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Contents

Short Papers

Viewpoint

Review

Mobile Technologies and Geographic Information Systems to Improve Health Care Systems: A Literature Review

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Abstract

Background: A growing body of research has employed mobile technologies and geographic information systems (GIS) for enhancing health care and health information systems, but there is yet a lack of studies of how these two types of systems are integrated together into the information infrastructure of an organization so as to provide a basis for data analysis and decision support. Integration of data and technical systems across the organization is necessary for efficient large-scale implementation.

Objective: The aim of this paper is to identify how mobile technologies and GIS applications have been used, independently as well as in combination, for improving health care.

Methods: The electronic databases PubMed, BioMed Central, Wiley Online Library, Scopus, Science Direct, and Web of Science were searched to retrieve English language articles published in international academic journals after 2005. Only articles addressing the use of mobile or GIS technologies and that met a prespecified keyword strategy were selected for review.

Results: A total of 271 articles were selected, among which 220 concerned mobile technologies and 51 GIS. Most articles concern developed countries (198/271, 73.1%), and in particular the United States (81/271, 29.9%), United Kingdom (31/271, 11.4%), and Canada (14/271, 5.2%). Applications of mobile technologies can be categorized by six themes: treatment and disease management, data collection and disease surveillance, health support systems, health promotion and disease prevention, communication between patients and health care providers or among providers, and medical education. GIS applications can be categorized by four themes: disease surveillance, health support systems, health promotion and disease prevention, and communication to or between health care providers. Mobile applications typically focus on using text messaging (short message service, SMS) for communication between patients and health care providers, most prominently reminders and advice to patients. These applications generally have modest benefits and may be appropriate for implementation. Integration of health data using GIS technology also exhibit modest benefits such as improved understanding of the interplay of psychological, social, environmental, area-level, and sociodemographic influences on physical activity. The studies evaluated showed promising results in helping patients treating different illnesses and managing their condition effectively. However, most studies use small sample sizes and short intervention periods, which means limited clinical or statistical significance.

Conclusions: A vast majority of the papers report positive results, including retention rate, benefits for patients, and economic gains for the health care provider. However, implementation issues are little discussed, which means the reasons for the scarcity of large-scale implementations, which might be expected given the overwhelmingly positive results, are yet unclear. There is also little combination between GIS and mobile technologies. In order for health care processes to be effective they must integrate different kinds of existing technologies and data. Further research and development is necessary to provide integration and better understand implementation issues.

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Introduction

The proliferation of mobile phones has provided a powerful communication channel to strengthen health information systems. Functional and structural properties of mobile phones, such as low start-up cost, text messaging, and flexible payment plans, make them attractive to use for contacts with patients in various health care processes. Often they are used to disseminate information to patients, but when used in conjunction with health care–related software apps, they can also provide real-time feedback needed to monitor treatment compliance or effect, and also serve as data collection tools. Further, back-end systems connected to mobile phones have the capability to serve as a platform for enabling preprogrammed, portable, automated services, which can make health care, and health information systems, increasingly decentralized.

Today, there is a lot of effort put into using mobile communication to improve various processes in health care, preventive as well as reactive. This is done in many ways, for example, by keeping doctors and patient better in touch (eg, by reminder systems), by keeping local health care centers in better touch with central hospitals (eg, by local doctors sending images for expert analysis), but also by providing preventive health information so as to decrease the number of people who become patients (eg, by support in leading a more healthy life), and providing better statistics so as to better plan actions and resource allocation in the health care system, such as, in conjunction with natural disasters or epidemics.

Many, if not all, of the systems used for the above purposes require backend systems, or will at least perform better if they have such. For instance, reminders to patients about visiting the doctor or taking their medicine must be integrated with a patient record so as to avoid a huge amount of manual labor. A text messaging (short message service, SMS) system for reporting cases of HIV/AIDS at a local health care center to a central hospital should be integrated with some apps for producing statistics and informing relevant actors about the development; for example, the developments of the number and the nature of cases at different care centers might vary over time that may require redistribution of resources so as to provide effective care. More generally, to be effective with respect to all stakeholders in health care, data collection systems should be technically integrated with systems for communication and decision making. As there is much health care data around, and many variables involved in making good decisions, medical as well as administrative, spatial, and economic, there is a need for effective data handling, analysis, and presentation. For instance, health data from various regions in a country could be presented in geographic information systems (GIS) so as to provide better means of communication to decision makers. It may make it easier to understand data by using graphical presentation, and it may make it easier to analyze data as they can be coupled with other data (eg, regarding population, geography, and economy), which may distinguish different regions from each other. Taking all such factors into consideration may be necessary for the purpose of optimizing the allocation of available health care resources across a country and making sure effective methods are used everywhere.

This research, therefore, looks into both technologies employed in operative processes of health care, the mobile phones, and technology aimed at providing support for decisions, the GIS, within health care. The study searches for cases where the two types of technologies are integrated and, based on the assumption that the integration would generally be as low as technology is relatively new, for clues to how best do this integration; what are the needs and the potential gains?

The purpose of this article is to provide a review of literature related to the use of mobile technologies and GIS in health-related research for improving health care. The major topics for the review are the use of mobile technologies and GIS to improve health care. The research questions that served as the basis of this literature review are:

1. What is the geographical distribution of publications on mobile technologies and GIS?
2. How have mobile technologies and GIS been used to improve health care?
3. What were the effects associated with the use of mobile technologies and GIS?

Methods

Search Criteria

This is a literature study aiming at identifying the state of the art in mHealth, use of mobile phones for communication with patients, and GIS as well as research gaps. A thorough search in prominent databases was conducted using predetermined keywords. The search targeted articles written in English and published in 2005 or later. The year 2005 was chosen because the literature on interventions using mobile technologies has increased substantially over the past few years, and apps before 2005 are not only rare, but would also be expected to be tentative in nature as mobile technology was generally less mature at that time, as concerns end user units as well as networks. Papers found were screened for relevance (ie, to confirm that they reported the use of mobile technologies or of GIS, leaving a resulting set of papers for full-text eligibility assessment.

Search Strategy

Articles were systematically identified through a combination of computerized database searches and manual searches of the reference lists in relevant articles found. The databases PubMed, BioMed Central, Scopus, ScienceDirect, and Web of Science were used. The search was restricted to studies reported in English-language journals and indexed with the following keywords: cell phone, mobile phone, SMS, text message combined with health; and GIS combined with health. The search was restricted to title and abstract fields, to avoid retrieving articles, which were not focusing on these things yet mentioned the terms.

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Exclusion/Inclusion Criteria

The following criteria were used for inclusion/exclusion of articles: (1) the literature review concentrates on research published from 2005 to 2012 (the first search was in December 2012 and the last in April 2013), (2) the study excluded research published before 2005 and also excluded non-English language publications, (3) articles had to be published in peer-reviewed journals and conference proceedings, and (4) articles addressing the use of mobile technologies had to use uni/bidirectional communication. Further, we only included articles where data could be extracted or, at a minimum, where the abstract was available.

Results

Search Results

The initial combined database search yielded 3376 articles (Figure 1). A title and abstract review was conducted, from which we identified 271 articles that met the eligibility criteria.

Given the large sample size, we further analyzed these articles and organized them into the following categories: mobile technologies: (1) treatment and disease management (n=34), (2) data collection and disease surveillance (n=29), (3) health support systems (n=38), (4) health promotion and disease prevention (n=50), (5) communication to or between health care providers (n=60), and (6) medical education (n=9). GIS: (1) disease surveillance (n=12), (2) health support systems (n=12), (3) health promotion and disease prevention (n=19), and (4) communication to or between health care providers (n=8). Of note, some papers sometimes overlapped in different categories, but we categorized them based on the technology use's primary purpose. For example, if the technology was aiding patient care via telediagnosis, then we placed the article in the category of communication.

Geographical Distribution of Publications

In terms of geographical spread of publications, Table 1 indicates that the highest number of publications were from developed countries.

Figure 1. Article selection process.
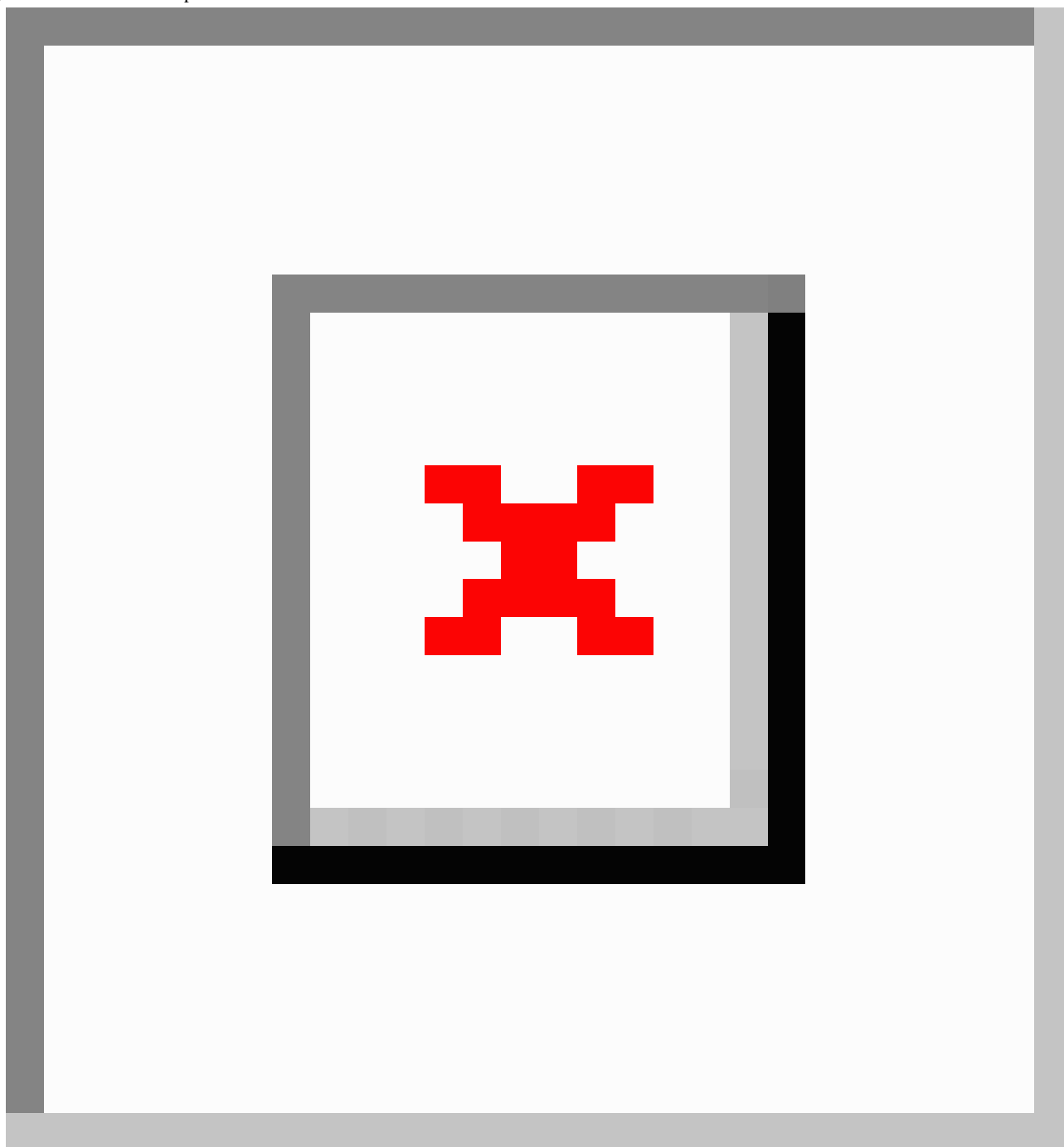
Table 1. Geographical distribution of publications between 2005 and 2012.

Country	Number of papers
Angola	1
Australia	8
Austria	4
Brazil	3
Cameroon	1
Canada	14
China	7
Congo	1
Croatia	1
Denmark	2
France	5
Germany	1
Ghana	1
Greece	1
India	10
Iran	1
Ireland	5
Israel	4
Italy	3
Japan	4
Kenya	12
Korea	11
Malaysia	3
Mexico	1
New Zealand	7
Nicaragua	1
Norway	5
Peru	9
Saudi Arabia	2
Singapore	2
South Africa	3
Spain	2
Swaziland	1
Sweden	2
Taiwan	2
Tanzania	2
Thailand	2
the Netherlands	6
Trinidad and Tobago	2
Uganda	3
UK	31
USA	81

Country	Number of papers
Vanuatu	3
Zambia	1
Total: 44 countries	271 papers

Research Findings by Category

Treatment and Disease Management

Interventions related to treatment and management focused on investigating patient adherence to treatment (eg, visiting a doctor as planned) [1-6], adherence to medication [7-13], and disease management (particularly for diabetes [14-23] and asthma [24-26]), including coordinated health care interventions between health care providers and patients using communication technologies (mobile phone-based apps and SMS) for patients self-care of chronic diseases. The literature contains 28 cases with sample sizes ranging from 25 to 424. The interventions are described in Multimedia Appendix 1. Interventions in both developed countries (United States [1,16,17,22-24,27-31], Ireland [2,11], United Kingdom [5,25,26], Denmark [6], Spain [9], France [10], the Netherlands [12,13], South Korea [14,18,32], Austria [19], and Canada [20,33]), and developing ones (Peru [7,8], Kenya [3,34], Cameroon [35], and Brazil [36]) have explored the use of mobile phone-based software, voice and SMS, and personal digital assistants (PDAs). In these interventions, the technology was used to send automated reminders to patients, either by voice or text messages. In addition to reminders from health care units to patients, health care units may receive text message from patients.

In interventions regarding adherence to treatment and to medication, mobile technologies were used to send reminders so as to improve antiretroviral therapy (ART) in HIV-infected adolescents [1]; send at least one medication-specific dosage reminder for a chronic oral medication [31]; measure asthma medication use and symptoms [30]; and to reduce out-patient clinic nonattendance [5]. Reminders were sent 3 days prior to patients' out-patient clinic appointment [2]; to HIV-positive patients with support content and enquire into how they are doing [3]; to patients to take their anti-asthmatic medication [6]; to soldiers to take their malaria chemoprophylaxis [10]; to patients to take antidepressant medication [11]; to patients with type 2 diabetes to take their oral antidiabetics [12,13]; to patients to take their oral antipsychotic medication [9]; and to take medications and provide additional support [34]. In addition, reminders were sent with instructions to patients reminding them to apply their morning and evening topical acne medication [28]; to support antiretroviral medication adherence [7,8]. Thus, motivational text message were sent to HIV-positive adults for adherence to ART [35]. In some interventions, patients received reminders 30 minutes before patients' last scheduled time for a dose of medicine during the day [36]; received reminders and were asked to acknowledge receiving their messages after taking the vitamins [33], and were required to send event-based messages whenever they experienced asthma symptoms or took asthma rescue or controller medications, and they received time-based messages daily that prompted for a response about asthma medications or symptoms [37].

For disease management, interventions focused on the use of mobile phone-based apps and SMS. Interventions using mobile phone-based apps used the technology to transmit blood glucose levels using a mobile phone with a glucometer integrated into the battery pack on management of type 2 diabetes to the Internet-based glucose monitoring system [14]; transmit blood glucose meter readings using a mobile phone with a glucometer integrated to the Internet-based glucose monitoring system [22]; transmit blood glucose levels to secure servers and receive real-time feedback [27]; and transmit blood glucose values, diabetes medications, and lifestyle behaviors to a remote server and receive real-time educational and behavioral messaging [23]. The same apps are also used to transmit peak flow reading and symptom score to secure server with immediate feedback of control and reminder of appropriate actions in supporting asthma self-management [25,26], and transmit diabetes-related data with synchronization to the remote database at the monitoring center [19]. The SMS function was to send personalized medication, and appointment reminders and text messages were received from patients on adherence [16]; send tailored daily messages prompting patients with type 2 diabetes to enhance their diabetic self-care behavior [17]; send peak flow reading each day to a Web server and receive a text reminder if they did not send it by 11 AM [24].

In these interventions mobile phone-based apps and SMS were found to be acceptable to patients [11,16], practical and acceptable [1], feasible [10,16,17,24], effective [9,14], and cost-effective [5,19,38]. Patients had positive perceptions [6,8,15,19-21,25], positive impact on some clinical outcomes (eg, medication taking) [17,18,23,26,27], and were highly satisfied [32]. These apps and SMS improved patient adherence to medication [12,18,31,34], and to health behavior (taking vitamin C for preventive reasons) over a 1-month intervention [33]; and they also assisted in preserving higher rates of adherence over time [31]. In addition, their use increased adherence of HIV-infected women to ART drug-based treatment regimen [36], increased adherence to asthma-preventer inhaler [37], and significantly improved self-reported adherence to ART [29]. In particular, SMS reminders are a simple and cost-effective way to improve nonattendance [2]; and provided an ubiquitous, easy-to-use, and cost-efficient solution to assist diabetes patients on intensive insulin treatment [19].

SMS were not associated with significant differences in adherence to topical medications in patients with mild to moderate acne and had no significant effect on therapeutic response [28]. They also did not significantly improve adherence to ART [35].

In most cases, in the above literature, the mobile phones were used to send messages from a health care center to patients, most commonly reminders for taking medicine, visiting the doctor, etc. In some cases there was integrated data collection,

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for example, by integrating a glucometer into the battery pack on management of type 2 diabetes or transmitting data on asthma symptoms.

In 11 cases, the front-end mobile system was connected to some back-end system. Most commonly this was done by sending automated reminders based on some database (eg, with data collected from patient records) but in some cases also incoming data (from patients) were automatically inserted in a database, such as, into an Internet-based glucose monitoring system.

Data Collection, Reporting, and Disease Surveillance

On this topic the survey found 28 studies using mobile communication technologies with samples ranging from 8 to 648 participants, and eight studies using GIS technologies. The interventions are described in Multimedia Appendices 2 and 3. Interventions using mobile communication technologies in both developed countries (Sweden [39], Norway [40,41], USA [42-45], Germany [46], Canada [47,48], UK [49,50], Austria [51], Japan [52,53]), and developing ones (Ghana [54], Kenya [55-57], Peru [58-60], Angola [61], Swaziland [62], Malaysia [63], India [64,65], Iran [66], China [67]) have investigated the use of mobile phone-based apps, mobile phone functions (SMS and voice), and PDAs. In these interventions, the technology was used to collect or report health data (eg, influenza vaccination, tuberculosis, and HIV) and for disease surveillance (eg, tracking infectious disease, communicable disease, and respiratory infections).

For interventions using the SMS and or voice functions of mobile phone, one [54] evaluated the acceptability of using SMS for reporting postpartum hemorrhage data; one [39] compared the feasibility of using SMS and telephone in collecting self-reported data about influenza vaccination; two [62,63] evaluated the effectiveness of using SMS, the first for delivering laboratory results and the second for patients' weekly symptoms reports. In addition, one [45] investigated the feasibility and acceptability of using two-way SMS texts communication to collect situational assessment data; one [64] provided a quantitative evaluation of data entry accuracy using SMS when compared with Internet and voice; one [65] investigated the effectiveness and efficiency gains in using mobile apps for detecting disease outbreaks in near-real-time; and one [49] tested the reliability, validity, acceptability, and practicability of SMS messaging for collecting patients' infant feeding method and future feeding plans.

For interventions using PDAs, two studies [40,55] evaluated acceptability, two [40,55] data quality, one [55] usefulness, one [59] efficiency, three [46,56,60] effectiveness of a PDA-based system compared with paper-based system; one [40] assessed how PDAs performed as collection tools of patient-reported outcomes in clinical research compared to pen and paper diaries in terms of feasibility, protocol compliance, data accuracy, and subject acceptability. In addition, one [41] compared daily and weekly registrations of self-reported health status measures between PDA and paper-pencil (PP) format regarding scores, variation, and feasibility; one [42] feasibility of using PDA-based system for tracking and analysis of food intake for pregnant women; one [43] compared the completeness of data collection using a paper and PDA-based system. Other studies,

assessed feasibility and patient acceptance of PDAs for collection of health data [68]; one [58] evaluated the quality of data on sexual behavior data collected with PDA-based system in comparison with paper-based questionnaires; and one [61] explored the acceptability of PDA for HIV/AIDS data collection and to identified potential barriers to acceptance.

For interventions using PDAs the technology was used to send individual's usual food intakes to registered dieticians for analysis [52,53]. Some benefits of using PDA-based system or mobile phones (voice and/or SMS) include improved data quality [56,65], improved data completeness [43,56], reduction in staff work hours [59,60], led to reduction in processing time [60], reduced errors in data entry [60], positive feedback from users [41,58], and lower number of inconsistencies and missing values [58,62]. In addition, some studies have adopted the use of open-source tools, which contributes to cost effectiveness [58,60]. Mobile phones were also found to be a useful tool for communication in conjunction with infectious disease surveillance in areas hit by natural disasters [67].

Disease surveillance is a field where GIS technology has been much used. GIS for disease surveillance is an epidemiological practice that monitors the spread of disease in order to establish patterns of progression. Examples of diseases having been monitored in both developed countries (Canada [69], France [70], US [71,72], the Netherlands [73]), and developing ones (South Africa [74], Nicaragua [75], India [76], Vanuatu [77], Congo [78], Trinidad and Tobago [79]) using GIS include injury [74], respiratory and acute gastrointestinal illness [71], HIV/AIDS [72,73,76,78], malaria [77,80], rabies epidemic [79], dengue fever [75], West Nile virus [69], and communicable disease [70]. In these interventions, GIS contributed to assessing visit rates for common illnesses in a defined community and identified spatial variability over time [71]; provided an effective and efficient operational tool for rapidly defining spatial distribution of malaria [77]; provided a useful tool to track trends in HIV incidence, HIV prevalence, and related risk behavior in a vulnerable population of women [72]. In addition, GIS provided a tool for analyzing risk factors that increase HIV infections [78], to accurately identify areas with high incidences of mosquito infestation and interpret the spatial relationship of these areas with potential larval development sites, such as garbage piles and large pools of standing water [75]. GIS also facilitated the collection, localization, management, and analysis of monitoring data; it also allowed for the display of the results of analysis on maps, tables, and statistical diagrams [69]; and supported key elements of surveillance-response, including understanding epidemiological variation within target areas, implementing appropriate foci-specific targeted response, and consideration of logistical constraints and costs [80].

Health Support Systems

On this topic, the survey found 38 studies using mobile communication technologies with samples ranging from 5 to 5800, and 26 studies using GIS technologies. The interventions are described in Multimedia Appendices 4 and 5. Interventions using mobile communication technologies in both developed countries (Norway [81,82], France [83], UK [84-89], Spain [90], US [91-97], Sweden [98], Greece [99], the Netherlands

[100], Italy [101], New Zealand [102-104], and South Korea [105]), and developing ones (Saudi Arabia [106], Tanzania [107,108], Peru [109-111], South Africa [112], Uganda [113], China [114,115], Trinidad and Tobago [116], Kenya [117], India [118]) have investigated the use of mobile phone-based apps (six studies); mobile phone functions (SMS, 20 studies), voice (three studies) and multimedia messaging service (MMS; two studies), and PDAs (10 studies).

Mobile phone-based apps were to design a mobile dietary management support system for people with diabetes [81], develop a smoking cessation support system [86], and support type 1 diabetes self-management [99]. These apps were also designed to support self-care process for patients with both diabetes and cardiovascular disease [116], and help individuals with weight problems to lose or maintain weight [93].

SMS-based technologies were used to integrate with an electronic medical record system on nonattendance rates in outpatient clinics [106]; support antimalarial stock management [107]; provide real-time collection and transmission of adverse events related with metronidazole administration for treatment of vaginosis among female sex workers [110]; provide tailored and stage-specific cessation messages to college smokers [94]; and provide on-going behavioral reinforcement for HIV-positive men who have sex with men [97]. In addition, the technology was used to develop a staff recall system for use after mass casualty incident [91] and to develop a support system to enhance self-efficacy, facilitate uptake of intensive insulin therapy and improve glycemic control in pediatric patients with type 1 diabetes [85]. The technology was also used to improve smoking cessation rates [87]; improve pain reporting, pain measurement, and adequate pain therapy for patients with cancer [100]; promote blood glucose monitoring [92]. Additionally, they were used to deliver tailored smoking cessation advice [88,96]; deliver individualized pharmaceutical care for medication compliance and safety [114]; deliver an automated support to young people with diabetes [89]; to collect, verify, and manage data on HIV/AIDS stigma and pregnancy in a rural area [117]; and transmit medical data collected and home by health care professionals [101].

PDA-based technologies were used to develop a PDA-based electronic system to collect, verify, and upload bacteriology data into an electronic medical record system [109]; develop a wireless clinical care management system [108]; and develop a data collection/entry system for public surveillance data collection [115]. In addition, they were used to display audio-visual animation for patient education in a clinical setting [84]; for medical professionals to access a centralized database system of patient data [105]; to assist tuberculosis-control programs to trace patients who interrupt treatment [112]; collect data from HIV patients and to support antiretroviral adherence [111]; and for dietary self-monitoring in patients with type 2 diabetes [95].

The use of mobile phone-based apps as health support systems doubled the self-reported quit rate in the short term [86] and improved patients' self-management of type 1 diabetes mellitus [99]. The use of mobile phone functions (SMS, MMS, and voice) showed a positive effect on the reduction of the nonattended appointments [106]; provided visibility of antimalarial stock levels to support more efficient stock management [107]; was feasible, safe, did not alter quality of life, and was associated with a trend toward improved metabolic control [83]. The technologies also rapidly mobilized sufficient numbers of anesthesia personnel in response to a mass casualty incident [91]; improved self-efficacy and adherence to uptake of insulin therapy [85]; significantly improved smoking cessation rates [87]; provided patients with rapid, effective medication guidance and pharmaceutical care after discharge [114]; proved to be a productive channel of communication to promote behaviors in overweight adults [93], and was potentially efficacious and easily disseminated method for providing smoking cessation interventions to young adult smokers [94].

The use of PDA-based technologies as health support systems significantly decreased delays in processing and errors with a positive user experience [109]. They provided a fast and efficient data communication mechanism [105]; were a useful and user-friendly medical decision support system for nurses in home care [98]; showed promise as a tool for assisting those with type 2 diabetes in their efforts to manage their disease [95]; and reduced or eliminated data entry errors, performed better in timeliness of receipt and data handling that PP and provided a cost-effective alternative to the paper-based [115].

Interventions using GIS technology in both developed countries (Australia [119,120], UK [121], US [122,123], Canada [124,125], France [126]), and developing ones (Zambia [127], Vanuatu [77,128], Mexico [129], Saudi Arabia [130]) have used the technologies to identify optimal settings for cancer prevention and control [131]; deployment, monitoring, and evaluation of entomological interventions for malaria control [127]; assess environmental exposure [122]; share disease information [124]. Additionally, the GIS was used to support public health decision making for end-stage renal disease [126]; support malaria elimination [77,128]; estimate population catchment area around specific health services in rural and remote areas [125]; prevention and control of vector-borne diseases [129]; and evaluate the spatial distribution of hospital demand and for defining hospital service area [130].

The use of GIS has enabled detection of spatial trends of parasite prevalence following extensive deployment of front line vector control interventions; improved the tracking of entomological indicators: species characterization and insecticide resistance status, including falciparum malaria parasite prevalence and impact assessment of insecticide treated nets and indoor residual spraying (IRS) [127]. GIS was found to be a useful tool in displaying environmental risk factors and potentially associated health effects [122]; enabled cross-border visualization, analysis, and sharing of infectious disease information through interactive maps and/or animation in collaboration with multiple partners via a distributed network [124]; and provided an effective and efficient operational tool for rapidly defining the spatial distribution of target populations in designated malaria elimination zones [77]. In addition, it has empowered program managers at the provincial level to implement and asses the IRS intervention with the degree of detail required for malaria elimination [128]; and helped health planners on evaluating the spatial distribution of hospital demand and for defining hospital

service area [130]. In special, using online analytical processing (OLAP)-GIS decision support system, tasks were completed more efficiently, with a higher rate of success, and with greater satisfaction [123].

Health Promotion and Disease Prevention

On this topic, the survey found 48 studies using mobile communication technologies with samples ranging from 5 to 5800, and 60 studies using GIS technologies. The interventions are described in Multimedia Appendices 6 and 7. Interventions using mobile communication technologies in both developed countries (US [132-154], Norway [155], Ireland [156,157], the Netherlands [158,159], Austria [160], New Zealand [161,162], Australia [163-165], and South Korea [166,167]), and developing ones (Kenya [168], Croatia [169], Singapore [170], Brazil [171], China [172-174], India [175-177], Malaysia [178,179]) have investigated the use of mobile phone-based apps, mobile phone voice call, SMS, and PDAs.

For interventions using mobile phone-based apps the technology was used to transmit patients' self-reported outcomes [180]; transmit self-monitoring data to a website for review and analysis by clinicians, parents, and patients [134]; and ocate missing persons with dementia [145]. Patients were also able to transmit twice daily recording of symptoms, drug use, and peak flow with immediate feedback prompting action according to an agreed plan or paper-based monitoring [143].

For interventions using mobile phone functions the technologies were used to send SMS reminders to patients that enabled improving adherence to sunscreen app [132], and send immunization reminders to children aged 11 to 18 years that needed either or both meningococcal and tetanus-diphtheria-acellular pertussis immunizations [133]. Particularly, text messages were used to send result after genital chlamydia trachomatis infection tests [142]; send reminders about pediatric malaria case-management to health workers [168], and to women toward the end of her menstrual period to do breast self-examination [176]. In some cases, patients sent their peak expiratory flow results daily and received feedback from health center [169]; patients sent weekly self-monitoring data on exercise and eating behavior and their mood, and in return they received tailored feedback messages [158]; patients transmitted images of their psoriasis (chronic skin disease) lesions and received feedback message [160]; patients sent a weekly message regarding their bulimic symptomatology and mood states and received automatic feedback [146]; monitor symptoms in patients with asthma [170]; monitor the functional mobility of elderly subjects in an unsupervised environment [156]; transmit blood pressure measurement unit from patients to a remote server and send notification information to users if patient's blood pressure is abnormal [173]; support educational intervention for patients with diabetes [166,167]; improve treatment results and reduce dropout rates in children with overweight [159]; remotely monitor the long-term mobility levels of elderly people in their natural environment [157]; monitor patients' appetite ratings hourly over 7 consecutive days [135]; provide smoking cessation advice, support, and distractions for patients willing to quit smoking [161,162]; provide voice counseling sessions to HIV-positive population

[137,138]; send tips on healthy eating and physical activity, as well as reminders to drink water and expressions of encouragement in a weight management program [139]; send sexual health education messages to young people aged between 16 and 29 years recruited from a music festival in Melbourne [163].

In particular, text messages were used as a tool to send reminders. Reminders were sent to promote receipt of influenza vaccination among children and adolescents [140]; to patients at pediatric clinic for appointments [149,151]; via text or call to patients after their missed clinic appointments [148,152]; via text or call to patients prior scheduled appointment [147,153,154,164,171,172,177-179]; and via text to patients after 7-days circumcision [141].

Some benefits of using mobile technologies as health support systems were improved attendance in return general ophthalmology clinic patients [147,150]; improved attendance rate in primary care [178]; improved attendance at the 7-day post-operative clinic visit following adult male circumcision [141]; improved immunization coverage in a low-income, urban population [133]; and improved and maintained health workers' adherence to treatment guidelines for outpatient pediatric malaria [168]. In addition, the technologies have improved asthma control when added to a written action plan and standard follow-up [169]; improved attendance rates at a health promotion center [174]; improved levels of glycosylated hemoglobin and 2 hours post meal glucose in type 2 diabetes patients [166,167]; improved health knowledge and sexually transmitted infections testing [163]; and significantly improved follow-up adherence in pediatric cataract treatment [172]. Thus, the technologies reduced failure to attend rate at outpatient clinics [148,149,151,164,165,171]; reduced the number of failed appointments significantly [153,177]; offered a time-, labor-, and cost-efficient strategy for encouraging engagement with psychiatric outpatient services [154]; and offered an innovative, low-cost and effective method of improving adherence to sunscreen app [132]; saved staff time per month and reduced number of days to diagnosis [142].

In particular, SMS was cost-effective compared with voice call reminder [150,178]; was a cost-effective method for improving patient attendance at dental appointments [153]; reduced dropout rates from a pediatric lifestyle intervention [159]; reduced the financial burden on health care services by facilitating more efficient use of health care resources [157]; doubled quit rates at 6 weeks [162]; decreased symptoms of distress while increasing self-efficacy [138]; increased short-term self-reported quit rates [161]; increased rate of influenza vaccination [140]; increased the practice of breast self-examination [176]; and increased adherence of obese adolescents enrolled in a weight management program [136]. Routine SMS texting was a cost-effective means of reducing nonattendance rates [147], cost-effective approach for improving patient attendance [165], and more cost-effective compared with call reminders [174].

Not all trials have proven effective, however. Mobile technology did not improve asthma control or increase self-efficacy compared with paper-based monitoring, and there was no positive effect of SMS maintenance treatment on weight, eating

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behavior, or psychological well-being in obese children [158]. There was no significant reduction in nonattendance rates, as a result of texting appointment reminders to patients who persistently fail to attend their general practice appointments [148]. Also, the mobile technology was not cost-effective in one study [143]. As most interventions of these kinds in fact were effective it seems the reasons for not succeeding in some, relatively few, cases may have to do with local conditions.

The GIS technology in the context of health promotion and disease prevention was used for several purposes, including to measure distance between individuals' area of residence and the location where each person used a computerized breast cancer education kiosk [131]; identify regional spots as potential territorial stations for a telemedicine service [181]; assess the neighborhood social and ecological contexts in mental health [182]; create a site selection strategy for the dissemination and pilot evaluation of a community-based fall prevention program for older adults [183]; and to analyze dental trauma using a GIS as a tool for integrating social, environmental, and epidemiological data [184]. In addition, GIS was used to discover the geographical variation of syphilis seeking clusters and hotspots [185]; plot measles cases on a digital map in real time [186]; visualize cancer risk patterns associated with incidence, mortality, and accessibility to care [187]; investigate factors associated with nosocomial transmission of resistant organisms [188]; and locate all out-of-hospital cardiac arrests (OHCAs) and identify clusters of OHCAs, as well as clusters of patients who did not receive bystander cardiopulmonary resuscitation [189]. In some studies, GIS was used to examine built environment characteristics and resident health behaviors as they relate to change in blood pressure [190]; quantify the effect of fish pond density on malaria occurrence [191]; identify geographic areas with elevated risk for the later development of amyotrophic lateral sclerosis among military personnel who served in the first Gulf War [192]; map the prevalence of malaria [193]; identify malaria hot spots [194]; create maps and charts displaying the geographic distribution of locations of injuries and their relationships with environmental and demographic parameters [195]; and examine sex-specific spatial patterns of overweight/obesity [196]. Some investigators, used GIS to explore the impact of the intervention coverage and the adherence to the intervention on malaria health outcome [197]; quantify the relationship between gonorrheal infection rates in California and a measure of poverty status and investigated how this relationship and the spatial dispersion of cases varied among the 4 dominant racial/ethnic groups [198]; develop spatial distribution maps of lymphatic filariasis in endemic areas [199]; and identify risk factors and affected areas of hantavirus infections in rodent hosts [200]. Furthermore, GIS was used to display the distribution of housing locations in relation to spatial dispersion, distress, stability, safety, and race/ethnic diversity for persons with psychiatric disabilities [201]; and assess the spatial distribution and associations for HIV testing and family planning use [202].

The use of GIS has enabled understanding of the interplay of psychological, social, environmental, area-level and sociodemographic influences on physical activity [203]; determination of actual travel time, and facilitation of the selection of community-based prevention program sites [183]. It has also enabled proving that space has an effect on outcome variables; mapping the prevalence of psychological distress, mental disorders, and use of mental health services and their correlates [182]; proving that there is significant variation in the occurrence of dental trauma [184]; enabled digital plotting cases of measles as they occurred in real time during the outbreak [186]; and finding significant relationships between the mapping of behavioral risk factors, health care services, transportation access, and policy advantages [187]. The technology was also used to demonstrated, by means of animated GIS, inappropriate patient placement for 19% of patients with methicillin-resistant Staphyloccocus aureus and insufficient time for hand hygiene in 14% (875/6248) of health care provider-patient contacts [188]; geographically map diabetes-risk scores and diabetes-screening rates [204]; and plot clusters of out-of-hospital cardiac arrests [189]. Through the mapping, fish pond density was found to be a significant predictor of malaria occurrence [191], and it was possible to see that service in particular locations of the Gulf was associated with an elevated risk for later developing amyotrophic lateral sclerosis, both before and after adjustment for branch of service and potential of exposure to chemical warfare agents in and around Khamisiyah, Iraq [192]. In addition, GIS identified 10 hot spots with extremely high risk of malaria and 14 hot spots with high risk of malaria [194]; enabled to create digital maps of injury spatial distribution and correlated injury type and location with patients' clinical data [195]; enabled revealing marked geographical variation in overweight/obesity prevalence with higher values in the Northern and Atlantic health-regions and lower values in the southern and western health regions of Canada. Significant positive spatial autocorrelation was found for both males and females, with significant clusters of high values or hot spots of obesity in the Atlantic and Northern health regions of Alberta, Saskatchewan, Manitoba, and Ontario [196]; as indicated on the GIS maps, villages with malaria cases, lower intervention coverage, and lower adherence were identified. Although no malaria cases were detected in most villages with the best access to the district center, several cases were detected in the distal villages, where the intervention coverage and adherence to the intervention remained relatively lower [197]. The degree of spatial aggregation varied substantially among groups and was especially pronounced for African Americans with gonorrhea in the highest poverty category [198]; filaria monitoring visualization system maps demonstrated that filariasis remained unevenly distributed within districts [199]; land cover and elevation were found to be closely associated with the presence of hantavirus-infected rodent hosts [200]; maps displayed the distribution of housing locations in relation to spatial dispersion, distress, stability, safety, and racial/ethnic diversity and indicated that the developmental disabilities population in supportive housing was more spatially dispersed, and lived in less distressed, less unstable, more secure, but equally racially/ethnically diverse neighborhoods when compared with the psychiatric disabilities population in supportive housing [201]. Clustering among those using services is found as are spatial associations, indicating significant spatial variability in the utilization of health services [202].

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Communication to or Between Health Care Providers

In this category the survey found 71 studies using mobile communication technologies with samples ranging from 8 to 4203, and 12 studies using GIS technologies. The interventions are described in Multimedia Appendices 8 and 9. Interventions using mobile communication technologies in both developed countries (Italy [205], US [1,92,206-228], UK [229-232], France [233], Canada [234-237], Japan [238], Australia [239], New Zealand [240], South Korea [241-245], and Denmark [246]), and developing ones (Thailand [247], Peru [248], Kenya [57,249,250], Taiwan [251,252], Israel [253-255], Uganda [256,257], Thailand [258], Singapore [259], Turkey [260], India [261], and South Africa [262]) have investigated the use of mobile phone-based apps, mobile phone voice call, SMS, and PDAs.

Interventions using mobile phone functions concerned providing automatic notification messages to the referring doctor and the consulted ophthalmologist on retinal diseases [205]; sending digital x-ray images via MMS [231,233,247]; and collecting patient diary information using an electronic peak flow meter linked to a mobile phone with an interactive screen to record current asthma symptoms transmitted to, and stored in, a server [229]. The video function was used to send reminders to assist with daily activities of persons with early dementia [230], and transmit teleconsultations, including clinical images of the amputated portion and stump as well as patient information between the physicians in the emergency room and the consultant plastic surgeon through Panasonic camera phones [251]. In addition, transmitting the 12-lead electrocardiography in an ambulance to the cell phone of the attendant emergency medical technician and then to the hospital and to cell phones of off-site cardiologists [252]. SMS was used to deliver diet, exercise, and behavior modification once a week to obese patients [241]. PDAs were used to track patient information during street outreach to the homeless in a major metropolitan area [208], and transmit radiological images to a remote physician [242].

Benefits of using mobile technologies include the possibility of identifying poor control more quickly and facilitating communication with health care professionals without the need for face-to-face consultation [229]. PDAs enabled clinicians to focus on building relationships instead of recreating documentation during patient encounters [208], and improve nursing work force, including accurate differential diagnosis and diagnostic reasoning, reduction of medication errors, reduction of health care costs, and development of effective treatment protocols [212]. A PDA-based technology providing behavioral messaging was an innovative, interesting, easy to use, educational, trustworthy, private, and nonjudgmental tool [248]. Teleconsultation using MMS is especially useful to improve remote management of orthopedic patients in local hospitals or for decisions of transfer when surgical treatment is needed [233]. SMS support had significantly improved ART adherence and rates of viral suppression compared with the control individuals [249], and enhanced chronic disease management support and patient-provider communications beyond the clinic setting [214].

Interventions using GIS technology in developed countries (US [263-267] and UK [268,269]) have used the technologies to map cancer rates and communicate the findings effectively [263]. This technology has also identified risk and developed potential interventions to address perinatal health problems [264], and developed a perinatal GIS model that helped community members to decide where to focus interventions and in continued use of GIS for planning [264].

Medical Education

On this topic the survey found eight studies using mobile communication technologies with samples ranging from 30 to 366. The interventions are described in Multimedia Appendix 10. All interventions used PDAs in developed countries (Austria [270], Canada [271], and US [272-274]). In these interventions the technology was used to enhance students' pharmacological and clinical contextual knowledge in both clinical practice and nursing education [270], and to determine a patient's stage of change, providing scripted motivational interviews targeted to their stage, and making relevant health behavior and stage-based interventions immediately accessible [273]. In addition, a PDA was primarily used for personal apps by students during their preclinical training and as drug references and clinical calculators during their clinical training [209].

The use of PDA led to significant increase in self-efficacy [271]; PDAs were easy to use and perceived students' use as beneficial to their learning in the clinical area [270]. A PDA-based tool did not increase key smoking cessation counseling behaviors compared with a paper-based reminder [273].

Discussion

Principal Findings

This research reviewed 271 articles on use of mobile technologies and GIS in improving health care. The articles were categorized into six predominant themes: treatment and disease management, data collection and disease surveillance, health support systems, health promotion and disease prevention, communication to or between health care providers, and medical education. Apps of GIS technology could be generally categorized into four predominant themes: disease surveillance, health support systems, health promotion and disease prevention, and communication to or between health care providers. These themes are not entirely distinct from one another and often overlap. For example, the use of GIS to examine the transmission of malaria is a disease surveillance app in that the spread of disease is mapped, but it is also a health support system in that disease spread is identified and tracked for the purpose of intervention development.

The overwhelming majority of the papers report positive results. Of course this is encouraging, but it also indicates some gaps in the body of research. First, it may mean that unsuccessful cases go unreported. Second, the papers we found focused on effects and tended not to discuss implementation issues. This means problems in making systems like the ones described implemented in the regular operations go unnoticed. This is an important gap as it may be an indication of a serious problem. Most studies in our sample are small-scale. It would of course

be very useful to be able to scale up the small successful cases to a scale where more people could be helped and more health care could be afforded (as economic gains are among the positive results reported). Why has this not happened yet, despite all the positive results reported? From the papers reviewed here it is impossible to tell, but usually, as evidenced by a vast number of reports in the information systems literature, there are organizational issues behind such nondevelopment. Large-scale change is complicated, it requires aligning many actors, changing work procedures, standardizing of data, often some upfront investment in digitalization of data, legal, economic, and practical issues regarding communication and more. While these issues are much researched in other contexts, they are not yet researched in the particular contexts discussed in the papers reviewed here, there is a need to investigate implementation issues.

The findings also show that there is little integration between GIS and mobile technologies. While mobile technologies are successfully used for many types of interaction between patients and health care providers, there is little systematic use of operational data for strategic decision making. The communication yields large amounts of data, which can be analyzed so as to better understand how to design the communication effectively. This is not yet done, which indicates that the mobile systems are still pilots, not integrated in the organizations' information infrastructure and not used for systematic monitoring, evaluation, and improvement of processes. This is a further urgent area for research and development. In order for health care processes to be effective they must integrate different kinds of existing technologies and data.

Introduction of Apps

In all, the set of papers reviewed here reveal a trade in its very early beginning and in need of more systematic development. The review shows a large number of small-scale tests with little or no attempts to integrate the new technologies into standard operations. There are today a large number of apps, for mobile phones in the eHealth area, which are designed to support various needs related to supporting individuals in their handling of various health problems. Support includes tools for the patient's own use, for collecting patient data for use by the doctor to support her analysis, and for communication between doctor and patient. Such apps are making their way into regular health care in many countries. This means data from mobile apps will increase in volume, which requires health care providers to find ways of systematically make use of incoming and outgoing data. Receiving and sending data effectively and reliably, quality control of data, security and privacy control, standardizing data formats for interoperability across systems, are examples of issues involved.

Conclusions

In the cases reported here, the main technology is SMS or voice, mainly for the reason that these technologies are most widely available. But the need to develop effective communication and make use of data for process improvement remains the same whether the data comes from an SMS or a smartphone app. Also, the availability of smartphones are increasing everywhere, also in developing countries. This means there is a general need for research and development concerning integrating data from mobile apps into the back-office systems that make up the backbone of data handling in health care, and with systems that can analyze communication and provide support for improving processes.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Treatment and disease management – overview of mHealth articles.

[PDF File (Adobe PDF File), 64KB - mhealth_v2i2e21_app1.pdf]

Multimedia Appendix 2

Data collection and disease surveillance – overview of mHealth articles.

[PDF File (Adobe PDF File), 54KB - mhealth_v2i2e21_app2.pdf]

Multimedia Appendix 3

Disease surveillance – overview of GIS articles.

