Report for the Asthma and Respiratory Foundation of New Zealand

Developing a free open-source smartphone application for studying tobacco use in the field (observing smoking in vehicles)

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Summary

Aims: (i) To develop a free open-source application ("app") to enable on-going data collection of observed smoking in vehicles by many observers internationally; (ii) To briefly describe the development of this app and an accompanying website; and (iii) To make the framework and methodology freely available, so that the technology can be used for other purposes.

Methods: We developed specifications for a smartphone app that described the: (i) variables that the app would collect; (ii) transfer of data to an online repository; (iii) user interface (including visual schematics); (iv) processes to ensure the data authenticity from distant observers. App functionality was trialled by using it in roadside situations to collect data on smoking in vehicles.

Results: A smartphone app and accompanying website were developed, tested and released over a period of six months. The framework and methodology (including the source code for the app) have been made freely available online. Users who have registered themselves (and who met authentication criteria), have reported no significant usability problems to date. The framework, methodology and source code for this project are now freely available online and can be easily adapted for other research purposes. The app and website are currently in preparation for a wider promotion and release to a broader public for participation.

Conclusions: This project indicates that it is practical and feasible for health researchers to work together with Information Science researchers and software developers to create smartphone apps for field research relating to tobacco control. Such apps may be used to collect observational data more widely, effectively and easily than through traditional (non-electronic) methods.

Introduction

"Smartphones" are mobile phones with enhanced computing ability and interactivity. They are typically equipped with a high-resolution touch-screen and include a number of features such as: Global Positioning System (GPS), light sensors, accelerometers, gyroscopes and compasses. By the end of 2011, one-third of all mobile phones shipped worldwide were smartphones,[1] and they are owned by at least 43% of all mobile phone subscribers in the United States.[2] Applications ('apps') are software programs designed to run on smartphones. They can be used to collect data and transmit it instantaneously via the Internet, allowing for international studies at a low cost (compared to non-electronic methods). Additionally, the location of data collection can be quickly and accurately fixed. Systems are being developed to use smartphones for rigorous data collection from distant, relatively untrained observers for a wide range of science, including epidemiology and ecology.[3 4 5]

We have developed and refined manual (non-electronic) methods to gather data on the point prevalence of observed smoking in road vehicles.[6 7] The benefits of such data include: (i) providing an objective indicator of exposure to others of secondhand smoke in confined spaces, as vehicles are uniquely confined and 'private' but also publicly observable; and (ii) the ability to collect large amounts of data relatively quickly (eg, over 900 observations per hour).

However, limitations in the existing data on observed smoking in vehicles include that it has been explored in only three published studies (as of January 2012). Two of these were in the same setting (Wellington, New Zealand[6 7]) and the other was in Veneto, Northern Italy.[8] Given growing international interest in legislating against smoking in vehicles (and the need to evaluate such laws when they are passed), it is desirable to improve on time-consuming and fragmented manual methods of data collection. Hence we describe here the development of a smartphone app and an accompanying website to enable on-going data collection of observed smoking in vehicles.

Methods

We developed the initial specification and processes for the app and website. These described the planned functions and activities, including the: (i) variables that the app would collect; (ii) transfer of data from the app to an online repository; (iii) user interface of the app (this included visual schematics of the app); (iv) processes to ensure the authenticity of collected data (see Appendix 1 for initial project specifications).

We then contacted commercial and other software developers, not only to obtain time and cost estimates for the project, but also to understand the development processes involved. The development process (as outlined by a software developer) involved considerable dialogue between the developer and us. It included detailing the processes for app and website development, consultation with us to produce work specifications, making requested changes to the specifications, the initial development of an app on a single smartphone platform, tests by us of the app, changes or additions

of features using our feedback, a revision of the app and development of a website, further tests by us, and then the creation of apps for the targeted smartphone platforms (eg, iOS, Android, Blackberry, Palm and Symbian operating systems).

The software development has been conducted as a University of Otago (UoO) 'summer student' project (funded in September 2011). The research and development work has been conducted by two UoO research teams in Dunedin and Wellington, New Zealand that are over 500km apart. Due to difficulties in face-to-face communication between the research teams, the project has been managed and coordinated through a variety of telephone calls, online video calls and emails. The UoO software developer was provided with our initial specifications for the mobile app, together with the planned development processes as outlined above.

We then agreed on project specifications that were amended to better suit the technical expertise of the software developer and the time constraints of the summer studentship (five months). Based on these specifications, the developers provided an initial, functioning version of the app (sent online) for an Android smartphone. Initial testing of the mobile app has been conducted concurrently in Dunedin and Wellington.

