizations especially in the private sector, is warranted to establish the broad acceptability of *WorkMyWay*. Finally, although the explicit mapping helps clarify causal assumptions and contributes to the identification of strong and weak mechanisms of action underlying specific BCTs, the primarily qualitative uncontrolled study design is not conducive to validating the causal pathways. Future studies can employ factorial [47] and "n-of-1" single-case designs [48] to test the effect of individual components on behavior. To this end, Table 4 can be used as a roadmap to link psychological constructs and underpinnings to specific technological components and BCTs.

The study reported in this paper is situated within the "feasibility" phase as per the MRC framework [18].The development of the *WorkMyWay* intervention has been in accordance with the UK Medical Research Council (MRC) guidance for complex intervention research [49], by following through the process of identifying and summarizing the best available evidence[16], developing a theoretical understanding that is likely to account for the process of change [37], theorizing the intervention in terms of the key BCTs and mechanisms, and involving the target recipients and stakeholders of the intervention before it was developed [17]. The current study suggests the interventional contents and technological approach of *WorkMyWay* are viable and it has great promise to become a successful behavior change intervention. Therefore, it is worth investing in further engineering and redevelopment work to improve the technology reliability. After that, pilot and formal RCTs with larger sample sizes and longer durations can be conducted.

Conclusion

Overall, this study has found the *WorkMyWay* a generally acceptable, highly promising, and potentially feasible intervention to reduce office workers' SB, given the technological issues can be fixed. The adherence and engagement rates were satisfactory and zero attrition was exemplary and notable for technology-based interventions. Participants valued the tracking, prompting and on-screen components and found the use of the overall system manageable. Promise for change is demonstrated by the significant improvement in several psychosocial determinants of regular break behaviors, corroborated by interview quotes highlighting both intended and unintended mechanisms of action. More technological development and engineering work on *WorkMyWay* is warranted for the system to fully deliver the BCTs (ie. higher quality and fidelity) and for all the BCTs to reach the participants (ie. higher exposure and dosage).

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[REMOVED FOR BLIND REVIEW]

Conflicts of Interest

None declared

Abbreviations

BCT: behaviour change technique
BLE: Bluetooth Low Energy
DBCIs: Digital Behavior Change Interventions
IoT: Internet of Things
JITAI: just-in-time adaptive interventions
LED: light-emitting diode
MRC: Medical Research Council
OSPA: occupational sitting and physical activity
RCT: randomised controlled trial
SB: sedentary behaviour

Multimedia Appendix 1

Questionnaires Used for Pre- and Post-Intervention Assessment

Multimedia Appendix 2

Debriefing Interview Guide

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Supplementary Files

Multimedia Appendixes

Questionnaires Used for Pre- and Post-Intervention Assessment.
URL: http://asset.jmir.pub/assets/5f047c55c266a7c4b4fb6ed814bc40e4.pdf

Debriefing Interview Guide.
URL: http://asset.jmir.pub/assets/d5fc452347a7e0c4f294aba87f4a1278.docx