[PDF File (Adobe PDF File), 48KB - mhealth_v2i2e21_app3.pdf]

Multimedia Appendix 4

Health support systems – overview of mHealth articles.

[PDF File (Adobe PDF File), 67KB - mhealth_v2i2e21_app4.pdf]

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Multimedia Appendix 5

Health support systems – overview of GIS articles.

[PDF File (Adobe PDF File), 41KB - mhealth_v2i2e21_app5.pdf]

Multimedia Appendix 6

Health promotion and disease prevention – overview of mHealth articles.

[PDF File (Adobe PDF File), 76KB - mhealth_v2i2e21_app6.pdf]

Multimedia Appendix 7

Health promotion and disease prevention – overview of GIS articles.

[PDF File (Adobe PDF File), 47KB - mhealth_v2i2e21_app7.pdf]

Multimedia Appendix 8

Communication to or between health care providers – overview of mHealth articles.

[PDF File (Adobe PDF File), 200KB - mhealth_v2i2e21_app8.pdf]

Multimedia Appendix 9

Communication to or between health care providers – overview of GIS articles.

[PDF File (Adobe PDF File), 39KB - mhealth_v2i2e21_app9.pdf]

Multimedia Appendix 10

Medical education – overview of articles mHealth articles.

[PDF File (Adobe PDF File), 37KB - mhealth_v2i2e21_app10.pdf]

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Abbreviations

ART: antiretroviral therapy
GIS: geographic information systems
IRS: insecticide treated nets and indoor residual spraying
MMS: multimedia messaging service
OHCA: out-of-hospital cardiac arrest
OLAP: online analytical processing
PDA: personal digital assistant
PP: paper-pencil
SMS: short message service

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Original Paper

Real-Time Monitoring of School Absenteeism to Enhance Disease Surveillance: A Pilot Study of a Mobile Electronic Reporting System

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Abstract

Background: School absenteeism is a common source of data used in syndromic surveillance, which can eventually be used for early outbreak detection. However, the absenteeism reporting system in most schools, especially in developing countries, relies on a paper-based method that limits its use for disease surveillance or outbreak detection.

Objective: The objective of this study was to develop an electronic real-time reporting system on school absenteeism for syndromic surveillance.

Methods: An electronic (Web-based) school absenteeism reporting system was developed to embed it within the normal routine process of absenteeism reporting. This electronic system allowed teachers to update students' attendance status via mobile tablets. The data from all classes and schools were then automatically sent to a centralized database for further analysis and presentation, and for monitoring temporal and spatial patterns of absent students. In addition, the system also had a disease investigation module, which provided a link between absenteeism data from schools and local health centers, to investigate causes of fever among sick students.

Results: The electronic school absenteeism reporting system was implemented in 7 primary schools in Bangkok, Thailand, with total participation of approximately 5000 students. During May-October 2012 (first semester), the percentage of absentees varied between 1% and 10%. The peak of school absenteeism (sick leave) was observed between July and September 2012, which coincided with the peak of dengue cases in children aged 6-12 years being reported to the disease surveillance system.

Conclusions: The timeliness of a reporting system is a critical function in any surveillance system. Web-based application and mobile technology can potentially enhance the use of school absenteeism data for syndromic surveillance and outbreak detection. This study presents the factors that determine the implementation success of this reporting system.

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Introduction

Disease epidemics occur easily now due to rapid transportation and increased social contact. Traditional disease surveillance that is based only on disease reporting systems may not be sufficient for timely detection of a disease epidemic. There is growing interest in applying syndromic surveillance to enhance outbreak detection capabilities. Unlike traditional surveillance, syndromic surveillance uses prediagnostic clinical data such as emergency department visits, laboratory ordering volume, and other surrogate data indicating early illness, such as school or work absenteeism and over-the-counter medication sales. Using these prediagnostic data can potentially improve timeliness in outbreak detection [1]. Syndromic surveillance systems are widely utilized; more than 80% of public health agencies in the United States and Canada have been using syndromic surveillance [2-4].

School absenteeism is a common data source used in syndromic surveillance [2-4]. Schoolchildren are at high risk for many infectious diseases and share common risk factors at school. Infectious diseases are likely to spread easily in schools due to frequent contact among students. Schoolchildren play an important role in disease transmission in the community, because of their contact patterns with adults and preschool children at home [5]. Monitoring school absenteeism, therefore, can be a useful tool for predicting disease outbreaks. The usefulness of school absenteeism data in predicting outbreaks was widely documented during the influenza H1N1 epidemic in 2009 [6-8]. However, timeliness of data is the most important requirement for using school absenteeism for syndromic surveillance. An electronic school absenteeism reporting system is required for real-time or near real-time monitoring of the absentees; this could limit the use of school absenteeism data in developing countries.

In Thailand, continuous monitoring of school absentees has not been applied in a disease surveillance system. Traditional school absentee reports rely on a paper-based system. Every morning, teachers are responsible for reporting the number of absentees in each class to the school registration unit where a daily summary report on absenteeism is manually generated and stored. Daily data on school absenteeism were reviewed and used only by individual schools. Summary reports are usually submitted to the centralized level (Department of Education) once a semester for financial and human resources consideration purposes. Data sharing between the Department of Education and Department of Health is very limited based on this traditional system. This study aimed to develop a real-time school absenteeism reporting system that also can be used for syndromic surveillance in Thailand.

Methods

Study Area

The study was conducted in primary schools under the Bangkok Metropolitan Administration (BMA), in Ladkrabang district, Bangkok, Thailand (Figure 1). Seven of 20 schools under the BMA were stratified by school size and randomly selected to represent all schools with different school sizes in the area. The number of students ranged from 100 to 2000 students per school, with a total of 5000 students. The basic characteristics of the 7 participating schools are shown in Table 1.

Table 1. Characteristics of the 7 participating schools.

School	No. students	Average class size	No. teachers	No. staff	Median percent of absence (range)	Median percent of sickness with fever (range)
1	1970	36	89	17	7 (0-91)[a]	0 (0-2)
2	238	30	11	9	7 (0-66)[a]	0 (0-3)
3	456	38	24	10	5 (0-51)[a]	1 (0-3)
4	636	35	37	5	3 (0-8)	0 (0-4)
5	633	35	30	13	3 (0-9)	0 (0-1.3)
6	813	39	44	18	6 (0-63)[a]	2 (0-14)
7	85	14	10	6	4 (0-29)[a]	0 (0-6)

[a]The extremely high absence rates occurred during examination week.

Figure 1. Study area (highlighted area), Ladkrabang district of Bangkok, Thailand.
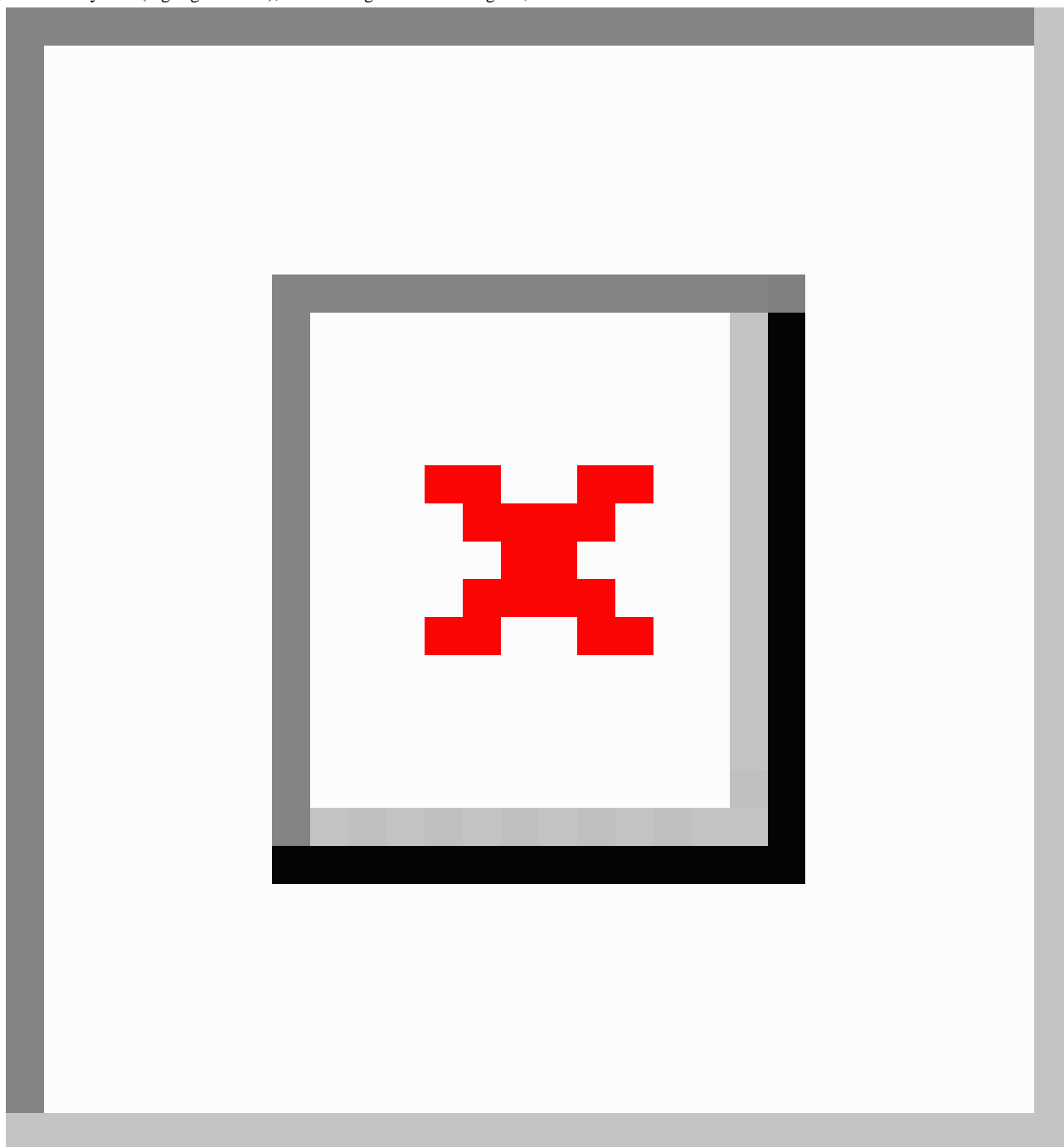
The Reporting System

An electronic school absenteeism reporting system was developed and implemented in 7 schools in 2011. The system was designed to use fingerprint scans as a measure of school attendance. Schoolteachers, parents, and students were informed of the new absenteeism reporting system, and students were required to provide fingerprint scans every morning when they arrived at the school. Attendance data from fingerprint scans from all 7 schools were then automatically sent to the centralized database, which is linked to the geographical information system database where data on the students' house location is stored. In addition, text messaging (short message service) function was integrated into the system so that a text message was automatically generated and sent to the parent of that specific absent individual. To increase the specificity of absenteeism data in predicting disease outbreak, parents were contacted by phone and asked for the reason for the student's absence, and if the student was sick, if he or she had a fever. A summary of initial work and data flow is shown in Figure 2.

After the implementation of the fingerprint scan system, potential problems were observed. A significant number of students failed to scan each day, an approximate 20% error rate, thereby requiring confirmation of school absenteeism data from the teachers; the assigned teachers had to submit confirmed absenteeism data through the Web-based system. A negative response was received after the system was launched due to the extra workload for schoolteachers.

The school absenteeism reporting system was then revised to embed the electronic reporting system into the routine process of absenteeism reporting (Figure 3). The traditional absenteeism reporting system required teachers to record absent student data onto a standard form (paper-based). To continue this routine, an electronic version of the absenteeism report form was created, and teachers could access this electronic form through a Web-based system. The parent's phone numbers were obtained from the electronic student registration system, which is an existing system created and used by the Department of Education.

To assist in the data entering process, tablet computers with Internet and phone connection were distributed to teachers. Teachers could update the school attendance status of the children in their classes immediately and the data were then automatically sent to a centralized database. The Web-based reporting system also provided the parent's phone number, which allowed teachers to call parents directly from the tablets to ask for the reasons for school absenteeism (Figure 4). In addition, a standard school absenteeism summary form could be automatically generated. This summary form was designed to look like the existing form that is submitted to the Department of Education once a semester. With this Web-based reporting system, data on school absenteeism, including reasons for absence in the 7 schools would be updated to the centralized database on a real-time or near real-time basis. Authorized persons from the Department of Education and Department of Health could view these real-time data via the Web-based system (Figure 5). Informative statistics such as graphs of number and percent of school absentees were generated to present patterns of school absenteeism over specific periods. After implementation of this revised system, teachers were very satisfied with this system, because the system could potentially reduce their workload and they can appreciate the usefulness of the system.

Figure 2. Initial data and work flow of the school absenteeism reporting system.
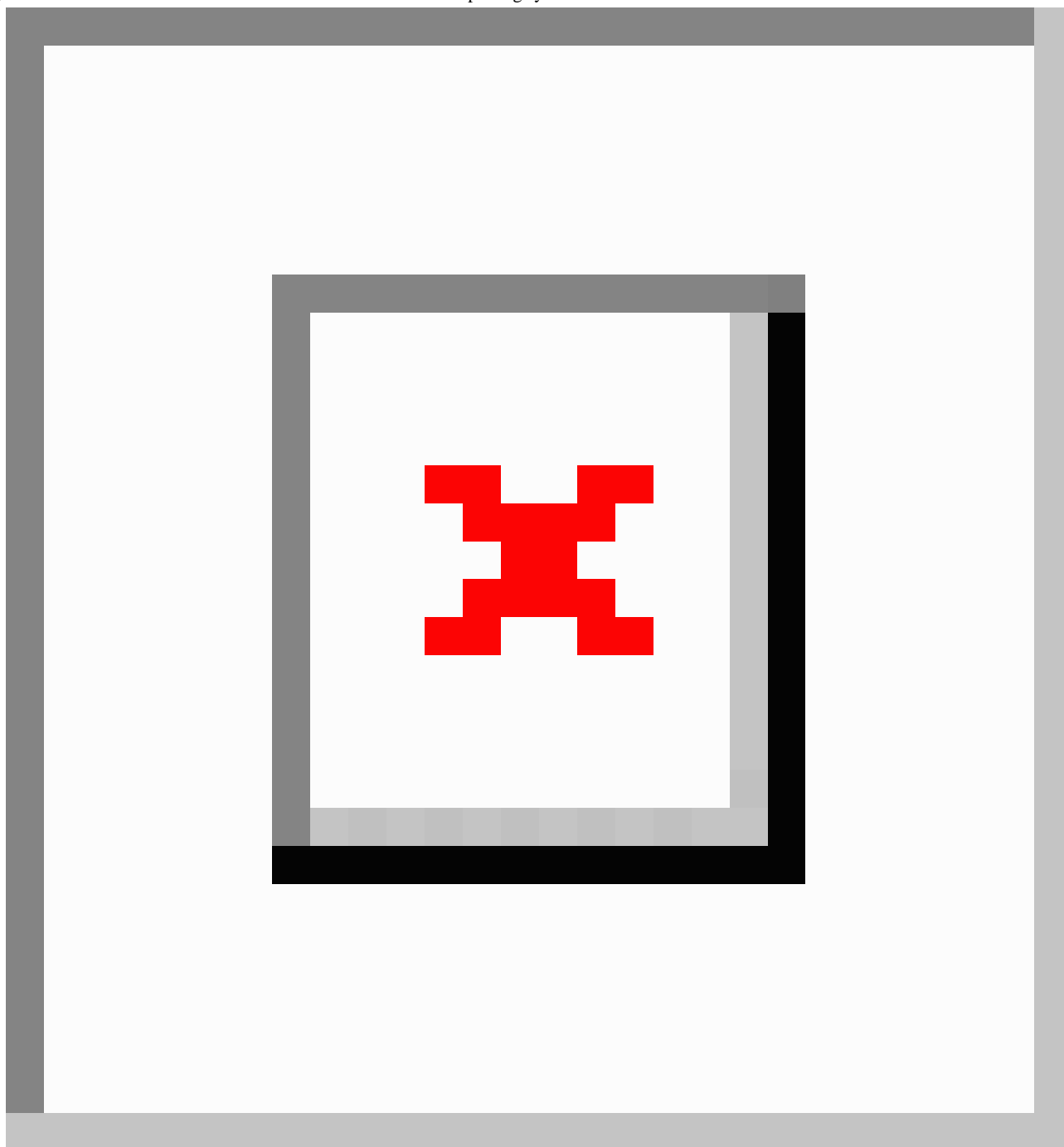
Figure 3. Revised data and work flow of the school absenteeism reporting system.
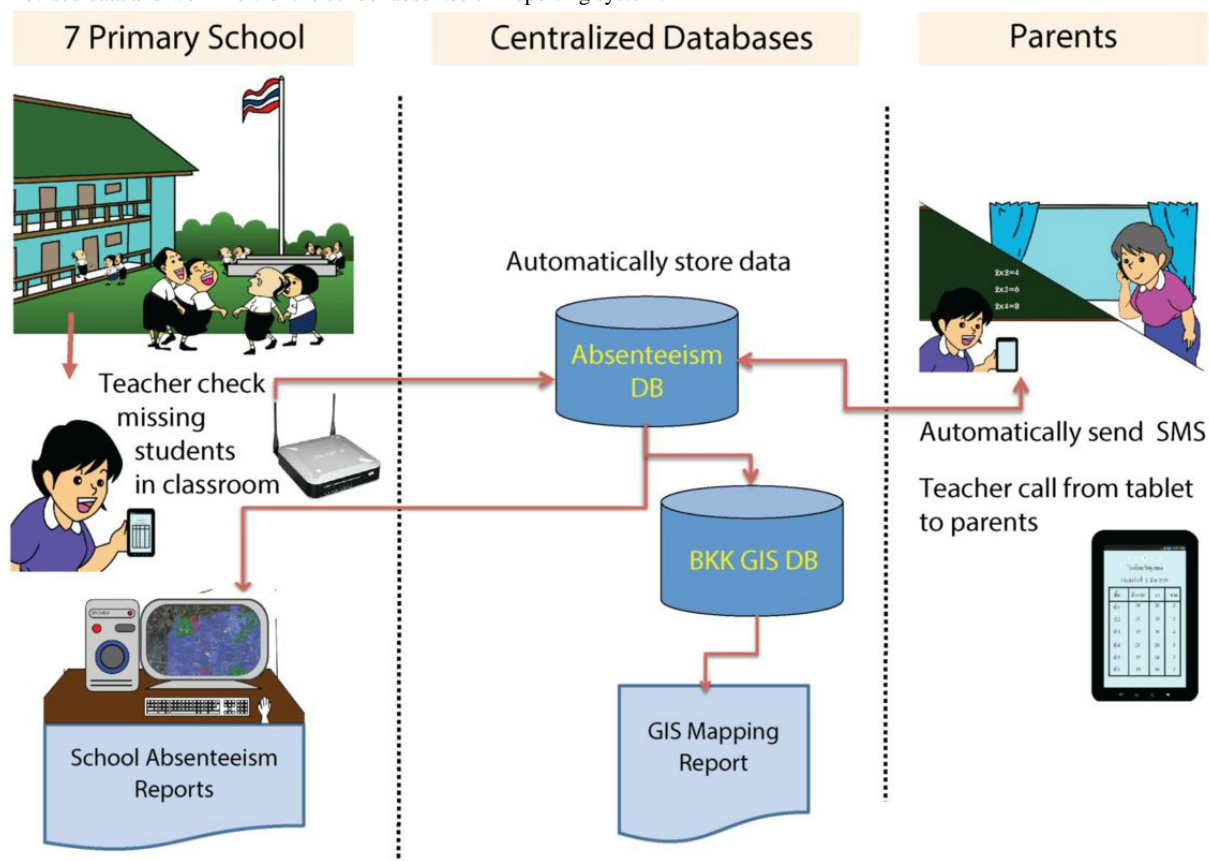
Figure 4. Web page for entering data of the school absenteeism reporting system.
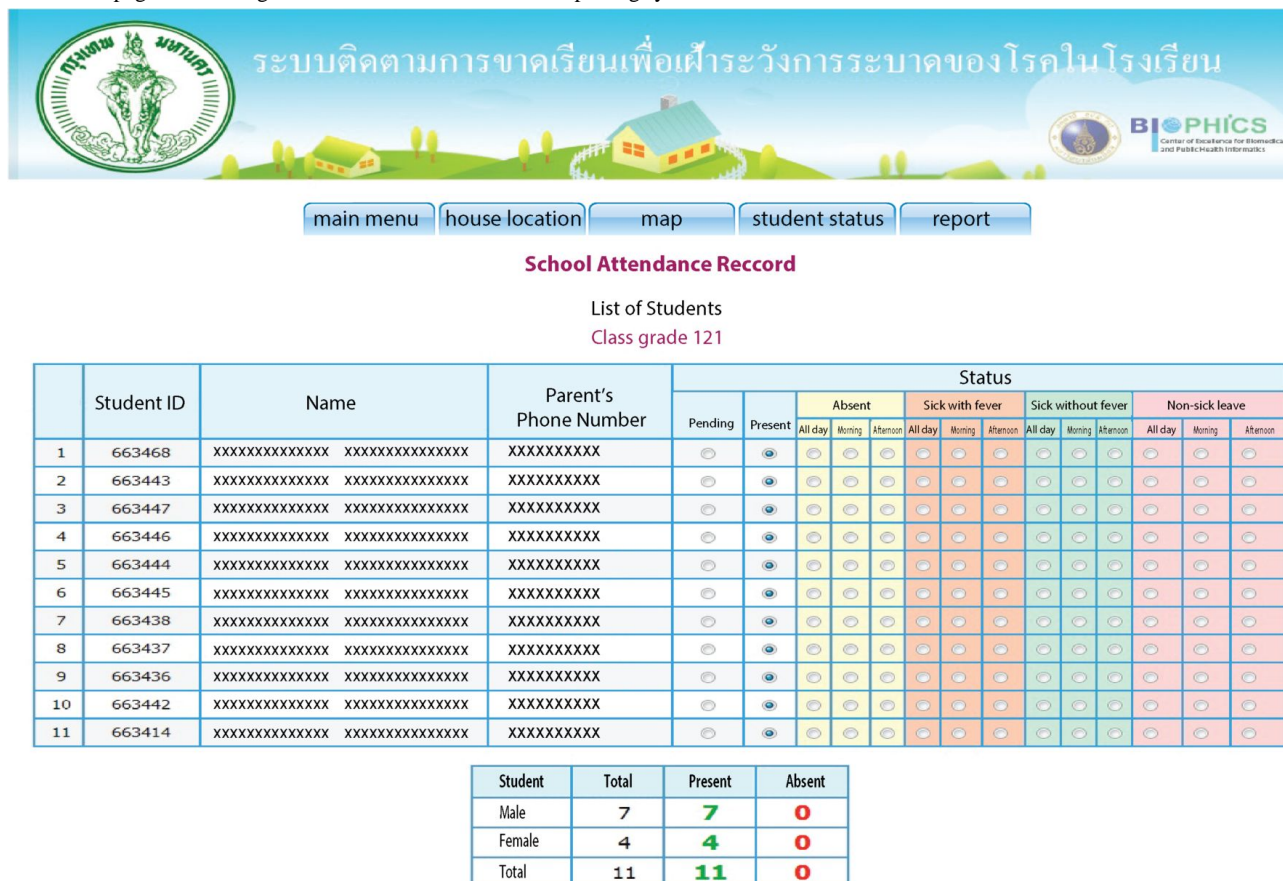
Figure 5. Graphs showing patterns of school absenteeism generated from the system from 24 May to 14 September 2012 (First Semester). a) Pattern of overall absenteeism; b) Pattern of sick leave with and without fever.
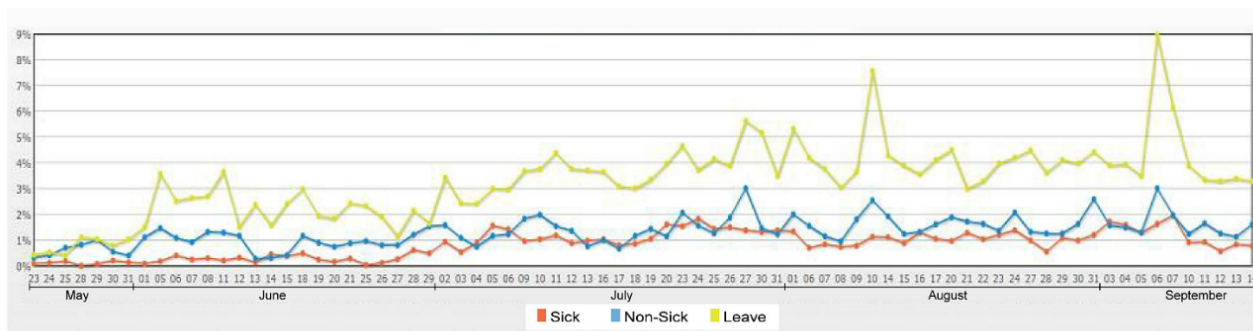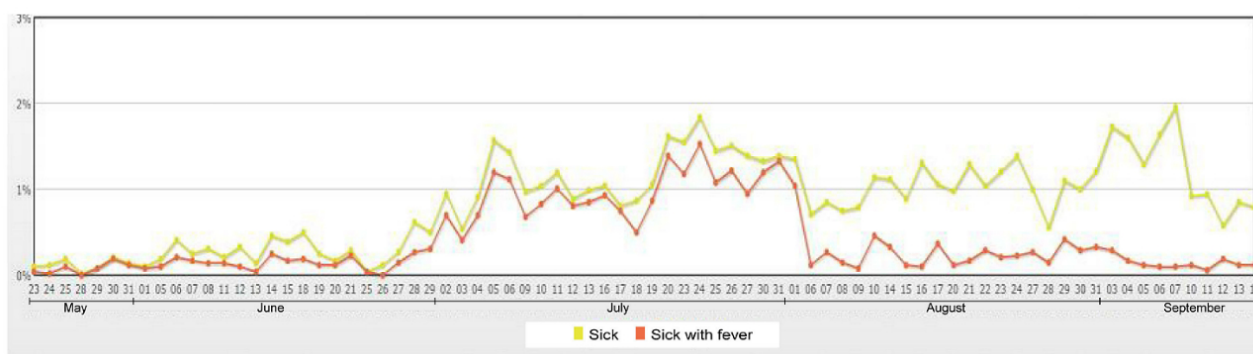
The Disease Investigation Module

Disease investigation is an important function in disease surveillance, especially during an outbreak. Communication between schools and health care sectors plays a critical role in disease investigation, especially when there is a suspected outbreak among schoolchildren. Therefore, an additional module that provides a link between school and local health care centers has been developed (Figure 6). In this disease investigation module, the system allows absent students with fever to be recognized at local health care centers via the Web-based application. In addition, health care personnel who are responsible for disease investigation can receive information about the sick student, including address and contact phone number via the mobile tablets. This module also allows health care personnel to collect results of their disease investigation through the tablet, and that data can then automatically be sent to the centralized database. This disease investigation module was implemented in October 2013.

Figure 6. Data and work flow of the disease investigation module.
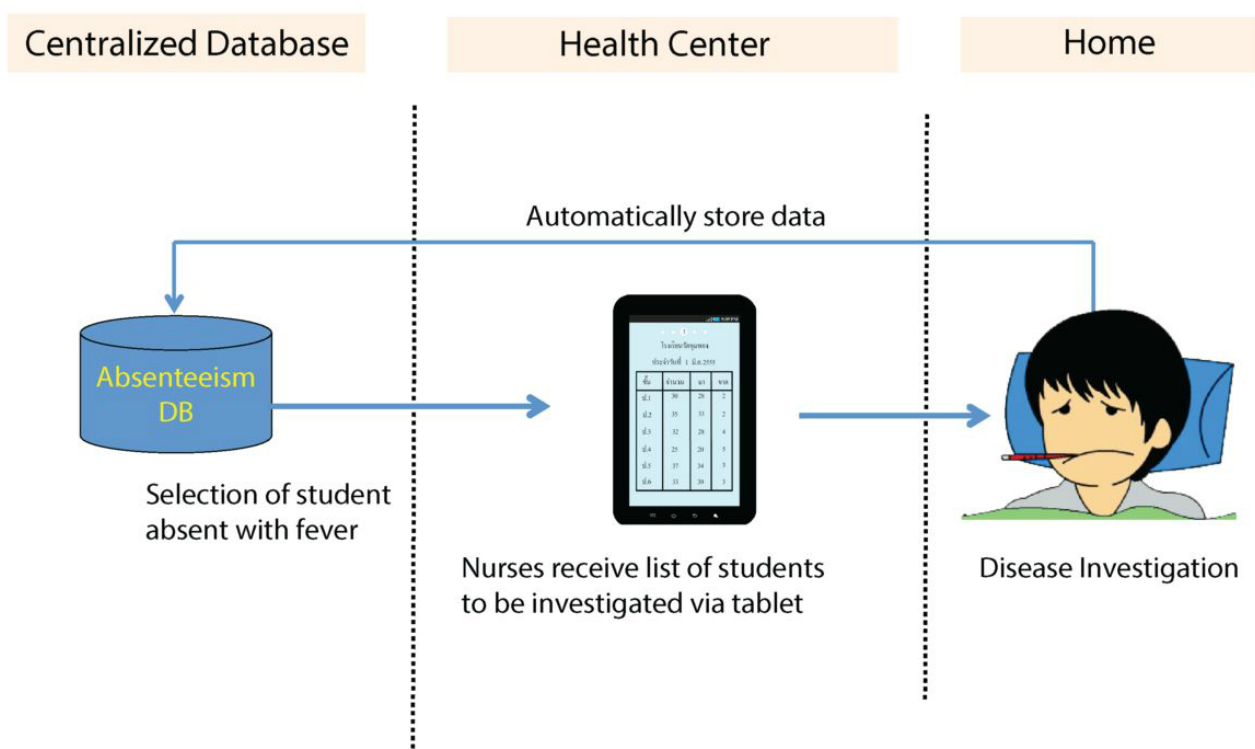
Results

The school absenteeism reporting system was fully functional in May 2012 (first semester of academic year 2012). The data on school absentees and their reasons for absence were updated every morning of each school day. At the beginning, teachers were not accustomed to the new routine and therefore staff members that monitored the centralized database would call or send a message to the teacher to remind him or her to submit the absenteeism information. The number of missing data significantly decreased over time. After the first few months of the operation, the completeness of absenteeism data was comparable with that of the original paper-based reporting system. Although the data on causes for the absence were not required in the original paper-based system, in the new electronic reporting system, teachers were asked to contact parents of absent students regarding the cause for the absence. If the first contact was unsuccessful, follow-up calls would be made. Overall, the percent of successful contact with parents has increased from approximately 70% in the first few months of operation to approximately 90% after 1 year of implementation.

Our results show that of 5000 students in 7 schools, approximately 1%-10% of students were absent each day. The absence rate also varied across schools (Table 1). When school absenteeism was classified according to the reason for the absence, the number of sick students ranged from 10 to 100 per day. Among sick students, approximately half of them had a fever. The percentage of student with sickness and fever varied, ranging from 0% to 2% (median = 1%). The pattern of absence rate and percent of sickness stratified by schools are illustrated

in Multimedia Appendices 1 and 2. The system also provided a function to query the number of children who had fever for 2 or more consecutive days, which is more specific for diseases with prolonged fever such as dengue infection, an endemic disease in the area. The number of school absentees who were sick with fever for 2 or more consecutive days ranged from 1 to 28 (median = 6) students per day, with the percentage ranging from 0% to 0.3% (median 0.1%). In addition, the house location of absentees could be observed from a map link, and clusters of school absentees were also detected by using the point density analysis with the spatial analysis tool in ArcMap (Figure 7). This geographical information system function can enable early warning of a possible disease outbreak in a community. Although the clusters of school absentees in this map may be biased due to a large number of students living near the large school, this geographical information system function would be more beneficial when the system is expanded to cover more schools distributed across the area.

School absenteeism also varied over the course of the year; during May-October 2012 (first semester), school absenteeism (sick with fever) peaked between July and September 2012. This period coincided with a peak of dengue cases in children 6-12 years old in Bangkok, according to the BMA surveillance system, with a correlation coefficient of .57 (Figure 8). The correlation with dengue cases was also observed when compared with the number of school absentees who were sick with fever for 2 consecutive days, with a correlation coefficient of .32. The first peak of dengue started in mid-June, then declined and rose again in early July, and then persisted until October; the pattern was consistent with the absenteeism pattern observed among students in the 7 schools (Figure 9). To explore the performance of the system for the early detection of dengue cases, the number

of dengue cases at the day report received and number of school absentees who were sick with fever at each day with different lag times were calculated. The correlation was stronger with lag times of 14 days (R^2=.57, .54, and .61 for a lag time of 0, 7, and 14 days), in which the case report in the existing passive surveillance system is usually delayed approximately 2 weeks.

Figure 7. Clusters of school absentees, generated by the school absenteeism reporting system.
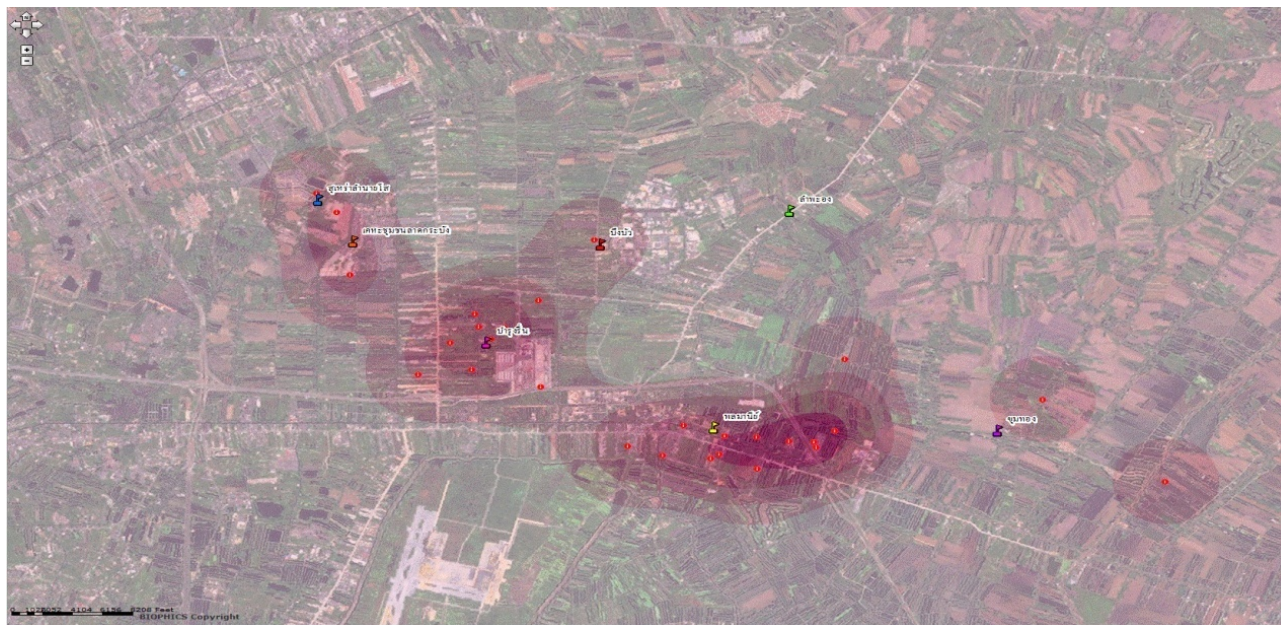
Figure 8. Patterns of daily number of school absentees (sick leave) and daily number of dengue cases during May 24 - October 9, 2012 (first semester).
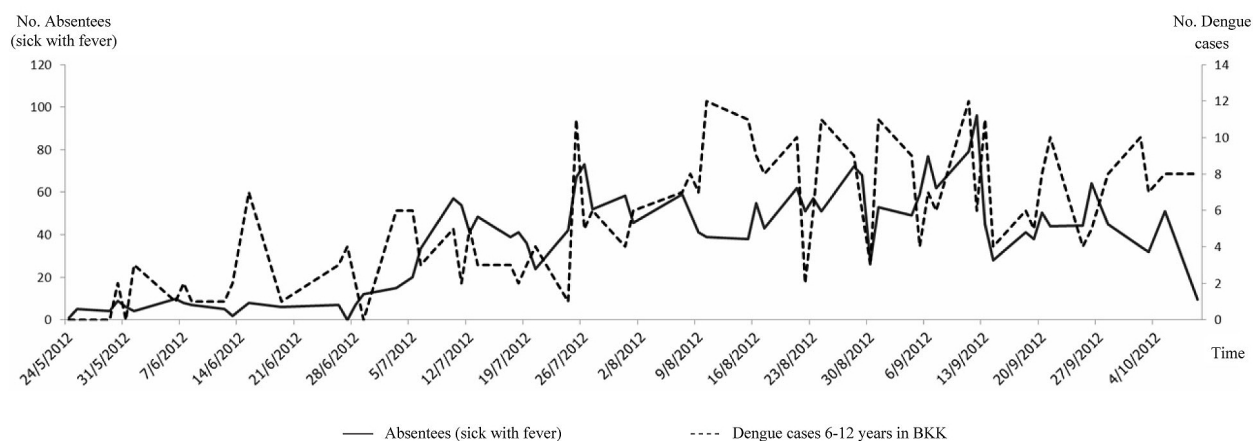
Figure 9. Patterns of daily number of schoolchildren who had fever for 2 consecutive days and daily number of dengue cases during May 24 - October 9, 2012 (first semester).
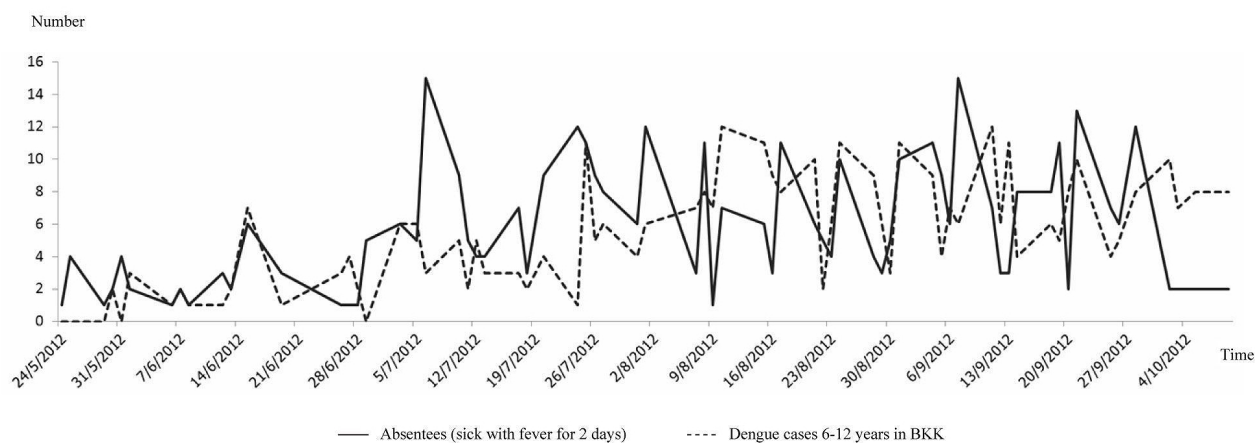
Discussion

School absenteeism data are among the most frequently used sources for a syndromic surveillance system [3]. However, timeliness of data is a key factor in using school absenteeism data for outbreak prediction. This study demonstrated the application of information technology to improve school absenteeism reporting systems. Electronic data entry via mobile devices and a Web-based reporting system was designed to replace the traditional paper-based school absenteeism report. In Thailand, school absenteeism data have not been routinely shared and used for prediction of disease epidemics. In this study, a centralized electronic school absenteeism database was created that can be shared among participating schools, the Department of Education, and the Department of Health. The data can be used not only for syndromic surveillance purposes, but also for educational and social purposes.

A successful health information system can be determined by factors including technical, social, and organizational [9]. A smart card or fingerprint scan can be used as an electronic method to record school attendance [6]. Fingerprint scans instead of smart cards were initially implemented in this study due to a concern about the accuracy of using smart cards; for instance, students may forget to bring their cards to school, or may give their card to friends to represent their attendance at school. After the implementation of fingerprint scans, a significant number of students were observed who failed to scan. Therefore, a Web-based reporting system was used to replace the fingerprint scan to record school attendance. Web-based school absenteeism reporting systems have been implemented in many countries [7,8,10]. In most Web-based reporting systems, all data of school absentees are recorded by teachers and usually input into the database by one or a few teachers who are responsible for this step. According to our study, this procedure did not work well due to the extra work required by teachers. In addition, this procedure was outside their normal routine and could therefore potentially affect the sustainability of the system.

A change in technical procedure outside the normal routine may determine the successfulness of the system. This study suggested that a system designed to follow routine procedures was likely to be a success. In our system, the only change from routine procedure was that teachers had to record data of school absentees into computer tablets, rather than on paper. This system also helped to reduce the school's administrative office workload by automatically generating a summary of school absenteeism. Computer tablets are now widely available at affordable prices and people have easier access to this kind of technology than in the past. In addition, computer tablets can be used for other purposes besides reporting school absenteeism. Therefore, this would be a worthwhile investment when policymakers want to expand this system to other schools.

Key stakeholders and an organization's staff perceptions are key factors to the implementation success of information systems; the system should be beneficial to all groups involved. At a national level, the school absenteeism database can be used to assist disease surveillance and outbreak prediction, whereas at the local or school level the system can automatically create absenteeism reports for that particular school. The commitment and perceptions of school principals were also important in system implementation. In this study, the participation of staff in each school depended mostly on the leader's commitment rather than school size or resources of each school.

Although school absenteeism data has been widely used as an adjunct indicator for outbreak prediction, the lack of specificity of this type of data remains a major concern [3]. A system that relies on school absenteeism data alone without knowing the reasons for absence are less likely to be useful for outbreak prediction [6-8,10,11]. In this study, parents of absentees were contacted by the teacher to ask about reasons for the absence. The reasons were classified as non-sick leave, sick with fever, or sick without fever. In addition, students who were sick with fever for 2 or more days could be simply identified by the system, which would increase the specificity of our system for outbreak prediction. However, more specific symptoms may be added into the system to improve the accuracy of the data.

The main limitation of using school absenteeism data for outbreak prediction is missing information during school breaks. However, the normal epidemic period of common diseases such as dengue and influenza is in the rainy season, between June and August, which falls during the normal school term. In addition, the causes of school absence could be varied; a high absent rate may be due to events such as examination or special events that are not related to health problems. Therefore, for the purpose of disease surveillance, extra care is needed when using school absenteeism data; using an absence rate due to sickness or sickness with fever may be more specific for disease surveillance purposes.

In this study, the peak of school absenteeism coincided with dengue occurrence in Bangkok among 6- to 12-year-old children. Dengue is a common disease in children, especially in a large city. In a cohort study of schoolchildren in a province of Thailand, dengue accounted for almost 7% of children with febrile illness [12]. In this study, the correlation was strongly observed when using absenteeism data of those who had fever for 2 or more days. However, the number of absentees was relatively higher than dengue occurrence, taking into consideration that the school absenteeism data in this study were obtained from only 7 schools in a district of Bangkok. This suggests that there could be diseases other than dengue that contributed to student absenteeism. The investigation of the cause of fever among schoolchildren is ongoing, using the disease investigation module in our system.

Only primary schools under BMA were included in this study. Disease transmission patterns may be different between primary schools and other school levels; however, incidences of important infectious diseases, such as dengue and influenza, are higher among children in primary schools than in secondary schools [13,14]. In addition, only schools under BMA may not be a good representative of all schools in Bangkok, which also include private schools and schools under the Ministry of Education. Therefore, an expansion of the system is planned to cover more schools in other districts of Bangkok that can be used as sentinel sites for syndromic surveillance in the near future.

Acknowledgments

Conflicts of Interest

None declared.

Multimedia Appendix 1

Pattern of absence rate, stratified by schools.

[PNG File, 245KB - mhealth_v2i2e22_app1.png]

Multimedia Appendix 2

Pattern of percent of sick leave, stratified by schools.

[PNG File, 356KB - mhealth_v2i2e22_app2.png]

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Abbreviations

BMA: Bangkok metropolitan administration

Investigating the Use of Smartphones for Learning Purposes by Australian Dental Students

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Abstract

Background: Mobile Internet devices and smartphones have at present a significant potential as learning tools and the development of educational interventions based on smartphones have attracted increasing attention.

Objective: The objective of this study was to obtain a deeper insight in the nature of students' use of smartphones, as well as their attitudes towards educational use of mobile devices in order to design successful teaching interventions.

Method: A questionnaire was designed, aiming to investigate the actual daily habitual use, as well as the attitudes of dental students towards smartphones for their university education purposes. The survey was used to collect data from 232 dental students.

Results: Of the 232 respondents, 204 (87.9%) owned a smartphone, and 191 (82.3%) had access to third generation (3G) mobile carriers. The most popular devices were the iPhone and Android. Most of the respondents had intermediate smartphone skills and used smartphones for a number of learning activities. Only 75/232 (32.3%) had specific educational applications installed, while 148/232 (63.7%) used smartphones to access to social media and found it valuable for their education ($P<.05$). Students accessing social media with their smartphones also showed significantly more advanced skills with smartphones than those who did not ($P<.05$). There was no significant association between age group, gender, origin, and smartphone skills. There was positive correlation between smartphone skills and students' attitudes toward improving access to learning material ($r=.43$, $P<.05$), helping to learn more independently ($r=.44$, $P<.05$), and use of smartphones by teaching staff ($r=.45$, $P<.05$).

Conclusion: The results in this study suggest that students use smartphones and social media for their education even though this technology has not been formally included in the curriculum. This might present an opportunity for educators to design educational methods, activities, and material that are suitable for smartphones and allow students to use this technology, thereby accommodating students' current diverse learning approaches.