One researcher (VP) then trialled the app (by using it to collect data on observed smoking in vehicles from the roadside) and provided feedback to the developers. The feedback focused on the app functionality and our experience of using the app. VP assisted with some of the design and user interaction elements of the project, by designing visual schematics for the app (see Figures 1 – 5 below).

At least six further iterations of the app were trialled, with subsequent iterations incorporating feedback (provided by both us and the software developers) on previous versions. The initial version (v1.1) of the mobile app was trialled by a number of researchers in Dunedin, to collect usage statistics and fine tune the internal application architecture. The first semi-public release (v1.2) has been installed in the Android Market upon completion of the summer studentship project in January 2012. The development of the website was beyond the scope of the summer scholarship and has been developed after the mobile app was already operational. The versioning of the website follows the protocols and versioning of the mobile app. The initial tests of the website user interface and functionality has been consulted and verified by a GeoSpatial researcher from UoO, Antoni Moore, and an Artificial Intelligence collaborator, Adrian Pearou.

Results

The resulting app

Creation of the app was a relatively smooth process with no major problems encountered. The main screens for the final app are shown in Figures 1-5.

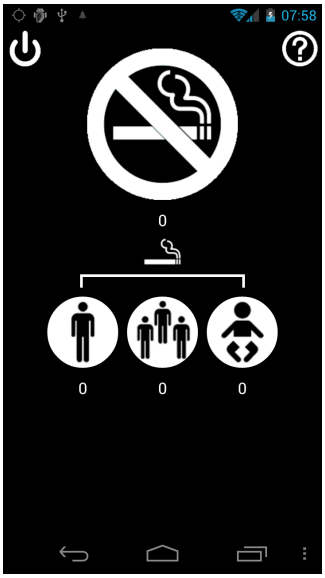
Figure 1: 'Home screen' for the app

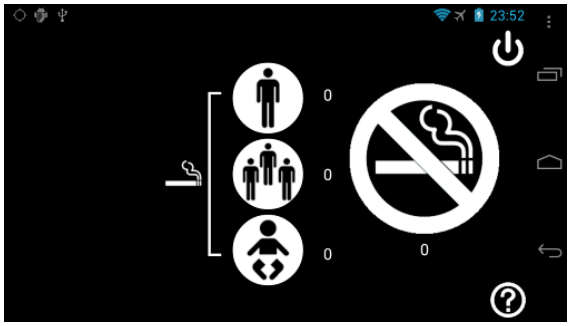
'Home' screen (equivalent to the homepage on a website). From top to bottom, the four buttons are:

- Record new data (leads to Figure 2)
- Stored data (leads to Figure 3)
- Upload data – sends collected data via the internet
- Preferences (leads to Figure 4)

Portrait and landscape modes for data collection are configurable by adjusting the orientation in which the smartphone is held. Additionally, landscape mode can be configured in either right or left-handed versions (in the Preferences screen; see Figure 4), which assign the three small circular buttons to the hand that is assumed to have the greatest dexterity. The function of the buttons is described below.

Figure 2: Data collection screens





The functions of the six buttons viewable in data collecting mode as seen in the *portrait* (left) version of Figure 2 are:

- On/off (top left): starts/ends the observation period.
- Question mark (top right): provides the observation protocol (leads to Figure 5).
- Four buttons to record data:
    - No other occupants (bottom left image of single person): pressed upon observing a car in which smoking occurs and there are no other occupants present
    - Other adults (bottom middle image of three people): pressed upon observing a car in which smoking occurs in the presence of other adult occupants (but no children)
    - Child ≤12 (bottom right image of infant): pressed upon observing a car in which smoking occurs in the presence of one or more children (there can be other adults as well)
    - No smoking (top centre large image): pressed upon observing a car in which there is no smoking

A 'click' sound is played when data recording buttons are tapped (pressed and then released), to help minimise accidental button presses (this function can be turned off). When data recording buttons are held for two seconds, an option is given to subtract one observation.

Figure 3: Stored data screen

Summaries of collected data can be viewed on this screen. From top to bottom, the four buttons provide options to: (i) email selected, (ii) email all, (iii) delete selected, or (iv) delete all data observation periods.

