Feasibility of using stopWatch smartwatch system for passive detection of cigarette smoking in the workplace

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ABSTRACT

Background: A number of different systems are available for passive detection of cigarette smoking, but few studies have reported the feasibility of using these in free-living conditions, and none so far have reported specifically on the feasibility of using these in workplace settings.

Methods: We conducted a feasibility study of using stopWatch, a smartwatch-based system for passive detection of cigarette smoking, in workers in the construction industry. Participants wore stopWatch for three days midweek at work. Some also wore for three days over a weekend at home. They also kept paper diaries of cigarettes smoked.

Results: Six cigarette smokers and two vapers were recruited. Mean number of cigarettes smoked per day was 6.1 and stopWatch detected on average 31% of these. Insufficient data were available for meaningful comparison of performance at work and home. No occurrences of vaping were detected as cigarette smoking by stopWatch.

Discussion: The percentage of cigarettes smoked detected by stopWatch was lower than previously reported in free-living conditions (71%). We identified a number of practical reasons for this, including not keeping the smartwatch battery properly charged, the stopWatch application not being restarted correctly after the battery ran flat, and participants not wearing the smartwatch correctly. We make recommendations for addressing these issues.

Conclusion: This is the first study of the feasibility of using a system for passive detection of cigarette smoking in a workplace setting. Several practical issues have been identified and recommendations made for improving the use of systems of this kind in future studies.

INTRODUCTION

In 2018, 55% of UK smokers stated that they intended to quit smoking, but only 61% were successful in quitting and staying smoke free¹. For people trying to quit, smoking cessation medications (e.g. nicotine replacement products, varenicline and bupropion) help control the background cravings to smoke, but are not as effective at reducing cue-induced cravings that can lead to individuals to relapse back to smoking^{2,3}. Environmental and contextual factors, including the presence of other smokers, being at home or at work, availability of cigarettes, and mood, all play a significant role in the likelihood of a relapse⁴.

Developments in Just-In-Time (JIT) behaviour change interventions offer the potential to help prevent smokers attempting to quit relapsing back to smoking². In one recent example, JIT support was triggered using a geofencing approach⁵. Smokers attempting to quit manually logged locations at which they smoked, then the smartphone system automatically detected when the person entered locations at which they had smoked previously (and likely to experience cue-induced cravings), and delivered support and feedback messages designed to help prevent relapse. The system was liked by participants but avoiding the need for the manual logging of smoking instances was identified as a potential improvement. Systems for passively (automatic) detecting cigarette smoking could automate interventions like this and provide low burden measurement of smoking behaviour and assessment of intervention effectiveness.

A range of methods for the passive detection of cigarette smoking have been reported⁶. One method, with the advantage that the user does not need to wear any bespoke sensing devices, is to use a commercially available wrist-worn activity sensor or smartwatch to detect the signature hand movement of cigarette smoking⁷⁻⁹. One such system is *stopWatch*. This system runs on a low-cost Android smartwatch, does not use any bespoke hardware, and does not need a data network connection or to be paired with a smartphone.

A preliminary examination of the ability of *stopWatch* to identify smoking occurrences was recently performed with 13 daily smokers in both laboratory conditions, and as the participants went about their normal daily activities (i.e. in free living conditions)⁸. In free-living conditions, the recall (percentage of cigarettes smoked detected by the system) was 71%, and the precision (percentage of events identified by the system as cigarette smoking that were actually cigarette smoking) was 86%. That initial investigation provided confidence that *stopWatch* can detect occurrences of cigarette smoking in free living conditions. To understand if systems like this could potentially be used in occupational environments, further testing of the more practical aspects of their use in robust workplace settings is required.

In this study we test the feasibility of using the *stopWatch* system for passive detection of cigarette smoking in a workplace setting. The original aims for the study were to both test the extent to which the system can distinguish between cigarette smokers, vapers, and non-smokers, and to explore the more practical aspects of using the system in a workplace study. Difficulties recruiting sufficient participants meant we instead focused on exploring the practical aspects of using the system in

studies in the workplace, and on making recommendations for optimising the use of *stopWatch* and similar systems in future smoking studies.

METHODS

Study Population

The study was conducted between February and April 2019 in South-West England. Participants were recruited from an international construction company. In order to be eligible for the study, current employees had to be current cigarette smokers, former cigarette smokers who vaped, or former cigarette smokers who did not vape.

Procedures

The researchers visited the company's offices and participants were provided with a LG G Watch smartwatch running Android Wear V1.5 operating system and the *stopWatch* smoking detection system. Participants were asked to wear *stopWatch* in free-living conditions for three continuous days during the week whilst at work. As participant numbers were low, they were also asked if they could also complete a weekend session while at home.

Participants recorded details of cigarettes smoked using a paper diary.

At the end of each testing period, participants were invited to provide qualitative feedback on their experiences using the *stopWatch* system.

Ethics approval for the study was obtained from the Faculty of Health Sciences Ethics Committee at the University of Bristol (ref: 78403).

RESULTS

Six cigarette smokers and two electronic vapers were recruited into the study. Half of the sample were male with a mean age of 43 years (range 31-55; IQR 12), and the mean age of females was 36 years (range 24-53; IQR 17). Participants reported working an average of 46 hours per week (range 30-60; IQR 7), and the mean number of self-reported cigarettes smoking events per day was 6.4 (range 0-17; IQR 1). All participants reported their current occupation as 'managers', two of whom described themselves as 'senior managers'.

For both vapers, no instances of vaping were classified as smoking events by *stopWatch*.

For the six cigarette smokers, all provided a dataset for a midweek three-day period while they were at work. Three participants provided weekend datasets.