Introduction

Educational methods must be dynamic and continuously adapt to an ever-changing social environment [1]. Information and communication technology (ICT) has been a critical component of teaching and learning in higher education over the last few decades. One particularly important trend we have recently witnessed with regard to the use of ICT is the increasing reliance on mobile-connected devices not only in daily tasks, but also within professional and educational environments [2].

Without a doubt, the effective use of mobile devices today has become one significant parameter of "computer literacy."

Consequently, primary and high schools are increasingly introducing mobile technology to enhance teaching and learning. It is not surprising, therefore, that students expect to use this technology when attending university courses [3,4].

Evidence of the current widespread use of smartphones in medical education has been reported in a Canadian study where not only 85% of medical students and faculty used smartphones daily, but they also expected the usage of this technology to increase in medical education and practice [5]. While medical students in the United Kingdom also reported to expect the usage of smartphones to be beneficial and likely to increase in the future, a reduced number of students reported owning and using smartphones [6].

The current generation of health care students has grown up surrounded by information technology. "Millennials," or those born after 1982, have embraced mobile technology and social media. It has been reported that social media can improve participation and link diverse and geographically dispersed groups of students and professionals [7] by enabling communication outside the classroom, improving collaboration, creativity, and connecting students with experts [8].

The use of mobile technology can significantly enhance blended learning [9], but can have a major role in also supporting on-campus teaching. Smartphones have been used in educational activities to access course content, acquire information related to students' performance, and to encourage discussion and sharing between students and teachers [10]. It is therefore apparent that mobile devices such smartphones can have a significant contribution to modern health care education, since these devices might offer possibilities to enhance teaching and learning.

As with every technology, however, understanding the skills of the main users and their attitudes toward the new tool is of fundamental importance, in order to guide development of appropriate educational innovation. At times, students have been reported to be reluctant to use smartphones for learning; they would rather use their smartphones for social and private activities [3].

Few reports are presently available on educational innovations with the use of smartphones. While they are often testing the use of specific applications or programs operating in smartphones [11-22], little is known on how students perceive their smartphones as an educational tool at their own initiatives and outside the framework of specific applications.

The purpose of this study was to objectively investigate whether and up to what extent dental students use their smartphones as learning tools in the first 3 years of their dental education, in the absence of a specific application or requirement provided by the university. In addition, the subjective attitudes of students toward smartphones as learning tools were to be investigated.

Methods

Ethics Approval

This study was approved by the Research Ethics Committee of Griffith University, Gold Coast, Australia.

Questionnaire

A descriptive questionnaire survey was developed, aiming to assess not only students' subjective attitudes, but also to provide an objective understanding of the extent and complexity in which students have used smartphones. The questionnaire was tested for face validity with a group of undergraduate students (Multimedia Appendix 1). For the purpose of this study, mobile use "for learning purposes" was extended to include any use that facilitates or relates to the learning process and educational activities. In that sense, looking at the timetable or course announcements was included, although such use does not constitute a direct learning activity, it does however facilitate the learning process and is part of the day to day educational process. The questionnaire was structured in three parts: (A) demographics, (B) assessment of use, and (C) assessment of attitudes.

The first part, part A, included demographic and social characteristics, as well as the type of smartphone and connection used by students.

Part B was composed of questions, which explored the nature and complexity of the tasks carried out by students with their smartphones, and in particular its use for learning purposes, including the use of social media. As the use of a smartphone is today perceived as an important parameter of computer literacy, the questionnaire was modelled after a widely-used design aimed to objectively assess computer literacy [23,24]. In that model, students were called to respond whether they had or had not performed a series of tasks of increasing complexity. These tasks included communication, access and sharing of information, commercial transactions, and creation of content such taking pictures and making movies. An area was available for students to add other tasks they might perform with the smartphone.

As based on the previous model [23,24], the sum of every positive response gave a score with the maximum possible score of 16. On the basis of the tasks, the ranges of scores 0-5 were categorized as basic, 6-10 as intermediate, and 11-16 as advanced.

Part C, the third part, aimed to measure some basic subjective attitudes toward the use of smartphones as educational tools. This was done by stating the degree of agreement/disagreement with three statements on a visual analogue scale (VAS).

Sample

The questionnaire was distributed to first- (n=126), second- (n=117), and third- (n=78) year dental students. At the time of this study, the curriculum used a learning management system through which digital content was made available at several occasions. However, the curriculum did not include any methodology, content, or application that involved the specific use of a mobile device.

Analysis

Data were analyzed with descriptive statistics. Chi-square tests were used to calculate the correlations between demographic elements and scores, while linear regression tests were used to calculate correlations between demographics and attitudes. The

analysis was done with SPSS version 21. Absolute values were used with percentages to indicate unanswered questions. Correlations were tested at 95% significance level ($P<.05$).

Results

Demographic Characteristics

In total, 72.2% (232/321) of students returned the questionnaires. One student did not fill in the demographic information, although he filled in all remaining parts. As a result the demographic data was received from 231 students. Of these 231 students, 193 (83.5%) were domestic (Australians) and 38 (16.5%) were from overseas. There were 130 male (56.2%) and 101 female (43.7%) respondents. One hundred and six students (106/231, 45.7%) reported having a part-time job.

Type of Smartphone and Connection

Smatphones were owned by 204/223 (91.5%) students, and 191/214 (89.2%) of the respondents had access to Internet data through a third generation (3G) mobile carrier. The devices used by students were as follows: iPhone (111/213, 52.1%), Androids (96/213, 45.0 %), Windows (4/213, 1.9%), and Blackberry (2/213, 0.1%).

Only 42/214 (19.6%) students owned a tablet, while 48/214 (22.4%) might be buying a tablet in the next few months, and 124/214 (57.9%) were unlikely to buy a tablet in the near future.

Assessment of Use

The average skills score with smartphones (as described in part B) was 8.52. This score was categorized as corresponding to intermediate skills. There were no significant differences in skills between age groups or gender (Figure 1, Table 1).

Table 1. Smartphones general skills scores per age group reported as mean, SD, and number of students per group.

Age by groups	Mean	SD	n (%)
17 to 20	8.30	3.7	120 (52.6)
21 to 25	8.75	4.6	57 (25.0)
26 to 30	9.12	4.3	26 (10.9)
≥31	8.00	4.3	25 (10.9)
Total	8.47	4.1	228 (100.0)

Figure 1. Number of students with basic (n=40), intermediate (n=113), and advanced skills (n=79).
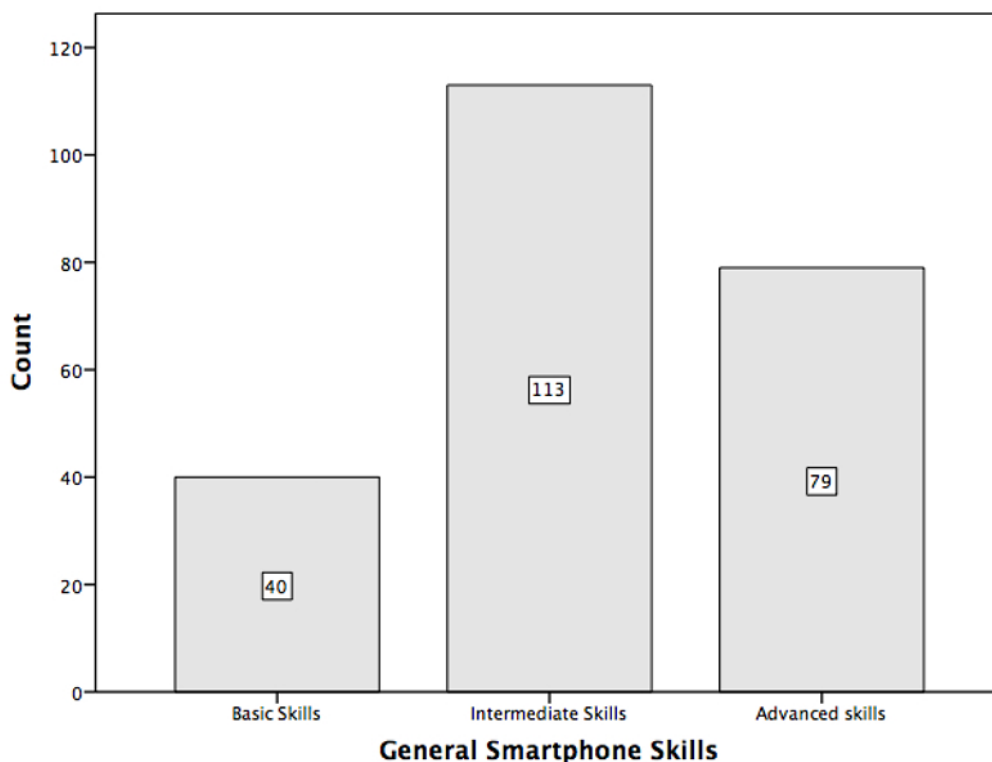
Use of Smartphones and Social Media for Learning

The smartphone features that students were more likely to use for learning purposes were: looking at the timetable and course announcements, followed by surfing the Web for learning material, and taking pictures of their work (Table 2). There were not significant differences between age, gender, and international or domestic students' response.

Table 2. Number and percentage of students using their smartphones for learning activities.

Activity	Students	
	n	%
Looking course timetable	177	83.1
Course announcements	175	82.2
Surf the Web for material	139	65.5
Picture of my work	139	65.3
Email staff/classmates	132	62.0
Read lecture notes	118	55.4
Share notes	86	40.4
Library/literature search	63	29.7
Watch instructional movie	52	24.5
Watch lectures	48	22.7
Make movies of my work	19	9.0

Only 76/204 (37.3%) responded to have dental and/or educational applications in their phones. Whenever reported, these included applications with quizzes on anatomy and chemistry. The Griffith University smartphone application [25] was present in 126/214 (58.8%) smartphones and 89/145 (61.3%) students stated that they use it regularly or often. Students were regularly or often using their smartphones on the go (156/208, 75.0%), on campus (154/207, 74.3%), at home (125/208, 60.1%), and in the lecture theater (116/206, 53.6%).

Some respondents found social media valuable for their education (155/201, 77.1%), and a significant number of them (148/201, 73.6%) accessed social media using their smartphones (*P*<.05) (Table 3). Students accessing social media with their smartphones also showed significantly more advanced skills with their smartphones than those who did not (*P*<.05) (Table 3). Age group, gender, or type of smartphone did not show significant association with the smartphone skills.

Students believed that social media enabled them to collaborate by sharing notes and tips, while it also helped them to stay informed. Younger students were more likely to access to social media with their smartphones than older ones (Table 4).

Table 3. Cross tabulation comparing number of students accessing social media with smartphones, and the number of students who find social media valuable for learning, and the number of students who accessed social media with smartphones and students' skills with the smartphone (chi-square *P*<.05).

	Access to Social Media				Total	
	Yes		No			
	n	%	n	%	n	%
Value Social Media						
Yes	148	95.4	7	4.5	155	77.1
No	30	65.2	16	34.7	46	22.8
Total	178	88.5	23	11.4	201	100.0
Smartphone Skills						
Basic	13	56.5	10	43.4	23	10.9
Intermediate	19	16.9	14	12.5	112	53.3
Advanced	74	98.6	1	1.3	75	35.7
Total	185	88.0	25	11.9	210	100.0

Table 4. Cross tabulation comparing number and percentage of students who access to social media by age group (Cross tabulation chi-square P=.035).

Age group	Yes		No		Total	
	%	n	%	n	%	n
17-20	94.7	104	6.3	7	53.9	111
21-25	86.0	43	14.0	7	24.3	50
26-30	81.0	17	19.0	4	10.2	21
≥31	75.0	18	25.0	6	11.7	24
Total	88.3	182	11.7	24	100.0	206

Assessment of Attitudes

The strongest attitude expressed through the VAS was that smartphones help improve access to the courses learning material (mean VAS score 7.21, SD 1.9). A lighter agreement appeared with smartphones enabling students to learn more independently (mean 6.1, SD 2.2), while a slightly stronger agreement was that teaching staff should use smartphones for teaching (mean 6.6, SD 2.3).

There was positive correlation between smartphone skills and student attitude toward improved access to learning material (r=.43, P<.05), helping to learn more independently (r=.44, P<.05), and use of smartphones by teaching staff (r=.45, P<.05) (Table 5).

No significant correlation was found between age, gender, origin, and part-time job, and any of the statements regarding students' attitude toward smartphones.

Table 5. Cross tabulation comparing VAS average score of attitudes toward smartphones (improving access to learning material and courses, helping to learn more independently, and use of smartphones by staff) with level of students' smartphones skills.

Smartphone skills	Improved access		Used by teaching staff		Independent learning	
	Mean	SD	Mean	SD	Mean	SD
Basic	5.5	2.3	4.7	2.0	4.2	2.1
Intermediate	7.0	1.8	6.2	2.1	5.9	2.1
Advanced	8.1	1.3	7.7	2.0	7.2	1.7

Discussion

Principal Findings

The results of the current study demonstrate that most students owned smartphones, were able users, and perceived them as learning tools that allow students to access to learning resources. Resources available without students having to physically visit libraries, desktops, or meeting with colleagues because reliable connectivity to the Internet is ensured by the university wireless connection and 3G services.

On a daily basis at this stage in their education, students are on campus, the last year of training is completed in outplacements often in remote areas. Smartphones have been reported to enable learners and practitioners to access not only learning resources, but also professional advice when used in remote areas [12,26,27], opening opportunities to enhance teaching and learning on the last year of students' training.

The ubiquitous nature of smartphones is an advantage but it could also be a disruption. This study shows that slightly more than one-half of the students used their smartphones in the lecture theater regularly and often. It is a common debate whether use of connected devices during lectures is a productive activity, as often, such use might be irrelevant to the learning activities.

However, it appears that this phenomenon is here to stay, and it probably reflects the current "multitasking" approach of

students to learning. Smartphones are often banned from classes [28], but have the potential to engage students' participation, for instance, by helping students creating their own content.

More than one-half of the students used their smartphones to take pictures of their work, probably preclinical work, since these are their first years of training. Content creation by students opens opportunities for the students to record and share their progress with peers and instructors. Students were inclined to think that smartphones improved access to learning material. However, they were much less positive regarding independence of learning and teaching staff using smartphones. Further exploration would reveal if this attitude might be different in a course with activities facilitated by the usage of smartphones.

The diversity of smartphone operating systems overtime and geographical location makes it necessary to use compatible learning applications. Web-based applications such social media are a good example. In this study 76/204 (37.3%) respondents had an educational application and 126/214 (58.8%) had the university application against 178/201 (88.5%) students using their smartphone to access social media. This finding differs from a study where medical students reported to have multiple educational applications [5]. Perhaps reflecting that there are more medical than dental applications available.

A significant number of those who accessed social media with their smartphones found it of value for learning. Social media blended into traditional educational environments might enhance learning and collaboration despite geographic location [7]. This

is promising for courses, as the one in this study, with outplacements activities, and with a portion of students whose vernacular is not the teaching language because social media is shown to improve participation of students whose first language is not English [7].

Social media is more popular among younger students. However, the average general skills with smartphones did not vary significantly among age, gender, or origin. This finding suggests that students out of the millennial group, older than 30, have adapted to the use of smartphones and are skilled users of this technology.

Future Research

Exploring educators' opinion on the use of smartphones for learning and teaching is not included in the present study. However, many faculties might not feel proficient with this type of technology and might find it disruptive. Using social media as a teaching tool might also require staff to have control over the site content because of the risk of students' inappropriate behaviors, such as breaching patients' privacy and authors' copyrights [8]. Whether students will continue to use social

media sites in the same way, if these are moderated or visited by their teachers, is an interesting question to be investigated.

The use of smartphones occurring without teaching staff intervention or guidance is an indication of the educational potential of such devices. Smartphones open opportunities for innovative ways to learn and teach. It is encouraging for instructors searching for new teaching methods to see that learning content is accessible, and interaction is possible through smartphones regardless of teaching staff intervention.

Conclusions

The results from this study corroborate that students use smartphones and social media for their learning activities even though this technology has not been formally included in the curriculum, and perceive their smartphones as learning tools. This might be an opportunity for teaching staff to use smartphones to enhance students' learning needs without the constraints of time and location. In light of the results of this study, it appears feasible to develop learning activities involving smartphones. It might be advisable to design learning material that not only allows access through computers but also through smartphones.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Questionnaire.

[PDF File (Adobe PDF File), 111KB - mhealth_v2i2e20_app1.pdf]

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Abbreviations

3G: third generation
ICT: information and communication technology
VAS: visual analogue scale

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Original Paper

The Development of an Automated Device for Asthma Monitoring for Adolescents: Methodologic Approach and User Acceptability

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Abstract

Background: Many adolescents suffer serious asthma related morbidity that can be prevented by adequate self-management of the disease. The accurate symptom monitoring by patients is the most fundamental antecedent to effective asthma management. Nonetheless, the adequacy and effectiveness of current methods of symptom self-monitoring have been challenged due to the individuals' fallible symptom perception, poor adherence, and inadequate technique. Recognition of these limitations led to the development of an innovative device that can facilitate continuous and accurate monitoring of asthma symptoms with minimal disruption of daily routines, thus increasing acceptability to adolescents.

Objective: The objectives of this study were to: (1) describe the development of a novel symptom monitoring device for teenagers (teens), and (2) assess their perspectives on the usability and acceptability of the device.

Methods: Adolescents (13-17 years old) with and without asthma participated in the evolution of an automated device for asthma monitoring (ADAM), which comprised three phases, including development (Phase 1, n=37), validation/user acceptability (Phase 2, n=84), and post hoc validation (Phase 3, n=10). In Phase 1, symptom algorithms were identified based on the acoustic analysis of raw symptom sounds and programmed into a popular mobile system, the iPod. Phase 2 involved a 7 day trial of ADAM in vivo, and the evaluation of user acceptance using an acceptance survey and individual interviews. ADAM was further modified and enhanced in Phase 3.

Results: Through ADAM, incoming audio data were digitized and processed in two steps involving the extraction of a sequence of descriptive feature vectors, and the processing of these sequences by a hidden Markov model-based Viterbi decoder to differentiate symptom sounds from background noise. The number and times of detected symptoms were stored and displayed in the device. The sensitivity (true positive) of the updated cough algorithm was 70% (21/30), and, on average, 2 coughs per hour were identified as false positive. ADAM also kept track of the their activity level throughout the day using the mobile system's built in accelerometer function. Overall, the device was well received by participants who perceived it as attractive, convenient, and helpful. The participants recognized the potential benefits of the device in asthma care, and were eager to use it for their asthma management.

Conclusions: ADAM can potentially automate daily symptom monitoring with minimal intrusiveness and maximal objectivity. The users' acceptance of the device based on its recognized convenience, user-friendliness, and usefulness in increasing symptom awareness underscores ADAM's potential to overcome the issues of symptom monitoring including poor adherence, inadequate

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technique, and poor symptom perception in adolescents. Further refinement of the algorithm is warranted to improve the accuracy of the device. Future study is also needed to assess the efficacy of the device in promoting self-management and asthma outcomes.

Introduction

Asthma and Adolescents in the United States

Asthma represents a serious health condition in children and adolescents in the United States, with increasing mortality and morbidity over the past two decades [1]. According to recent national statistics [2], current asthma was reported by over 7 million children (9.6%) ages 17 and younger in the United States, of which, 39% (2.8 million) were adolescents (12-17 years old). Nearly 12% of high school students in the United States reported a current asthma diagnosis in 2011 [3]. Adolescents suffer greater asthma-related morbidity than other age groups [4,5]. Serious adverse outcomes requiring hospitalization, intubations, and cardiopulmonary resuscitation are more common in adolescents than in younger children [6]. Moreover, asthma mortality among adolescents is approximately twice that of younger children [7]. Given the high prevalence and substantial adverse outcomes of asthma and its overall impact on quality of life in adolescents, it is imperative to implement effective strategies that can improve self-management and health outcomes in this population.

Asthma Self-Management

Prior research has generated compelling evidence that programs promoting self-management can reduce morbidity and improve asthma outcomes in children [8-11]. Successful asthma management strategies require the patients' active commitment to engage in care processes by establishing self-monitoring routines [12]. Adequate self-monitoring of asthma symptoms is considered to be the cornerstone of appropriate asthma management, leading to fewer cases of asthma exacerbation and acute care visits, as well as better functional outcomes and higher quality of life in children and adolescents [13]. Symptom monitoring informs patient decisions to initiate necessary self-management behaviors (eg, adjust medication, alter activity level, alter the surrounding environment, or seek medical assistance), as well as the health care providers' decisions related to an appropriate treatment course. Thus, current guidelines by the National Heart, Lung, and Blood Institute Expert Panel Review 3 [14] highlight the importance of ongoing symptom monitoring. Programs that increased patient understanding and perception of asthma control could improve asthma control, quality of life, and reduce acute health care utilization [15].

Nonetheless, studies of children have raised concerns about the adequacy and effectiveness of current methods of asthma self-monitoring, including symptom-based and peak expiratory flow (PEF) monitoring [13,16,17]. Poor adherence and inadequate technique by children further diminish the clinical usefulness of PEF monitoring. The uncertainty of current monitoring strategies underscores the imperative of an alternative symptom monitoring strategy that addresses the issues of accuracy and patient adherence.

Accurate symptom monitoring by patients is the most fundamental antecedent to effective asthma management, yet existing monitoring strategies have not been conducive to adolescents' cooperation, nor yielded accurate or clinically useful information [13,18-20]. Having recognized these limitations, we developed an innovative device that can facilitate continuous and accurate monitoring of asthma symptoms with minimal disruption of daily routines, thus increasing acceptability to adolescents. The objectives of this paper were to: (1) describe the development of this novel symptom monitoring device to support optimal asthma self-management for teenagers (teens), and (2) assess their perspectives on the usability and acceptability of the device.

Methods

Description of an Automated Device for Asthma Monitoring

The automated device for asthma monitoring (ADAM) is a novel device that quantifies symptoms in numbers, based on predetermined algorithms of symptom sounds including coughs and wheezes. The device uses the iPod as a platform. It automatically processes and analyzes raw symptom sounds, and displays and stores the number of identified symptoms. It simultaneously monitors activity using the iPod's built in accelerometer, which allows patients to view the symptoms in relation to their level of activity. Secondary functions of the device include electronic asthma diary keeping, and medication tracking and reminding. Figure 1 shows the selected screenshots of the device.

Figure 1. Selected screenshots of the automated device for asthma monitoring (ADAM).

Overview of the Study Design for the Development and Validation of the Automated Device for Asthma Monitoring

This study consisted of three phases, including development (Phase 1), validation (Phase 2), and post hoc validation (Phase 3). During Phase 1, we collected raw symptom sounds that became the basis for the delineating symptom algorithms. A case-control design was used for Phase 2 involving an asthma group and a nonasthma group, who participated in a 7 day trial to determine the validity and feasibility of the new device. In Phase 3, we reevaluated the modified and improved device for its sensitivity and specificity. Figure 2 shows the overall flow of the study phases. Below are the detailed descriptions of the methods implemented in each phase. The Institutional Review Board approved the study protocol for each phase, and informed parental consent and teen assent were obtained for each phase prior to data collection.

Figure 2. Overview of the study flow from Phase 1 to Phase 3.
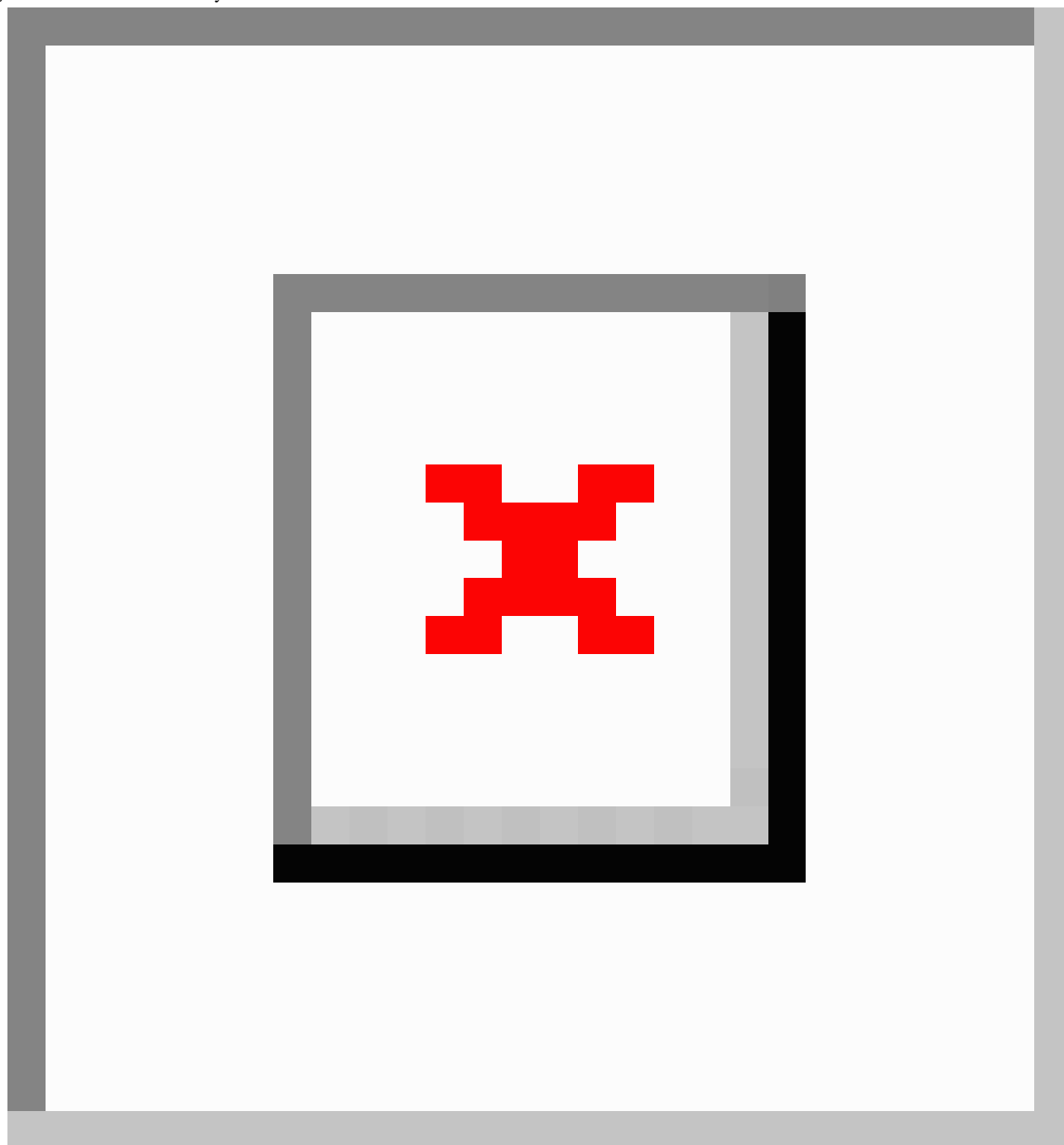
Phase 1: Development Phase

Study Design and Sample

To develop symptom algorithms, we collected raw symptom sounds using a digital recorder. The identified algorithms were then programmed in a popular mobile device, the iPod, which was used as a platform to capture, process, and store symptom information. Subsequently, the prototype device was beta-tested with the subjects to evaluate its operation. Subject eligibility criteria were: (1) 13-17 years old, (2) physician-diagnosed asthma for at least one year, (3) active asthma symptoms within the last 24 hours, and (4) ability to understand spoken and written English. Those subjects, with other diagnoses that can produce asthma-like symptoms (eg, cardiac disease, cystic fibrosis) or significant cognitive impairment that would present concerns in following the study protocol, were excluded. There were 29 adolescents that participated in the sound collection stage. Of those adolescents, 16 continued on to participate in the beta-testing period, along with 8 additional subjects who enrolled only for beta-testing. The majority of participants (54%, 20/37) were recruited from the emergency department, and the rest (46%, 17/37) were recruited from pediatric outpatient clinics affiliated with a major academic medical center through clinical referrals or recruitment flyers. Figure 3 shows the numbers of teens from screening to enrollment.

Figure 3. Enrollment flowchart for Phase 1.
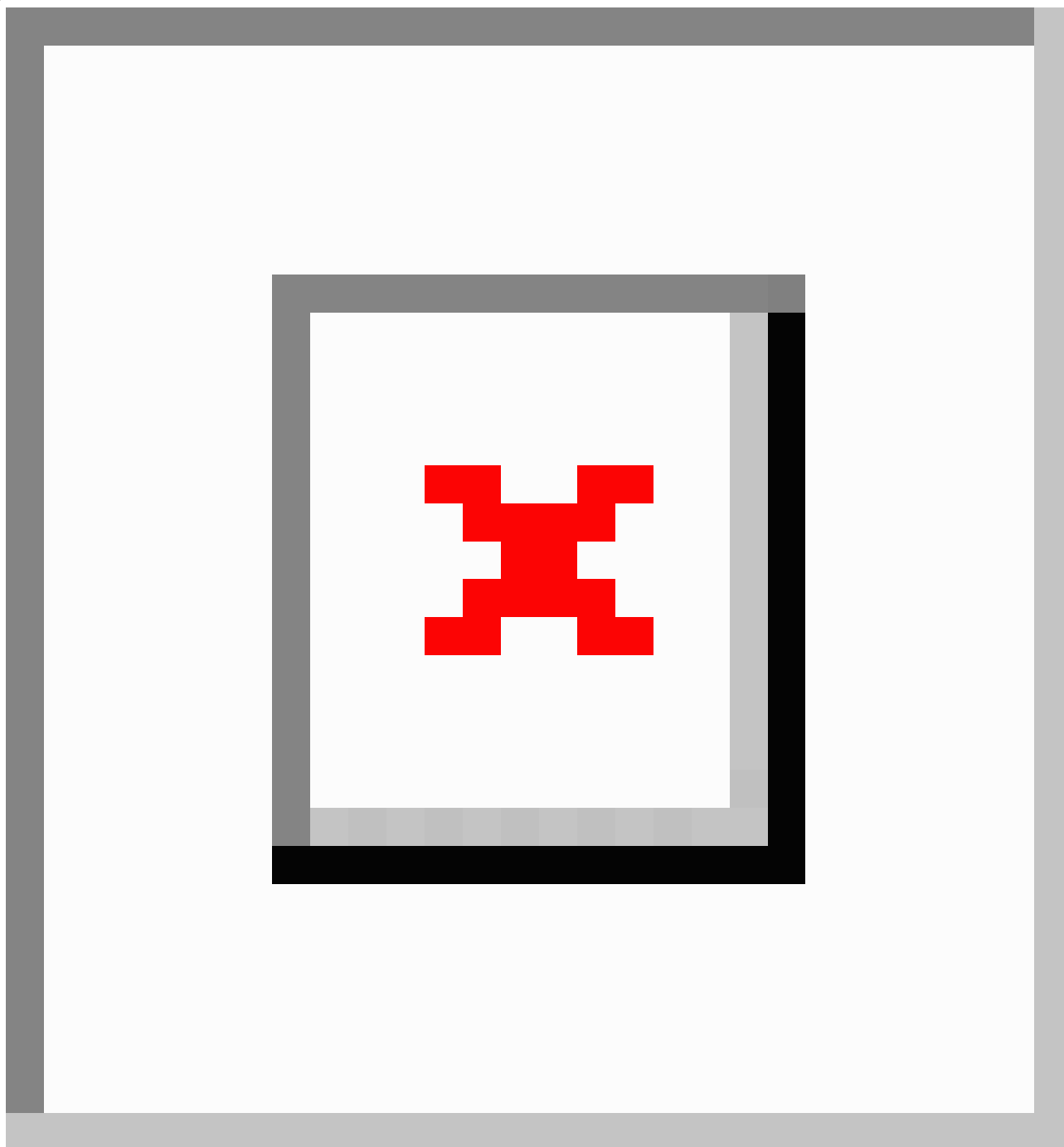
Procedure and Instruments

The subjects continuously recorded breathing sounds for 24 hours during the sound collection stage using a digital recorder (Olympus WS-331M). A small external microphone was attached mid line on the shirt collar to amplify the breathing sounds for recording. The subjects carried the recorder either in their clothing pockets or a carrying case. They were instructed to pause the recording during times they desired privacy. Over night, the recorder and microphone were placed on a surface close to the head of the bed to record any nighttime symptoms, while the device was recharging. Each subject provided a minimum of 10 hours of sound recording. The subjects simultaneously completed a 24 hour asthma diary, recording symptoms, feelings, activities, and medication use.

Sound Analysis

The recorded sounds were downloaded to a computer, and two research nurses carefully listened independently using audio software, Adobe Audition, to extract the sounds of asthma symptoms including coughing, wheezing, and throat clearing. The sounds of interest were sorted and annotated for further validation and analysis. There were three clinicians, including a pediatrician, a pulmonologist, and the principal investigator (HR) who did the validation. The principal investigator independently evaluated the pool of randomly selected symptom sounds, and classified them into cough, wheeze, and others.

They agreed on 96.6% of the cases (116/120 total cases), and any discrepancies that failed to reach agreement were removed from the symptom database.

Beta-Testing of the Prototype

Following the initial development of the prototype, a 3 day prototype trial was conducted with 24 teens, of which 16 also participated in the sound recording stage earlier. During the 3 day beta-testing period, the subjects carried the prototype device during the daytime, and kept it running over night while recharging.

Phase 2: Validation and User Acceptance of the Device

Study Design and Sample

This phase used a case-control design involving an asthma group (n=42), and an age matched nonasthma group (n=42) to evaluate the validity of the newly developed device. Figure 4 shows the flow of participants.

The most common reasons for ineligibility were unverifiable current asthma diagnosis for the asthma group, and having past asthma diagnosis or respiratory symptoms for the nonasthma group. Each group participated in a 7 day trial during which the device was used continuously for 24 hours. The asthma group eligibility criteria for Phase 2 were similar to those in Phase 1, except that they were not required to be symptomatic at the time of enrollment. The nonasthma group consisted of those who were with no current/past history of asthma or other health conditions producing asthma-like symptoms, and free of any current respiratory symptoms.

We performed validity testing, comparing results among adolescents with and without asthma, and correlating data from the asthma group to other measures of the asthma condition, including Forced Expiratory Volume in 1 second, Asthma Control Test, *Fractional exhaled nitric oxide*, daily symptom diaries, visual analogue scale, health care utilization, and asthma related quality of life. The data were collected at pre and post 7 day trial. Asthma control, health care utilization, and quality of life were reassessed at a 3 month follow-up after the trial for the asthma group. The results of our validity testing are beyond the scope of this paper.

Figure 4. Enrollment flowchart for Phase 2.
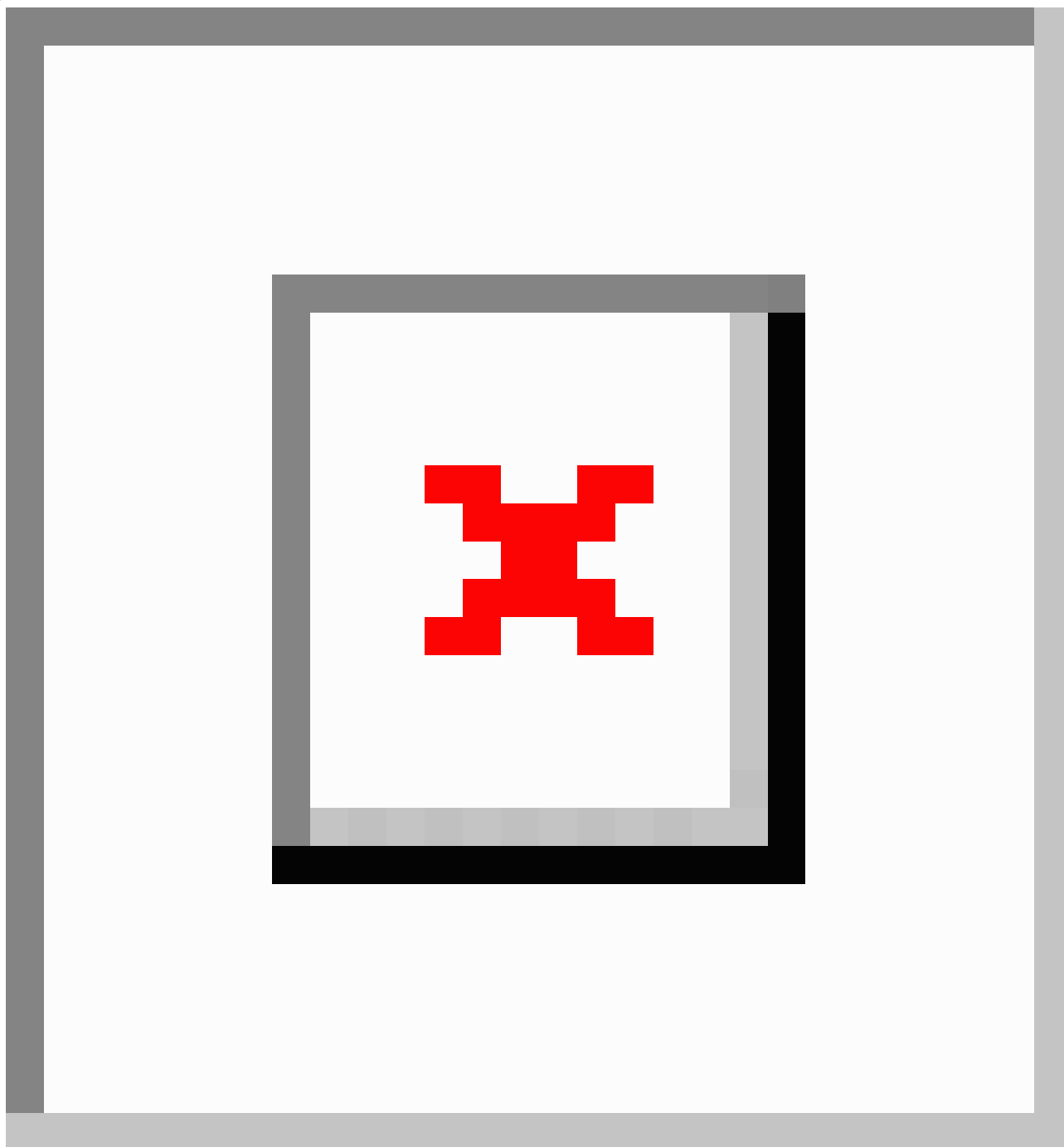
Acceptance Evaluation

We assessed user acceptance using a brief survey and in-depth interviews with the participants. The user acceptance data were collected at the completion of the 7 day trial period from the asthma group participants only, because they represented the future users of the device. For the quantitative data, we devised a 7 item user acceptance survey to assess ADAM's usefulness, user-friendliness, convenience, and social acceptableness on a 5 point scale, from strongly agree (5) to strongly disagree (1). The study staff went over each item with the participants. Total scores of 28 or higher on the 7 item acceptance survey were considered an indication of the participants' satisfactory acceptance. The cutoff point was predetermined, because it would identify those who responded favorably in all 7 items by choosing either "agree" or "strongly agree". The items were reviewed individually, and the proportion of "agree" and "strongly agree" responses for each question was computed.

To obtain in-depth feedback and perspectives on the device, we conducted brief semistructured individual interviews (10-15 minutes) with the asthma teens (n=42). The interviews were audiotaped and transcribed verbatim for analysis. *ATLAS.ti* 7 was used for data storage and management, and the basic qualitative description method was used to derive simple descriptions of the data in order to best understand the contents [21]. We used conventional content analysis to analyze the data [22]. There were two researchers that analyzed the data independently using content analysis techniques, and codes

were compared. Any discrepancies between their analyses were discussed and reconciled. The coding was guided by the purpose of the interview, which was to determine the acceptability and usefulness of the device. No preconceived categories or a priori codes were used for analysis.

Phase 3: Post Hoc Validation Phase

Modification of the Algorithm and Device Features

Phase 2 revealed the unstable performance of the device in detecting symptoms, particularly wheezing. On several occasions, we noted incremental wheezing counts even in a quiet environment. Moreover, during exit interviews, several of the participants reported incidents that suggested inaccuracies of the device (eg, "I saw the symptom number going up even when I wasn't wheezing or coughing"). These indications of the suboptimal performance of the device prompted us to further refine the symptom algorithm to improve the sensitivity and specificity of it. Given the subtlety and wide variation of acoustic signatures of wheezes within and across individuals, the study team agreed that developing a stable and universal wheeze algorithm would be unattainable. We therefore decided to concentrate our focus on refining the cough algorithm. We enhanced the algorithm by incorporating a standard framework used in speech recognition to effectively filter in symptom sounds from speech and background noise. We manipulated the device so that it could record raw symptom sounds. In doing so, we could confirm whether the sounds identified by the algorithm were indeed asthma symptoms (true positive). To adequately assess specificity (true negative), the device automatically retained samples of the raw audio data that it captured. The device processed individual segments of 6 seconds. Whenever the algorithm identified a cough, the corresponding 6 seconds of raw audio samples were retained. Also, 6 second intervals of raw audio data were randomly retained when no coughs were identified. These audio files were retrieved, and allowed us to compute the performance metrics of the detection algorithm (ie, we were able to compare the device symptom counts against the audio data by manual listening). In Phase 2, activity levels were monitored inconsistently, resulting in incomplete data. To enable the built in accelerometer to monitor activity levels continuously for an extended time, we encouraged the participants to leave the device on all the time and to charge the battery whenever possible, in addition to using an external battery pack.

In the exit interview, some of the participants suggested that symptom and activity data be displayed in a graphical manner instead of raw numbers. We then modified the user interface so that symptom data would be presented in a bar graph that showed the aggregated number of coughs each hour along with the corresponding line chart of averaged activity scores (see the image on the right in Figure 1). In doing so, the users can readily keep track of changes in symptom patterns in the 24 hours, thus making the device data more meaningful. To enhance clinical relevance, we added a function that allowed the users to enter medication usage in the device, control and rescue medication separately, and when the medication was taken. This function was not only to assess the users' medication adherence, but also to help the users visualize short- and long-term changes in symptoms after medication use. The users who understand how medications affect their symptoms might be more likely to adhere to their medication regimen.

Beta-Testing of the Enhanced Device

The small scale post hoc phase (Phase 3), involving ten adolescents with active symptoms, was designed to evaluate the adequacy of the enhanced algorithm, and to test the adequate operation of the revised and additional device features, including displaying data in a graphic form and recording medication use. The eligibility criteria and recruitment strategies were the same as those in Phase 1. The participants used the enhanced device for three consecutive days.

Results

Phase 1: Sample Demographic Characteristics and Symptom Algorithms

Summary

The demographic characteristics of the sample are summarized in Table 1.

Table 1. The demographic characteristics of the sample in Phase 1 (n=37).

Characteristics		
Sex, n (%)		
	Males	21 (57)
	Females	16 (43)
Age		
	Mean (SD)	14.7 years (1.4)
Race, n (%)		
	White	16 (43)
	Nonwhite	21 (57)
Annual household income, n (%)		
	Less than US $30,000	22 (59)
	$30,000 to 69,999	6 (16)
	$70,000 or more	7 (19)
	Missing	2 (5)

Asthma Symptom Severity

Of the sample of the participants (n=29) who provided raw symptom sounds, only 28% (8/29) reported their asthma was well controlled. Specifically, 14 teens reported nighttime symptoms once per week or more often, and 72% (21/29) had >2 days/week or more frequent daytime symptoms. About 80% (23/29) used rescue medication >2 days/week or more frequently, and all but one participant reported limited activities of some degree.

Development of Symptom Algorithms

The algorithm for detecting coughs processed audio data in two steps following a standard pattern common to speech and other recognition frameworks. In the initial preprocessing step, the incoming stream of digital audio samples was arranged into fixed length frames from which a set of audio features (feature vector) was computed. The sequence of feature vectors was then passed to a hidden Markov model (HMM) Viterbi decoder (using a token passing implementation) [23,24], using HMMs trained on our database of symptom and background noises. This basic methodology has previously been shown to be applicable to the ambulatory detection of coughing sounds [25]. Subsequently, the number and times of the detected symptoms were stored in the platform device memory, and displayed for patient review. Figure 5 illustrates the schematic overview of the audio data processing by ADAM. Although our initial intention was to detect both coughing and wheezing, we were only able to successfully apply our automated techniques to coughs. The detailed technical descriptions about the development and validity of the symptom algorithm for coughs are reported elsewhere. The samples of wheezes gathered were too sparse, and varied too much across each individual teen, thus, we did not have enough data to reliably train an HMM for wheeze detection. The sensitivity (true positive) of the updated cough algorithm was 70% (21/30), and, on average, 2 coughs per hour were identified as false positive.

ADAM was also designed to measure activity levels using an incorporated accelerometer. However, we encountered challenges in monitoring activities consistently due to the device's limited battery life. Later in our trial, we attached an external battery pack to the device to address the issue. Figure 6 shows the images of the prototype device with an external battery (a), and a teen wearing the device (b and c).