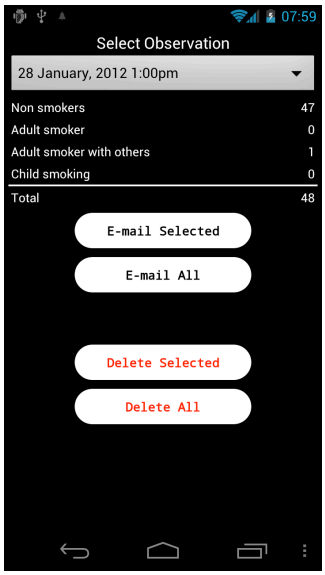


Figure 4: Preferences screen

From top to bottom, this screen shows various options for data recording:
1. View instructions (leads to ‘Figure 5’ page)
2. Activate either left or right handed data collection modes
3. Turns button press sounds either off or on
4. Enter user account details
5. Provide feedback (which is sent to the app developers)

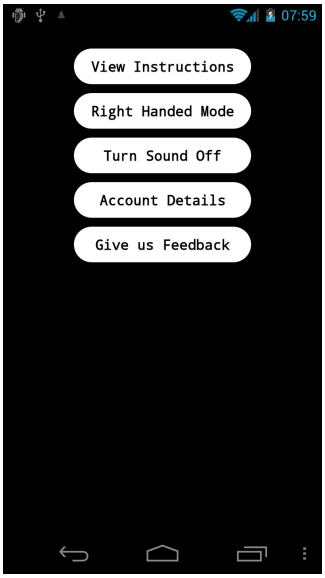


Figure 5: Instructions and guidelines for data collection

Access to the app
The final app (to record data on smoking in vehicles) for Android smartphones can now be downloaded at the Android Market website: https://market.android.com/details?id=nzdis.tobaccofree. This is best done from the smartphone, by visiting the online "Android Marketplace" and could be done via a computer if a user is logged in with their Google Android account. Once installed, a username and password need to be entered in 'Account Details' from the preferences menu.

Data authentication
To ensure data authenticity (by distant and/or unknown observers), we planned to limit usage of the app to a members of a trusted, third-party website. However, this was found to be unfeasible for technical reasons. Therefore, we developed a website (http://tobaccofree.nzdis.org) to accompany the app. For observers to send data to the website, they must: (i) register at the website (and supply a username, password and credentials including their affiliation details); (ii) have their registration authenticated; and (iii) enter their username and password into 'Account Details' on the Preferences screen (unregistered/unauthenticated users are still able to collect data for their own purposes).

Data transfer and storage
Authenticated users are able to send data to the above named website by connecting to the internet, using either a cellular data network or a wireless internet network (Wi-Fi). Once sent, data are automatically stored and displayed on the website. Future analysis of the collective data will consider statistical identification of outlier results – for potential removal in summary statistics.

Usability of the app
The app was found to be usable by members of the research team (VP, HM, MN) and external volunteers who performed trials. Registered and authenticated users include 10 people external to the project and three internal to the project (the project has not yet been widely promoted). Data have been collected by four of these users, with no reported usability problems. One registered and authenticated user did suggest that instructions for data collection could be clearer.

Further development of the app
At the above named website, there is a link to a technical website (see: https://github.com/marni/NZDIS-TobaccoFree). This website contains the open-sourced code for the app (computer code in the form of text that constitutes the app, and from which the app can be 'reconstituted'). The code is released to the public under the Apache Open Source Licence version 2. Thus, the source code can be used as the basis for further refinements to the existing app, or to modify the app for other usages (eg, other observational data such as observed mobile phone use).

Discussion

This project indicates that it can be practical and feasible for health researchers (without software development skills) to work with software developers to create apps as data collection tools for field work in tobacco control.

Quality of the method and results

While we were fortunate to have the software development of this project incorporated into a 'summer student' project, the alternative of employing commercial software developers could also be considered. It may have been quicker to work with commercial developers, who may have been able to allocate their entire workload to the project. It may also have been useful to have received input from relevant professionals with extensive and particular experience in developing the design and user experience of smartphone apps. Against these potential benefits, commercial developers are likely to be more expensive, and less willing to open-source the software code developed. Additionally, certain aspects of the software development arrangement with a commercial software developer would then need to be handled by the health researchers themselves. These include aspects of user authentication, management of data credibility, and the internal representations of the data structures. Also, future refinements which address open research questions, such as verifying and ranking the credibility and accuracy of data recording, and assessing observer honesty/ bias.

To ensure the authenticity of collected data, we planned to integrate our app with a trusted third-party website. However, this was not feasible, so we developed our own website to provide this authentication functionality at a relatively late stage in the overall project. While this latter method is perfectly functional and ultimately more accessible (to potential data collectors), in hindsight it would have been prudent to determine whether integration into the third-party website was possible at a much earlier stage of the development process.

Implications for research and further research

This study indicates that the development of smartphone apps may be a practical avenue to facilitate and/or improve the collection of standard data over a wide range of settings and different data collectors. By making the framework and methodology freely available online, we hope to encourage the use of this technology for other research purposes.

Using an app to collect observational data may provide greater efficiency than traditional (non-electronic) methods. In particular, data collected by many distant observers can be transmitted instantaneously to an online repository. The use of the app may also help ensure that data *recording* (as opposed to observation) is accurate.