In total three datasets (one weekend and two weekday datasets) had to be removed prior to analysis; two because application logs indicated *stopWatch* had not been operating throughout the test period, and one because the participant did not return the self-reported paper diary.

Table 1 presents the *stopWatch* and diary measurements for cigarette smokers. Across all datasets, the mean percentage of cigarettes smoked recorded in the diary that were detected by *stopWatch* (recall) was 31% (95% CI 13%-49%).

Spearman's Rank Correlation coefficients were computed to compare rank performance of the *stopWatch* and self-reported paper diary on different days. The coefficient between *stopWatch* and paper diary for day 1 was 0.71 (95% CI 0.15-1.27), for day 2 was 0.73 (95% CI 0.19-1.28) and for day 3 was 0.32 (95% CI -0.43-1.08).

Table 1: stopWatch and Diary measurements

Participant ID	Midweek/Weekend	Day 1: stopWatch	Day 1: Diary	Day 2: stopWatch	Day 2: Diary	Day 3: stopWatch	Day 3: Diary	% Cigs Detected
1	Midweek	2	6	6	14	0	15	23
2	Midweek	6	7	2	10	1	9	35
3	Midweek	0	1	4	9	0	5	27
4	Midweek	0	3	1	5	0	2	10
3	Weekend	5	6	5	13	1	8	40
6	Weekend	5	4	0	1	1	3	75

* stopWatch refers to the number of smoking events detected by the stopWatch

**Diary refers to the number of self-reported smoking events recorded by the participants in the paper diary

DISCUSSION

The overall performance of *stopWatch* across all setting in this study (recall of 31%) was lower than is a previous study (71%). From detailed logs from the *stopWatch* application, and our experience with the system, we identified three potential reasons for this. These were practical issues that will apply to any system of this kind, so we discuss these broadly here, then make recommendations for addressing these issues.

Firstly, it was observed from the log files produced by the *stopWatch* application that on many occasions' participants failed to keep the smartwatch battery charged. For two participants this affected their entire three-day midweek test session; for others, this affected occasional periods during their session. Smartwatches continue to have limited battery life, often needing charging daily. This contrasts with other wearable devices, such as activity sensors, that have longer battery lives and last many days between charges. The trade-off between the additional functionality and flexibility offered by smartwatches, and their poorer battery life, is likely to be an issue for some time. This is an important consideration in the workplace setting, where individuals will have limited time and a degree of organisation is required to make sure the charger is in the right place.

Secondly, on a number of occasions following a flat battery the *stopWatch* application did not relaunch correctly and so the system failed to record any smoking

events. After the battery of the LG G smartwatch used in this study runs flat it is necessary to reset the time and date before re-launching the *stopWatch* applications. Additional steps like this may not have been performed in the correct sequence by participants, and this would have prevented correct operation of the system.

Thirdly, we suspect that the way in which participants wore the smartwatch lowered sensitivity. *stopWatch* operates by using data from the motion sensors in the smartwatch to detect signature hand movements of smoking. If the smartwatch is worn too loosely, it will move around on the wrist, and this will prevent the motion-based detection algorithm operating correctly. In the original validation study participants came into a university setting to be provided with the smartwatch and instructions, whereas in the current study the watch and instructions were delivered in the workplace setting. This may have negatively influenced the extent to which participants attended to and complied with the instructions provided.

The pattern of Spearman Rank correlation coefficients observed over the three days, reducing considerably by the third day, indicates how the impact of issues such as these can accumulate over time to degrade performance of the passive detection system.

All participants were invited to take part in a short interview at the end of their test session to provide qualitative feedback. However, no participants completed the interview and we were therefore unable to collect participants' views on acceptability and experiences of using the *stopWatch* system.

Ideally, we would have compared the performance of *stopWatch* in workplace and home settings. Unfortunately, we did not have sufficient data for meaningful comparisons. Recruitment of participants was more difficult than expected. The host company had recently implemented no-smoking policies and provided a range of smoking cessation support initiatives for employees, and this may have reduced the number of employees willing and eligible to take part in this study. Possibly as a consequence of this, the cigarette smokers recruited were only moderate smokers, smoking on average just six cigarettes per day. This was lower than the initial study, in which participants had to smoke at least ten cigarettes per day⁸

RECOMMENDATIONS

1. Wearable device power issues

Make battery life a key consideration in device selection for studies. Also, ensure study documentation and participant briefings make clear that regular charging of devices is an essential part of the study (doing this overnight might be a good routine to suggest).

2. Ease of system restart

Make the process for re-starting any systems after an unexpected shutdown (e.g. when the battery runs flat) as automated, low burden, and robust as possible. Even

simple steps such as requiring the time and date be manually checked and set can be barriers in encouraging participants to correctly restart systems.

3. Instructions for use of system

Emphasise the importance of issues such as correct fitting of devices in study documentation and briefings. Provide easily accessible instructions for attaching the device (e.g. use brief video clips), in addition to a demonstration in person for each participant.

4. Completion of all study elements

Ensure study information makes clear all parts of the study, including qualitative feedback, are vital to the study. If offering incentives for the study, consider making completion of qualitative aspects a mandatory requirement for receiving these. Also consider methods for making completion of qualitative aspects as low burden as possible (e.g. using online questionnaires that can be completed away from the workplace).

CONCLUSION

To the best of our knowledge, this is the first study to explore the use of a system for the passive detection of cigarette smoking (in this case *stopWatch*) in a workplace setting. A number of practical issues have been identified and recommendations made for optimising use of systems like *stopWatch* in future studies, and for conducting future workplace-based feasibility studies of new behaviour measurement methods using wearable devices.

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COMPETING INTERESTS

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Care disclaimer: The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

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