Figure 5. Schematized flow of the data processing used in the automated device for asthma monitoring (ADAM) application. HMM=hidden Markov model.
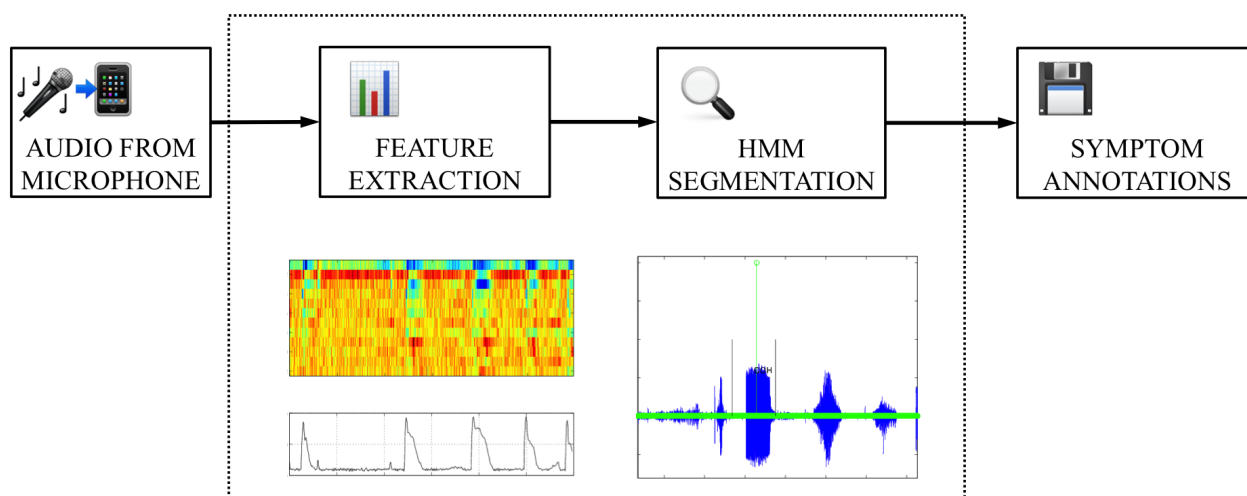
Figure 6. Images of the automated device for asthma monitoring (ADAM) with an external battery attached (a), and a teen wearing the device (b and c).

Phase 2: Participants and Procedures

Recruitment and Procedures

A total of 84 teens (42 asthma teens and 42 nonasthma teens) participated in Phase 2. The sample characteristics are summarized in Table 2.

Both of the groups of teens, asthma and nonashthma, were recruited from the researcher-affiliated academic medical center. There was 73% (61/84) of the final sample that were recruited from the pediatric emergency department, some were from

outpatient clinics (4%, 3/84), and some from recruitment fliers (23%, 19/84). All of the participants but one in the nonasthma group completed the 7 day trial. We learned that some schools do not allow students to use mobile devices during instructional hours. So, we provided an official letter addressed to a school administrator asking permission for the participants to continuously use the device during school hours. No participants reported any other issues related to using the device at school. All of the devices except for one were safely recovered. The missing device was assigned to a nonasthma teen, who did not complete the follow-up after enrollment.

Table 2. The demographic characteristics of the asthma and nonasthma groups in Phase 2 (N=84).

Characteristics		Asthma group	Nonasthma group
Gender, n (%)			
	Male	17 (40.5)	16 (38)
	Female	25 (59.5)	26 (62)
Age			
	Mean (SD)	15.2 years (1.5)	14.8 years (1.3)
Race, n (%)			
	White	16 (38)	29 (69)
	Nonwhite	24 (57)	13 (31)
	Missing	2 (5)	0
Annual household income, n (%)			
	Less than US $30,000	22 (52.4)	12 (28.6)
	US $30,000 to 69,999	7 (16.7)	11 (26.2)
	US $70,000 or more	12 (28.6)	19 (45.2)
	Missing	1 (2.3)	0

Results of the Acceptance Survey

Table 3 summarizes the responses for each acceptance item. The user acceptance data were collected only from the asthma group (n=42). Overall, the majority of the teens responded positively to each item. Particularly, 83% (35/42) of the asthma group reported having no trouble in remembering to wear the device for 24 hours to monitor their symptoms. Cronbach alpha of the 7 item acceptance survey was .78. The total acceptance scores ranged from 18 to 35 (mean 27.1, SD 4.4). Over 57% (24/42) of the sample responded with a total score of 28 and greater, indicating overall satisfaction with the device. No significant differences in acceptance were found by gender, age, race, family income, or the current status of symptom control (symptomatic vs asymptomatic). We computed correlations between the 7 acceptability items and the 5 items of the asthma control test. Significant negative relationships were found between the "embarrassment" item, the frequency of daytime symptoms (r=-.43, P=.004), and rescue medication use (r=-.45, P=.003). That is, those who reported higher levels of daytime symptoms or rescue medication use were more likely to be embarrassed about using the device in the presence of others.

Table 3. Summary of the user acceptance survey for each item (n=42).

Items	Agree, n (%)	Neutral, n (%)	Disagree, n (%)	Missing, n (%)
I like the idea of having the device record my asthma symptoms to monitor how well my asthma is being controlled and managed.	34 (81)	8 (19)	0	-
The device helped me be more aware of my asthma condition.	24 (57)	16 (38)	2 (5)	-
The device would make it easier for me to manage my asthma.	20 (47)	13 (31)	9 (21)	-
I don't mind using the device for a week or longer for continuous monitoring of my asthma.	29 (69)	7 (17)	6 (14)	-
I found it easier operating the device than my peak flow meter.	23 (55)	9 (21)	2 (5)	8 (19)
I would not have any trouble remembering to wear it every morning throughout the day and put it by my bed for nighttime symptoms.	35 (83)	2 (5)	5 (12)	-
I would not be embarrassed to use the device in front of my friends.	30 (72)	3 (7)	9 (21)	-

Results of the Qualitative Interview Data

Categories of Acceptability

After establishing a preliminary set of codes after content analysis, two researchers presented them to other team members for their input and feedback. Revisions were made to the codes, and all of the interviews were recoded until a consensus was reached. The team then clustered the codes into categories that best described the acceptability of the device. We chose to create a series of descriptive data categories, as it fit the direct and exploratory nature of the work [26]. The initial set of categories was presented to the team. We created a final set of categories following further discussion and consensus with the team. Member checking was done by presenting the categories and codes to a group of adolescents with asthma (n=6) who did not participate in the interviews. The following are five categories

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of acceptability identified from the interview data, with examples of statements from the teens.

Comfortable and Cool

This category describes the cognitive and emotional aspect of using the device. The adolescents reported feeling comfortable wearing the device. They did not feel self conscious or embarrassed about using it around their peers, and they perceived the iPod format to be "cool" and "stylish".

> *It was kinda' cool the way y'all set it up, the iPod. It didn't make it look like something suspicious. It made it look, you know, a regular person having an iPod.* [Judy]

> *I just kind of went through my regular activities, woke up, put the iPod in my pocket, went to school and told my friends...they were like, "dude, that's awesome"...* [Mark]

Easy and Convenient

This category represents the participants' perceptions about the levels of needed skills and convenience in using the device. The majority (n=37) described the device as being "easy" to use and understand. They concurred that the device was easy to operate and convenient to use daily.

> *Like, I could understand everything and it's not like its difficult or inconvenient or anything. It just listens and you have to remember to keep it on you.* [Jeremy]

> *It was easy. Just put it in my pocket. Go to school and when I go to sleep, just put it by my bed. Simple. Then you wake up again and do the same thing all over.* [Johnny]

Useful and Helpful

The adolescents recognized that the device was useful and helpful in changing their perspectives on their asthma management, as well as conversing with others about their asthma. It assisted in the recognition of symptoms and triggers, and promoted the reflection of symptom-triggering behaviors and environments. Some of the participants stated that this awareness led to changes in their asthma self-management behaviors.

> *I really think it was a great experience because it really showed me during my activities, daily lives, and what I do, whether I am controlling it or what I shouldn't be doing. If I'm around smoke or running, it shows me whether I'm coughing or wheezing or how good, how level my asthma is...* [Emma]

> *[I]t really like put it in front of me and I'm like "wow, I did not know that that was how bad I was today and yesterday I was worse" and it definitely helped me.* [Alice]

> *The numbers on the diary thing...helps with the triggers because if you're around certain things or you're doing certain activities and your numbers go up for coughing or wheezing, then you know that activity makes you cough or wheeze a lot...it really shows people...so if you think running probably affects*

> *your asthma that could really tell you instead of telling yourself, "oh I'm out of breath. I'm wheezing." That tells you how many wheezes...it shows you whether or not are you controlling your asthma or is it out of control...* [Tom]

The participants also recognized that using the device was helpful in initiating and stimulating dialogues with peers, family, and health professionals about asthma. While this often started as a conversation about the device itself, it also led to deeper conversations about their health condition with others.

> *A lot of people question me. Like what the device was...And I kind of explained to them that I was doing as asthma study and they kind of took it, "Oh that pretty cool", but others "What is that? I never knew you had asthma." So, I had to explain to them...how the entire device worked.* [Vicky]

> *My friends are pretty much alright, so they say "Oh I think that's pretty cool" or a couple of my friends were like "Oh I wish they had stuff like that for me. Where did you find out from?" Because I have a couple of friends who have asthma too and um one of my friends who doesn't have asthma, she was really, really like really excited. "Maybe they'll figure out something to help manage your asthma." I'm like I hope so...* [Justin]

We Would Wear It

Most of the participants (n=37) concurred that the device was conducive to everyday use for anyone who has asthma, and would recommend it to other teens with asthma.

> *[I would recommend it] definitely if they're struggling with asthma, I feel like it would be a really good, easy way to see how you're actually doing.* [Mickey]

Suggestions for Improvement

The participants made several constructive suggestions for improving the device. Although the majority of the teens (n=23) favored using an iPod as a platform, 19 participants stated that they would prefer a smaller and lighter device. Additionally, 18 participants recommended simplified accessories (microphone, cords) that would make it easier and more convenient to use. There were six of the adolescents that suggested making the device available in a smartphone application (app) format, and three suggested that the device be equipped with audio prompts for worsening symptoms or reminders. For some, the numeric and graphic presentation of the symptoms displayed on the device screen were confusing, suggesting the need for further refinement of the user interface of the device.

Phase 3: Sample and Enhanced Device Data Summary

Of the 10 teen participants in Phase 3, six were females (60%), and seven were black or African Americans (70%), and from families of an annual income under US $30,000. Of a total of 146,167 data points recorded in the device (mean 18,271 data/teen), coughs were recorded 3784 times (2.59%). The device sampled 27,404 sound clips (6 seconds each). The total number of accelerometer data of one minute length each was

36,040 (4004 per teen). The volume of data indicated that activity levels were monitored for, on average, 2.7 days per participant, accounting for most of the 3 day period. The range of the accelerometer data was 0-24 (mean 0.83, SD 2.89). There was significant correlation found between the number of coughs and the accelerometer data (r=.037, P<.001), indicating that the greater number of coughs was associated with the higher activity levels. The medication tracking feature was used by eight teens (80%, 8/10) for 3 days. On average, each teen reported using controller medications three times and rescue medication four times throughout the three day period. All of the participants concurred that the graphical presentations of the symptom and activity data helped their understanding of it, and the medication tracking feature was easy to use.

Discussion

Asthma Symptom Monitoring

Accurate symptom monitoring by patients is the most fundamental antecedent to effective asthma management, yet existing monitoring strategies have not been conducive to adolescents' cooperation, or yielded accurate or clinically useful information [13,18-20]. Having recognized these limitations, we attempted to offer an innovative alternative to symptom monitoring through the development of a new device, ADAM, that would stimulate an adolescents' engagement, and ultimately lead to effective asthma management. Developing and validating a new device is complex, inherently involving multiple steps of meticulous planning and implementation, as demonstrated in this study. The objective of this paper was to describe the procedural elements that had been chosen to develop and validate the ADAM prototype to quantify asthma symptoms, and to examine the user acceptance of the device. A few attempts have been made to quantify the symptoms such as coughs and wheezes. However, most of these attempts have not been translated into addressing clinical issues, such as the inadequate patient monitoring of the symptoms. To our knowledge, this was the first attempt to incorporate symptom quantifying technology into mobile technology in developing a device that facilitates continuous monitoring of symptoms in vivo, particularly in adolescents with asthma. Because of the fluctuating nature of asthma symptoms during a given day (eg, more symptoms during nighttime than daytime), researchers have advocated for continuous symptom monitoring to obtain the abundance of useful information that it can generate to help health care providers make informed decisions regarding treatment [27].

ADAM was intended to automatically monitor coughs, wheezes, and activity level continuously for 24 hours. We sampled and validated the sounds of wheezes and coughs by employing a rigorous and lengthy process, and delineated algorithms of these symptoms based on the sound samples. Unlike coughs that were rather conspicuous, wheezes were subtle, adventitious, and had wide variations in acoustic manifestations, which made it difficult to establish a sensitive, generalizable algorithm that could sufficiently distinguish the wheezes from other noises. While wheezing sounds were often captured using a stethoscope and a quiet laboratory setting in earlier studies [28-33], our

wheeze algorithm was based on the sound data captured using an ordinary external microphone in everyday environments that were exposed to a wide range of noises. In the future, advanced sound capturing technology could help delineate wheeze algorithms effectively, while ruling out other noises. Due to the challenges involved in distinguishing wheezes from environmental noises using regular microphones, we decided to concentrate our efforts on coughs alone for the further refinement of the device. A cough is the most common symptom experienced by pediatric patients with uncontrolled asthma [34-37]. Therefore, we believe detecting coughs alone could add value to this device as a monitoring tool. The algorithm of coughs underwent several modifications throughout the study period to improve its performance. Beta-testing of the device raised concerns about accuracy, as it had initial challenges in differentiating noises (eg, door slamming, some speech sounds) from legitimate coughs. As a result, the algorithm was further refined and strengthened through multiple iterations. The sensitivity (true positive) of the updated algorithm was 70% (21/30), and, on average, 2 coughs per hour were identified as false positive. Further refinement of the algorithm is warranted to increase the accuracy and overall performance.

We used an existing mobile phone, the iPod, as a platform for processing, analyzing, and storing the data transmitted from a microphone. The iPod was selected as an age appropriate platform for ADAM because of its widespread ownership among, and potential appeal to, adolescents. The popular nature of the iPod among teens could make the device inconspicuous, should it be used for symptom monitoring in social settings. Peer influence is one of the barriers to self-management in adolescents [38]. In fact, adolescents often feel uncomfortable or embarrassed about their asthma, and are reluctant to take their asthma medication in the presence of their friends [39-44]. Therefore, using an inconspicuous platform such as the iPod was essential for the device to be accepted and utilized by adolescent users as intended. In addition, the iPod operating system (iOS) has a built in accelerometer that keeps track of the intensity of the users' movement, which indicates the level of activity. This function was incorporated in ADAM not only to monitor any impairment in daily activities, but also to facilitate the understanding of the symptoms in the context of the users' activity levels. That is, the device could potentially help to make distinctions between the symptoms that occur in connection with activity (eg, exercise induced symptoms), and those occurring independent of activities. Because the device design enables continuous monitoring of the symptoms and activities in real life situations, the new device provides a powerful option for comprehensive asthma monitoring that is also developmentally compelling.

Limitations

Several limitations of the study are noteworthy. First, our attempt to develop a reliable algorithm of wheezes was faced with challenges because of the wide variations of the acoustic signature of wheezing. Furthermore, the subtle nature of wheezing presented difficulties in detecting the sound using an external microphone in the teens' everyday life contexts. Therefore, wheezing detection by the device was not accomplished. Second, we learned later in Phase 2 that in order

for the iPod's built in accelerometer function to run continuously, the device should not to be on a "sleep" mode, which depleted battery power rapidly. As a result, we were unable to collect sufficient activity data to correlate with the number of symptoms. To remedy the issue, we attached an external battery pack to the iPod, which made the device bulky and less attractive, as commented by some of the teens. Third, some of the teens felt the cord of the external microphone was a nuisance. Further incorporation of advanced technology in the modification of the device (eg, power efficient operation of accelerometer, wireless microphone) is necessary to overcome the identified technical challenges and increase user convenience. Fourth, the user acceptance was based on only 7 days' use of the device. Therefore, we were unable to make any predictions about changes in the users' perceptions and attitudes toward the device over time. Further research is needed to examine the teens' attitudes over time, and how the attitudes affect the sustainability of the device. Last, although we speculated that displaying symptom data in a graphical form, a modification done in Phase 3, would aid the users' grasp of the clinical meaning of the detected symptoms, we did not collect data to support the assumption. Likewise, it is yet to be determined whether the medication tracking function we added in Phase 3 would improve medication adherence. Since Phase 3, we have further updated the user interface to make the device more user-friendly and effective in communicating data with the users (eg, automated "pop-up" messages triggered by the levels of detected symptoms). In addition, as suggested by some of the teens, the ADAM system is being developed as an "app" downloadable to mobile iOS systems, which will further enhance the device's accessibility in the future.

Positive Reviews

Despite the identified limitations, the new device was positively reviewed and accepted by the adolescent users who found it appealing, convenient, and conducive to daily use. The identified potential benefits of the device shed light on the positive impact of the device on promoting self-management, and ameliorating the burdens of asthma in adolescents. The endorsement of the device from the adolescent users is an encouraging first step to adherence to adequate self-monitoring, which has been challenging and elusive, particularly in this age group. Incorporating suggestions from the users in enhancing the device is critical to ensure its consistent use, and to increase its developmental and clinical relevance.

Conclusions

In summary, this new device can potentially automate daily symptom monitoring with minimal intrusiveness and maximum accuracy. Due to its foreseen safety, noninvasiveness, objectivity, convenience, user-friendliness, and cost containment, the approach has the potential to greatly enhance asthma management by adolescents and health care providers, thereby reducing the risk of inappropriate treatment and ameliorating asthma related impairments. As suggested in our qualitative data, this device has the potential to bring about changes in patient behaviors, such as avoiding triggers and adjusting medications by increasing the patients' awareness through real time assessment of symptoms and feedback. Further study is needed to evaluate the efficacy of the device in improving self-management and asthma outcomes.

Conflicts of Interest

None declared.

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Abbreviations

ADAM: automated device for asthma monitoring
app: application
HMM: hidden Markov model
iOS: iPod operating system
PEF: peak expiratory flow
teens: teenagers

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<u>Original Paper</u>

Feasibility and User Perception of a Fully Automated Push-Based Multiple-Session Alcohol Intervention for University Students: Randomized Controlled Trial

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Abstract

Background: In recent years, many electronic health behavior interventions have been developed in order to reach individuals with unhealthy behaviors, such as risky drinking. This is especially relevant for university students, many of whom are risky drinkers.

Objective: This study explored the acceptability and feasibility in a nontreatment-seeking group of university students (including both risk and nonrisk drinkers), of a fully automated, push-based, multiple-session, alcohol intervention, comparing two modes of delivery by randomizing participants to receive the intervention either by SMS text messaging (short message service, SMS) or by email.

Methods: A total of 5499 students at Luleå University in northern Sweden were invited to participate in a single-session alcohol assessment and feedback intervention; 28.04% (1542/5499) students completed this part of the study. In total, 29.44% (454/1542) of those participating in the single-session intervention accepted to participate further in the extended multiple-session intervention lasting for 4 weeks. The students were randomized to receive the intervention messages via SMS or email. A follow-up questionnaire was sent immediately after the intervention and 52.9% (240/454) responded.

Results: No difference was seen regarding satisfaction with the length and frequency of the intervention, regardless of the mode of delivery. Approximately 15% in both the SMS (19/136) and email groups (15/104) would have preferred the other mode of delivery. On the other hand, more students in the SMS group (46/229, 20.1%) stopped participating in the intervention during the 4-week period compared with the email group (10/193, 5.2%). Most students in both groups expressed satisfaction with the content of the messages and would recommend the intervention to a fellow student in need of reducing drinking. A striking difference was seen regarding when a message was read; 88.2% (120/136) of the SMS group read the messages within 1 hour in contrast to 45.2% (47/104) in the email group. In addition, 83.1% (113/136) in the SMS group stated that they read all or almost all the messages, compared with only 63.5% (66/104) in the email group.

Conclusions: Based on the feedback from the students, an extended, multiple-session, push-based intervention seems to be a feasible option for students interested in additional support after a single-session alcohol intervention. SMS as a mode of delivery seems to have some advantages over email regarding when a message is read and the proportion of messages read. However, more students in the SMS group stopped the intervention than in the email group. Based on these promising findings, further studies comparing the effectiveness of single-session interventions with extended multiple-session interventions delivered separately or in combination are warranted.

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Introduction

Risky drinking among college and university students is a global problem that is a tremendous challenge to overcome by preventive measures [1]. In previous research, we highlighted the magnitude of risky drinking among Swedish students; we found repeatedly that at least 50% of students could be classified as risky drinkers [2,3]. Alcohol is known to be an important underlying factor for a substantial proportion of the global burden of disease [4,5].

Although brief face-to-face interventions delivered in various health care settings have been shown to be effective, implementation has been poor so far [6,7]. Because risky drinking is a major problem among students, there has been a call for more cost-effective interventions in order to reach large groups of students [8,9].

With the rapid development of the use of computers and the Internet, not least among students, a number of online alcohol interventions have been developed and evaluated in recent years. Systematic reviews provide some evidence of the effectiveness of online alcohol interventions targeted toward students [10-12]. However, there is great variety in the length and content of these online interventions from automated single sessions to online intervention provided at several time points during a semester [8,13-16].

Among the many challenges, online interventions that require participants to log on several times face a major challenge with compliance, for instance the participants do not use the intervention as intended. Thus, Web-based interventions where a person is guided to a Web page with reflective information, exercises, and home work to be done before logging in at a later stage have been shown to be difficult to implement, not at least in the area of alcohol interventions [17].

More recently, it has been suggested that various combinations of single-session interventions with email or SMS text messaging (short message service, SMS) might increase compliance [18-22]. This was also supported by a meta-analysis by Riper et al [9] who found that a significant difference was found between single-session, personalized, normative feedback and more extended Internet-based intervention.

Only a few studies so far have reported the use of emails as a part of an extended alcohol intervention. In a study by Moore et al [23] participants were interviewed for perceived barriers and acceptability of an extended alcohol intervention and it was found that SMS was preferred over email and Web-based methods. In other health behavior change areas, such as diet and physical exercise, the results so far appear promising for extended email interventions. Prompting by email to remind about self-monitoring of physical exercise was just as effective as prompting via email plus telephone [24]. Also, the Alive! email-based intervention for increasing physical activity and

healthier diet was found to be effective compared with a wait-list control group. The intervention consisted of 25 personalized emails over a 3-month period [25].

In contrast to email-based extensions, previous research has, to a much larger extent, explored the use of SMS as part of an extended intervention, for example using SMS as reminders to log-on to a website or to perform self-monitoring of a health behavior [19-22]. In a review of 14 studies on behavior change interventions delivered by SMS messages, a positive outcome from the intervention could be measured in 13 studies [26]. However, participant retention ranged widely and in many studies at least 25% dropped out of the study. Also, the mode of initiating the intervention varied among studies and was found to be important for the effect of the intervention. Although the results were promising, a number of research issues were identified in order to learn how to optimize and enhance SMS message-based interventions [26].

An SMS-based alcohol intervention as a stand-alone intervention has so far only been tested in a few studies, however, promising results have been achieved in other areas such as tobacco use and weight loss [27,28]. One study using only SMS communication as an alcohol intervention showed promising results among young people discharged from an emergency department. Weekly assessment for 12 weeks followed by feedback were shown to increase reduction in alcohol consumption compared with a control group [29]. Another trial explored the perceived acceptability of adult trauma patients receiving SMS messaging as an aid to reduce harmful drinking behaviors. The patients recognized the potential benefit of such an intervention, although the study did not test whether a SMS-based intervention would be acceptable to the target group [30].

Two studies have explored the feasibility of collecting alcohol consumption data via SMS over a longer period of time, and compared the validity of the data with more traditional alcohol consumption questionnaires [23,31]. In both studies, SMS messages were found to be a valid source of data on consumption.

A few comparisons have been done between the use of SMS and email for an extended alcohol intervention. In a previous study, the Trial and Optimisation of Push-based High Alcohol Treatment 1 study (TOPHAT), we invited students participating in a single-session alcohol intervention to sign up for an extended push-based intervention over a number of weeks. The participants were given a choice of mode of delivery: SMS, email, or using an Android application and they could decide the length of the intervention (3-6 weeks) and the number of messages per week (3, 5, or 7 messages per week) [29]. Most students chose email as the mode of delivery; only 2.88% (33/1145) chose to download the Android application. In a follow-up immediately after the end of the intervention, no major difference was found concerning satisfaction with the

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mode of delivery, length of the intervention and frequency of messages. Overall, the participants (N=1138) who answered the follow-up questionnaire (response rate 82.68%, 941/1138) provided support for the feasibility and acceptability of a multiple push-based intervention delivered by SMS or email [32].

Since the effect size of single-session alcohol interventions is small, a large number of individuals who receive a brief Internet-based intervention continue to drink at levels that are considered risky [2,3,14,16]. Therefore, more developmental work and research is needed in order to optimize existing interventions or develop new means of communicating a health behavior change in order to accomplish an effect at the population level.

The present study, the TOPHAT-2 study, elucidates further on the feasibility of an extended push-based intervention by SMS or email to a nontreatment-seeking student population who have participated in a fully automated single-session alcohol intervention. Thus, the objective of the study was to compare the feasibility and user perception of an extended multiple-session intervention to students randomized to either an SMS or email push-based intervention.

Methods

Population and Recruitment

In mid-February 2013, all students on semesters 2, 4, 6, and 8 (a total of 5499 students) at the university in Luleå in northern Sweden were invited via their official university email address to complete a fully automated single-session online alcohol intervention by clicking on an embedded link in the email. The content of the invitational email and the single-session intervention was similar to that used in routine practice at universities throughout Sweden, as reported previously [2,3,16]. The only additional information was an offer to join a research project after having received the usual three pages of feedback from the single-session intervention. The invitation was signed both by the director of the local student health care center and the research leader (PB). After 1 and 2 weeks, a reminder was sent to those who had not completed the single-session intervention, and after 3 weeks the questionnaire was closed and no more responses were possible. The students completed the single session on a computer, smart phone, or tablet at their own convenience. After having completing the single session screening, all participants received personalized feedback direct on their computer and was also mailed a copy of the feedback.

After completing the single-session intervention (screening and personalized feedback), the students were offered participation in a draw for an iPad if they were willing to take part in an additional extended intervention after the single session, as part of a research project. Only participants who answered the follow-up questionnaire were included in the draw. All students, regardless of alcohol consumption, were invited to join the research project and participate in the extended intervention. The students were told that they would be randomized to either an SMS or email intervention. No other means of registering for the extended intervention was made available. An overview of the recruitment process and study design is shown in Figure 1.

Figure 1. Consort flow chart.
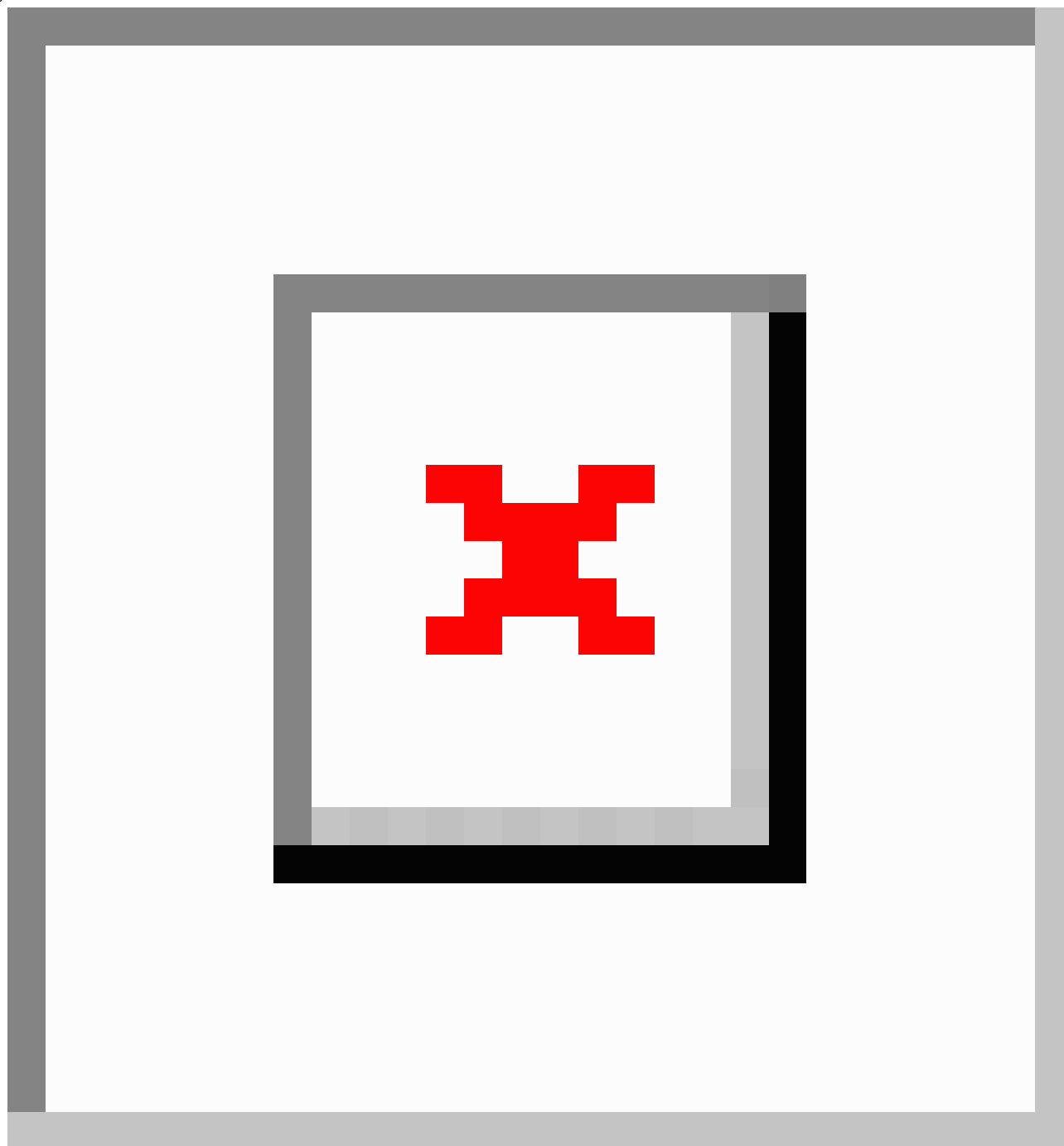
Signing Up and Completion of the Extended Intervention

All participants interested in joining the extended intervention were asked to submit their telephone number. They were then randomly assigned to receive the extended intervention via email or SMS. Randomization was done using Java's built in random number generator (java.util.Random). Randomization was thus fully computerized, did not use any strata or blocks, and could not be subverted because this and all subsequent study processes were fully automated (programmed by MB).

Initially, the participants were invited via email to complete the single-session intervention, therefore no further steps were necessary for those randomized to email because we already had their email address. However, all participants who were assigned to SMS were asked to confirm their participation by responding to an initial SMS in order to ensure that the telephone number was correct.

Thirty-two of the students who were randomized to the SMS intervention (n=261) did not manage to activate the intervention (ie, gave an incorrect telephone number, did not respond to the initial SMS or typed the wrong confirmation word) and therefore never received the intervention. This lead to a study group of 422 participants, with 229 participants assigned to the SMS group, and 193 to the email group (Figure 1).

Once a participant was randomized (and for the SMS group having confirmed the telephone number) the intervention ran

for 4 weeks. All participants received the same intervention content. The participants could terminate the intervention at any time by sending an SMS with the text "Stop" or answering an email with the word "Stop." After the participant received the last message, an email was sent containing a link to the follow-up questionnaire. The follow-up questionnaire was only sent to those completing the intervention and therefore those who actively terminated the intervention (n=56) did not receive the follow-up questionnaire.

Content of the Extended Intervention

The new extended intervention consisted of messages delivered to participants at a specific time during the week. There were four messages per week, for a total of four weeks.

The textual content of the messages was created based on prevailing theories within the field of behavior change, including Self-Determination Theory, Social Cognition Models, Social Cognitive Theory, Theory of Planned Behavior, and Model of Action Phases. The messages were also inspired by some of the assessment questions commonly used in alcohol research. The content of the messages was labeled in order to keep track of when a particular type of message was sent. The labels used for the construction of the messages schedule were "food for thought," "task," "challenges," and "reflective." Examples of these messages are outlined in Textbox 1.

To allow participants to get a current assessment of their alcohol consumption, a direct link was enclosed to the study's home page after each message, where more information on safe drinking limits was available. In addition, a direct link was provided to the same Web-based single-session alcohol assessment as used in the baseline assessment.

Textbox 1. Examples of messages sent to motivate less drinking.

Examples of "food for thought" messages:

What are the most important things in your life? How does drinking affect them?

How convinced are you that you are OK with your alcohol habits?

Examples of "task" messages:

List three good things and three not so good things about your drinking.

Think about a recent situation where you drank more alcohol than you indented. Formulate a sentence that starts with "what if… then I would not have been in that situation. Ask yourself how you could avoid similar situations in the future.

Examples of "challenge" messages:

Tonight or next time you are going out for a drink – decide to take a glass a water between every drink. This will make you feel better the next day – and you will probably save some money.

Tonight or next time you are going out for a drink – decide before you start drinking how much you are going to drink – and try to keep track and stick to this goal during the evening. If you fail to stick to your own goal – think about what went wrong?

Examples of "reflective" messages:

Is the way that you drink fully in accordance with your own values?

When you get time, now or perhaps later, consider how you normally feel the day after you have been drinking. Is there anything that you are dissatisfied with?

Extended Intervention Message Schedule

The messages were sent out on Wednesdays, Fridays, Saturdays, and Sundays. "food for thought" messages were sent on Wednesdays, "tasks" were sent on Fridays, "challenges" on Saturdays and "reflective" messages on Sundays.

Measurements

Risky Drinking at Baseline

Risky drinking was defined according to the official definition used in Sweden, which includes two criteria: total weekly consumption, and frequency of heavy episodic drinking. Risky total weekly consumption of alcohol was defined as drinking more than 9 (females) or 14 (males) standard drinks/units per week (1 standard unit = 12 g of alcohol; eg, a small glass of wine). Heavy episodic drinking was defined as drinking more than 4 (females) or 5 (males) standard units on a single occasion (eg, during an evening). Having one or more episodes of heavy drinking per month was considered risky drinking. Participants were considered risky drinkers if they fulfilled either or both of the definitions described above. These drinking limits for safe drinking are the official limits used in Sweden [33].

Weekly alcohol consumption was calculated by adding the number of standard drinks consumed during the last 7 days. Heavy episodic drinking was assessed by responding to how often the participants drank 5 (men)/4 (women) or more standard drinks on a single occasion with the following response options: less than once a month, once a month, 2 to 3 times a month, once a week, or 2 or more times a week.

Motivation to change was assessed with the following response options: "I have not thought about decreasing my consumptions," "I have thought about decreasing my consumption, but I am not thinking about it right now," "I am thinking about decreasing my consumption," "I have started to decrease my consumption," " I have tried to decrease my consumption, but failed."

Perceived Drinking Compared With Peers at Baseline

Students were asked if they thought they drank "more," "less," or "the same" as their peers as part of the assessment in the single-session intervention. This was used in the analysis of the feasibility evaluation for the extended intervention. In the single-session feedback, the students were shown a graphic comparison between their actual consumption compared with peers of the same age group and sex. The comparison was based on a reference database held by the authors from the previous 5 years of surveys completed throughout Sweden, consisting of more than 200,000 measurements on students.

Follow-Up Questionnaire

The follow-up questionnaire comprised 12 questions exploring the feasibility and usefulness of the extended intervention as perceived by the students. Two questions explored whether the student had changed their alcohol consumption and the reasons for a reduction in consumption: satisfaction with the length of the intervention period (too long, just right, too short, don't know), and the number of messages (too many, just right, too few, don't know).

One question explored satisfaction with the delivery method. The participants were told that the messages could be received via SMS or email. The response options were "Yes I was satisfied with the delivery method," or "I would have preferred the other delivery method." One question explored the estimated proportion of messages read (all, nearly all, most of the messages, about half, a few, very few, none). Another question asked the participants to estimate the average time it took before a message was read (immediately, within 1 hour, within 3 hours, the same day, next day, several days later, read almost none of the messages).

One question explored the students' overall perception of the content of the messages (very good, good, poor, very poor). Two questions explored the proportion of messages that the participants considered to be good, useful or bad, not useful (all, nearly all, most of the messages, about half, a few, very few, none).

The last questions asked whether the student would recommend the intervention to a friend who drinks too much (yes definitely, possibly, doubtful, don't know). The participants could also comment on their responses to each question and give an overall comment on the intervention. The study was approved by the regional ethical committee in Linköping, Sweden (no. 2013/94-31).

Statistical Analysis

All data from the single-session assessment were used to characterize the students using the following variables: age, sex, social status, semester, perceived drinking compared with peers, motivation to change, and risky drinking status. Differences between students within different response options to the questions in the follow-up questionnaire were examined using chi-square tests without any adjustment for baseline characteristics. In cases where cell values were too small for reliable chi-square output, the Fisher exact test was used. If cell values were too small for both the chi-squared and Fisher tests, an attempt was made to pool the variables. Only tests where P<.05 were considered. All statistical analyses were performed using R version 2.15.1.

Results

Response Rate and Characteristics of the Participants

Among the 5499 students who were invited to participate in the first stage of the study, 1542/5499 (28.04%) completed the single-session intervention and received feedback. The initial single-session intervention was sent to all students on semesters 2, 4, 6, and 8 at Luleå University using the official university mailing list and therefore we did not know the age, sex, and social status of the total population of the students invited to participate. However, the baseline characteristic of the students who agreed to participate in the extended session intervention (n=454) compared with those declining participation (n=1088) did not differ significantly, except for motivation to change; more participants than nonparticipants had started to decrease their consumption (100/454, 22.0% vs 167/1088, 15.35%) (Table 1).

The characteristics of the participants are presented in Table 2. No significant differences between the groups were seen. Approximately one-half of the participants in both groups were risky drinkers.

Table 1. Baseline characteristics of the participants who agreed to participate or declined participation in the extended intervention (*N*=1542).

	Participated n=454 (%)	Did not participate n=1088 (%)	χ^2(df)	*P* value
University semester			3.63 (3)	.588
2	186 (40.97)	469 (43.11)		
4	109 (24.01)	276 (25.37)		
6	112 (24.67)	236 (21.69)		
8	47 (10.35)	107 (9.83)		
Sex			0.9 (1)	.342
Female	218 (48.02)	553 (50.83)		
Male	236 (51.98)	535 (49.17)		
Age			2.48 (3)	.289
18–20 years	81 (17.84)	198 (18.20)		
21–25 years	265 (58.37)	670 (61.58)		
26–30 years	69 (15.20)	125 (11.49)		
31+ years	39 (8.59)	95 (8.73)		
Social status			0.37 (1)	.542
No partner	234 (51.54)	581 (53.40)		
Have a partner	220 (48.46)	507 (46.60)		
Motivation to change [a]				.019[b]
I have tried to decrease my consumption, but failed	1 (0.26)	6 (0.65)		
I am thinking about how to change my habits	9 (2.34)	30 (3.23)		
I have thought about changing, but I`m not thinking about it right now	37 (9.64)	107 (11.52)		
I have started decreasing my consumption	100 (26.04)	167 (17.97)		
I have not had any thoughts regarding change	237 (69.53)	619 (66.63)		
Risky drinking			0.32 (1)	.570
No	232 (51.10)	537 (49.36)		
Yes	222 (48.90)	551 (50.64)		

[a]Only includes students who had been drinking in the previous 3 months.

[b]Fisher exact test.

Table 2. Characteristics of the students in the SMS (N=229) and email groups (N=193).

	Email group (N=193) n (%)	SMS group (N=229) n (%)	χ^2(df)	P value
Sex			0.41 (1)	.524
Female	90 (46.6)	115 (50.2)		
Male	103 (53.4)	114 (49.8)		
Age			0.57 (3)	.904
18-20 years	35 (18.1)	38 (16.6)		
21-25 years	112 (58.1)	134 (58.5)		
26-30 years	28 (14.5)	38 (16.6)		
31+ years	18 (9.3)	19 (8.3)		
Social status (pooled data)			0 (1)	.960
No partner	100 (51.8)	117 (51.1)		
Have a partner	93 (48.2)	112 (48.9)		
Perceived drinking compared with peers (pooled data)			2.32 (2)	.313
More	25 (12.9)	22 (9.6)		
Same	49 (25.4)	52 (22.7)		
Less	119 (61.7)	155 (67.7)		
Motivating to change (pooled data) [a]			2.3 (2)	.317
No thoughts of change	95 (57.9)	124 (64.6)		
Thought of change	19 (11.6)	23 (12.0)		
Taken action	50 (30.5)	45 (23.4)		
Risky drinking			2.03 (1)	.154
No	91 (47.2)	125 (54.6)		
Yes	102 (52.8)	104 (45.4)		

[a]Only includes students who had been drinking in the previous 3 months.

Drop-Out During the Extended Intervention and Response Rate to the Follow-Up

During the extended intervention, 10/193 participants (5.2%) in the email group asked to stop the intervention and 46/229 participants (20.1%) in the SMS group asked to stop the intervention (χ^2_1=20.22, P<.001). There were no significant differences between those who asked to stop the intervention for any of the baseline characteristics such as semester, sex, age, social status, drinking compared with peers, motivation to change or risk drinking status.

A total of 240/454 follow-up questionnaires were returned giving a response rate of 52.9%. There were no significant difference in the response rate between the two groups; 53.9% (104/193) responded in the email group and 52.1% (136/261) in the SMS group (χ^2_1=0.14, P=.700).

All questions had to be completed. Therefore, no internal data were missing for any of the questions (Figure 1).

Main Findings

Satisfaction with the length of the intervention and number of messages per week did not differ between the SMS and email groups (Table 3). Only 4.2% (10/240) thought that the intervention was too long but around 72.9% (175/240) found the length just right. Of the participants, 57.9% (139/240) were satisfied with the number of messages per week, but 42.1% (101/240) thought that there were too many messages. Only 4 participants thought that there were too few messages (Table 4). There were no differences in satisfaction with the frequency of messages and the number of messages per week with regards to baseline characteristics, such as sex, age, risk drinking status, perceived drinking compared with peers, or motivation to change.

There were 84.6% (203/240) of the participants who found the overall content of the intervention to be good or very good, and 48.8% (117/240) perceived that all or almost all of the specific messages were good. No differences were seen with regard to mode of delivery or any of the baseline characteristics except that participants with risky drinking at baseline were less satisfied with the content than nonrisky drinkers (74.0%, 54/73 vs 89.2%, 149/167; P=.015, Fisher exact test).

We asked the participants whether they would recommend the intervention to a friend who needed to cut back on their alcohol consumption. The intervention would definitely be

recommended by 30.4% (73/240), 34.6% (83/240) would possibly recommend it, 24.2% (58/240) were doubtful, and 2.5% (6/240) did not know. No difference was seen between risky and nonrisky drinkers or by mode of delivery. Of the participants, 80% (192/240) were satisfied with the mode of delivery offered to them, but 14.0% in the SMS group (19/136) and 14.4% (15/104) in the email group would have preferred the other delivery method and 5.8% (14/240) did not know which method they preferred.

Table 3. Satisfaction with the length of the intervention in relation to background characteristics (n=240).

	Satisfaction with the length of the intervention					
	Too long, n (%)	Just right, n (%)	Too short, n (%)	Don't know, n (%)	χ^2(df)	*P* value
University semester						
2	3 (2.7)	85 (76.6)	16 (14.4)	7 (6.3)	6.82 (9)	.656
4	1 (2.0)	38 (76.0)	6 (12.0)	5 (10.0)		
6	5 (8.5)	39 (66.1)	8 (13.6)	7 (11.9)		
8	1 (5.0)	13 (65.0)	4 (20.0)	2 (10.0)		
Sex						.259[b]
Female	2 (1.8)	85 (78.0)	13 (11.9)	9 (8.3)		
Male	8 (6.1)	90 (68.7)	21 (16.0)	12 (9.2)		
Age						.877[b]
18-20 years	2 (4.7)	31 (72.1)	7 (16.3)	3 (6.9)		
21-25 years	5 (3.5)	103 (72.5)	21 (14.8)	13 (9.2)		
26-30 years	2 (5.6)	25 (69.4)	4 (11.1)	5 (13.9)		
31+ years	1 (5.3)	16 (84.2)	2 (10.5)	0 (0.0)		
Perceived drinking compared with peers (pooled data)						.282[b]
More	1 (3.2)	20 (64.5)	4 (12.9)	6 (19.4)		
Same	4 (7.7)	37 (71.2)	6 (11.5)	5 (9.6)		
Less	5 (3.3)	114 (74.5)	24 (15.7)	10 (6.5)		
Motivation to change (pooled data) [a]						.146[b]
No thoughts of change	5 (4.1)	88 (72.1)	21 (17.2)	8 (6.6)		
Thoughts of change	0 (0.0)	23 (88.5)	2 (7.7)	1 (3.8)		
Taken action	4 (7.4)	35 (64.8)	6 (11.1)	9 (16.6)		
Risky drinking						.509[b]
No risk	3 (2.6)	85 (73.3)	19 (16.4)	9 (7.7)		
Yes risk	7 (5.6)	90 (72.6)	15 (12.1)	12 (9.7)		
Mode of delivery						.329[b]
Email	4 (3.9)	74 (71.2)	13 (12.5)	13 (12.5)		
SMS	6 (4.4)	101 (74.3)	21 (15.4)	8 (5.9)		

[a]Only included students who had been drinking in the previous 3 months.

[b]Fisher exact test.

Table 4. Satisfaction with the number of messages per week in relation to background characteristics.