The three main areas for further research for this particular app are: making sure that the data is collected reliably (unknown observers are not cheating the system), making sure that the models for the occurrence of smoking in cars follows some assumed Poisson distribution; and ensuring that statistics based on the collected data has a reasonable error rate.

A further refinement is to include instruction on the training and testing of observers (eg, through an online video tutorial), to reduce observer error, and to provide measures of inter-observer variation. For our particular observations, the most subjective aspect of the observation is the judgement of whether or not the observed children are aged 12 years or younger. So, for instance, information could be included on improving the accuracy of observers by training with photos of youth of known ages.

In the case of data collection on observed smoking in vehicles in public settings, the ethical issues (data or observer safety) appear relatively minimal to us. This is given the lack of identifying data collected, and the low likelihood that observers will be confronted. Furthermore, the data collection relates to an important public health issue, where improving interventions such as campaigns and laws can help reduce the harm from secondhand smoke exposure to non-smoking adults and children. Nevertheless, there are some situations (eg, counting smokers in hospitality venues) where it may be necessary to be more mindful of issues around ethics and observer safety.[9] Indeed, ethical approval from national bodies may be appropriate for some types of observational data collection. It is also ideal if there are systems developed that allow for international bodies to provide ethical oversight for such international data collection systems.

Policy implications

More effective and efficient data collection methods may enable wider, quicker, more accurate and cheaper monitoring of policy changes, such as before and after: law changes, publicity campaigns, smoking bans, car smoking bans and tobacco price increases. Even the effectiveness of bans on cell phone use while driving could be monitored with apps such as this (by roadside observers).

Acknowledgements

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Appendix 1: Project specifications (as provided initially to software developers)

The research aims to develop and trial a smartphone app to enable data collection on smoking in vehicles by many observers at many observation sites internationally. The relevant steps in the methods are:

(ii) Develop (a) a smartphone app and (b) an accompanying website in collaboration with a software developer.

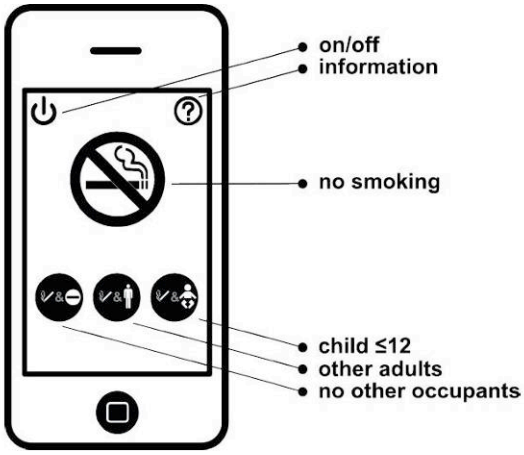
We will first iteratively develop the specifications and processes for both the app and the website as thoroughly as possible, prior to engaging a software developer.

A) Smartphone app development

The app will collect the following data points for each period of observation:

- Observer's and unique ID code (for registered observers)
- Site location (geographic coordinates from the smartphone)
- Observation start and end times
- The total number of vehicles, and of those with observed smoking, the numbers with:
  - Single occupants
  - Other adult occupants
  - Children ≤12

Figure 1: Diagram showing the preliminary layout of the app on a phone screen



We plan for the app to automatically send the above data in the following spreadsheet format to an (online) repository.

Figure 2: Table showing proposed format of spreadsheet for each period of observation by a single observer.

Unique code	Site location	Start	End	Number of vehicles	Cars with observed smoking		
					Total number	Other adults	Children ≤12
XYZ456	-41.310226, 174.782963	7:32:45	9:12:47	2545	114	16	2

Observation protocol:
In the data collection mode, there are six buttons on the app:

- On/off: starts/ends the observation period.
- Information: review the observation protocol (operational only prior to observation)
- No smoking: pressed upon observing a car in which there is no smoking
- No other occupants: pressed upon observing a car in which smoking occurs and there are no other occupants present
- Other adults: pressed upon observing a car in which smoking occurs in the presence of other adult occupants (but no children)
- Child ≤12: pressed upon observing a car in which smoking occurs in the presence of one or more children (there can be other adults as well)

Site selection criteria include: low traffic speed and good visibility of vehicle occupants (at vehicle speeds above 60kmph, accurate observation is difficult); location (to permit sampling of a representative population); high traffic flows.

Definition of smoking: one or more people within a motor vehicle holding a cigarette, pipe or cigar in their hand.
Definition of children: occupants appearing to be aged 12 years or younger.

Sampling frame*:* Include cars, taxis, courier vans and utility vehicles, and exclude buses, all trucks and vehicles where it is impossible to see inside (for instance those with heavily tinted windows).

B) Website development

The website will comprise: (a) a homepage describing the research/data collection process; (b) registration page.