	Satisfaction with number of messages per week				
	Too many, n (%)	Just right, n (%)	Too few, n (%)	Don't know, n (%)	P value[b]
University semester					
2	40 (36.0)	67 (60.4)	1 (0.9)	3 (2.7)	.362
4	17 (34.0)	30 (60.0)	3 (6.0)	0 (0.0)	
6	25 (42.4)	33 (55.9)	0 (0.0)	1 (1.7)	
8	11 (55.0)	9 (45.0)	0 (0.0)	0 (0.0)	
Sex					.537
Female	38 (34.9)	68 (62.4)	1 (0.9)	2 (1.8)	
Male	55 (41.9)	71 (54.2)	3 (2.3)	2 (1.5)	
Age					.400
18-20 years	14 (32.6)	25 (58.1)	2 (4.6)	2 (4.6)	
21-25 years	56 (39.4)	83 (58.5)	1 (0.7)	2 (1.4)	
26-30 years	17 (47.2)	18 (50.0)	1 (2.8)	0 (0.0)	
31+ years	6 (31.6)	13 (68.4)	0 (0.0)	0 (0.0)	
Perceived drinking compared with peers (pooled data)					.814
More	13 (41.9)	17 (54.8)	1 (3.2)	0 (0.0)	
Same	22 (42.3)	30 (57.7)	0 (0.0)	0 (0.0)	
Less	57 (37.3)	89 (58.1)	3 (1.9)	4 (2.6)	
Motivation to change (pooled data) [a]					.108
No thoughts of change	52 (42.6)	67 (54.9)	1 (0.8)	2 (1.6)	
Thoughts of change	5 (19.2)	19 (73.0)	1 (3.9)	1 (3.9)	
Taken action	21 (38.9)	31 (57.4)	2 (3.7)	0 (0.0)	
Risky drinking					.417
No risk	67 (40.1)	94 (56.3)	2 (1.2)	4 (2.4)	
Yes risk	26 (35.6)	45 (61.6)	2 (2.7)	0 (0.0)	
Mode of delivery					.216
Email	41 (39.4)	60 (57.7)	0 (0.0)	3 (2.9)	
SMS	52 (38.2)	79 (58.0)	4 (2.9)	1 (0.7)	

[a]Only included students who had been drinking in the previous 3 months.

[b]Fisher exact test.

Number of Messages Read and the Timing

The participants in the SMS group reported reading more of the messages than the participants in the email group. Thus, 55.9% in the SMS group (76/136) stated they had read all messages versus 42.3% (44/104) in the email group and 27.2% (37/136) versus 21.2% (22/104) stated that they had read almost all (P=.030, Fischer exact test).

When the messages were read also differed between the SMS group and the email group. In the SMS group, 51.5% (70/136) read most of the messages immediately on receipt; in contrast, only 22.1% (23/104) in the email group read the messages at once. In the SMS group, 88.2% (120/136) of the participants read the messages within 1 hour in contrast to 45.2% (47/104) in the email group. In the email group, 19.3% (20/104) read the messages the next day or later, whereas none did so in the SMS group.

Change in Alcohol Consumption

Although the study did not aim to evaluate the actual effect of the messages on alcohol consumption, we did ask the participants to estimate any potential change in their alcohol consumption during the last 2 months. Twenty-three percent (55/240) stated that they had decreased their consumption (21.1%, 23/109 among females and 30.5%, 40/131 among males). In the youngest age group (18-20 years), a larger proportion (37.2%, 16/43) reported a decrease in consumption compared with 25.4% (36/142) among those aged 21 to 25 years and 20% (11/55) in those aged 26+ years (χ^2_8=16.03, P=.042).

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However, no significant difference in reduction of alcohol consumption was seen between the two modes of delivery.

Those stating that they had decreased their consumption (n=63) were asked to evaluate with a yes/no response if the messages contributed to the reduction in alcohol consumption. Thirty-seven stated that the messages did not contribute to the reduction, whereas 41% (26/63) agreed that they did. Among those who received the messages via email, 20.8% (5/24) stated that the messages contributed to a reduction in contrast to 53.8% (21/39) in the SMS group (χ^2_1=5.39, P=.020).

Discussion

Principal Findings

This study explored the feasibility and user perceptions of an extended alcohol intervention to students who had participated in a fully automated online single-session alcohol intervention. The students were randomized to receiving the intervention either by SMS or email. To our knowledge, this is the first study to compare two modes of delivery of an extended intervention using the same messages.

No differences between the two modes of delivery were seen with regard to satisfaction with the length of the intervention and the number of messages per week. In this study, the length of the intervention was 4 weeks for all participants and only 4.2% (10/240) of the participants thought that this was too long. On the other hand 42.1% (101/240) of the participants thought that the number of messages per week was too many (four messages per week).

In a previous study, we gave the participants a choice on the length of the intervention and the number of messages per week and we found that most participants chose the shortest length (3 weeks) and the lowest number of messages per week (3 per week) [32]. Satisfaction with the length of the intervention in the present study was higher than in the previous study indicating that the participants are somewhat hesitant to sign up for a longer intervention. No difference in satisfaction was seen with regard to the length of the intervention and the number of SMS messages among risky and nonrisky drinkers. Risky drinkers would likely have to receive a longer intervention. In a recent study on perceived acceptability of an SMS intervention, concern was raised about receiving messages to often without specifying the frequency [30]. In another study in university students of SMS messages as surveillance of students, an SMS per day was acceptable for most participants, and the participants perceived SMS messages as a more positive means of delivery, compared with telephone calls or email [23]. Further studies needs to explore the optimal balance between what is needed in order to support a behavior change and what is acceptable for the target population.

We found no difference between the SMS and email groups with regard to perceived satisfaction with the content of the intervention, which in general was perceived as good or very good. This was similar to our previous study where the participants could choose the mode of delivery [32].

Importantly, most of the participants were satisfied with the mode of delivery given to them and around 14.2% (34/240) in both groups would have preferred the other mode of delivery. This should be seen in the light of our previous study; the students were given a free choice between email, SMS, and an Android application and 83% (952/1145) chose email [32]. In the present study, we noticed a higher dropout rate in the SMS group (20.1%, 46/229) compared with the email group (5.2%, 10/193), which is difficult to explain because we did not see any difference in the baseline characteristics between the dropouts and those who remained in either of the groups. However, this dropout rate is in parity with a number of previous studies [26]. One reason for the higher dropout rate in the SMS group could be that SMS messages were perceived as more intrusive; the mobile phone likely gave an incoming SMS alert each time a new message was received and this may have led to some inconvenience for the students. The need for careful timing of the messages was also emphasized in a study on university students who did not want a message too early in the morning [23] and in another study, messages during dinnertime were perceived as potential annoying [30]. On the other hand, students receiving emails could also have perceived the messages as intrusive because an incoming email might also give rise to an alert. Future studies needs to take this into account.

In the present study, we added some additional explorative follow-up questions such as the self-reported number of messages read and the timing of reading the messages. We noted that students receiving the messages via SMS read more of the messages compared with the email group. The timing for receiving challenging information should be right (ie, just before going out for a drink on a Friday evening). Thus, 88.2% (120/136) of the participants in the SMS group read the messages within 1 hour, but only 45.2% (47/104) of the participants in the email group. In a review on SMS messages for behavioral change, it was highlighted that there is a lack of process studies exploring how messages are treated and stored by the user [26]. Our results contribute somewhat to our understanding that SMS messages are more likely to be read relatively soon after receipt, in contrast to email. This study consider calculating the cost of sending mail to a group of students compared with the cost of sending SMS. Pending on local technical solutions the cost may be comparable, which was the case in the present study since we were able to set up a technical solution with minimal cost. However, if an SMS intervention has to be administrated by an external commercial company the cost for SMS may be considerably more than for an email intervention.

On a more subjective note, 54% (21/39) of those in the SMS group that had decreased their alcohol consumption stated that the messages had helped them in their effort, in contrast to only 21% (5/24) in the email group. Although encouraging, this finding needs to be explored further in a forthcoming randomized controlled trial.

Limitations

The study was performed in an unselected group of students primarily not seeking help for their alcohol consumption and

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including both risky and nonrisky drinkers. We also introduced a bias when offering the participants entry to a draw for an iPad. However, from previous studies, we know that this helps in getting a sufficient number of participants, which we decided would be acceptable in this explorative study. This means that the results should be taken with some reservations. Still, the purpose of this explorative study was to get an idea of what is feasible among students in order to get good compliance with the intervention. Single-session and extended interventions will always include individuals with a strong motivation as well as less strong motivation and preferably should satisfy both groups.

Due to the larger drop-out rate in the SMS group than in the email group 20.1%, (46/229) versus 5.2% (10/193) we cannot be sure that the apparently equal satisfaction with the intervention in both groups reflects the opinion of all who signed up for the intervention. There might be a greater dissatisfaction with the intervention when considering all who signed up for the SMS intervention. However, we do not have data about satisfaction on those who dropped out.

The response rate to the initial single-session intervention was 28.04% (1542/5499), which is somewhat lower than in our previous studies [2,3,16]. Also, despite offering the participants to participate in a draw of an iPad if they completed the follow-up questionnaire, the follow-up rate in the present study was only 52.9% (240/454), which was lower than in the previous study (82.7%) [32]. The two studies were performed at two different universities in Sweden, which could partly explain the difference in the response rate.

Participation was offered to both risky and nonrisky drinkers since we wanted as many views as possible on the structure and content of the extended intervention. The proportion of participants signing up for the extended intervention was equally distributed with regard to all baseline characteristics (Table 1) and between the participants randomized to the SMS and email groups (Table 2).

Conclusions

Based on feedback from the students, an extended push-based intervention delivered via SMS or email seems to be feasible to offer those interested in additional help after a single-session intervention This is further emphasized by the large proportion of students who would recommend the intervention to a friend needing to cut back on their drinking. The perception of the intervention did not differ between mode of delivery with regards to the length of the intervention, the number of messages per week and overall satisfaction with the given mode of delivery.

However, the number of messages read and the timing of reading them differ between the SMS and email groups. This may indicate that SMS is more effective in delivering messages as intended (eg, when sending challenges that should be read in real time) say on a Friday night before starting drinking. On the other hand, more students dropped out in the SMS arm. How best to get participants to stay with the intervention as well as ensuring that the messages are read at the intended time is something that needs to be explored in future studies.

In a forthcoming randomized controlled trial, based on the findings in the present study, we are now confident that a realistic comparison will be to study the effectiveness of a single-session intervention with an extended SMS or email intervention, comparing these in separate arms and in a combined arm.

Conflicts of Interest

Both authors own shares in and work in a private company that develops and distributes mobile health interventions.

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Abbreviations

SMS: short message service
TOPHAT: Trial and Optimisation of Push-based High Alcohol Treatment

Original Paper

Exploring the Usability of a Mobile App for Adolescent Obesity Management

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Abstract

Background: Obesity is a global epidemic. Behavioral change approaches towards improving nutrition, increasing physical activity level, improving sleep, and reducing sitting time are recommended as best practices in adolescent obesity management. However, access to evidence-based treatment is limited and portable technologies such as mobile apps may provide a useful platform to deliver such lifestyle interventions. No evidence-based validated app exists for obesity intervention; therefore, a novel mobile app (Reactivate) was developed for use in the Temple Street W82GO Healthy Lifestyles Program (W82GO).

Objective: This study aimed to test the usability (technical effectiveness, efficiency, and user satisfaction) of the Reactivate mobile app in obese adolescents.

Methods: Ten adolescents (7 males and 3 females, aged 12-17 years) who had been treated for obesity (>98th percentile for body mass index) at the Temple Street Children's University Hospital were recruited. Participants were given 8 tasks to complete in order to test the technical effectiveness of the app. A research assistant timed the user while completing each task in order to test the relative user efficiency of the app (time-on-task). The tasks fell into 5 categories and required the user to enter personal settings, find and answer surveys, create a message, use the goal setting feature, and enter details regarding their weight and height. In exploration of user satisfaction, each participant completed the standardized software usability measurement inventory (SUMI), which measures 5 aspects of user satisfaction: efficiency, effect, helpfulness, controllability, and learnability. Descriptive statistics were used to explore the mean relative user efficiency and SUMI scores.

Results: Mean age was 14.26 (SD 1.58) years. All adolescents completed each of the tasks successfully. The mean relative user efficiency scores were two to three times that of an expert user. Users responded that they would use Reactivate to monitor their growth over time, for motivation, and for goal setting. All users described Reactivate as an important mobile app.

Conclusions: Our study describes the usability of a mobile app used in adolescent obesity management. Adolescents found Reactivate easy to use and their SUMI results indicated that the app scored high on user satisfaction. Usability testing is an important step towards refining the development of the Reactivate app, which can be used in the treatment of obesity. The study on the clinical efficacy of the Reactivate app is currently underway.

KEYWORDS

obesity; mobile health; usability testing; adolescent; participatory health care

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Introduction

For adolescents who are identified as being obese, prompt and effective lifestyle interventions are required in order to minimize associated comorbidities and to prevent further progression of obesity into adulthood. Due to cost and resource limitations, effective obesity interventions can be challenging to deliver to the adolescent population in need of care. The Temple Street W82GO Healthy Lifestyles Program, (as of May 2014) is Ireland's only obesity treatment for children and adolescents [1]. Based on recent data, it is estimated that there are around 100,000 children and adolescents who are clinically obese in Ireland [2]. With current clinical services facilitating the treatment of approximately 150 families per year, it is clear that efforts to scale up treatment are needed.

Given the development of mobile technology, it may be possible to adapt face-to-face obesity interventions for a mobile platform and deliver secure and effective care remotely [3,4]. Previous work in the area of mobile health has highlighted the potential benefits of including a remote treatment option in the management of chronic disease [5-7]. In addition, recent work in adult weight management has suggested that mobile health interventions may be effective [8]. The effective design and development of mobile health interventions is influenced by adequate evaluation of the device interface by the end user, such that an iterative cycle of development can support optimal functioning of the remote device/intervention [9]. Little data exists regarding the use of mobile health interventions in adolescents, although studies have reported that short message service (SMS) texting and image-based interventions are acceptable and perceived as relevant to adolescents who are obese [10,11]. In an effort to augment the W82GO service, the Reactivate mobile app has been designed as a remote treatment aid for adolescents who are obese. Development of the Reactivate app included participation by end users and a previous study examining the acceptability of such a mobile app in a separate cohort of parent-child dyads (unpublished data). In short, semi-structured interviews and two focus groups with service users were undertaken to collect qualitative data regarding the necessity of such an app for obesity treatment and the features it must include. The main features and issues described by participants included design attributes, the perceived benefits of using an app for treatment, concerns regarding data protection, and privacy. Design of the Reactivate app was facilitated by contemporarily published evidence-based studies related to obesity interventions and by results from the acceptability study. In brief, the app is underpinned by the social cognitive theory, the theory of planned behavior, and the capability, opportunity, and motivation (COM-B) framework [12-14]. It incorporates behavioral change tools such as self-monitoring, goal setting, a rewards system, and peer support (Figures 1 and 2). Evidence-based tips such as education regarding the importance of sleep for weight management [15] are sent to the user in the form of a text, video, or an image and the user is encouraged to engage in daily goal setting and goal review.

Although thousands of commercial health and fitness-related mobile apps exist, few developers report whether apps have been developed in line with best-practice guidelines [3,16] or with the end user in mind [17]. The user experience with mobile apps varies depending on the type of mobile used and users often report difficulty using mobile apps [18] due to small screen size, limited processing power, and the incompatibility of apps across devices [19]. It is vital that the end user is considered throughout the app development process (particularly where the app is to be used in clinical cohorts) and that testing for both technical and clinical effectiveness is completed so that functionality can be optimized. Recently, electronic health interventions have been evaluated for usability and their testing has assisted in developing interventions for chronic conditions, which are technically effective and acceptable for use in adolescents [20]. The current study aimed to test the usability of the Reactivate mobile app with a clinical cohort of adolescents who were obese.

Figure 1. Schematic of Reactivate behavioral change components.
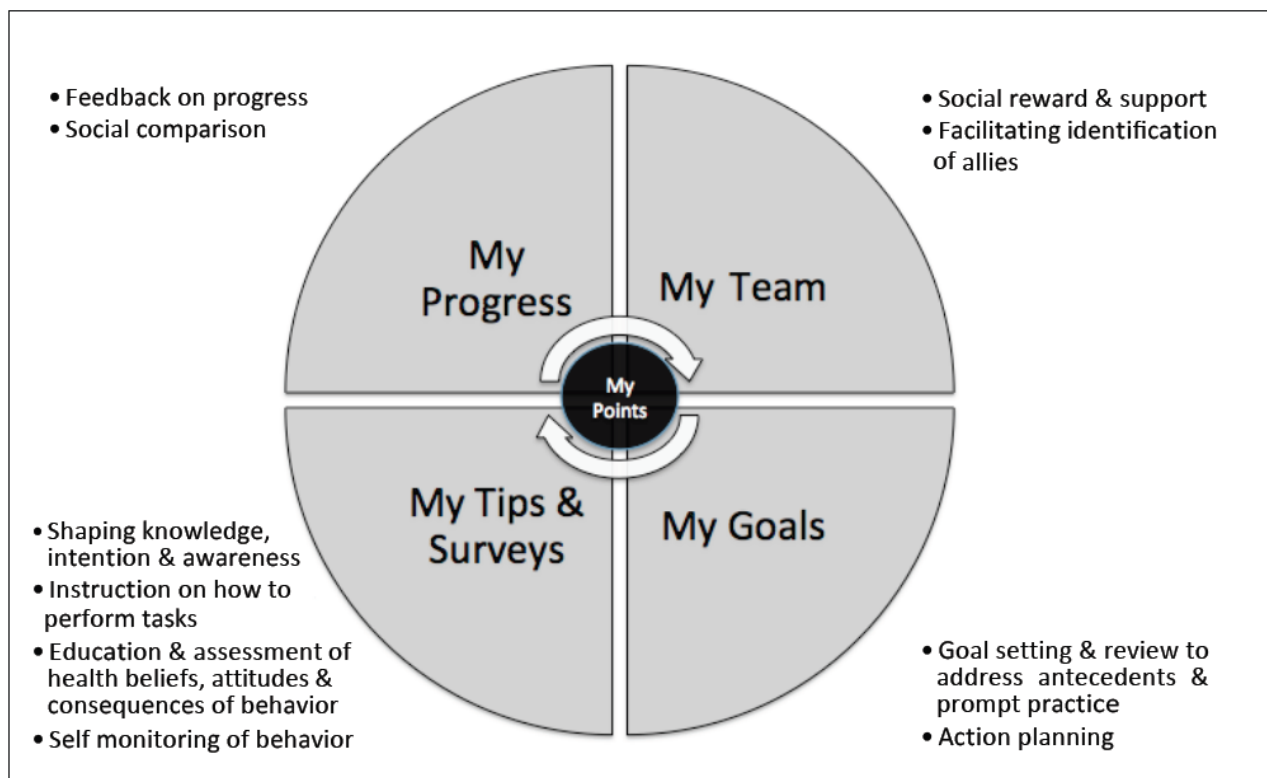
Figure 2. Screenshot of Reactivate home screen.

Methods

Overview

Usability was defined as the extent to which the app could be used by a clinical cohort of obese adolescents, to achieve specified tasks with technical effectiveness, efficiency, and satisfaction. This definition is in line with the international organization of standardization (ISO) 9241-11 [21].

Participants

Parent-adolescent dyads attending the W82GO healthy lifestyles program at Temple Street Children's University Hospital, Dublin, Ireland for at least six months were invited to participate in the study. Adolescents attending the service had a diagnosis of clinical obesity (body mass index >98th percentile). The study was approved by the ethics committee of Temple Street Children's University Hospital (TSCUH 11-024). Participants were excluded if the adolescent resided in foster care, if they had a moderate to severe learning disability, and/or if either the adolescent or parent were not proficient in understanding English. Adolescents and their parents who agreed to participate signed age-appropriate consents and assents.

Procedure

Usability testing methods proposed by Kushniruk et al and Schneiderman were followed [22,23]. A test plan of three stages was developed. Stage 1, sought to test the technical effectiveness of the app (ie, whether the user could complete a given task or not). Stage 2, tested the relative user efficiency of the app, with the user being timed while he/she undertook standardized tasks in order to examine whether the app was easy to navigate. Stage 3, examined user satisfaction with the app. Subsequently, participants representative of the end users were recruited and 8 representative tasks using the Reactivate app were chosen for testing. Prior to testing, the Reactivate app was installed on 10 Android mobiles (Samsung Galaxy Y). All devices were fully

charged and the Reactivate app was tested to ensure that it had downloaded correctly, was functioning without error, and was connected to the WiFi network.

Finally, the manner by which the testing would take place was planned. A usability testing booklet was developed for participants and for testers in collaboration with the human factors research group at the University College Cork – National University of Ireland, in Cork, Ireland. The usability testing was undertaken at the Vodafone user experience center in Dublin and each adolescent was accompanied by a research assistant/tester. The research assistant and each adolescent participant were advised that the aim was to test the app and not the participant. They received written and verbal information regarding the testing procedure, and study participants also received a brief introduction to the app before usability testing commenced.

Technical Effectiveness

Participants were given 8 tasks to complete in order to test the technical effectiveness of the app. Each task required, or requested, that the participant obtained or entered specific data that would be used in a typical task (Table 1). The task was completed when the tester indicated that the task goal had been obtained (whether successfully or unsuccessfully) or when the participant requested and received sufficient guidance to warrant scoring the scenario as a critical error.

A critical error was defined as an error resulting in an incorrect or incomplete outcome. If a participant required assistance in order to achieve a correct output, then the task was scored as a critical error and the overall completion rate for the task was affected. A noncritical error was an error that would not have an impact on the final output of the task but resulted in the task being completed less efficiently. These errors could also be associated with confusion (eg, selecting the wrong function initially, or using a user interface control incorrectly such as attempting to edit an non-editable field).

Table 1. Testing tasks.

Task	Description
Task 1	Find and answer the mood survey.
Task 2	Enter your personal settings into the app and save them.
Task 3	Look at the Fizzy drink video in the *Tips* section and choose that you 'like' it. Submit your response.
Task 4	Send a message saying what day it is today and what age you are.
Task 5	Go to the *My Goals* section and pick 2 goals - (one goal from the *Chill* section and one from *Change* section) Make these goals for everyday of the week and set a reminder of 6 p.m. for each goal.
Task 6	Go to the *My Goals* section and add this new personal goal to the *Fuel* section – I will try a new type of vegetable today (make this goal for everyday of the week and set the reminder for 4 p.m.)
Task 7	Enter your *height* and *weight* for today, and look at your body mass index (BMI).
Task 8	Look at your BMI for today and post this on the *Message Board*.

Relative User Efficiency

Relative user efficiency measured the mean time a user took to complete a task in comparison with an expert user of the app [24]. The research assistant timed the user completing each task using a stopwatch in order to test relative user efficiency of the

app. Time scores were divided by the time taken by an expert user to complete the task. Throughout all the tasks, the tester kept a written record of any subjective comments made by the adolescent. Upon completion of the tasks, the subjective comments were categorized based on the tasks, time to perform each task, features, and app functionality.

User Satisfaction

The standardized software usability measurement inventory (SUMI) [1,25] was completed by participants at the end of testing to measure the five aspects of user satisfaction. SUMI follows the ISO 9241, the standard method of testing user satisfaction. SUMI is a reliable and validated standardized questionnaire which uses the agreement type of response. Each questionnaire item takes the format of a statement with a fully anchored 3-point Likert type response, with options being "Agree", "Undecided", and "Disagree". Each item is then scored positively or negatively, depending on the statement, and the scores are summed based on their contribution to each of the five main SUMI factors; efficiency (sense of the degree to which the software enables the task to be completed in a timely, effective, and economical fashion), affect (the respondents emotional feelings towards the software), helpfulness (the perception that the software communicates in a helpful way to assist in the resolution of difficulties), controllability (the feeling that the software responds to user inputs in a consistent way), and learnability (the feeling that it is relatively straightforward to become familiar with the software), and the sixth overall SUMI factor of user satisfaction which gives the global score. A global score of 50 out of 100 is considered to be an average score. Participants completed the SUMI and asked the tester for assistance with wording when necessary. Upon completion of the SUMI, participants were asked to highlight anything they liked about the app or give their suggestions on improving the app. Descriptive statistics of the quantitative data were used to explore the mean relative user efficiency and SUMI scores. Notes and comments recorded during the testing process were also transcribed and emergent themes were grouped together.

Results

Participant Characteristics

Twelve adolescents (8 boys and 4 girls, aged between 12 and 17 years) who had been treated for obesity were recruited from the obesity clinic. On the day of testing, two families were unable to attend. Hence, a total of 10 adolescents participated in the study. The mean age of participants was 14.3 (SD 1.6) years old; mean weight was 84.7 (SD 55.9) kilograms; mean height was 164 (SD 11) cm; mean body mass index (BMI) was 31.1 (SD 55.9) m/kg^2; and BMI standard deviation (SD) score was 2.8 (SD 0.3).

Technical Effectiveness

All tasks were completed successfully and users commented on how easy the interface was to navigate. Noncritical errors recorded included difficulty in recognizing what the app icons represented (5 participants) and difficulty with reading the text on the app at times (2 participants).

Relative User Efficiency

The time taken by an expert user to complete each task was 5.93 seconds for task 1; 24.37 seconds for task 2; 8.25 seconds for task 3; 17.37 seconds for task 4; 37.50 seconds for task 5; 16.81 seconds for task 6; 20.82 seconds for task 7 and 16.06 seconds for task 8. The mean relative user efficiency scores (RUS) are detailed in Table 2.

User Satisfaction

The score results of the SUMI are presented in Table 2. All participants rated the app as being important (n=9) or extremely important (n=1) for them. Comments made by participants throughout testing of the app included the ease of use (n=2); the benefit of the weight tracking and reward systems (n=9), and the appealing look and feel of the app (n=3). Participants commented that improvements were needed so that the app could run on an iPhone (n=1); that the colors could be brighter (n=3), and that the text could be larger (n=2).

Table 2. Relative user efficiency and SUMI scores.

Characteristic	Mean (SD)
RUS Task 1 (second)	1.7 (1.3)
RUS Task 2 (second)	2.4 (1.4)
RUS Task 3 (second)	2.5 (2.1)
RUS Task 4 (second)	1.2 (0.8)
RUS Task 5 (second)	2.2 (1.3)
RUS Task 6 (second)	3.6 (1.7)
RUS Task 7 (second)	2.2 (1.2)
RUS Task 8 (second)	1.7 (1.3)
SUMI Global	64.40 (4.99)
SUMI Efficiency	60.60 (6.70)
SUMI Affect	67.00 (5.06)
SUMI Helpfulness	60.80 (8.63)
SUMI Controllability	60.30 (5.06)
SUMI Learnability	60.80 (9.21)

Discussion

Principal Findings

A representative cohort of adolescents who were obese was recruited to test the usability of a mobile app designed for use in the Temple Street W82GO Healthy Lifestyles Program. Adolescents who had already commenced treatment were recruited as it was anticipated that they would already have an understanding regarding the fundamentals of obesity treatment such as planning and goal setting. In addition, we did not exclude participants based on their level of literacy so that the needs of all users could be taken into account. Overall, the results of testing were promising and participants rated the app as important for them and easy to use. Each of the test tasks were completed successfully without critical error indicating that technical effectiveness was achieved.

The relative user efficiency of the app was compared to that of an expert user and the time taken for novice participants to complete tasks was one to three times that of the expert user. As recommended by Bevan [24], measuring the relative user efficiency highlights the potential usability gap between typical users and an expert user and it is anticipated that it often takes normal users two or three times longer to complete a task than an expert. Users were satisfied with the app and reported a number of ways to improve the app further, which were implemented by the developer. A global SUMI score of 64 was promising as 50 is an average score and 68% of software falls within one standard deviation of the mean (ie, scores between 40 and 60) on the SUMI.

To our knowledge, this was the first study to report on the development and usability testing of a mobile app to be used as an adjunct to adolescent obesity intervention. Given the popularity of mobile apps with adolescents and the limited access to evidence-based treatment, we anticipated that a mobile app would be a useful tool for obesity treatment and the results

of this study support this. Strengths of the study include the participation of end users in the iterative development process and our use of validated methods for testing.

Few studies have been conducted to assess the usability of mobile app with adolescent patients. One recent study explored the usability of a mobile app for measuring pain in children with cancer [26]. Similar to our findings, participants in the Stinson study [26], commented positively on the aesthetics of the app, on the rewards system, and future use of the app. Testing also revealed important changes to development that were necessary in order for the pain app content to be completely interpreted by adolescents and to avoid navigating away from a chosen page mistakenly. With regard to user satisfaction, participants completed a questionnaire and 86% reported that they liked using the pain app while 79% reported that they found it user-friendly. These results suggest that the app could be used as a tool to assist adolescents in making decisions around pain management. In a similar study involving adult patients with type 2 diabetes mellitus, 25% of participants expressed frustration with using a mobile app as part of their care due to errors in functioning of the app [27] and a systematic review of apps for diabetes management revealed that the look and feel of the app could impact the perceived usefulness of the app [28]. Considering our study against the background of the above study, it is clear that usability testing is paramount for the optimal design and development of mobile apps used in clinical cohorts.

Limitations

Although the test sample for this study might be considered small in number, a minimum of 8 participants is recommended in heuristic usability testing [29]. We recruited 12 participants for the study but on the day of testing, 2 families could not attend. Given that testing was undertaken with a group of adolescents attending a single urban hospital for weight management, the results cannot be generalized. Future study is

warranted to test the usability of the app with a larger number of participants. In addition, the app should be tested in a cohort of adolescents who are not attending a clinic for weight management, as we do not know whether the user's level of motivation for lifestyle change affects their perceptions regarding technical usability.

In addition, as the testing was undertaken in one building using the same WiFi network, we could not ascertain whether the technical effectiveness could be guaranteed when users are dispersed across the 3G network. However data regarding such limitation will be collected in the ongoing clinical trial. In addition, the clinical trial will reveal whether adolescents engage with the app in a "real-life" scenario over a 12-month period and whether there is a dosing effect with regard to use and effect on health outcome. Finally, we assessed satisfaction of using the app as a whole rather than satisfaction with completing each particular task. Future work to explore each individual component of the app may also be warranted.

Conclusions

Overall, the Reactivate mobile app performed well in usability testing and the results provide support for its usability by end users. Results of this study guided the final development cycle of the app prior to its use in a randomized controlled clinical trial (NCT01804855). The usability testing of mobile apps designed to address clinical problems is vital, as the needs of the user can be taken into account for better optimization of the mobile app, with respect to its acceptability and utility.

Conflicts of Interest

None declared.

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Abbreviations

BMI: body mass index
HRB: Health Research Board
ISO: International Organization of Standardization
RUS: relative user efficiency score
SUMI: standardized software usability measurement inventory

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<u>Short Paper</u>

The Application of Telemedicine in Orthopedic Surgery in Singapore: A Pilot Study on a Secure, Mobile Telehealth Application and Messaging Platform

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Abstract

Background: The application of telemedicine has been described for its use in medical training and education, management of stroke patients, urologic surgeries, pediatric laparoscopic surgeries, clinical outreach, and the field of orthopedics. However, the usefulness of a secure, mobile telehealth application, and messaging platform has not been well described.

Objective: A pilot study was conducted to implement a health insurance portability and accountability act (HIPAA) compliant form of communication between doctors in an orthopedic clinical setting and determine their reactions to MyDoc, a secure, mobile telehealth application, and messaging platform.

Methods: By replacing current methods of communication through various mobile applications and text messaging services with MyDoc over a six week period, we gained feedback and determined user satisfaction with this innovative system from questionnaires handed to the program director, program coordinator, one trauma consultant, all orthopedic residents, and six non-orthopedic residents at the National University Hospital in Singapore.

Results: Almost everyone who completed the questionnaire strongly agreed that MyDoc should replace current systems of peer to peer communication in the hospital. The majority also felt that the quality of images, videos, and sound were excellent. Almost everyone agreed that they could communicate easily with each other and would feel comfortable doing so routinely. The majority felt that virtual consults through MyDoc should be made available to inpatients as well as outpatients to potentially lessen clinic loads and provide a secure manner in which patients can communicate with their primary teams any time convenient to both. It was also agreed by most that the potential of telerounding had advantages, especially on weekends as a supplement to normal rounds.

Conclusions: Potential uses of MyDoc in an orthopedic clinical setting include HIPAA-compliant peer to peer communication, clinical outreach in the setting of trauma, supervision in the operating room or watching procedures being performed remotely, providing both patient and parent reassurance in pediatric orthopedic patients, and finally in the setting of outpatient clinics. With our pilot study having excellent results in terms of acceptance and satisfaction, the integration of a secure, mobile telehealth application, and messaging platform, not only in the orthopedic department but also the hospital in general, has an exciting and limitless potential. More so in this era where downsizing hospital costs is beneficial, doing so may also be mandatory in order to comply with the soon to be introduced personal data protection act.

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Introduction

Recent advances in technology have challenged the ideology and the means by which traditional healthcare is provided. The application of telemedicine has been described for its use in medical training and education [1,2], management of stroke patients [3,4], urologic surgeries [5], pediatric laparoscopic surgeries [6], clinical outreach [5,7], and in the field of orthopedics [8]. However, its practicality in the field of secure messaging and other necessary functions in orthopedic surgery is yet to be described. Recently "MyDoc", a private but government-incubated healthcare platform startup was introduced into the market. This platform integrated a number of functions, including a patient diary, virtual teleconsults through a live video conferencing system accessible from any location in the presence of an Internet or a Wi-Fi connection, and a secure communications application. The objective of our pilot study was to determine staff reaction to MyDoc and its secure, mobile telehealth application and alternative messaging platform at an orthopedic clinical setting in Singapore.

Methods

A prospective study was done to assess the effects of the implementation of an alternative secure messaging system and its effect on staff satisfaction. The orthopedic surgery program director, program coordinator, one trauma consultant, all orthopedic surgical residents, and six non-orthopedic residents at the National University Hospital (NUH) in Singapore were included as participants in the pilot study. All participants were able to understand, speak, and read English. Verbal consent was obtained prior to the study. Our study had a total of 25 staff members with an average age of 32 years (ranging from 25 to 53 years) and comprised of 23 males and 2 females. By using MyDoc as an alternative messaging tool, we commenced communication in the form of personal messages (Figure 1), announcements for residents, case discussions (Figures 2 and 3), as well as providing patient details for referrals. Figure 4 shows a photo of a radiograph being taken to upload on MyDoc for a referral (Figure 5). The feedback from the use of these applications on MyDoc helped determine participants' satisfaction. At the end of six weeks, the lead author designed a questionnaire based on a previously validated questionnaire [9] and all study participants were asked to complete it.

Figure 1. Screenshot of the personal messages user interface.

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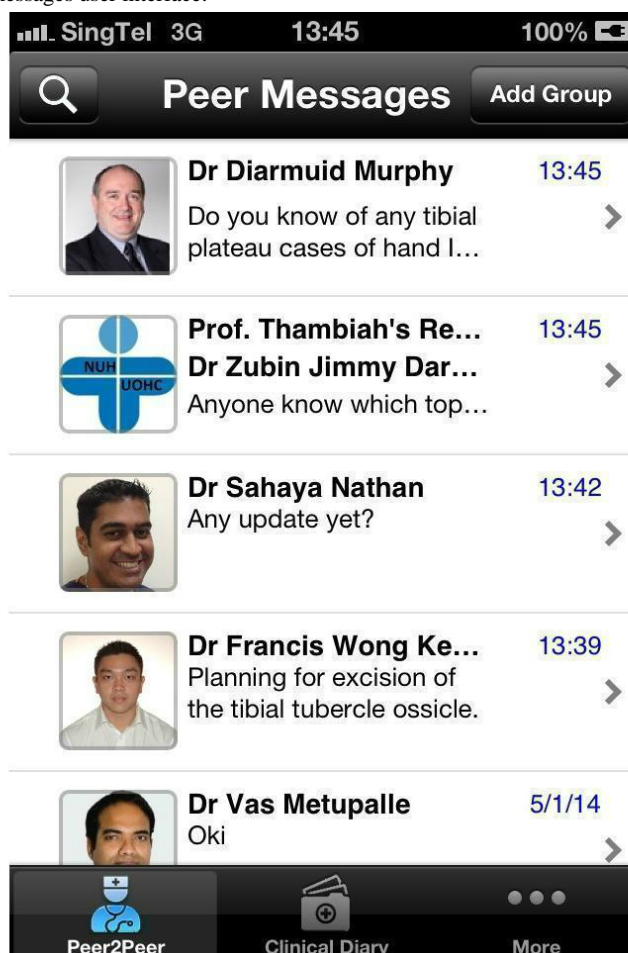
Figure 2. Screenshot of a case discussion including a radiological image.
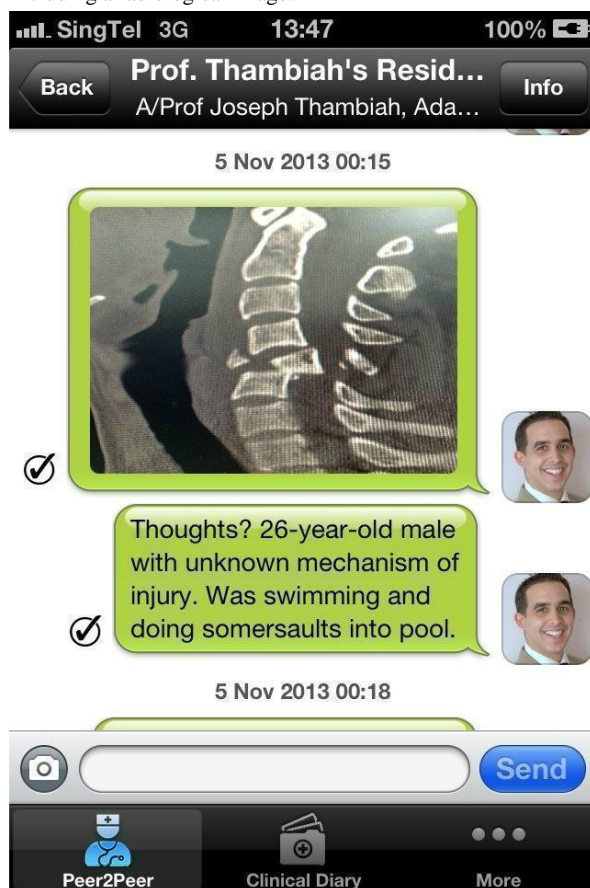
Figure 3. Screenshot of a case discussion including a clinical photograph.
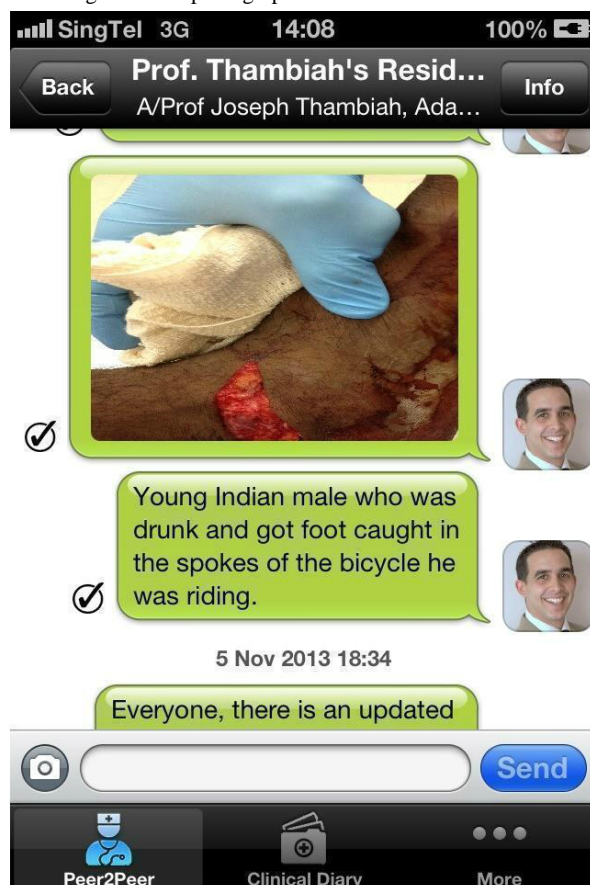
Figure 4. Using an individual mobile phone to take a photo of a radiological image to upload and share through the secure messaging platform.
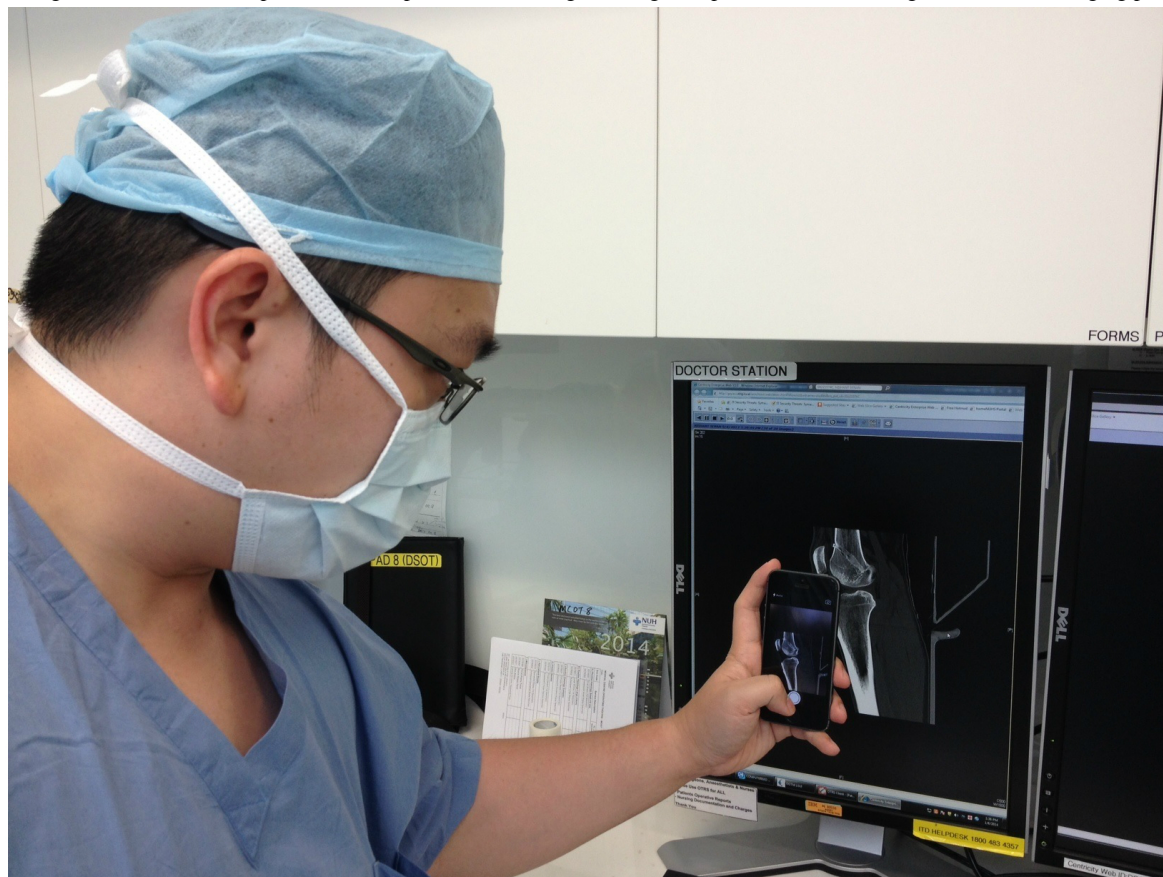
Figure 5. Screenshot of the provision of patient details during a referral.
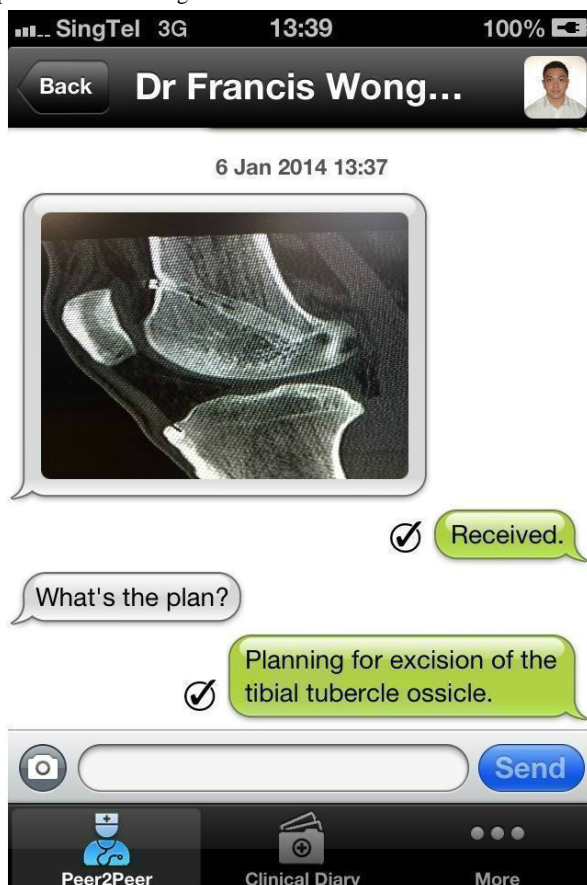
Results

All 25 (100%) participants responded to the questionnaire. Almost all (23/25, 92%) participants who filled in the questionnaire agreed (4/25, 16%) or strongly agreed (19/25, 76%) that MyDoc should replace current systems of peer-to-peer communication in the hospital. The remaining two (8%) were unsure.

The majority (22/25, 88%) of participants felt that the quality of images was excellent or very good. Of the remaining 3, 2 (8%) felt they were good and one (4%) felt they were fair. All users (25/25, 100%) felt that the quality of videos and sound was excellent or very good.

Almost all (23/25, 92%) participants also agreed or strongly agreed that they could communicate easily with each other and would feel comfortable doing so through MyDoc on a daily basis. Most of them (20/25, 80%) felt that virtual consults through MyDoc should be made available to inpatients as well as outpatients to potentially lessen clinic loads and provide a secure manner through which patients can communicate with their primary teams at a time and manner convenient to both parties. Of the remaining 5, 3 (12%) were unsure and 2 (8%) disagreed. The majority (22/25, 88%) also agreed or strongly agreed that the potential of telerounding exists and may have advantages, especially when conducted on weekends as a supplement to normal rounds. They also agreed that telerounds could help residents adhere to the number of hours they are allowed to be onsite. Of the remaining 3, 2 (8%) were unsure and one (4%) disagreed.

Discussion

Principal Findings

Our pilot study received positive feedback from all staff members with regard to using MyDoc's secure messaging system. The health insurance portability and accountability act (HIPAA) was enacted by the United States Congress and signed by the President at the time, Bill Clinton in 1996 to give individuals the right to privacy. A summary of the HIPAA can be found on the United States department of health and human services website [10]. Divided into two parts, HIPAA's first title covers health care access, portability, and renewability. Its second title covers the prevention of health care fraud and abuse, administrative simplification provisions, and medical liability reform. Unsurprisingly, the establishment of national standards for electronic health care transactions and national identifiers for providers, health insurance plans, and employers is a requirement for the second title. While no equivalent act exists in Singapore at present, the closest one, namely the private hospitals and medical clinics act, provides details regarding medical records and the sharing of personal data. It can be found on the Medical Protection Society website [11]. It is thus not surprising that the personal data protection commission (PDPC) of Singapore recently announced the launching of a public consultation exercise to help roll out initiatives to build organizations' knowledge and capabilities in data protection practices and requirements [12].

While the transmission of personal data in a hospital setting is inevitable, not all methods are secure. This point is reiterated by the American Academy of Orthopedic Surgeons (AAOS), which clearly states that while texting accelerates communication, it puts us at risk and increases liability because it is inherently insecure and incompliant with safety and privacy regulations under the HIPAA [13]. In the month of June 2013 alone, 185,572 messages were sent from the hospital messaging system (HMS) currently in use at the NUH. It should be noted that any service that sends text messages, which are readily accessible to anyone gaining access to the device the messages were sent to, is not completely secure. Considering that the data sent in hospitals is of a sensitive nature, this would be unacceptable should any of these services be used. Although none of the authors of this manuscript condone the words or actions of a medical student who mocked a patient on Twitter earlier this year [14], this example clearly illustrates the dangers of using a social media tool as a platform for transmitting any form of personal data.

In our study, all staff members had very positive reactions towards MyDoc and strongly agreed that this technology be integrated as part of the routine messaging systems currently in use. With traditional teaching claiming that a diagnosis can be made through history alone in 90% of cases and in the remaining 10% with a subsequent physical examination, this emphasizes the pivotal role of communication to the art of medicine. While physical findings are undoubtedly important for making clinical decisions, many decisions are made on gathering this clinical information by conversing with the patient as well as other physicians and nurses. The power of observation and its importance must not be forgotten. For example, during the postoperative ward rounds, wound reviews, dressing changes, and assessment of range of motion require conversational and observational skills. MyDoc includes these in its features. Few clinicians claim that neglecting bedside examination results in medical errors while others suggest that rather than bridging barriers between patients and doctors through bedside interaction, remote presence systems of any form actually increase interactions. Literature however suggests that the use of remote critical care in intensive care units (ICU) managed by internists demonstrated a considerable improvement in measureable patient parameters [15-17].

The provision of specialist care to patients in remote areas who would otherwise have these services unavailable to them only dispels the myth that it increases barriers to appropriate medical care [18]. There are also vast amounts of literature supporting operative telementoring with many studies showing no measurable increase in adverse event rates when patients are operated on by less experienced surgeons supervised by a senior surgeon from a remote location through audiovisual communication [19-24]. In fact, the ethical code and ethical guidelines of the Singapore Medical Council (SMC) clearly states about remote initial consultations in section 4.1.1.2 that,

"No doctor-patient relationship can be established through electronic means and consequently no consultation fee may be received. However, in view of developments in telemedicine and remote-control surgery, it is acceptable for a doctor to manage a patient remotely provided this is in the context of a

system of care in which a patient has timely or concurrent access to another doctor who manages him in person. A doctor who provides remote management is responsible for any outcome related to his management"

Regarding remote consultations in continuing care, in section 4.1.1.3, it is mentioned that,

"If a doctor has already established a professional relationship through direct personal contact with a patient, previously made a diagnosis and has commenced treatment, adjusting treatment or providing continued treatment following remote contact with a patient or receipt of electronically transmitted medical data is allowable. If on the other hand it appears from the communication that the patient has developed a new problem or a significant complication, then the doctor shall endeavor to see the patient personally for a further evaluation before offering further treatment."

The objective of our pilot study was to determine the reaction of our staff over the use of MyDoc in an orthopedic clinical setting in Singapore. Almost all of them found it to be an excellent tool and gave positive feedback. While the introduction and integration of MyDoc may prove to be advantageous in a number of ways, there are various disadvantages and key issues that need to be addressed. For example, the integrity of a secure wireless network and the transmission of sensitive and confidential information is a concern. Ensuring the same is of paramount importance and forms the basis of the implementation of this technology. From a practical point of view, possible loss of the internet connection or network may make the use of the system both impractical and frustrating. Lastly, the speed of message transmission was an issue a number of study participants raised, stating that it is not as fast as other applications (two to three seconds per message or image sent compared to one to two seconds on current messaging applications). However, it must be understood that unlike other systems in use where messages can be read by anyone, forwarded to anyone, remain unencrypted on telecommunication providers' servers, and most importantly stay forever on the sender's and receiver's phones [13], messages on MyDoc are not stored on the phone. The latter, together with the various levels of security, account for the slightly slower transmission speed. These measures, including MyDoc's assurance of being HIPAA-compliant and having all data stored on a dedicated medical data storage server ensure the security of this messaging platform.

Potential Uses of MyDoc in Orthopedic Surgery

Regional Teleconsults for Specialist Referral

As Singapore is one of the most popular medical hubs in Southeast Asia, the use of virtual consults has the potential to exponentially increase the volume of referrals from around the region. In turn, while the potential increase in patients improves revenue for hospitals and specialists, patients also benefit by the decreased costs they have to face in terms of less travel and accommodation expense as well as the lower doctor's fees currently in place for a virtual visit.

Clinical Outreach in the Setting of Trauma

In tertiary referral centers, the ability to provide greater expertise in the management of trauma patients in centers where specialist expertise is limited has great potential. With the use of MyDoc, inappropriate referrals can also be prevented and appropriate referrals be managed better. Thus the optimal outcome for patients can be achieved by providing expertise at a moment's notice. This may be most beneficial in the emergency room (ER) setting where often the attending orthopedic surgeon may be scrubbed in the operating room, thereby not being able to attend to the referral at the ER immediately.

Supervision in the Operating Room

We have all heard the phrase, "see one, do one, teach one." Taking this into account, being supervised as opposed to unsupervised is far better for both the trainee and more importantly, the patient. MyDoc has tremendous potential in the operating room as a tool for supervision through its interactive and real time feed. Knowing that they are under the watchful eye of a trainer, reassures the trainees. By the trainer being remotely present, the trainee is forced to think on their feet and be meticulous. While the trainer guides and teaches, the trainee does the procedure themselves. An added benefit includes saving costs by not having the trainer to be on site.

Providing Both Patient and Parent Reassurance in Pediatric Orthopedic Patients

In comparison to adult orthopedics where very often we have to deal with just the patient, pediatric orthopedics requires the reassurance of not only the patient who is a child, but also that of the child's parent or parents. It has been shown that any patient who is discharged from an ER and referred to an orthopedic clinic feels more reassured when they hear the same management plan from the orthopedic surgeon rather than the emergency physician [8]. For this reason, the presence of MyDoc in the emergency department and more so at a pediatric ER, allows the provision of such reassurance. This in turn not only ensures appropriate discharges and referrals but also improves patient satisfaction and lowers costs for unnecessary admissions to the orthopedic surgeon on call.

In the Setting of the Outpatient Department

MyDoc may serve a multitude of functions with regard to outpatient clinics. It could help with the concurrent running of two or more clinics, *all* under supervision. Remote clinics could function without added time, travel, and cost constraints. A wound dressing clinic could accept patients without having to wait for the physical presence of a surgeon; as the surgeon could examine the wounds of patients using MyDoc even while running his or her trauma or elective clinic. Furthermore, taking a high-resolution macro photo without running the risk of contaminating the wound allows accurate documentation of what the wound looks like and makes it possible for a different surgeon to objectively assess the healing or worsening of a wound over time. It is noted however, that optimal environmental conditions such as the light intensity would be required and that training on image capturing standards would also need to be done. MyDoc also facilitates the sharing of radiographs between members of an orthopedic team. This

however, would also require further validation with users having to be aware of the risks and limitations of such images. While obvious fractures may allow adequate discussion on management, more subtle ones may not.

Weekend Ward Rounds

The current economic climate dictates cost savings to be the priority of hospitals. Hence, the necessity for the physical presence of a doctor to perform ward rounds may be substituted by conducting a ward round through the use of virtual consults. This would be applicable only when decisions regarding discharge or necessary management are based more on observational findings rather than the need for clinical examination.

Conclusions

In early 2013, an article stated that telehealth is expected to grow six fold by 2017 [25]. Subsequently, the fact that telehealth may even be a remedy for chronic hospital readmissions [26] and the reasons why virtual doctor visits are better than in-person ones [27] have been justified. Our pilot study had excellent results in terms of acceptance and satisfaction by all staff members with regard to using MyDoc as a secure messaging system. The integration of the application in an orthopedic clinical setting to provide a variety of other functions as discussed in this paper has an exciting and limitless potential. Downsizing operational costs, despite being beneficial is also needed in order to comply with the Accreditation Council for Graduate Medical Education (ACGME) standards (Singapore has adopted the American system of training) and the recently introduced personal data protection act (expected to be adopted before July 2014). With MyDoc being fully functional on all iPhones already and on the majority of Android devices by end of April 2014 (according to the developers), it is one of the first secure messaging platforms founded and available in Southeast Asia designed explicitly for clinical use. Built by doctors and for doctors, the secure messaging platform MyDoc ticks all the boxes and is something all hospitals and healthcare personnel should consider promoting.

Conflicts of Interest

None declared.

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Abbreviations

ACGME: Accreditation Council for Graduate Medical Education
AAOS: American Academy of Orthopedic Surgeons
HIPPA: health insurance portability and accountability act
PDPC: personal data protection commission
SMC: Singapore Medical Council

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Original Paper

Efficiency and Usability of a Near Field Communication-Enabled Tablet for Medication Administration

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Abstract

Background: Barcode-based technology coupled with the electronic medication administration record (e-MAR) reduces medication errors and potential adverse drug events (ADEs). However, many current barcode-enabled medication administration (BCMA) systems are difficult to maneuver and often require multiple barcode scans. We developed a prototype, next generation near field communication-enabled medication administration (NFCMA) system using a tablet.

Objective: We compared the efficiency and usability of the prototype NFCMA system with the traditional BCMA system.

Methods: We used a mixed-methods design using a randomized observational cross-over study, a survey, and one-on-one interviews to compare the prototype NFCMA system with a traditional BCMA system. The study took place at an academic medical simulation center. Twenty nurses with BCMA experience participated in two simulated patient medication administration scenarios: one using the BCMA system, and the other using the prototype NFCMA system. We collected overall scenario completion time and number of medication scanning attempts per scenario, and compared those using paired t tests. We also collected participant feedback on the prototype NFCMA system using the modified International Business Machines (IBM) Post-Study System Usability Questionnaire (PSSUQ) and a semistructured interview. We performed descriptive statistics on participant characteristics and responses to the IBM PSSUQ. Interview data was analyzed using content analysis with a qualitative description approach to review and categorize feedback from participants.

Results: Mean total time to complete the scenarios using the NFCMA and the BCMA systems was 202 seconds and 182 seconds, respectively (P=.09). Mean scan attempts with the NFCMA was 7.6 attempts compared with 6.5 attempts with the BCMA system (P=.12). In the usability survey, 95% (19/20) of participants agreed that the prototype NFCMA system was easy to use and easy to learn, with a pleasant interface. Participants expressed interest in using the NFCMA tablet in the hospital; suggestions focused on implementation issues, such as storage of the mobile devices and infection control methods.

Conclusions: The NFCMA system had similar efficiency to the BCMA system in a simulated scenario. The prototype NFCMA system was well received by nurses and offers promise to improve nurse medication administration efficiency.

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Introduction

Background

Medication errors continue to represent a source of patient harm and can lead to increased health care utilization and costs [1-4]. Studies estimate the rate of adverse drug events (ADEs) to be between 6.5 and 15 ADEs per 100 hospital admissions with 28% to 75% of ADEs being preventable [5,6]. Of all hospital ADEs, 34% take place during medication administration, and less than 2% are caught before administration is complete [7,8].

Barcode-enabled medication administration (BCMA) coupled with an electronic medication administration record (e-MAR) has been shown to reduce nontiming medication administration errors by 41%, potential adverse drug events by 51%, and eliminate transcription errors [9]. During BCMA in our hospital, nurses scan the medication barcode and the barcode on the patient's wristband to verify they are administering the right medicine to the right patient, at the right dose, at the right time, and by the right route. Finally, the nurse scans their hospital identification badge to record the medication administration event in the medication administration record. While the sequence of scanning events may vary slightly between hospitals, all BCMA workflows require scanning the patient, the provider, and the individual medications.

Importance

Medication administration is an essential clinical task for hospital-based nurses, accounting for up to 28% of nursing activity [10]. Using medications safely is a Joint Commission National Patient Safety Goal [11] and using assistive technologies in conjunction with e-MAR to track medications from order to administration is a requirement for hospitals to meet Stage 2 Meaningful Use of health care information technology [12]. Despite these important safety benefits and incentives for e-MAR use, there are reports of clinicians not using the barcode system or finding workarounds due, in part, to difficult to maneuver computers on wheels, barcode scanners that often require multiple scans, and devices that require clinicians to repeatedly identify themselves (login) and their patients [13]. Innovations in mobile technology may overcome some of these challenges and make e-MAR more efficient. Improving usability and saving just a few seconds with each medication administration could dramatically improve efficiency when extended to the millions of medication administration events that occur across all patients, providers, and hospitals.

Goals of This Investigation

We developed a novel, next generation prototype near field communication-enabled medication administration (NFCMA) system taking advantage of a mobile device equipped with a reader for near field communication (NFC), a wireless communication protocol that allows secure exchange of small amounts of data by proximity or touch. We compared the efficiency and usability of this prototype NFCMA system with an established laptop BCMA system in high-fidelity simulated medication administration scenarios. With the ability to provide contactless identification of patient, provider, and medications and to enter data directly on the handheld mobile device, we hypothesized that NFCMA would be more efficient and usable than traditional BCMA solutions riding on "workstations on wheels" (WOWs).

Methods

Study Design and Setting

In this mixed-methods study, we evaluated the feasibility of a prototype NFCMA system, using a randomized cross-over study, a survey, and one-on-one interviews. We performed the study in an academic medical simulation center that provided a controlled environment without interruption, concern for patient privacy or the need to integrate our prototype with other clinical systems [14]. The Partners Health Care institutional review board (Partners Health Care, Boston, MA) approved this study.

Brigham and Women's Hospital (BWH) is a leader in BCMA and custom developed a workstation-based BCMA that went into widespread hospital use in 2005. Licensed independent practitioners order medications through computerized provider order entry (CPOE). Nurses review electronic medication orders and retrieve ordered medications from the automated medication dispensing system. At the patient's bedside, nurses use fixed workstations or WOWs with Bluetooth-linked handheld barcode scanners. The nurse scans barcodes on the medication (label affixed to medication packaging), the patient (hospital bracelet), and themselves (hospital identification badge). The system confirms the five rights of medication administration (right patient, right medication, right route, right time, and right dose) and alerts the nurse, as necessary, to prevent medication errors. The BCMA system then electronically records the medication administration event.

Intervention: Pilot NFCMA System

We developed a prototype NFCMA system using the 7" Google Nexus. The Google Nexus was used because it was the first tablet available with the Android 4.0 (Ice Cream Sandwich) operating system version with support for NFC. Currently, there is a wide selection of commercially available mobile devices that include both NFC and application programming interfaces enabling custom application development. NFC standards for communications protocols and data exchange formats are based on existing radio-frequency identification (RFID) standards including ISO/IEC 14443 and FeliCa and the ISO/IEC 18092 modulation schemes [15]. When embedded in a mobile device, NFC technology allows a user to "tap" their mobile device to establish an electromagnetic data exchange with an NFC tag (which can be incorporated in a sticker) to collect information or register an action.

RFID technologies allow readers to communicate wirelessly with tags on objects to collect information about that object [16]. RFID operates across a spectrum of frequencies, each with different capabilities. In comparing different RFID data acquisition technologies it is important to note various frequencies and protocols that are options for automated information data collection using radio frequency. These can be divided into two categories, passive and active RFID. Active RFID tags have a transmitter that requires a power source (typically a battery), which are expensive to both charge and to

replace. Passive tags draw power from electromagnetic waves transmitted by the reader that induce a current in the tag's antenna. Common frequencies used in passive RFID systems include [16]:

- Low-frequency: limited range and slow read rate (eg, tracking animals);
- High-frequency (HF): NFC, generally near-field electromagnetic data exchange in close proximity (eg, smartcard applications for secure identification and access control); and
- Ultra high frequency: 10-m high speed reader capability (eg, supply chain applications).

NFC HF passive RFID operates at the 13.56 MHz frequency, building on standards for smartcards including ISO/IEC 14443 and ISO 15693, which are already used in many hospitals to identify both providers and patients. NFC HF RFID works by close proximity of electromagnetic coupling (a couple millimeters), ensuring only one NFC tag is read at a time. For medication administration, we use a passive NFC tag that does not require an expensive power source (ie, a battery); the tag draws its power from electromagnetic waves transmitted by the reader that induce a current in the tag's antenna. The close proximity (touch) required for NFC tag reading may be less difficult to achieve than the precise alignment, scan distances and issues with low light levels and/or print quality required for successful barcode reading. Further, the tap feature may resolve inefficiencies introduced by linear or two-dimensional barcodes that are difficult to scan when wrinkled or inadvertently torn. The availability of "off the shelf" NFC smartphones makes this technology an attractive and cost effective alternative to dedicated barcode reader/laptop workstations. For these reasons, NFC may be superior to bar codes and low frequency RFID for medication administration.

The prototype NFCMA app was developed using the Android Software Development Kit. To ensure the study evaluated differences in mobile platform and NFC, the NFCMA software was designed to closely mimic existing barcode functionality; workflow and screens were similar to the current BCMA system. Differences were limited to the mobile footprint and the ability to identify the clinician, patient, and medication via NFC proximity touch. The mobile app also has the capability to confirm the five rights of medication administration and alert users with messages/warnings combined with sounds or vibration. Similar to the BCMA software, the NFCMA app prompted the user for additional information, including indication for "as needed" (PRN) orders, dose for variable dose medication orders, and pain level for pain medication orders. Importantly, the prototype NFCMA was developed as a standalone app; fictitious scenario data was hard coded into the app. The app did not capture real patient data or integrate with CPOE or other clinical information systems. Figures 1 and 2 show sample screenshots from the NFCMA app.

Instead of optical linear barcodes, NFC uses radio frequency tags encoded with unique identification numbers, such as the Global Trade Identification Number for medications. We used commercial off-the shelf NFC tags that were programmed and affixed to the hospital bracelet (patient identification [ID]), the hospital identification badge (nurse ID), and the medication packaging. We found medication blister packs interfered with NFC tag operation, so blister packs were placed in plastic bags and NFC tags were affixed to the plastic bags.

Figure 1. Prototype near field communication-enabled medication administration (NFCMA) system screenshot:medications due screen.
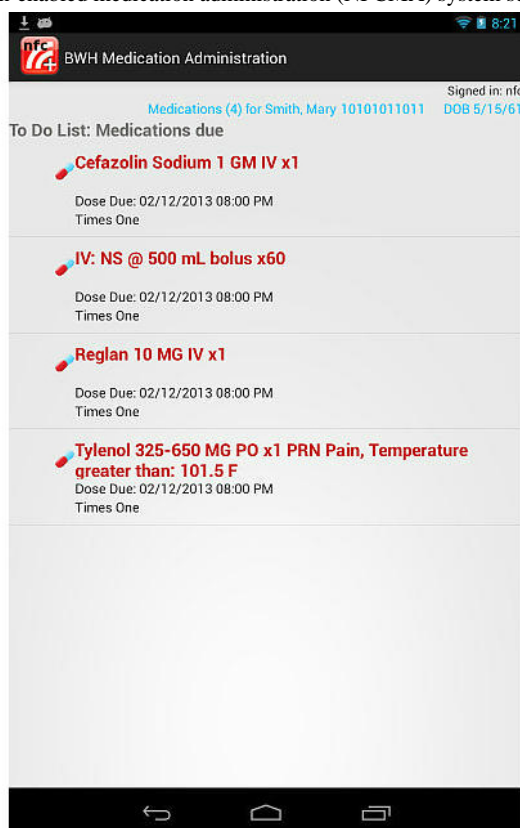
Figure 2. Prototype near field communication-enabled medication administration (NFCMA) system screenshot: pain scale dialog box.
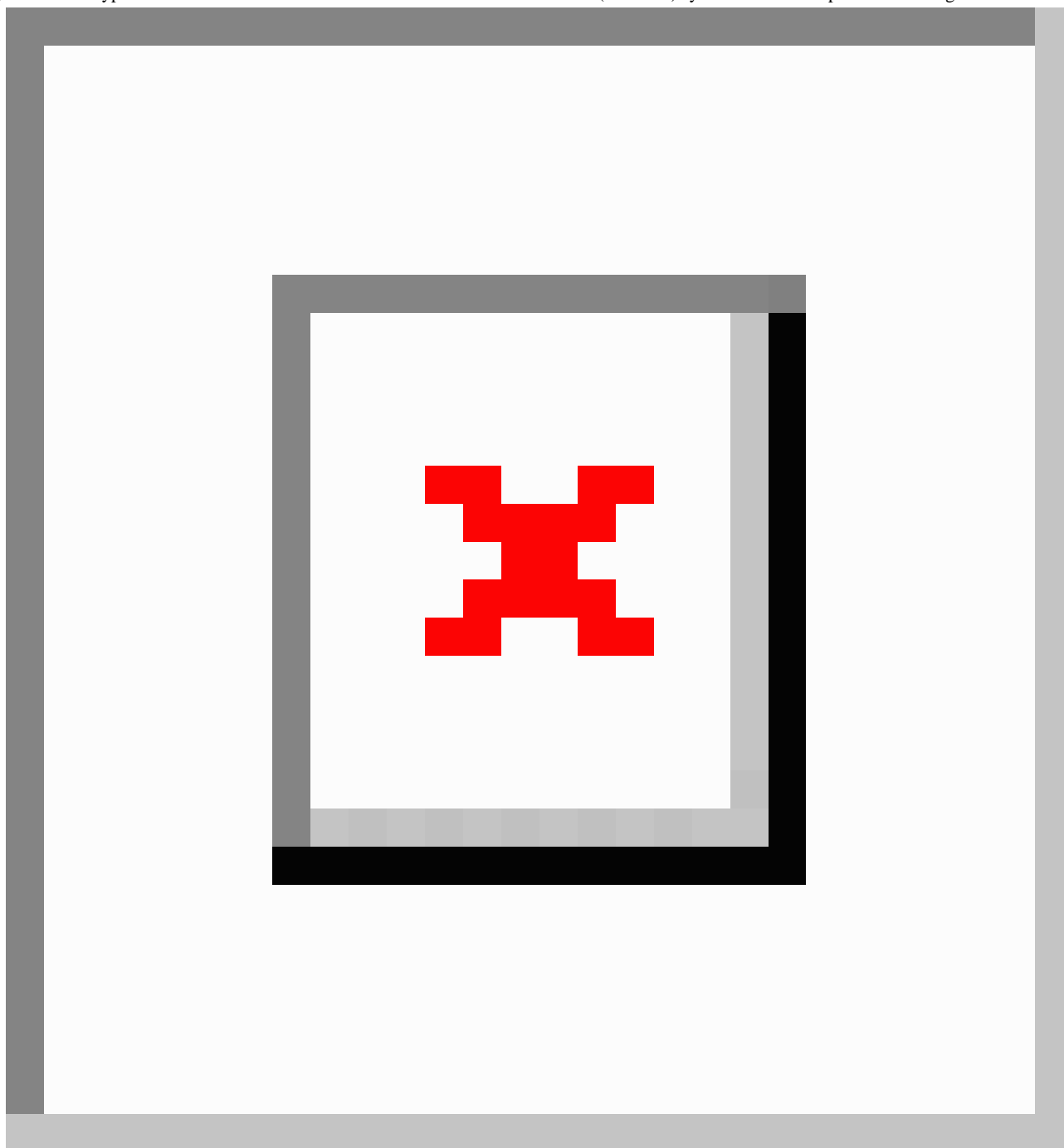
Participant Selection

This pilot recruited 20 hospital-based nurses with BCMA experience. A sample size of 20 participants were selected given resource constraints and prior work establishing that 5 users are able to detect 85% of user interface issues [17,18] and 20 are able to detect 95% [19].

With the approval and assistance of nursing leadership, we identified email distribution lists including all hospital nurses. Given that this email distribution list included 2943 nurses, a 20.32% (598/2943) random sample of nurses was contacted with information about the study, including a frequently asked questions document explaining their role in the study and privacy/confidentiality statements. Participation was voluntary and had no effect on employment status or performance evaluations. Participants were selected based on order in which response was received and availability for study sessions. All participants provided verbal informed consent and were compensated US $100 for their participation in this study.

Study Protocol

This study was conducted in a medical simulation center using a patient examination room that simulated a typical hospital room [14]. Each participant performed two simulated medication administration scenarios: one using the existing BWH BCMA system and the second using the prototype NFCMA system. Scenario order was randomized to minimize bias from carryover effects.

In collaboration with e-MAR process flow experts, we designed two simulated medication administration scenarios involving administration of a series of medications to a simulated hospitalized patient (Multimedia Appendix 1). To test the use of the e-MAR systems, the scenarios were designed to replicate typical inpatient medications and to include administration tasks similar to those typically performed with the existing BCMA system. Each scenario included a pain medication, an antiemetic medication, intravenous solution, and an antibiotic. A PRN order and variable dose range order were included in both scenarios, requiring the nurses to enter the dose administered and reason for administration on the barcode workstation or mobile device.

On arrival, study staff reviewed general study information with the participants and the participants provided verbal informed consent. Participants were instructed to complete medication administration as usual, identifying the patient, provider, and medication using the BCMA or NFCMA system. Prior to each scenario, nurses were provided a written script describing the clinical scenario and medication administration directives (Multimedia Appendix 1). Medications for each scenario were organized on a table in the simulated room. For the NFCMA scenario, nurses used the prototype NFCMA system and NFC tags were placed on each medication, patient ID bracelet, and nurse badge. For the BCMA control, nurses used standard hospital WOWs with handheld barcode scanner and the current version of our BCMA software using a test patient. Participants had the opportunity to review the script and ask questions before the scenario began.

Immediately before completing the NFCMA scenario, participants received a brief training on the NFCMA system using an additional scenario. This approximately 3-minute training session involved the administration of an antibiotic (Nitrofurantoin) and an analgesic (Phenazopyridine) to a patient with a urinary tract infection. Participants also practiced scanning the patient ID bracelet and nurse ID badges. Of note, Nitrofurantoin and Phenazopyridine were not included in the administration scenarios and NFCMA training did not include practice responding to allergy alerts, entering indications for PRN medications, or specifying the dose for medication orders with range dosing. Nurses did not receive training or practice with BCMA as the hospital e-MAR system currently in use, and on which these nurses have considerable experience, was used.

Study staff observed from a control room separated from the exam room by one-way glass. The patient in each scenario was a high fidelity mannequin with life-like functions including respiration, breath and bowel sounds, heart tones, pulse, and blood pressure. Nurses could talk to the patient mannequin and study staff would provide appropriate responses through the simulation center communication system.

After completion of both simulation scenarios, participants completed a Web-based survey covering demographic information, e-MAR experience, and the usability and workload of the prototype NFCMA system, through a modified International Business Machines (IBM) Post-Study System Usability Questionnaire (PSSUQ) [20]. Finally one research member (PN) conducted brief (10-15 minute), semistructured interviews with each participant, using an open-ended interview guide (Multimedia Appendix 2), to collect more detailed feedback on the experience and prototype NFCMA system, including scanning technology, portability/size, and workflow. The entire simulation encounter, including the one-on-one interview, was audio and video recorded using the simulation center's audio-visual equipment and a backup digital audio recorder.

Outcome Measures

Our primary outcome measures reflected efficiency and usability of the e-MAR systems. Efficiency was measured by the overall time to complete each medication administration scenario and the total number of scanning attempts per scenario. Overall time started when the participant entered the simulated patient's room and ended when the nurse scanned her ID badge, the electronic signature and last step in the medication administration event. Total scanning attempts included scan attempts for patient ID, nurse ID, and medication. Under perfect circumstances, participants will have had seven scan attempts: one scan each for three medications; two scans for one medication that required two tablets; one scan for nurse hospital ID badge; and one scan for patient identification bracelet.

System usability refers to the efficiency, effectiveness, and satisfaction with which specific users can achieve a specific set of tasks in a particular environment [21]. We measured usability and workload of the prototype NFCMA system through a modified PSSUQ and from qualitative responses from the one-on-one interview.

Data Collection and Analysis

Research study staff observed all participant sessions in real-time and recorded overall scenario time and scanning attempts. To standardize and to improve measurement, scanning attempt criteria were established (Table 1) and a trained observer (DM) reviewed video recordings of each session to confirm overall scenario completion time and total number of scanning attempts. Because several scenarios were interrupted by technical issues such as bugs in the tablet prototype, problems with previously entered medication orders in the barcode system, and other equipment issues, interruption start and end times were also recorded. Scenario times, interruption time, and scanning attempts were recorded in Microsoft Excel. Video recordings were not available for 2 participants, so these participant results were excluded from the time and scanning attempt results. For the analysis, we assumed these participants were missing completely at random.

Survey responses were collected using SurveyMonkey and transferred to Microsoft Excel for analysis. In addition to the video and audio recording, the interviewer and research assistants kept detailed notes of the one-on-one participant interviews, including key words and phrases used by participants.

Participant demographics were presented as descriptive statistics with frequency with percentage or mean for categorical and continuous data respectively. Participant's overall time and total scanning attempts between the prototype NFCMA and BCMA

systems were compared using a paired *t* test. We justified using parametric tests after viewing the differences graphically and using the Shapiro-Wilk test. We considered alternative distribution assumptions for the outcomes and analyzed the data using Wilcoxon signed-rank test and general estimating equations with bootstrap resampling. There were no contradictions between the *P* values from the paired *t* test compared with the nonparametric tests and general estimating equations; therefore, we report just the results of the paired *t* test for brevity and simplicity. In a sensitivity analysis, interruption time was subtracted from total time, to determine if interruptions impacted overall time. While interruptions did not impact number of scanning attempts, some participants entered their hospital identification number manually instead of scanning their barcode hospital ID badge. In order for hospital ID barcodes to be used with our barcode system, the badges must be activated. Some participants' badges did not activate correctly and were not able to be scanned. Therefore, we performed an additional sensitivity analysis by adding a scan attempt to those participants who did not scan their hospital ID badge. Mean scores were summarized for each PSSUQ survey question. All statistical analysis was performed in Stata 12.0 and two-sided *P* values of less than 0.05 were considered to indicate statistical significance.

We performed a content analysis of the one-on-one interview data using a qualitative description approach, where notes from interviews and observations, supplemented with audio/video recordings, were reviewed, coded, and sorted to identify key phrases and meaningful text units as well as similarities and differences among the participants [22-24]. A subgroup of the research team (PN, AR, DM, and AL) met to discuss categories and subcategories of feedback, which were iteratively revised during the process. The group then selected representative quotes for each of the categories. Selected quotations were extracted from video recordings to ensure accuracy. Qualitative data was managed in Microsoft Excel.

Table 1. Scanning attempt criteria for barcode-enabled medication administration (BCMA) and near field communication-enabled medication administration (NFCMA) systems.

BCMA	NFCMA
Successful scan attempt	Successful scan attempt
Barcode scanner activation via button without a scan registering	Failed scan sound
Intentional barcode scanner manipulation	Intentional tablet manipulation (tapping or sliding) near NFC tag without a scan

Results

Participants

Twenty nurses with a mean of 14 years of nursing experience and 4.9 years of experience with the existing BCMA system participated in the study (Table 2). The majority (18/20, 90%) worked primarily on the medical/surgical floors and intensive care units, using the BCMA system during their shifts. Two participants worked primarily in the emergency department, but also serve as clinical educators and work with trainees on the medical/surgical units using and teaching BCMA. Almost all participants reported having their own computers (18/20, 90%) or smartphones (17/20, 85%), and 50% (10/20) reported owning tablets.

Table 2. Nursing participant characteristics (N=20).

Characteristic	n (%) or mean (range)
Nursing experience (years), range	14 (2-38)
Brigham and Women's Hospital barcode-enabled medication administration (BCMA) experience (years), range[a]	4.9 (1-8)
Nursing Unit Type, %	
Medical/surgical	15 (75)
Intensive care unit	3 (15)
Emergency department[b]	2 (10)
Computer/Mobile Device Experience, %	
Own personal computer	18 (90)
Own smartphone	17 (85)
Own tablet	10 (50)

[a]One nurse excluded due to invalid data entry.

[b]These participants work primarily in the emergency department without BCMA, but also serve as clinical instructors on the medical surgical floors where they use (and teach) BCMA.

Efficiency

Mean total scenario completion time was 202.4 seconds using the prototype NFCMA system compared with 182 seconds when using the BCMA system (Table 3). No statistically significant difference was observed (P=.09). Further, after adjusting for unplanned scenario interruptions, there was also no difference between total time using the prototype NFCMA system (188.2 seconds) and BCMA system (178.6, P=.32).

Mean scanning attempts were 7.6 using the prototype NFCMA system compared with 6.5 attempts using the BCMA system (Table 3). No statistically significant difference was observed (P=.12). In sensitivity analysis, the addition of one scan attempt to those using the barcode scanning system but manually entering their nurse ID yielded results that were even more similar to the mean NFC scan attempts (mean scan attempts 7.4, P=.80).

Table 3. Summary of quantitative results comparing the efficiency of the prototype near field communication-enabled medication administration (NFCMA) system to barcode-enabled medication administration (BCMA) system.

	NFCMA Mean (seconds) (SD)	BCMA Mean (seconds) (SD)	Mean difference	95% CI of the difference	P value
Total scenario completion time	202.4 (39.0)	182.0 (42.1)	20.4	−3.6-44.4	.09
Total scanning attempts	7.6	6.5	1.1	−.3-2.4	.12

System Usability

Using a validated survey instrument, 19/20 (95%) participants agreed or strongly agreed that the prototype NFCMA system was easy to learn and use, enabled efficient task completion, and offered a pleasant interface (Table 4). Overall, 19/20 (95%) participants were satisfied with the prototype NFCMA system. No participants disagreed or strongly disagreed with any of the usability metrics.

Participants provided three major categories of feedback on the prototype NFCMA system during the one-on-one interviews: implementation and operational concerns, usability, and functional/feature enhancements. Table 5 summarizes representative quotes from nurse participants in these categories and subcategories.

Participants noted implementation concerns about how the prototype NFCMA system would be operationalized in the

hospital environment. For example, participants expressed concern about no longer having the WOW, which they often use to transport medications to the patient. Participants also questioned how the tablets would be safely cleaned, disinfected, and stored.

In addition to implementation concerns, participants discussed issues relating to the usability of the tablet, including the current functionality, scanning, and interface of the tablet. While participants gave mixed feedback on the portability and size of the tablet as compared with the current system (Table 5), they were pleased with its ease of use. Participants provided constructive feedback about the sound and touch interface potentially being challenging in the clinical environment.

Finally, participants suggested enhancements to the prototype NFCMA system, such as a link to the hospital's drug administration guide, which they have in their current BCMA system.

Table 4. Usability and workload of the prototype near field communication-enabled medication administration system, assessed through a modified International Business Machines Post Study System Usability Questionnaire.

Question	Strongly Agree ------------> Strongly Disagree							Rating average
	1	2	3	4	5	6	7	
Overall, I am satisfied with how easy it is to use this system.	13	6	0	1	0	0	0	1.45
It was simple to use this system.	14	5	1	0	0	0	0	1.35
I could effectively complete the tasks and scenarios using this system.	14	5	0	1	0	0	0	1.40
I was able to complete the tasks and scenarios quickly using this system.	12	7	0	1	0	0	0	1.50
I was able to efficiently complete the tasks and scenarios using this system.	12	7	0	1	0	0	0	1.50
I felt comfortable using this system.	12	7	1	0	0	0	0	1.45
It was easy to learn to use this system.	15	4	1	0	0	0	0	1.30
I believe I could become productive quickly using this system.	14	4	1	1	0	0	0	1.45
The organization of information on the system screens was clear.	15	4	1	0	0	0	0	1.30
The interface[a] of this system was pleasant.	15	4	0	1	0	0	0	1.35
I liked using the interface[a] of this system.	14	5	0	1	0	0	0	1.40
Overall, I am satisfied with this system.	13	5	1	1	0	0	0	1.50

[a]The "interface" includes those items that you use to interact with the system. For example, some components of the interface are the keyboard, the mouse, the microphone, and the screens (including their use of graphics and language).

Table 5. Summary feedback on the prototype near field communication-enabled medication administration (NFCMA) system by category with example participant quotes.

Category	Quotes
Implementation concerns	
Transmission of infection	*This [tablet] could transmit bacteria from room to room.* [Participant 10]
	I just wonder what would be done for infection control [when using the tablet]. [Participant 14]
Cleaning tablet	*Are you going to be wiping it [the tablet] down every time you go to the patient?* [Participant 1]
	The concern of if we are able to use the aseptic wipes to clean it [the tablet]. [Participant 17]
Carrying meds and holding tablet	*I find that all the nurses will lay out all their meds on the cart [WOWᵃ] and bring it into the patient's room. And if you're just holding this [tablet] I don't know where everything else would go.* [Participant 20]
	We've become attached to our computers in using the flat surface [of the WOW] to carry meds into the room, and maybe a cup of water or something for the patient. [Participant 16]
Dropping/losing/protecting the tablet	*Those [tablets] will get lost, they'll get broken, they'll get dropped.* [Participant 12]
	Just a case or something to make it [the tablet] durable – because I can guarantee that it will get dropped. [Participant 19]
Tablet storage and availability	*I wonder when we are actually using them will we all have our own tablet.* [Participant 7]
	I'm not sure if this [tablet] would be one device for all the patients. [Participant 8]
Usability	
Portability and size	*It [the tablet] seems kind of big though ... maybe it could be a little smaller.* [Participant 4]
	It's [the tablet] a nice size, nice and small. [Participant 2]
	I'm just afraid it's [the tablet] a little too portable, in terms of just leaving it somewhere. [Participant 8]
	I like the fact that you don't have to bring the computer into your room – you know it's [the tablet] just a little more portable. [Participant 1]
Ease of use	*It [the tablet] was small, it was easy to use – it's user friendly basically.* [Participant 12]
	I think it [the tablet] was user-friendly obviously pending getting used to it, it's just a matter of time. [Participant 19]
Tablet	*If it's [the tablet] easy to touch with gloves on it would be fine – it would kind of be a pain to be taking on and off your gloves.* [Participant 3]
	The beeps [from the tablet when scanning medications] are not loud though, when it does go through. [Participant 5]
	Some people would probably feel like that keyboard [on the tablet] is too small. [Participant 14]
Enhancements	
Access to additional applications/information	*Would we be able to get to the DAG [Drug Administration Guide] from here [tablet]? .... Often times some meds say it goes over three hours, but if you go on the DAG in an emergency case you can run it over an hour – it's nice to have that immediately.* [Participant 11]
	At least being able to get [on the tablet] the hospital nursing policies, and the pharmacy drug administration guidelines and MicroMedex would be really important for med administration. [Participant 14]

ᵃWorkstations on wheels

Discussion

Principal Results

We developed a prototype e-MAR system using a tablet and NFC. In a pilot study conducted in a medical simulation center, we found no statistically significant difference in medication administration efficiency (total scenario time and scanning attempts) between the existing BCMA system and the prototype NFCMA system running on a mobile device. Nurse participants overwhelmingly found the prototype NFCMA system highly

usable and offered next steps required for implementation. Given increasing attention to EHR efficiency and usability and the inclusion of e-MAR use as part of Stage 2 Meaningful Use, the mobile NFCMA platform or its components may eventually be an effective alternative to BCMA systems.

With only 3 minutes of training, participants were able to successfully complete all medication administration tasks using the prototype NFCMA system. Importantly, participants were able to complete these scenarios as efficiently with the prototype NFCMA systems they were with a BCMA system with which they had an average of 4.6-years' experience. This is partly explained because the prototype NFCMA system was designed to have a similar look and feel to the existing BCMA system. Further, participants had considerable experience with mobile devices, which may have increased their ability to rapidly learn the prototype NFCMA system. These results further support the survey and qualitative findings that the prototype NFCMA system was well-designed and easy to use.

In addition to highlighting the high usability of the prototype NFCMA system, the qualitative interviews raised important barriers for use of this prototype NFCMA system as well as other mobile apps in the health care environment. There is increasing attention to reducing nosocomial transmission of infection, including those from inanimate objects, such as tablets. Previous work suggests that mobile devices can harbor infectious organisms [25,26]; however, safe ways of cleaning mobile devices have not been definitively described. Adding waterproof protective covers and building tablets using durable health care plastics allow tablets to be disinfected. Dedicating mobile devices to individual patient rooms is another possible solution to prevent spread of hospital-acquired infection. The infection risk with the prototype NFCMA system is similar to the current BCMA system. Finally, there must be attention to where tablets will be stored and how they will be charged. While seemingly minor details, if these implementation details are not defined in advance with attention to the workflow and efficiency implications, NFCMA and other mobile health care application implementations may have limited success.

Comparison With Prior Work

While barcode technologies are well established in health care, this study is among the first assessing the potential for NFC apps to improve electronic medication administration. One early pilot assessed NFC as a tool for general nursing tasks and training, including e-MAR [27]. Other reports have used mobile phones with NFC to track self-reported patient outcomes [28] and medication compliance in both routine treatment and clinical trials [29]. Other work proposes more general health care apps for NFC [30]. These previous NFC health care app reports have limited evaluations, typically leverage mobile phones rather than tablet devices, and omit the efficiency and usability testing central to this evaluation.

Limitations

This study has some important limitations. First, this was a prototype study conducted in a simulation setting. We attempted to replicate the clinical environment in a high-fidelity simulation center, but our results may not be generalizable to clinical settings. Second, this was a pilot study with a small sample size. We may not have had adequate power to detect small differences in time and scanning efforts between the two systems. Further, our scenarios were short, limiting our ability to detect differences that may be apparent with longer, more complicated clinical situations. Fourthly, participants experienced some technical difficulties during the encounters. While these unexpected events showed no impact on outcome measures in sensitivity analyses, they will need to be addressed prior to implementation. These technical difficulties were generally experienced with the prototype NFCMA system (coupled with brief training and experience with NFC) biasing the study toward the existing BCMA environment.

While NFC is a promising technology to improve medication administration, there are several limitations that must be overcome before this technology can be broadly applied to e-MAR. NFC supports ISO 14443 smartcard standards, therefore these devices can read patient and provider ID systems that may be deployed in hospitals today. What are missing are NFC labels for medications, which are currently labeled with optical barcodes. In our study, we manually labeled medications with NFC tags. This is time consuming and not feasible on a larger scale. Ideally, pharmaceutical manufacturers or distributors would incorporate NFC tags into product packaging, as is the current practice with barcodes. These NFC tags could be seamlessly incorporated into packing materials, and ideally identified with a common symbol. Further, the NFC tags could be printed on a label with a barcode and human readable medication identification number as a backup in case the NFC reader or tag failed.

Not all US mobile devices support NFC. However, NFC is estimated to have been included in one out of three smartphones sold in 2013, increasing total NFC-enabled devices to 400 million globally [31]. Broader support of NFC in mobile devices will increase availability and drive down costs. In the short-term, a subset of medications might be identified, such as specialty pharmaceuticals, where extra efforts to place NFC tags are outweighed by the benefits of product authentication and reliable recording of product/patient interactions.

Conclusions

One important clinical tool that has been shown to reduce medication errors and potential adverse drug events at the point of medication administration is e-MAR [9]. Use of e-MAR is now a core measure of Stage 2 Meaningful Use, so e-MAR use will continue to increase over the next few years. NFCMA on a tablet device offers an alternative to traditional workstation-based BCMA. We found similar operational performance with improved usability in this prototype simulation study. While additional clinical studies and additional NFC/mobile operational tools will be required for future evaluations, NFCMA is a promising tool to improve medication administration.

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Acknowledgments

Authors' Contributions

AL, AB, and SM conceived the study. AL, SM, MD, AB, MS, and PN contributed to the design of the study. DM, PN, AR, AL, and ST analyzed and interpreted the data. AL, PN, AR drafted the manuscript. All authors revised the manuscript and approve the final version for publication.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Clinical scenarios for prototype near field communication-enabled medication administration (NFCMA) system and barcode-enabled medication administration (BCMA) system.

[PDF File (Adobe PDF File), 134KB - mhealth_v2i2e26_app1.pdf]

Multimedia Appendix 2

Qualitative interview guide.

[PDF File (Adobe PDF File), 93KB - mhealth_v2i2e26_app2.pdf]

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Abbreviations

ADE: adverse drug event
BCMA: barcode-enabled medication administration
BWH: Brigham and Women's Hospital
CPOE: computerized provider order entry
e-MAR: electronic medication administration record
EHR: electronic health record NFC: near field communication
HF: high-frequency

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IBM: International Business Machines
ID: identification
NFCMA: near field communication-enabled medication administration
PRN: "as needed"
PSSUQ: Post-Study System Usability Questionnaire
RFID: radio frequency identification
WOW: workstations on wheels

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<u>Original Paper</u>

A Persuasive and Social mHealth Application for Physical Activity: A Usability and Feasibility Study

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Abstract

Background: Advances in smartphones and the wide usage of social networking systems offer opportunities for the development of innovative interventions to promote physical activity. To that end, we developed a persuasive and social mHealth application designed to monitor and motivate users to walk more every day.

Objective: The objectives of this project were to conduct a focused review on the fundamental characteristics of mHealth for physical activity promotion, to develop an mHealth application that meets such characteristics, and to conduct a feasibility study to deploy the application in everyday life.

Methods: This project started as an analytical study to review the fundamental characteristics of the technologies used in physical activity monitoring and promotion. Then, it was followed by a technical development of the application. Next, a 4 week deployment was conducted where participants used the application as part of their daily life. A think-aloud method and in-depth semistructured interviews were conducted following the deployment. A qualitative description method was used to thematically analyze the interviews. Feasibility measures included, adherence to the program, user-system interactions, motivation to use, and experience with physical activity and online social interactions.

Results: There were seven fundamental characteristics of physical activity monitoring and promotion that were identified, which were then used as a foundation to develop the application. There were fourteen participants that enrolled in the application evaluation. The age range was from 24 to 45; body mass index ranged from 18.5 to 42.98, with 4 of the subjects falling into the category "obese". Half of them were experienced with smartphones, and all were familiar with a social network system. There were thirteen participants that completed the study; one was excluded. Overall, participants gave high scores to almost all of the usability factors examined, with averages of 4.52 out of a 5.00 maximum. Over 29 days, participants used the application for a total of 119,380 minutes (average=7.57 hours/day/participant; SD 1.56).

Conclusions: Based on the fundamental characteristics, the application was successfully developed. The usability results suggest that the system is usable and user satisfaction was high. Deploying the application was shown to be feasible for the promotion of daily physical activity.

Introduction

Physical Activity and Smartphones

Despite the numerous proven benefits of physical activity (PA) [1-3] and widely publicized exercise guidelines [4,5], only 38% of adults in the United States engaged in regular leisure-time PA, and at least 25% were completely inactive [6]. Furthermore, most individuals who do begin exercise programs do not continue [7]. To promote PA, we need a system that meets the following two requirements: (1) complies with established health behavior change theories and strategies, and (2) is able to deliver effective and innovative interventions. At this moment, simple guidelines informing people of how to meet these requirements are not available. Fortunately, on the other hand, technological advances in smartphones offer innumerable opportunities for the development of such interventions as using them to monitor PA, and to encourage people to engage in more PA. As a result, a number of mobile applications (app) for PA have been developed. Unfortunately, most of these apps were not developed based on established health behavior change theories and evidence-based strategies, such as reinforcement and goal setting [8], which are keys to successful PA interventions [8,9].

Persuasive Social Network for Physical Activity

We thus reviewed and analyzed a theoretical foundation for a PA monitoring and promotion system that complies with behavior change theories and strategies. Then we used the result from the previous step to develop a mHealth app called Persuasive Social Network for Physical Activity (PersonA). Technically, PersonA was designed to automatically receive raw data from PA sensors, calculate the data into meaningful information, store the information on a secure server, and show the information to the users as persuasive and real time feedback, or publish the information to a social networking system (SNS) for further social support purposes. PersonA was also designed to persuade users to have more PA by taking more steps every day. Increasing PA by taking more steps was chosen mainly for the fact that walking and running are the easiest, safest, cheapest, and most common PA for the general population, and at the same time, yield positive overall health outcomes [10-12]. It was also inspired by a public acceptance guideline of "10,000 steps/day" as a benchmark for an active lifestyle [13].

PersonA incorporates important features from previous projects or commercial products available on the market, including automatic data collection (as done by UbiFit, It's LiFe!, Fitbit, BodyMedia, Actigraph, RunKeeper, Endomondo, and iSmoothRun) [14,15], an aesthetically appealing interface for data display and feedback (as done by UbiFit, Fish'n'Steps, Flowie, Young & Active, Fitbit, BodyMedia, RunKeeper, Endomondo, iSmoothRun, Actigraph) [14,16-18], social comparison and display of information trends (as done by UbiFit, Fish'n'Steps, Ambient Display, Wellness Partner, Fitbit, BodyMedia, Endomondo, and Actigraph) [14,16,19,20], and ease of integration into everyday life (as done by all these projects, Fitbit, BodyMedia, RunKeeper, Endomondo, and Actigraph) [14-21]. Nevertheless, PersonA introduced new features in not only allowing a sharing of data, but also facilitating advanced social interactions among users, such as sending greetings and messages, giving comments, and setting up challenges similar to the NBC reality television show *The Biggest Loser*. The interactions can take place between two individual members, among several group members, or with any social network friends. PersonA uses the smartphone's accelerometer to generate PA information (as done by RunKeeper, Endomondo, and iSmoothRun) to replace additional devices, such as traditional pedometers (necessary for Fish'n'Steps, Flowie, and Chick Clique) [16,17,21] or extension data monitoring devices (necessary for UbiFit, Fitbit, BodyMedia, Nike+, and Actigraph) [14]. Given these main features, PersonA was not designed as an invasive and very accurate tool to measure PA; rather it was designed as an easy to use tool, even though it may not provide very accurate information.

This paper reports the review and analysis of a theoretical foundation for a PA monitoring and promotion system, the development of a PA monitoring and promotion system called PersonA, and the results from a usability and feasibility evaluation of the system. Here, mainly viewed from the technological perspective, the evaluation serves two purposes: (1) to identify whether the system is usable and accepted by users; and (2) to reveal other issues in the deployment of this technology that contribute to an informed preparation for clinical trials. To our knowledge, this is the first study conducted to incorporate all of the purposes listed above.

Methods

Review of Fundamental Characteristics of Physical Activity Monitoring and Promotion System

Prior to the technical design of PersonA, an analysis to establish a theoretical foundation for the development of a PA promotion system was conducted. The purpose of the analysis was to identify the technical characteristics of a PA promotion system that: (1) complies with established health behavior change theories and strategies, and (2) is able to deliver effective and innovative interventions. Compliance with the behavior change theories and strategies has been recognized as a key component of successful PA interventions [8,9]. The characteristics were distilled from the research literature on 11 fundamental theories and models related to health behavior change, six design principles of behavior change systems, and 27 studies deploying health behavior change. The theories and models include, the Health Belief Model (HBM) [22,23], the theory of reasoned action (TRA) / theory of planned behavior (TPB) [24,25], the Elaboration Likelihood Model (ELM) [26,27], the social cognitive theory (SCT) [28,29], the social support and health link theory [30], the uses and gratifications theory (UGT) [31,32], the common bond and common identity (CBCI) theory

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[33], the Technology Acceptance Model (TAM) [34], the Unified Theory of Acceptance and Use of Technology (UTAUT) [35], and the Fogg Behavioral Model (FBM) [36]. The six design principles are, the functional triad and design principle [36], the persuasion theories and information technology design [37], the eight-step design process [38], the persuasive system design [39], the framework for health behavior change through social media [40], and the five strategies for supporting healthy behavior change [41]. The characteristics were also distilled from 27 studies on health-based promotion programs [17,30,42-66].

From this set, the characteristics of the interventions or technologies discussed were identified. In creating a list of characteristics, we focused on the characteristics that: (1) have an apparent relationship with the success of the health behavior intervention, (2) have the potential to be applied broadly across the health and wellness domain, especially PA promotion, and (3) have the potential to be leveraged in technologies currently available.

PersonA Development

Sensing Technology, Smartphone, and Social Network Platforms

To accommodate the required characteristics, as a result of the analysis described above, three technology platforms were utilized: (1) sensing technology, (2) smartphones, and (3) social network technology. It has been recognized that self-monitoring using manual data input can be cumbersome; data input by the subject is largely unreliable due to biases associated with retrospective recall [66-69]. As a result, low adherence to manual self-monitoring commonly occurs [63,64,68]. Sensing technologies offer an alternative to the manual self-measuring tools by providing reliable, comfortable, and automatic data collection. Currently, sensing technologies are available with multi-functions, small sizes, and low prices, and are anticipated to be in more than 400 million devices by 2014 [70]. In PersonA, we use an internal-phone movement sensor, called an accelerometer, which can be used to generate PA information such as, number of steps, distance travelled, average speed, and energy expenditure.

The use of smartphones for PA monitoring and encouragement is appealing for a number of reasons. First, they have widespread use; their usage has reached a critical mass, with market penetration in the United States reaching 55% in early 2013 [71]. Second, the smartphone's constant proximity to the user means that users can perform self-management and social interaction at any time or place. The addition of positive social support from social networks can amplify the smartphone's persuasive power. Third, the ongoing improvements in mobile computing power and Internet connection allow for a more sophisticated assessment, calculation, analysis, and intervention, which can be remotely processed on the device itself or on a server. Together with more convenient interaction features (eg, bigger screen size, touch screen), these advanced functions may result in an increase of adherence and quality of health behavior programs.

PersonA uses Facebook as a platform for social support and networking. Facebook is the most widely used SNS in the world, with 1.11 billion monthly active users and over 655 million daily active users [72]. We utilized Facebook's social interaction functions that are open to third party apps. The third party can access Facebook functions through an open application-programming interface (API), called Graph API. The API provides almost all of the functions necessary for the online interactions used in PA promotion. These functions include posting feeds, giving comments, authentication, security settings, and privacy/confidentiality settings.

Architectural Design

PersonA's hardware architecture consists of the accelerometer sensor on an Android smartphone as a data point of input (POI), the Android smartphone as a personal gateway, portal server, SNS bridge, and Facebook infrastructure. The data POI detects and feeds PA data to PersonA. The personal gateway stores the sensory data temporarily, analyzes the sensory data, offers post analyzed and meaningful feedback on the smartphone app, and transmits the data to the remote portal server where the data will be stored. Because Hypertext Transfer Protocol is used in the data transmission from the personal gateway to the portal server, the gateway must have an Internet connection service such as General Packet Radio Service, 3rd generation (3G), 4th Generation (4G), or a wireless local area network. The portal server uses distributed database architecture to store the PA data, mapping it with user's profile data. In addition to serving as a data repository, the portal server also acts as a Web server, hosting the PersonA engine system and Web services. The SNS bridge is a system connecting the portal server or personal gateway with the SNS (Facebook) server. The Android smartphone was chosen as a primary personal gateway because the Android Operating System (OS) is a free and open source, allowing apps to be easily developed on top of it, and is a predominant OS on smartphone devices [71]. PersonA was designed to work on any phone with an Android OS version 2.3 or higher. In this study, the Android smartphones used were the Samsung Droid Charge, Nexus S, and Nexus S 2. A majority of the phones used the Verizon Wireless service 4G. The 2010 Microsoft SQL Server Enterprise Edition was used as the database server and the Apache Tomcat 6.0 was used as the Web server. For data transmission among the components, a RESTful Web service with JavaScript Object Notation (JSON) data format was used. Figure 1 shows this architecture.

In addition to the mobile app, a Web app was developed with the exact same features, with the exception of data collection. The difference between the two apps lies in how often and extensive PA information is provided. The mobile app provides more immediate feedback than the Web app, while the Web app provides more extensive summaries and views of PA participation for individual users and group aggregates. These differences are mainly caused by the nature of the technologies (smartphone and computer) by which PersonA is accessed. The mobile phones are carried on the person, always turned on, personal, and portable; but are limited on computation power and screen size. On the other hand, computers have better computation power and larger screen sizes.

Figure 1. PersonA general architecture. POI: point of input; SNS: social networking system.
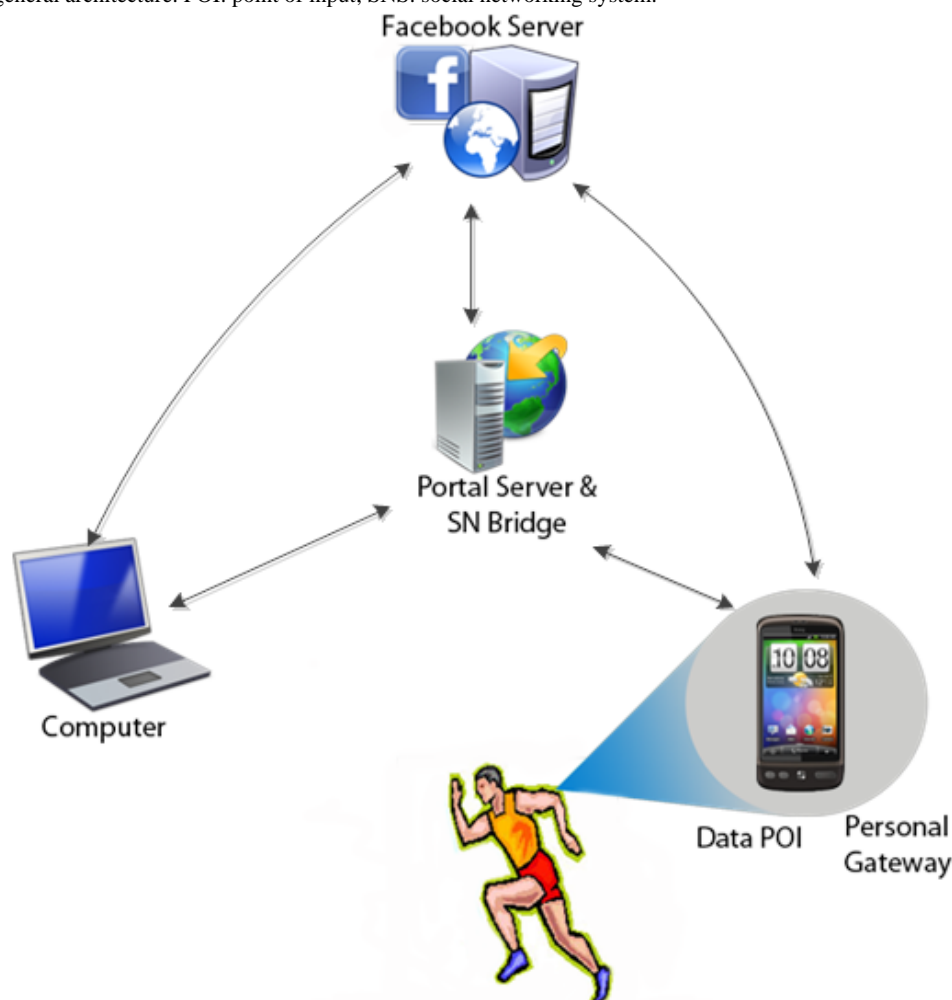
Usability and Feasibility Evaluation

The Five Usability Factors

Usability testing is a technique utilized in user-centered interaction design to evaluate a product by testing it on users [73]. The testing is traditionally associated with these five usability factors: (1) learnability, the system should be easy to learn so that the user can rapidly start getting work done; (2) efficiency, it should be efficient to use so that the users, having learned the system, are able to perform their tasks productively; (3) memorability, it should be easy to remember so that the casual user is able to return to the system, after some period of not having used it, without having to learn everything all over again; (4) error recovery, it should have a low error rate so that users make few errors while using the system, and these errors are easy to recover from. Further, catastrophic errors must not occur. And (5) satisfaction, the system should be pleasant to use so that users are subjectively satisfied when using it [73].

To evaluate the five factors, the formative usability assessment generally utilizes the following three protocols: (1) think-aloud assessment; (2) post study questionnaire; and (3) in-depth semistructured interview. First, the think-aloud assessment (think-aloud protocols, or talk-aloud protocol) is a method used to gather data in usability testing where, while performing a test task, users are asked to talk about what they are thinking, what they are trying to do, voice questions that arise as they work, and ask about things they read. This protocol was first introduced in the usability field by Lewis [74], and then was explained in more detail in another work [75]. Second, the post study questionnaire was designed to evaluate the five usability factors quantitatively. A few researchers proposed a, "ready to use tool" of post study questionnaires that all refer to the Nielsen work [73].

In this PersonA study, during the development phase, we conducted two in-lab usability tests to identify problems on the app, and to increase the performance. Participants of the test were four researchers and two potential users. The results from this initial usability test were used to iteratively refine PersonA. After PersonA had been successfully developed and tested without any critical errors or problems with usability, an everyday life usability and feasibility evaluation was conducted, from which the results are presented in this paper. The purpose of the evaluation was to assess whether PersonA is usable and easy to utilize by users, as well as to assess whether PersonA can be deployed in real, everyday life settings. The University of Pittsburgh Institutional Review Board (IRB PRO12020634) approved the evaluation.

Participant and Recruitments

To evaluate the usability and feasibility of PersonA, potential users were recruited through paper pamphlets and a Web-based advertisement (Facebook page). Potential users were included if they were: (1) 18-65 years of age, (2) able to operate a computer and smartphone, and (3) able to walk or run without difficulty. The exclusion criteria were: (1) inability to tolerate sitting for 2 hours or more, (2) history of cardiovascular disease, and (3) history of breathing problems and/or respiratory disease with associated breathing problems. Participants were compensated US $50.00 for taking part in the study. The participant sample size of evaluation was determined using the Problem Discovery Rate Model [76-78] that has been widely used to serve formative evaluations. The model estimates that 85% of usability problems will be revealed using five participants, and almost 100% of problems will be revealed using 14 participants [79-81].

Study Design and Procedure

Participants started taking part at the end of the development phase of PersonA. Participants were invited to two 2-hour visits at the University of Pittsburgh. At the first visit, the purpose and overall procedures of the study were explained to the participants. After signing a consent form, participants were asked to complete two questionnaires eliciting demographic information and experience with the Internet, smartphones, and social networking sites. Then, a brief orientation and demonstration on how to use PersonA was provided. After the orientation, participants were sent home and asked to use PersonA daily for four weeks. A smartphone with an unlimited data plan was provided to each participant. During the four week study period, the built-in tracking function in PersonA was active to monitor all activities done within the app, including how much time participants spent using PersonA, how often they accessed PersonA, and which features of PersonA were most used. In order to explore whether online social interaction may associate with PA performance, we decided to have a pilot baseline intervention design. Therefore, to build a baseline for personal PA, the participants had no social interaction (social menu) in the first week; then the social menu was introduced in the beginning of the second week and was available until the end of the study. At the end of the fourth week, the participants were asked to come back to perform a number of tasks using a think-aloud method, then asked to complete a customized usability questionnaire. At the end of this process, participants were then asked to take part in an in-depth semi-structured interview. The interview served two purposes: (1) to clarify participants' answers on the usability questionnaire, if necessary, and (2) to answer several questions related to the feasibility evaluation, especially those related to participants' experiences during the study period. This interview was recorded as an audio and video format for transcription and further data analysis.

Outcome Measures

Usability

Usability data was distilled from the answers provided on the questionnaire and the interview. The questionnaire was focused on investigating usability factors adapted from the International Business Machine Post Study System Usability Questionnaire (PSSUQ) [82], Nielsen's attribute of usability [73], and TAM [34]. These usability factors are learnability, efficiency, memorability, error recovery, and subjective satisfaction. The questionnaire also investigated one additional factor related to the technologies used in this study, especially smartphones. That factor is navigation, which is very important in smartphone apps, but was not included in the original PSSUQ, Nielsen's attribute, or TAM.

Feasibility

Information on feasibility was obtained through the interview and the embedded function that tracked users' activities with PersonA. No existing standardized or validated measurement tools or methods were used to obtain this information. There are several aspects of feasibility that were evaluated in this study, including participants' adherence to the program, system usage, user-system interactions, participants' preferences with regards to the systems, participants' motivation to use PersonA, and participants' experience with PA and online social interactions.

Persuasiveness

A variety of data was intentionally collected in order to explore the persuasiveness of PersonA. The tools used include, questionnaire, interview, user-system interaction, and PA data. To avoid confusion or a misunderstanding, the concept of persuasion in this manuscript always refers to the persuasive concept in the Computer Science field, not lifestyle behavior change, unless stated otherwise.

Pilot Physical Activity Data

There were four sets of objective PA data that were collected in this study: (1) number of steps, (2) energy expenditure, (3) distance traveled, and (4) average speed. The number of steps was obtained using the smartphone's accelerometer sensors. These sensors were tested in a laboratory environment where two researchers put the smartphone in their front pants pocket, walking (and mentally counting) 400 steps in a flat area; this procedure was repeated 7 times. The sensors recorded an average of 392 (SD 13) steps. These results may be different in a free-living condition. Energy expenditure data was estimated based on a calculation of number of steps and body weight. Distance traveled was calculated based on the multiplication of the number of steps and step length. Average velocity was calculated based on the number of steps, step length, and the duration of system while in an active status of collecting data. Since the reliability and validity of the four PA datasets have not been evaluated, the data were neither highlighted nor included in the discussion or in the conclusion of this paper.

Results

PersonA Characteristics Model

Physical Activity Monitoring Systems and Health Behavior Change Theories

As a result from the analytical study described above, we identified seven technical characteristics that a PA monitoring and promotion system must have to comply with the established

health behavior change theories and strategies, as well as to be able to deliver effective and innovative interventions (Figure 2

shows these characteristics).

Figure 2. PersonA Characteristics Model.
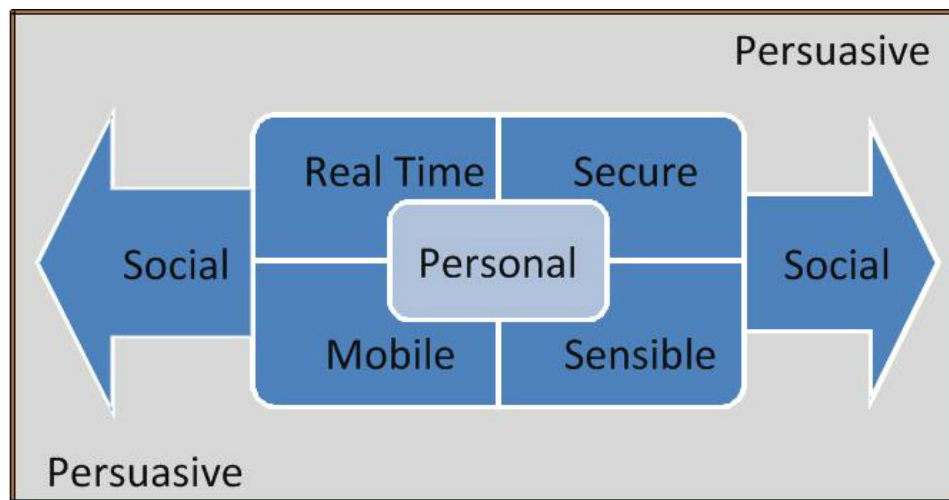
The Seven Characteristics

Personal

The system should be attached, or at least connected, to users whenever and wherever they are. It should also provide users ownership of their physical phenomena data, allowing them to decide with whom, and for what reason, their data will be shared. Moreover, the system should be able to deliver a personalized or tailored intervention, instead of a general or fit-for-all intervention.

Sensible

The system should give users the ability to collect their physical phenomena data easily (automatically or with minimum effort), and then store the data to an appropriate designated location with unobtrusive communication channels.

Real Time

The system should provide the necessary information that users need within milliseconds so that it is virtually available at the time it is needed.

Secure

The system should protect the confidentiality and privacy of users' health and personal data. The protection should be applied

at the start of the user/system data collection, storing processes, retrieving processes, and other processes, such as sharing with others.

Mobile

The system should be able to move easily and freely in tandem with the users.

Social

The system should support or provide users with the ability to compare their performance with that of others, to have companionship, and to have social interaction as part of their health behavior activities.

Persuasive

The system should be able to induce action, or foster belief, through reasoning, inspiration, or encouragement.

The Seven Characteristics and Health Behavior Change Theories

The relationship between the seven characteristics and the established health behavior change theories, from which the characteristics are distilled, is illustrated in Table 1.

Table 1. PersonA characteristics and the established health behavior change theories which include, the HBM, the TRA / TPB, the ELM, the SCT, the social support and health link theory, the UGT, the CBCI theory, the TAM, the UTAUT, and the FBM.

| PersonA characteristics	Distilled from
Personal	The theoretical construct of the behavioral intention of the TRA; the perceived behavioral control of the TPB; and the self-efficacy of the HBM and SCT
Sensible	The theoretical construct of self-efficacy in the HBM and SCT; and the perceived behavioral control in the TPB
Real time	The principles of self-efficacy and cue to action of the HBM; and the theoretical construct in the UGT, which tells that one important gratification for people to use technology is to get information
Secure	The principles of the supportive and environmental factors of the SCT; the principle of convenience of the UGT; and the perceived usefulness (acceptance) of the TAM and UTAUT
Mobile	The principles of perceived benefit, self-efficacy, and cue to action of the HBM; the perceived usefulness and perceived ease of use of the TAM; and the performance expectancy of the UTAUT
Social	The principles of the SCT, social support, the UGT, the common bond and common identity theory, and the social support and health link theory (which include the supportive environmental factor, influence of belief and cognition, social categorization, cooperative interdependence, intergroup comparison, social interaction, exchange of personal information, personal attraction through similarity, sense of belonging, social enhancement, and maintenance of interpersonal connectivity)
Persuasive	The principles of cues to action of the HBM; the self-efficacy of the HBM and SCT; the perceived behavioral control of the TPB; the central and peripheral routes of persuasion of the ELM, the entertainment and convenience of the UGT, the perceived ease of use of the TAM, the experience of the UTAUT, and the motivation and trigger of the FBM

PersonA Application

PersonA Capabilities

Capability Descriptions

It has been widely recognized that self-management and social support have a positive impact on PA participation [9,14-20,30,37,39,40,46,83]. Therefore, PersonA was also designed to accommodate users to perform self-management and social support practices [84]. Figure 3 illustrates PersonA's capabilities that were designed to meet the self-management and social support requirements; while detailed descriptions for each capability follow.

Figure 3. PersonA functional requirements. 1: self-measurement; 2: goal setting; 3: self-monitoring; 4: self-comparison; 5: peer support; 6: peer comparison - competition; 7: social support; 8: social comparison - competition.
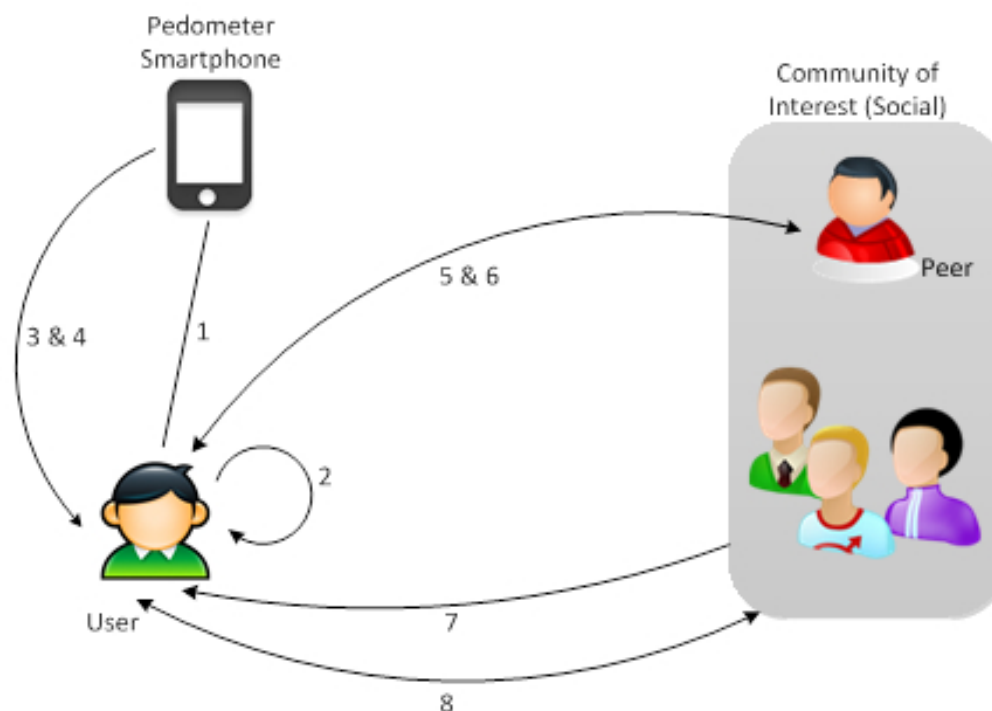
Self-Management Functional Requirement

The Four Requirements

PersonA includes the four most important self-management requirements: (1) self-measurement, (2) goal setting, (3) self-monitoring, and (4) self-comparison.

Self-Measurement

Self-measurement allows expected PA data to be captured automatically using sensor devices and then transferred to a smartphone. Once the data is stored on the smartphone, it can be displayed as immediate and persuasive feedback. Alternatively, the data can be sent to the health portal server for further analysis or for display on the portal side. The automatic data collection can potentially increase users' adherence to the PA program. It allows patients to measure their physical phenomena and to obtain reliable data with less dependency on health practitioners. Moreover, it reduces the users' effort and is also more comfortable for them than manual data collection.

Goal Setting

Goal setting allows users to define a target that they want to reach. Using this capability, users can more easily set a realistic PA goal for a specific time. Before doing so, however, users can compare the new target with one that is already set, and a new default target is set automatically by PersonA. Comparing the three may encourage the user to set and reach a better goal every day.

Self-Monitoring

Self-monitoring helps users to monitor and compare a predefined goal against their current status. It also helps users to positively self-enforce a commitment to that predefined goal. The ideal scenario is that automatic and real time data collection is available along with immediate feedback so that users know how far they are from their target. The self-monitoring chart (Figure 4 shows the self-monitoring features-left) shows how users can easily check the actual value for each activity item while they are performing a physical task. They can also monitor the progress they make by looking at the progress bar for each item and its percentage count, all of which is displayed on the same screen. The progress bar is used in order to convey the user's progress for PA tasks. For example, Figure 4 (left side of Figure) shows clearly that the user has reached 6501 steps, which is 65.01% (6501 actual steps/10,000 target steps) of the target.

Figure 4. PersonA self-management features.
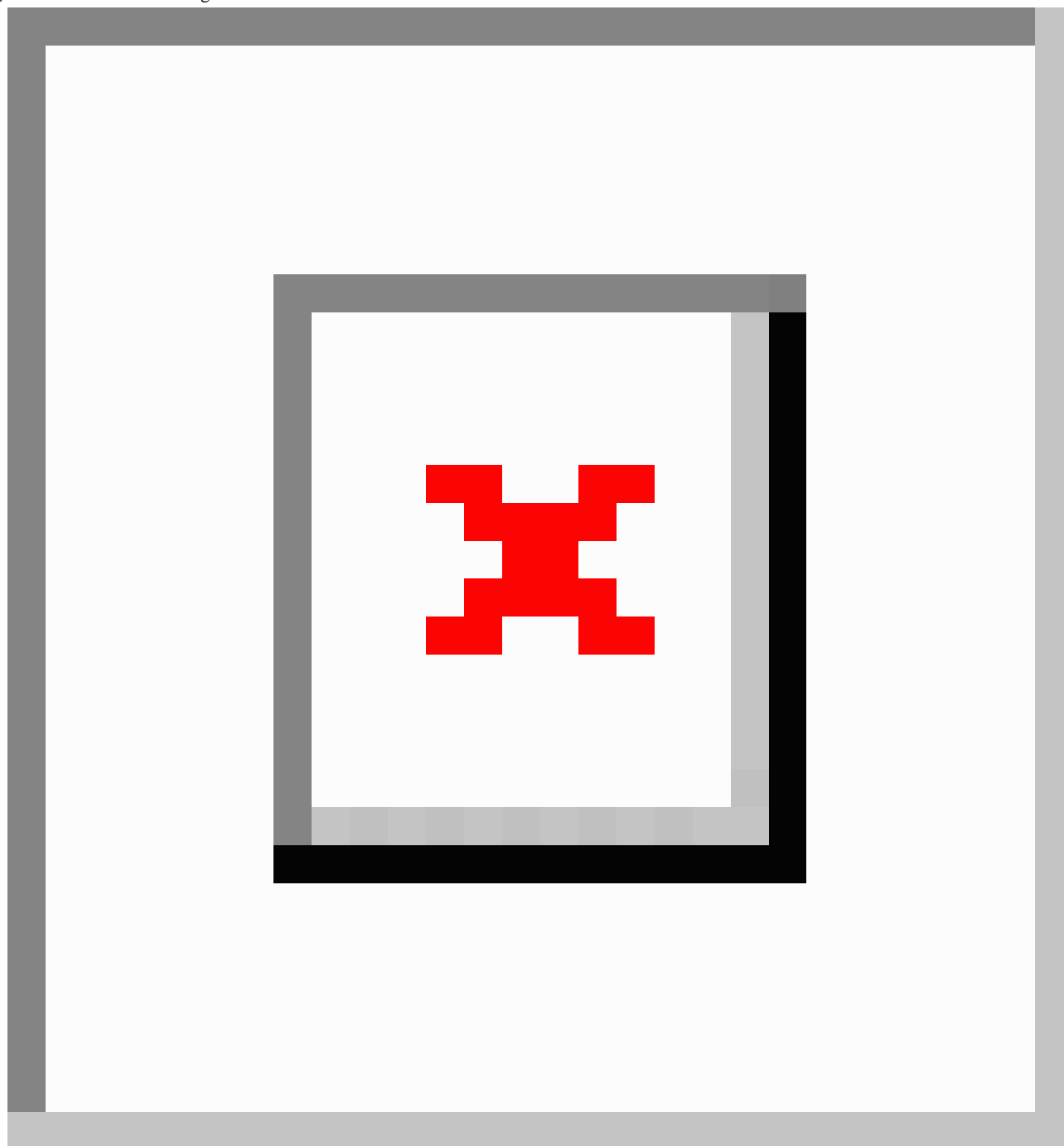
Self-Comparison

Self-comparison allows users to monitor and compare their activity data over time. It provides a longitudinal chart that shows a comparison between a user's target and the actual achievement; it also occasionally shows long-term trends or even dips and spikes (Figure 4-middle).

Encouraging Performance

Being able to monitor all of these activities may encourage users to perform better while engaged in PA. In relation to the implementation of the persuasive concept in the FBM, self-monitoring is part of an intrinsic strategy to persuade people to change behavior [36]. Using this strategy, PersonA was then designed to motivate users by triggering intrinsic personal drive,

such as by setting goals, creating awareness, or by conditioning through positive reinforcement that may lead to increased PA.

In addition to visual feedback, mobile PersonA also provides aural feedback. This aural feedback is implemented because real time feedback is sometimes needed when users are performing PA, and it is difficult to view feedback on smartphones while moving. Users can set up which information they want to hear and at a specified frequency (Figure 4-right).

### Social Support Functional Requirement

Social-support requirements are designed to help users engage with peers or social networks that can positively affect their PA performance. PersonA provides four functional features to facilitate the peer and social interactions. First, the

peer-comparison feature allows an individual to compare his/her performance with that of one person in the app. This allows a more personal comparison, especially with a peer who is personally known, such as a close friend or spouse. Second, the group-comparison feature, which allows an individual to compare his/her current PA performance and target with the group average, the larger community average, or the normal standard set by health practitioners. Figure 5 illustrates a chart that compares the summary of a user's caloric expenditure with that of the social network (left). The chart also provides the comparison longitudinally. Third, the peer-support feature that allows individuals to support each other with one peer in a closed interaction where the individual and her/his peer only can see and communicate using this channel. Fourth, the group-support feature that allows users to support each other in open interaction where every member of the group can see and interact. While using the above four features, the following positive support activities can be done by users: (1) giving rewards or greetings for reaching a goal, (2) sharing experiences or activities, and (3) "liking" others' status or data. The user can choose to share data with a friend, a member group, or even all friends on Facebook. As an illustration, Figure 5 (middle) shows that users can share their selected data with members of a Facebook group. As with other standard posts on a Facebook wall, these posts can be liked or commented upon by friends of users. PersonA also provides users with a message archive where the users can access all related communication that they made using PersonA, and perform further social interaction (Figure 5-right).

As inspired by other studies finding that social interaction had a positive effect in increasing PA performance [14,16,17,19,21], or at least it did reduce participant attrition even though it did not increase average PA performance [83], PersonA was designed to have the above social feature, which may boost users' performance and increase the likelihood of their adherence to the program. In relation to the persuasive concept, the social-comparison and peer-support are part of an extrinsic strategy to persuade people to change behavior [36]. Using this strategy, PersonA was designed to motivate users to build on the social psychology where other people are the source of the motivation, for example, through competition, cooperation, or comparison, which may finally lead to increased PA.

Figure 5. PersonA social support features.
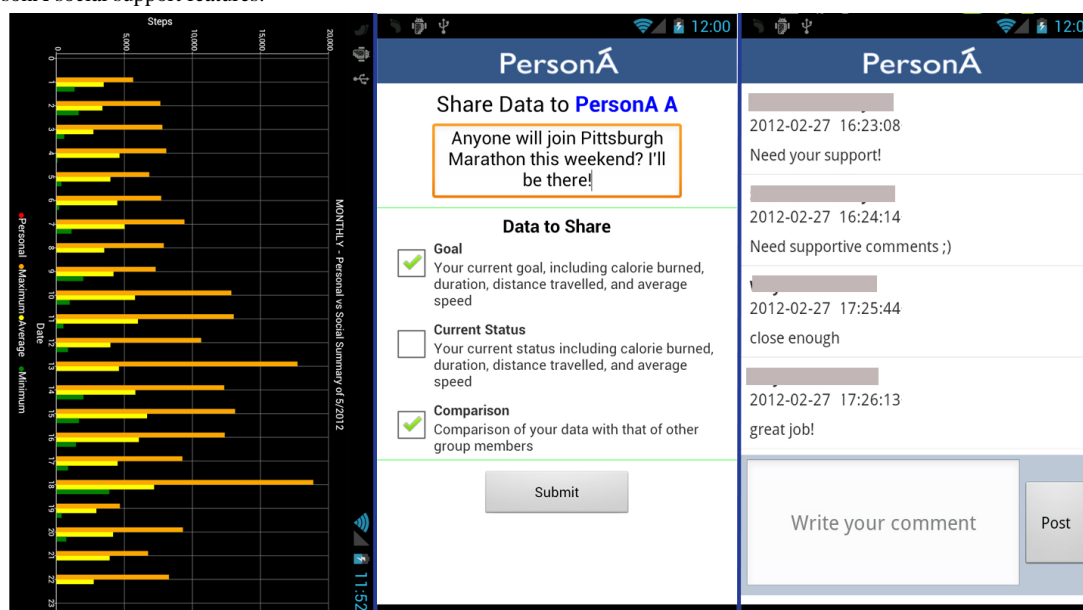
Persuasiveness

To increase the persuasiveness of PersonA in encouraging people to perform more PA, we addressed the following methods. First, since the integration increases the likelihood of a system to be adopted [36,55], PersonA was integrated with an app that has demonstrated to have psychological and social value to the users. PersonA was bundled with the most widely used SNS, Facebook. Second, the PersonA interface is designed to be as interactive as possible, where interactive experiences that are easily accessible and convenient have greater persuasive effects [36,55,85]. Third, PersonA is designed to have simple tasks, which may increase a user's adherence to a health promotion program [36,55]. For example, automatic input in PersonA is simpler than paper-pencil or manual typing input. Fourth, in order to achieve an optimal result, PersonA will trigger users' attention when they are most open to persuasion [36,55], by designing a system that gives immediate feedback, reminders, and greetings at opportune moments according to users' preferences, health professional recommendations, or specific contextual information.

To illustrate more detail about the persuasive methods implemented in PersonA, the Persuasive System Design (PSD) framework [39] was used to classify the PersonA features by its persuasive functions. The PSD framework classifies the persuasive functions of a technology as primary task support, dialogue support, social support, and credibility support [25]. By using the PSD framework, we can systematically look at how all PSD elements are implemented in PersonA. The relation between the PersonA features and PSD elements is illustrated more detail in the Table 2.

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Table 2. PSD framework elements and PersonA features.

| Principle and definition according to PSD framework [39]			PersonA features
Primary task support			
	Reduction	A system reduces complex behavior into simple tasks that help users perform the target behavior, and it may increase the benefit/cost ratio of a behavior	Once a user turns on the PersonA app, PA data is collected automatically
	Tunneling	Using the system to guide users through a process or experience provides opportunities to persuade along the way	Goal setting pop-up message appeared every morning for daily goal, every Sunday morning for weekly goal, and the 1st morning of the month for monthly goal
	Tailoring	Information provided by the system will be more persuasive if it is tailored to the potential needs, interests, personality, usage context, or other factors relevant to a user group	The default value of goal is determined based on the user goal and performance from the previous day, week, and month
	Personalization	A system that offers personalized content or services has a greater capability for persuasion	The default value of goal is determined based on the user goal and performance from the previous day, week, and month
	Self-monitoring	A system that keeps track of one's own performance or status supports the user in achieving goals	A user is able to monitor and compare a predefined goal against their current status, which eventually may positively self-enforce a commitment to the goal
	Simulation	A system that provides simulations can persuade by enabling users to observe immediately the link between cause and effect	-
	Rehearsal	A system that provides means with which to rehearse a behavior can enable people to change their attitudes or behavior in the real world	-
Dialogue support			
	Praise	By offering praise, a system can make users more open to persuasion	-
	Rewards	A system that rewards target behaviors may have great persuasive powers	Reward message will appear when users achieve certain percent of their target or achieve certain level (eg, top 10%) of the groups
	Reminders	If a system reminds users of their target behavior, the users will more likely achieve their goals	Users can setup a reminder to do PA
	Suggestion	A system offering fitting suggestions will have greater persuasive powers	The default value of goal is determined based on the user goal and performance from the previous day, week, and month
	Similarity	People are more readily persuaded through a system that reminds them of themselves in some meaningful way	Users can setup a reminder to do PA at their convenience
	Liking	A system that is visually attractive for its users is likely to be more persuasive	Users are able to see the information of their performance in real time. The information might be displayed in a stratified interface such as a garden or aquarium or a simple progress bar
	Social role	If a system adopts a social role, users will more likely use it for persuasive purposes	-
Social support			

Principle and definition according to PSD framework [39]		PersonA features
Social learning	A person will be more motivated to perform a target behavior if (s) he can use a system to observe others performing the behavior	Users are able to compare his/her performance with that of one person using the app. This is a generally more closed and intimate comparison, especially with a peer who is personally known, such as a close friend or spouse. In addition, users are able to compare his/her performance with the group average, the larger community average, or the normal standard set by health practitioners
Social comparison	System users will have a greater motivation to perform the target behavior if they can compare their performance with the performance of others	
Normative influence	A system can leverage normative influence or peer pressure to increase the likelihood that a person will adopt a target behavior	-
Social facilitation	A system user is more likely to perform target behavior if they discern via the system that others are performing the behavior along with them	One user is able to support another user with one peer in a closed interaction where the individual and her/his peer only can see and communicate using this channel. Moreover, users are also able to support each other in open interaction where every member of the group can see and interact. These closed and open interactions might drive a competition
Cooperation	A system can motivate users to adopt a target attitude or behavior by leveraging human beings' natural drive to cooperate	
Recognition	By offering public recognition for an individual or group, a system can increase the likelihood that a person/group will adopt a target behavior	
Competition	A system can motivate users to adopt a target attitude or behavior by leveraging human beings' natural drive to compete	

Security and Confidentiality

Security and confidentiality in a health app is of paramount importance; thus, we implemented the following methods to ensure that communication is secure and confidential. First, the authentication process requires a combination of the device's phone number, the International Mobile Equipment Identity number, the email address, and a Facebook account. Only devices with a proper and registered combination will be able to push data to PersonA and access information from PersonA. However, the Web version of PersonA uses only a combination of an email address and a Facebook account to authenticate users who want to access the information. Second, the communication framework of PersonA handles the encryption and authentication process. Third, all infrastructures were hosted at the tertiary care center behind a firewall in a network secure environment. Fourth, by default, personal health data will be privately protected and just for personal access; but summary data, such as maximum/minimum/average data, will be available for all members of the PA promotion group.

Finally, all above features were successfully developed based on the PersonA Characteristics Model. Figure 6 illustrates the relationship between the model and the features.

Figure 6. Relationships between PersonA Characteristics Model and PersonA features.
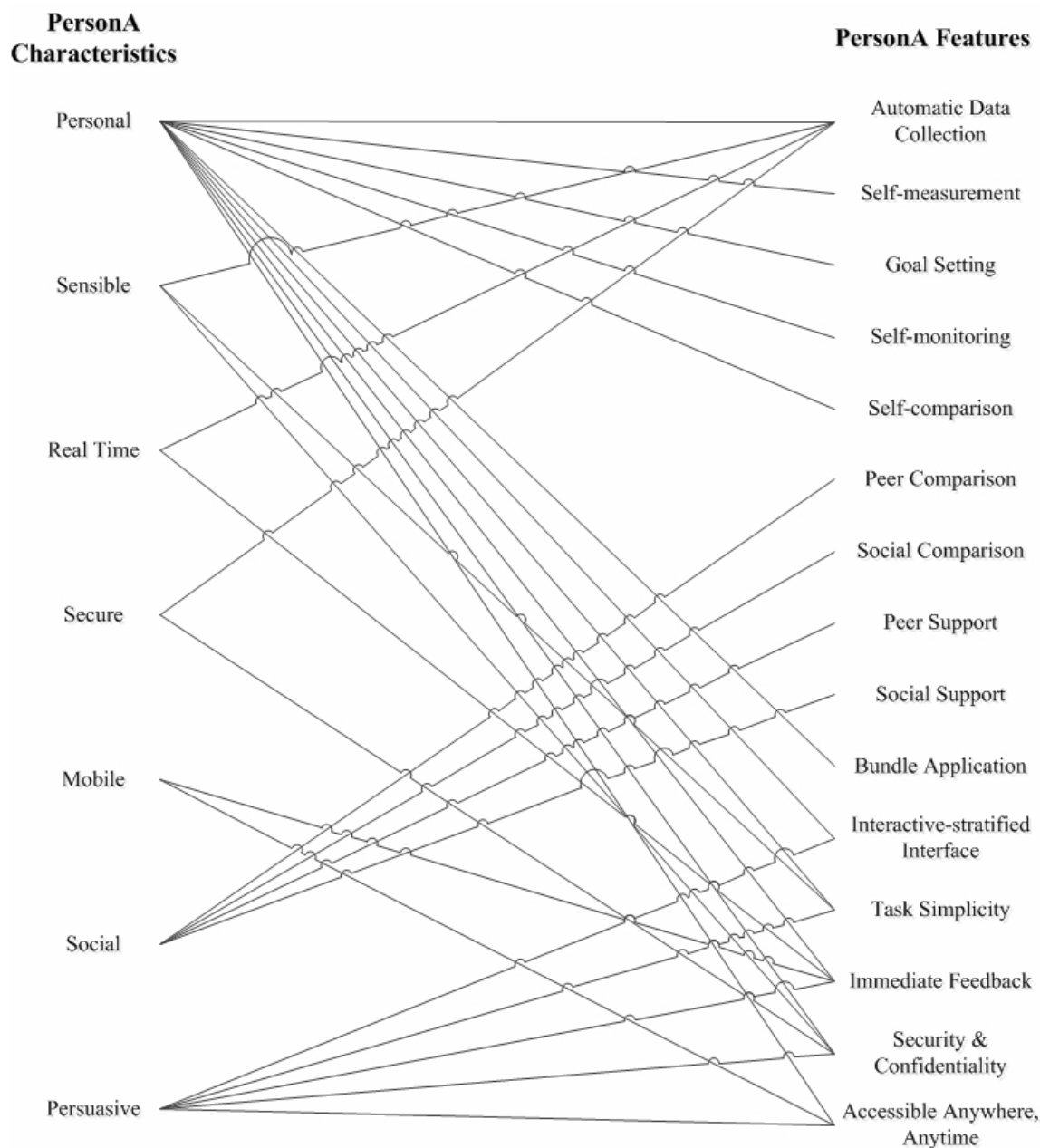
Qualitative Measure Results

The Usability and Feasibility Evaluations

Qualitative measures from the usability and feasibility evaluation result are presented first, followed by results from the quantitative data. Due to the nature of this study, all quantitative data was analyzed mainly through a descriptive means rather than by hypothesis testing. There were fourteen potential users that were recruited, with thirteen participants completing the study. There were two participants that were overweight and four that were obese according to the body mass index (BMI) formula with self-reported body height and weight parameters. Another type of subjective information collected was "what type and in what frequency of intended PA that participants regularly do" which is then referred as PA habit in Table 3. The detailed self-reported demographic data is provided in Table 3.

Table 3. General demographic, PA habit, smartphone experience, and SNS experience.

Participant	Gender	Age	BMI	PA habit	Smartphone experience	SNS experience
P01	F	33	23.3	Jogging once a week and exercise intended walking 2-3 times a week	No experience	Several times a day, for more than 3 years
P02	F	40	30.1	None	No experience	Several times a day, for 2-3 years
P03	F	32	22.5	Occasionally	No experience	Several times a day, for more than 3 years
P04	F	35	42.9	Occasionally	Less than 1 year	Several times a day, for more than 3 years
P05	F	25	30.1	Twice a week (jogging, cycling, rowing, and strength training)	No experience with smartphone	Several times a day, for more than 3 years
P06	F	24	34.6	None	No experience	Once a day, for more than 3 years
P07	F	45	22.3	3-4 times a week (treadmill, elliptical, zumba/latin heat, weight lifting)	1-2 years	Several times a day, for 2-3 years
P08	F	30	21.3	2-3 times a week tennis and jogging; 5 times a week stretches	1-2 years	Regularly log on, for more than 3 years
P09	F	31	18.6	3 times a week jogging	No experience	Regularly log on, for more than 3 years
P10	F	30	26.8	Walking once a week, jogging once in two weeks	1-2 years	Several times a day, for 2-3 years
P11	M	34	24.2	Once a week running and swimming	2-3 years	Regularly log on, for more than 3 years
P12	M	29	26.6	Twice a week running	More than 3 years	Regularly log on, for more than 3 years
P13	M	30	24.1	2 times a week running and tennis, and 3 times a week swimming	6 months-1 year	Several times a day, for 2-3 years

Overall Usability Score

Overall, participants gave high scores to almost all usability factors, with an average of 4.52 of a 5.00 maximum. A breakdown of the numbers for each factor asked about is presented in Table 4.

Accuracy

Participants gave various scores for "accuracy" and scores of overall usefulness; and provided various comments on willingness to use the system when it was available. When asked to estimate the percentage of total steps captured daily by PersonA (sometimes they did not have the phone with them), answers varied widely, as can be seen in Table 5.

Usefulness

Most participants thought that the mobile app was very useful or extremely useful. One participant stated it was moderately useful, as can be seen in Table 6.

Willingness to Use

When participants were asked whether they would use the system when it becomes available, most of them expressed a willingness to use it, as can been seen in Table 7.

Table 4. Quantitative results for overall usability.

Usability factors (1=totally disagree, 5=totally agree)	Average (SD)
It was easy to learn how to use this system.	4.72 (0.33)
It was easy and simple to use this system.	4.69 (0.33)
It was easy to obtain what I need.	4.67 (0.32)
The interface of this system is pleasant.	4.35 (0.20)
I like the interface of this system.	4.41 (0.20)
The organization of information was clear.	4.38 (0.30)
It was easy to navigate to find what I need.	4.38 (0.22)
Whenever I made a mistake using the system, I could recover easily and quickly.	4.29 (0.36)
The system gave error messages that clearly told me how to fix problems.	4.29 (0.40)
This system has all the functions and capabilities I expected it to have.	4.67 (0.33)
Overall, I am satisfied with the quality of the service/information being provided via this system.	4.87 (0.28)
Average	4.52

Table 5. Percent of steps captured using PersonA.

Estimated % of steps captured	Number of participants
> 80.00	3
> 60.00 and ≤80.00	7
> 40.00 and ≤ 60.00	2
> 20.00 and ≤ 40.00	1
< 20.00	0

Table 6. Reported usefulness level.

Level of usefulness	Number of participants
Extremely useful	6
Very useful	6
Moderately useful	1
Slightly useful	0
Not useful	0

Table 7. Reported willingness to use PersonA when available.

Level of usefulness	Number of participants
Definitely use	7
Probably use	5
Not sure	1
Probably not use	0
Definitely not use	0

Estimating Steps Taken

Although perceptions varied, participants thought that PersonA was useful because it provided a good estimation of the number of steps taken. Typical comments included,

> The apps may not give a very accurate step number, but it perfectly cues the estimation range... [P01]

> ...I am more interested in relative numbers than absolute numbers. I wanted to know if I walked more today than what I did yesterday... [P05]

> It's still useful even with this current level accuracy... [P07]

When asked in which ways PersonA was useful, participants recorded a variety of answers, shown below in Table 8.

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Table 8. Reported usefulness factors.

Usefulness factors	Number of participants
Making new friends	0
Self-monitoring PA levels by comparing current and target level	12
Knowing the activity levels of others or aggregate of the group	6
Comparing your activity with others	6
Finding people to exercise together	3
Sharing experience with others	3
Supporting each other	5
Finding useful information about PA	1

Motivation to Use

There were three themes of motivation to use PersonA that emerged from the qualitative sampling of participants' comments. There was one motivation that wanted to know more about the number of steps taken throughout a day, inside and outside the gym. Especially those having poor or fair daily PA levels expressed this motivation. A typical response was,

> ...I want to know how many total steps that I have throughout a day. [P02]

Another motivation participants expressed was to balance calorie intake-outtake. Especially those having good or very good daily PA levels expressed this motivation. Typical comments include,

> I was interested knowing more about my energy expenditure. I was curious to see how many more calories that I burned outside the gym...Simply because I care whether my total calorie intake-outtake is balanced or not. [P05]

The last motivation that emerged was being curious about how social interaction influences PA habits,

> I was curious to know whether the social aspect of PersonA would change my exercise habit or not. At the end of the day, indeed, it changed my habit... [P03]

Suggestions for Improvement

There were three themes that arose when participants were asked for suggestions to improve PersonA. The first theme is a suggestion to include other types of PA,

> That would be nice if it includes other kind of activities, not just running and walking; like cycling and rowing. [P05]

The second theme was to resolve the battery problem,

> The battery is a problem because it lasts for only 5 hours. [P06]

The last theme was to have smaller devices,

> If possible, I want the apps [PersonA] running on smaller phone [not a smartphone]. It's a lot easier to carry or put it in the pocket. [P01]

Mobile Applications Over Web Applications

PersonA has two versions: (1) mobile app, and (2) Web app [84]. A comparison between these two versions was conducted to evaluate participants' preferences between the Web and mobile versions. All of the participants chose the mobile version, typical comments included,

> I like the smartphone one because I'm more likely to see the data on smartphone, for example while waiting for the bus or even on the bus. When I access a computer, I have so many other things to do, like working, checking email, etc. I would forget to access the apps [on the Web]. [P05]

> I like the smartphone version. It's easy to check the data. We have everything on our fingers; I don't really need the Web version. What I have in my smartphone version is more than enough. [P03]

> I prefer the mobile simply because I bring the phone whenever and wherever I go... [P01]

Online Social Interaction

Participants' responses with regards to online social interaction revealed that PersonA may leverage this interaction to improve PA in a variety of ways, and on many levels, as presented in the following few comments.

There was one participant that expressed that social interaction may not work for her or some other people,

> I have my own personal plan and personal schedule, so I never compared and never wanted to be encouraged to do walking. I know that I need to do physical activity; I know 10,000 steps per day [guidelines] is good for me and definitely I will do it when I have time... [P07]

A tool equipped on PersonA for comparing user data to a target or to others' performances may increase motivation to do more PA in some participants. The participants also said that online social interaction indirectly encouraged them to do more PA, at least in the sense that they see there is company while doing so,

> A function to compare my physical activity with that of my friends is really nice. It maps myself in the group as well as informs that there are other people

doing the same thing, so that I feel I'm not alone in doing it. [P02]

Even though the social interaction feature is mainly intended to provide social support, some participants utilized the feature as a means of self-motivation,

...I only post my physical activity data on my own wall, because it's more like to tell myself that I have to work out today. It's used to remind myself. [P05]

Other participants recognized the real effect of online social interaction in encouraging and improving levels of PA,

The social interaction changed my walking behavior. I still remember about two months ago, when I wanted to meet a friend in Pitts [about 3 miles from her home], I usually took a bus that sometime takes about 30 minutes, including waiting time. After using PersonA, I don't do it anymore because of knowing

that some people on the group have thousands of steps more than me. So, right now, I just walk to have more number on my apps... and, you know what makes me feel better, it turned out I only need about 20 minutes to get there! It saves time and makes me feel healthy. [P03]

User-System Interaction

Over the 29 days of the study, participants used PersonA for a total of 119,380 minutes (average=454 minutes=7.57 hours/day/participant with SD 1.59 hours), and they accessed various system features an average of 28 times/day/participant. In addition to evaluating the overall usage, another purpose of collecting user-system interaction data was finding which PersonA features were used the most. As Table 9 shows, it seems that accessing personal data was favored over social interaction.

Table 9. User-system interaction per week.

Action	Week 1	Week 2	Week 3	Week 4	Total
Accessing home[a]	1046	1194	1025	1563	4828
Accessing personal data[b]	548	889	683	526	2646
Social interaction[c]	0	356	498	261	1115
Accessing goal or changing goal[d]	106	434	428	256	1224
App setting[e]	215	135	113	106	569

[a]Accessing home represents how many times the participants accessed the home page of PersonA. This number also represents the frequency of users' access to the PersonA since the home page is the first page loaded when accessing the app.

[b]Accessing personal data represents how many times the participants viewed personal PA information. This information is a comparison between actual performance and target for the selected day, one day before, the current week, the current month, and total period since the participant began using the app.

[c]Social interaction represents how many times the participant utilized social interactions, including social comparison and social support. Social comparison includes sharing data with a friend, a group member, or even all friends on Facebook. It also includes equating their PA performance and target with those of others in the group, the group average, the larger community average, or the normal standard set by health practitioners. Social support activities include giving rewards or greetings for reaching a goal, sharing experiences or activities, and "liking" others' status or data.

[d]Accessing goal and changing goal or target represents how many times users set up and reviewed their daily, weekly, or monthly goals.

[e]App setting represents how many times users set up the app. This includes setting email, setting body weight, setting or changing sensitivity of the accelerometer sensor, setting or changing PA type, running or walking, and setting or changing theme, only in Web version.

Physical Activity and Usage Data- Comparison Between Baseline and Social Intervention

An average difference of 2150 steps was recorded on average, per day, per participant for the first week, and all the following weeks. Figure 7 shows a detailed step-by-step comparison for all weeks. Figures 8-10 show other PA data comparisons; Figure 11 shows a system usage data comparison.

Figure 7. Steps comparison between baseline and social intervention.
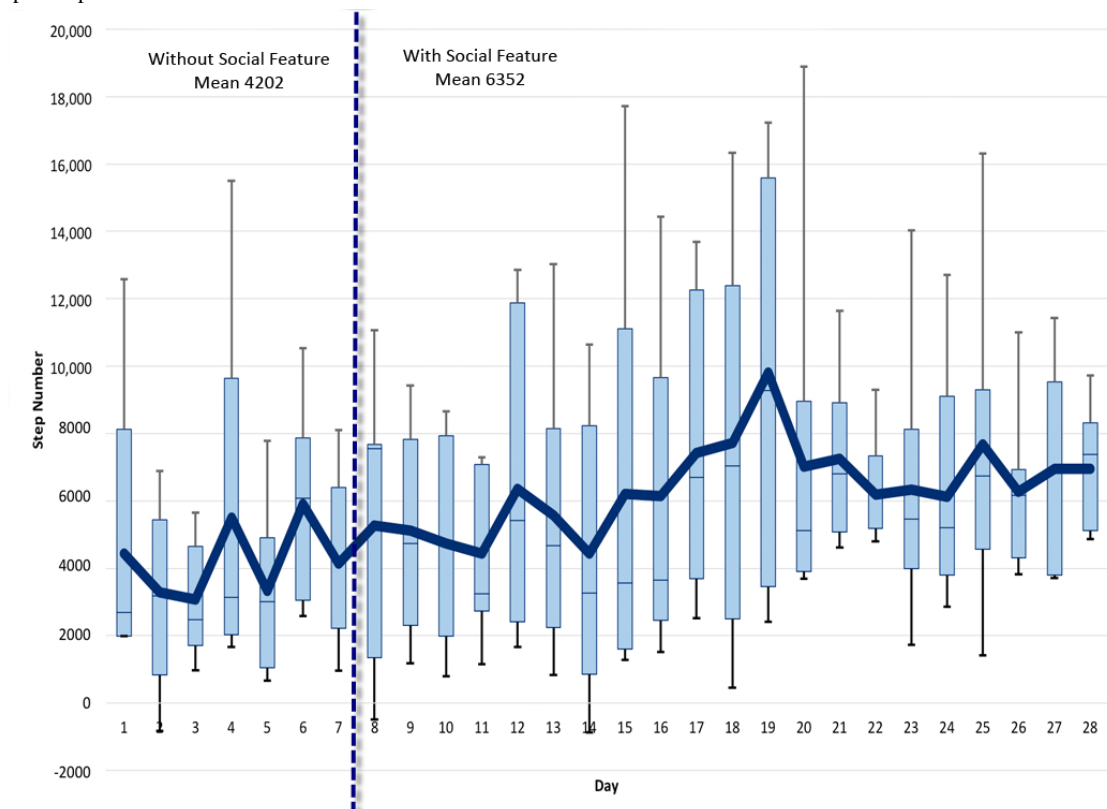
**Figure 8.** Distance comparison between baseline and social intervention.
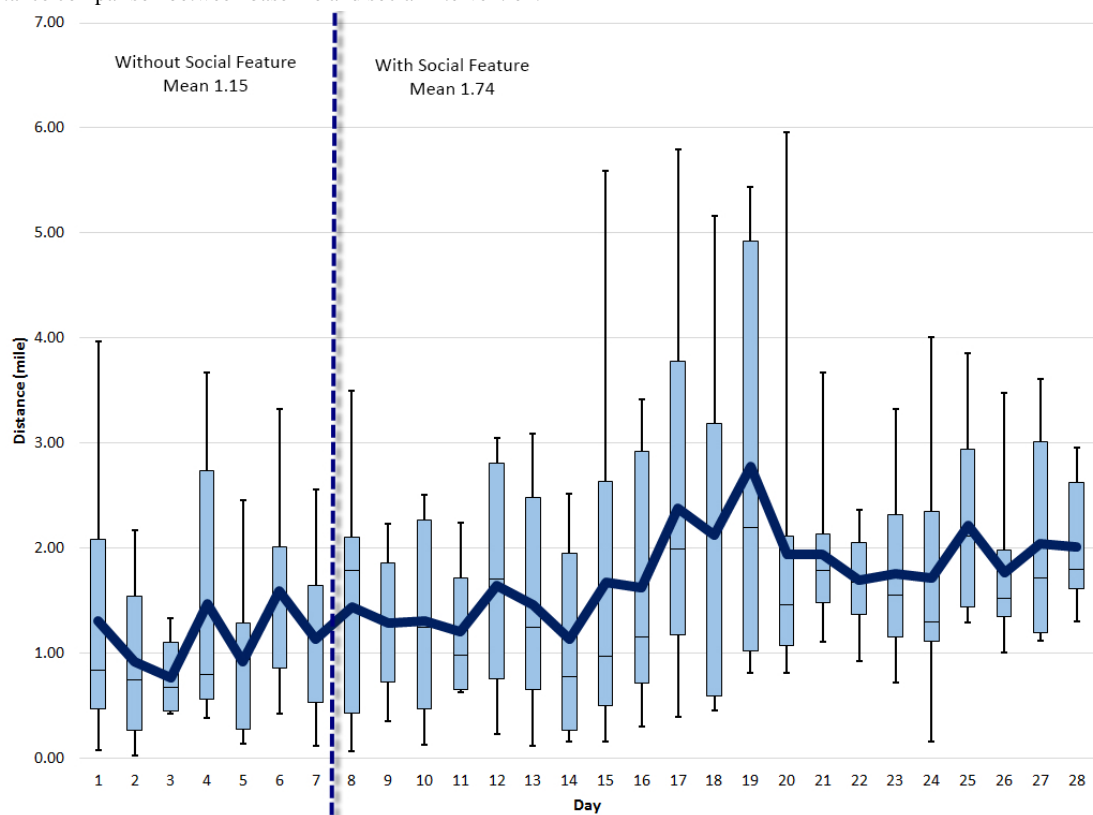
Figure 9. Average speed comparison between baseline and social intervention.
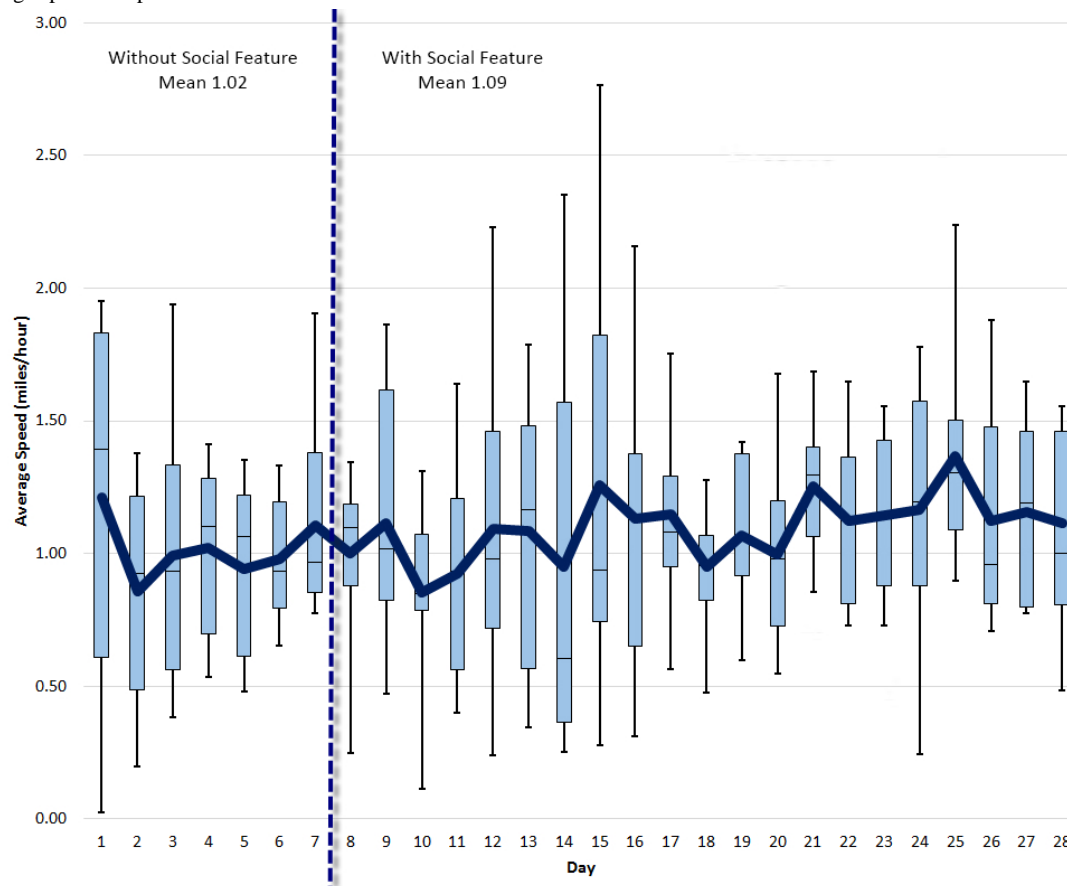
Figure 10. Energy expenditure comparison between baseline and social interaction.
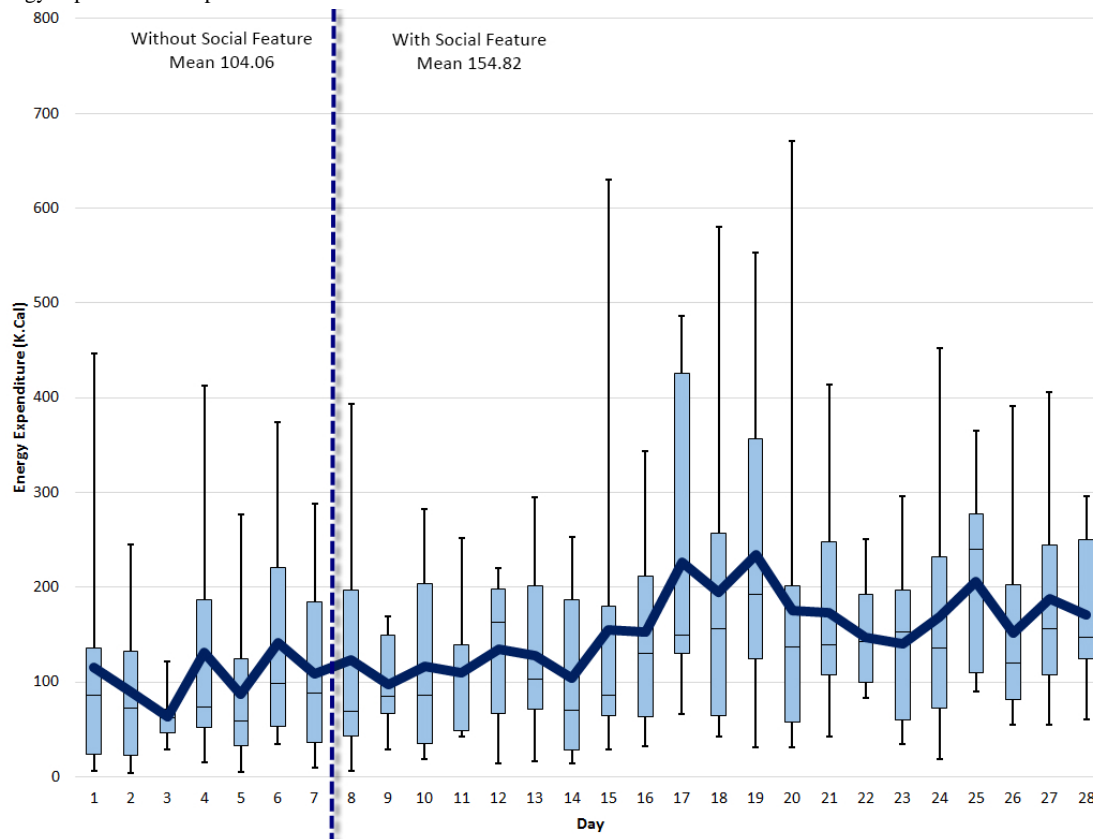
Figure 11. Duration of system usage comparison between baseline and social intervention.
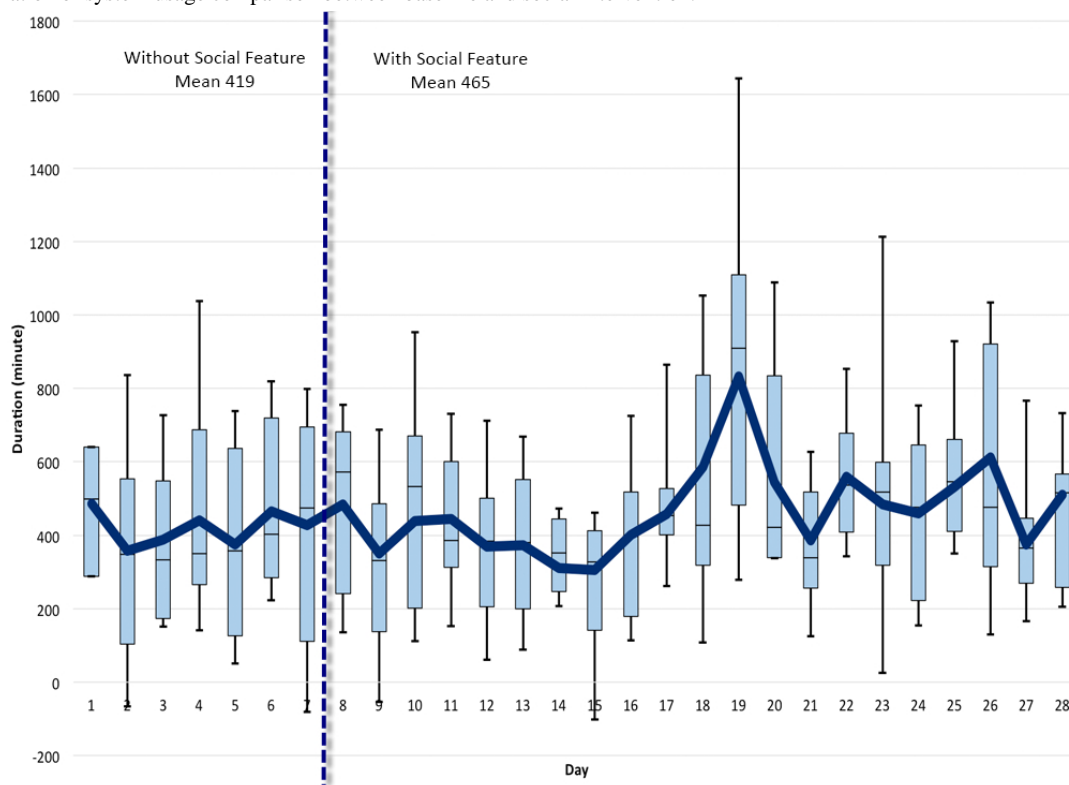
Social Interaction and Number of Steps

No trends were apparent in the relationship between the number of average steps/day/participant and social interaction. Figure 12 shows a bubble chart to plot the time, average steps/day/participant, and average social interaction/day/participant.

Figure 12. A plot of duration, social interaction number, and step number.
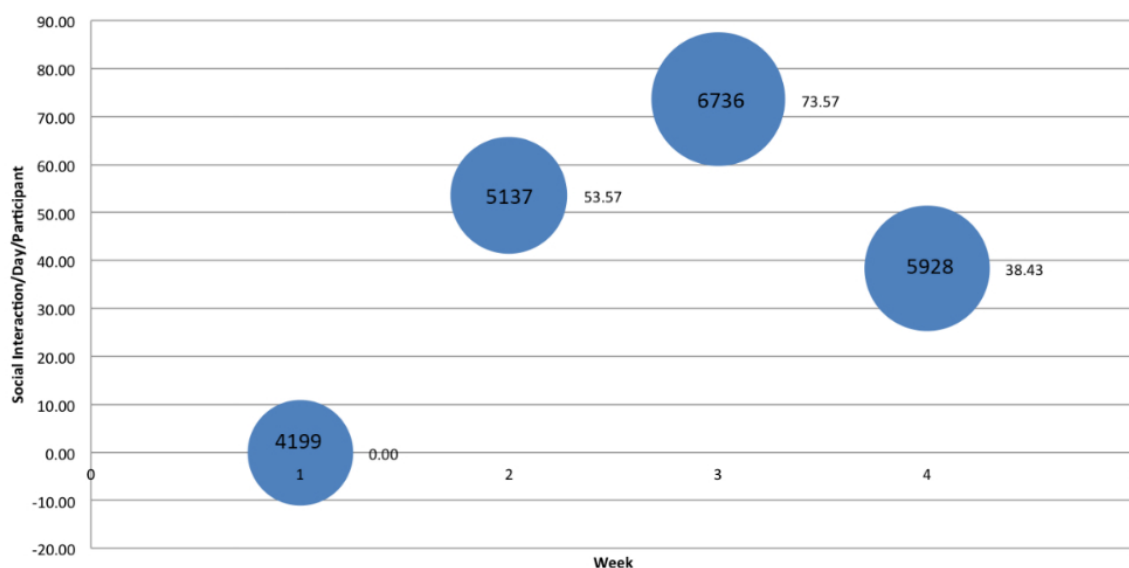
Discussion

An Important Goal

An important goal of this research was to develop an app that can monitor PA levels and effectively encourage users to engage in more PA. To that end, we need to ensure that the app complies with the established health behavior change theories and strategies, as well as delivers effective interventions. The PersonA Characteristics Model depicts the necessary characteristics needed for such a PA promotion app. Each individual and/or a combination of the characteristics on the model have been successfully implemented in many studies, and have given positive impact so that the model can be used as a blueprint and simple guideline by developers to build a system for PA promotion. In this study, the PersonA Characteristics Model was used as a foundation to develop the PersonA app. After the PersonA was developed, a typical

usability study was conducted to find out whether it is usable and can be accepted by users. As a result, participants gave a high score for each factor of usability (ie, learnability, efficiency, error recovery, and subjective satisfaction), with an average of 4.52 out of a 5.00 maximum. Even with the small sample size of this pilot study, and no other apps to serve as comparisons for direct testing, the usability results suggest that the system is usable and that users were satisfied and enjoyed using it.

We also examined the feasibility of using PersonA for daily life PA promotion from a technological perspective. The specific purposes of the feasibility evaluation were to explore users' experiences with the system, to determine the acceptability of the interventions and protocols, and to reveal other technology deployment issues to prepare for larger scaled studies and/or clinical trials. The quantitative analysis of this study demonstrated positive results. The dropout rate of this study was 7% (1 of 14), which is within the average dropout range of 4% to 16% reported by a meta-analysis of PA interventions [86], and is better than the 20% of another meta-analysis [87]. With regards to adherence, participants used the system for an average of 454 minutes (7.57 hours) per day per participant with SD 1.56 hours, and they accessed various system features an average of 28 times per day (SD 7.2). These numbers were high when compared with use numbers from a survey conducted by the Consumer Health Information Corporation. This survey found that smartphone apps have a high rate of dropout, with 26% being used only once, and 74% being discontinued by the 10th use [88]. The high usability scores, the high frequency of use, and the usefulness scores indicate that participants not only liked the design of the app, but also found it convenient, useful, and used it daily. The numbers also indicate that users would likely continue to use it long term, as it has been established that for a user to adopt and frequently use a smartphone app long term, the user must consider it both usable and useful [89,90]. This is consistent with the fact that lack of usability and usefulness are top reasons for users to discontinue smartphone app usage [88].

Limitations and Strengths

The qualitative analysis identified a few utility limitations, as well as highlighted the acceptability of different parts of the intervention and its protocol. We identified that PersonA has some utility limitations, such as limited battery life, limited accuracies, simple measures, limited placement of the devices, and recording only user walking and running [84]. For example, to get an accurate number of steps, the smartphone was required to be placed on the hip (with a belt clip) or in the front pocket of the pants. We identified that this limited placement might impact the utility of the app, especially for female participants who tend to place their smartphone in their bags. Nevertheless, the qualitative analysis also highlighted the acceptability of PersonA to be used in daily life. The acceptability is indicated in the participants' comments expressing that it helped them, to self-monitor their PA levels easily, to compare their performance with that of others, to facilitate a sharing experience, and to enable them to support each other. Thus, most participants also answered that they were willing to use PersonA if it became available in the future.

Thematic Analysis

The thematic analysis of the qualitative data indicates that PersonA sometimes acted as a virtual coach, motivating a portion of the participants to be more physically active. Moreover, in looking at the participants' perspectives, it appears that the combination of self-management practices and social support may act synergistically to keep some of them working toward their goals to have a more active lifestyle. New areas of inquiry were also identified during qualitative analysis, including: (1) the need to refine sources of motivation to use PA promotion, (2) to explore emergent health behaviors in response to smartphone-based health apps (such as users' preference of the mobile over the Web version, if both are available), and (3) to explore users' preferences as to data visualization type.

PersonA and Social Interaction

The qualitative analysis also indicated that the social interaction on PersonA had various effects on the individual participants. These ranged from feeling pressured about PA, to feeling neutral, to feeling encouraged to do more PA. These different effects of social interaction on PA performance are consistent with the findings in other studies: (1) it increases PA performance [14,16,17,19,21]; and (2) it did not increase average PA performance, but did reduce participant attrition [83]. A possible explanation for this spectrum is that the effect of social interaction on PA performance is affected by personality type. Halko and Kientz [91], in a study, recognized such an association between the effect of persuasive technology, like PersonA, and personality type.

Future Studies

In the future, PersonA's validity evaluation should be the first priority because an inaccurate measurement in PA monitoring and promotion program has the potential to lead toward ineffective programs/support; frustration from the lack of results, and an inappropriately placed belief that increasing activity does not result in improved health outcomes. In addition, such an evaluation will give the system greater credibility, which will yield greater persuasive effects [92]. A potential method that can be applied for the evaluation is a comparison against other step monitoring devices, especially the widely known and more accurate pedometer. Until now, that is the most feasible method to validate a steps counter over a long duration in free-living conditions, as was done in three previous studies [93-95].

To fully elucidate the potential benefit of PersonA in increasing PA levels, long term and large sample size randomized control trials in the outpatient setting are required. Such trials should include heterogeneous participants in terms of age, gender, socioeconomic status, personality type, and experience with SNS and smartphones. A similar trial with a more appropriate research design (eg, baseline-intervention or randomized controlled trial) should also be conducted to explore the association between online social interaction and PA performance. This future trial may lead to the development of effective social interaction techniques, and the exploration of effective methods of ecological intervention using a SNS. Last, the online social interactions in this PersonA study included

two or more types of social interactions (viewing others' data, comparing data, sending messages, receiving messages, etc), so that the independent contribution of any one of these components is difficult to establish. Hence, a more detailed and structured study to examine the effects each type of social interaction has on PA performance is also warranted.

To examine usability, the sample size of this study appears appropriate according to the Problem Discovery Rate Model [76-78]. Nonetheless, the number for this study seems to be a bit low when taking into account the fact that it was a homogeneous sample population. Our participants tended to be adult, female, college educated, and already experienced with the technologies used in PersonA (smartphones and online social interaction). Additional research would be needed to determine whether the findings extend to a demographically more heterogeneous sample, and to those who have no prior experience with smartphones and social interaction technologies. A similar theme arises when evaluating the feasibility of using PersonA in PA promotion. The results from the quantitative and qualitative analyses demonstrate that deploying PersonA with self-management and social network features to promote PA in daily life is feasible. Nonetheless, these results should be interpreted with caution because of the study limitations: (1) the small size and homogeneous characteristics of the sample, (2) the short term duration of study, (3) no other apps as a comparison, and (4) unstandardized and invalidated outcome measures. Thus, the findings are not conclusive and will require validation from a larger trial study with a more representative population.

Conflicts of Interest

None declared.

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Abbreviations

4G: 4th generation

API: application-programming interface

app: applications

CBCI: common bond and common identity theory

ELM: Elaboration Likelihood Model

FBM: Fogg Behavioral Model

HBM: Health Belief Model

IT: information technology

JSON: JavaScript Object Notation

OS: operating system

PA: physical activity

PersonA: Persuasive Social Network for Physical Activity

POI: point of input

PSD: Persuasive System Design

PSSUQ: International Business Machine Post Study System Usability Questionnaire

SCT: social cognitive theory

SNS: social networking system

TAM: Technology Acceptance Model

TPB: theory of planned behavior

TRA: theory of reasoned action
UGT: uses and gratifications theory
UTAUT: Unified Theory of Acceptance and Use of Technology

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A Mobile App Offering Distractions and Tips to Cope With Cigarette Craving: A Qualitative Study

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Abstract

Background: Despite considerable effort, most smokers relapse within a few months after quitting due to cigarette craving. The widespread adoption of mobile phones presents new opportunities to provide support during attempts to quit.

Objective: To design and pilot a mobile app "DistractMe" to enable quitters to access and share distractions and tips to cope with cigarette cravings.

Methods: A qualitative study with 14 smokers who used DistractMe on their mobiles during the first weeks of their quit attempt. Based on interviews, diaries, and log data, we examined how the app supported quitting strategies.

Results: Three distinct techniques of coping when using DistractMe were identified: diversion, avoidance, and displacement. We further identified three forms of engagement with tips for coping: preparation, fortification, and confrontation. Overall, strategies to prevent cravings and their effects (avoidance, displacement, preparation, and fortification) were more common than immediate coping strategies (diversion and confrontation). Tips for coping were more commonly used than distractions to cope with cravings, because they helped to fortify the quit attempt and provided opportunities to connect with other users of the application. However, distractions were important to attract new users and to facilitate content sharing.

Conclusions: Based on the qualitative results, we recommend that mobile phone-based interventions focus on tips shared by peers and frequent content updates. Apps also require testing with larger groups of users to assess whether they can be self-sustaining.

Introduction

Background

Quitting smoking is difficult. Although more than 90% of smokers have tried to quit at least once, between 85% and 97% of all quit attempts fail within 1 year [1,2], depending on the population and the extent of help they receive. A key challenge is managing cravings for cigarettes, particularly in the first month after quitting [3]. During this time, smokers who have quit (quitters) frequently experience cravings, often triggered by particular times of the day, activities, places, emotional states, and the presence of other smokers. Although nicotine replacement products can reduce withdrawal symptoms, people must manage these situations and cope with cravings to prevent a lapse or relapse [4,5].

Relapse prevention programs focus on providing quitters with skills to identify factors and high-risk situations that may lead to a lapse [6,7], including simple action plans like the four Ds of quitting: delay, deep breathing, drink water, or do something else. Additionally, relapse prevention programs focus on

anticipatory strategies to help quitters prevent cravings and restorative strategies to help them in the aftermath of cravings [8,9]. The delivery of such relapse prevention programs through Web-based services can be effective [10,11] and cost-effective for counseling services [11,12].

The widespread adoption of mobile phones offers new opportunities to help quitters cope. In principle, mobile phones offer support at any time and place, ensuring that resources for coping are available in the high-risk situations when quitters may be tempted to lapse [13]. Studies of mobile phone services for quitters have focused on the delivery of personalized advice through text messages [14-18], video messages [19], and mobile apps [20]. A recent review of commercially available mobile apps for quitting found that most focus on providing personalized information through functions like calendars and cost-saving calculators [21]. However, other possible uses of mobile apps in smoking cessation remain under-researched.

Two potential benefits of mobile apps that form the focus of this study are first, to provide a source of distractions from cravings in the form of interactive content such as games and websites; and second, to provide opportunities for social interaction among quitters to exchange support. To explore these, we developed and evaluated a mobile app called DistractMe that presented two distinct types of content for coping: distractions and quitting tips. Social interaction was supported through sharing items and comments on those items. Cognitive distractions have long been used in other health interventions, for example to help patients cope with pain [22]. In the context of smoking cessation, previous studies have shown that distractions, together with breathing exercises and food and drinks, are among the most commonly used techniques to prevent relapse [23]. Some researchers have noted that mobile phones might play an important role in providing distractions from cravings [23,24], both as a cognitive distraction (through engaging content) as well as a behavioral distraction (by keeping one's fingers' busy). In a rare study, Rodgers et al [25] included general interest messages (about sport, fashion, trivia) as well as advice and tips relevant to quitting in their text messaging intervention, which improved cessation outcomes. However, there remains a lack of understanding about the effects of such distractions and the strategies of coping with cravings they might support, including the social interactions around them.

Therefore, the aim of this study was to identify the various coping strategies enabled by the DistractMe app and to provide insights and recommendations for similar mobile phone-based interventions. The approach chosen was a detailed qualitative analysis of a small sample of real-life quit attempts using the app, rather than a summative evaluation of its longer-term effectiveness in quitting.

Methods

A Research Through Design Approach

The study followed a research through design approach, involving the making and deployment of a technological prototype to generate knowledge about how it is used in practice [26,27]. Following this approach, the analysis phase of

technology design was extended and centered on users and other stakeholders. We conducted several rounds of workshops with technology designers, smokers, and smoking cessation counselors to generate design ideas. Mock-ups of emerging elements were produced and evaluated in interviews with smokers [28,29], leading eventually to the design of the DistractMe app. Also following a research through ,design approach, the app was evaluated in a naturalistic setting to understand whether and how people adopt and use it in practice. Here the emphasis is on how the technology is appropriated by its users into their particular situations rather than presuming that they will use it in a way prescribed by the design. The analysis was based on a small sample of participants to develop a rich understanding of how the content items of the DistractMe app and related social interaction were deployed by participants in coping with cravings during the first few weeks of quitting.
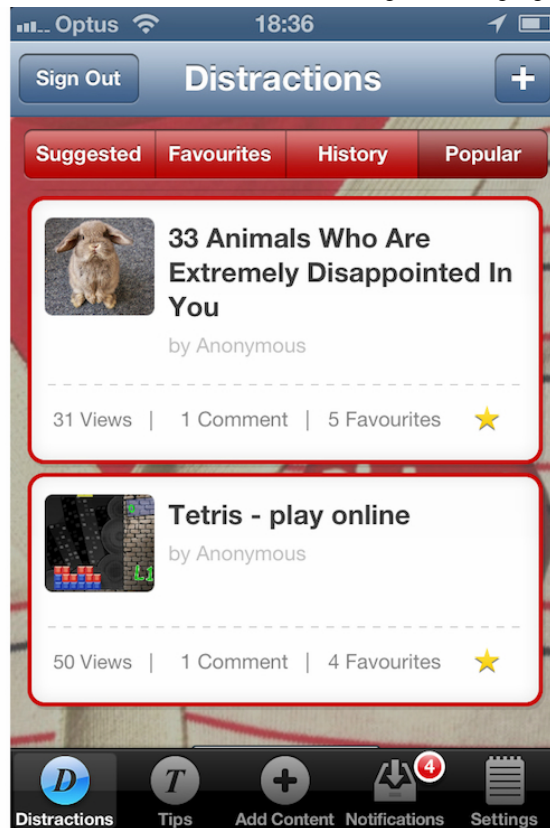
DistractMe App Design

The essential idea of the DistractMe app was to provide quitters with convenient access to two kinds of content—distractions and tips—and to allow them to communicate with each other through comments on specific items. *Distractions* were nonsmoking related items that were intended to take people's minds off cravings and were typically links to interactive games and diverting Web-based content such as amusing images and videos. Users of DistractMe could access and filter a suite of digital content (videos, games, websites, images, etc) to distract themselves from craving as the need arose (Figure 1). *Tips,* in contrast, consisted of smoking-related information in the form of suggestions on how to cope with cravings and craving-inducing situations, such as "drink water during a craving" (Figure 2). Users could filter tips according to different types of situations, including feeling stressed or bored, or after they had eaten.

We envisioned different uses of distractions and tips. Distractions were to serve situations in which participants wanted to avoid thinking about smoking, whereas tips were for situations in which participants wanted to think about and fortify their quit attempt. DistractMe was intended for personal use to cope with cravings, but it also created possibilities for social interaction around the exchange of distractions and tips, and through shared comments on their effectiveness. Familiar social media functions were included in the app that allowed, for example, users to express "likes" and to see the number of views, comments, and favorites for each distraction (Figures 1 and 2). Furthermore, there was a notifications feature to highlight responses from other users and encourage contributions and comments. As discussed by Engeström [30] and as evidenced by popular social media such as YouTube and Reddit, images, videos, and short anecdotes are a popular means to encourage information sharing and social support among users.

DistractMe was implemented as an app rather than a Web service to ensure that it would be available to quitters at any time and place, even if they did not have mobile phone reception. The app was designed for iPhones because at the time of design, Apple's IOS dominated the smartphone market with a share of 46% [31].

Figure 1. DistractMe includes a scrollable list of distractions. The red circle in the navigation bar highlights notifications of responses from other users.

Figure 2. DistractMe provides tips to cope with cravings with the option to add a comment. The red circle in the navigation bar highlights notifications of responses from other users.
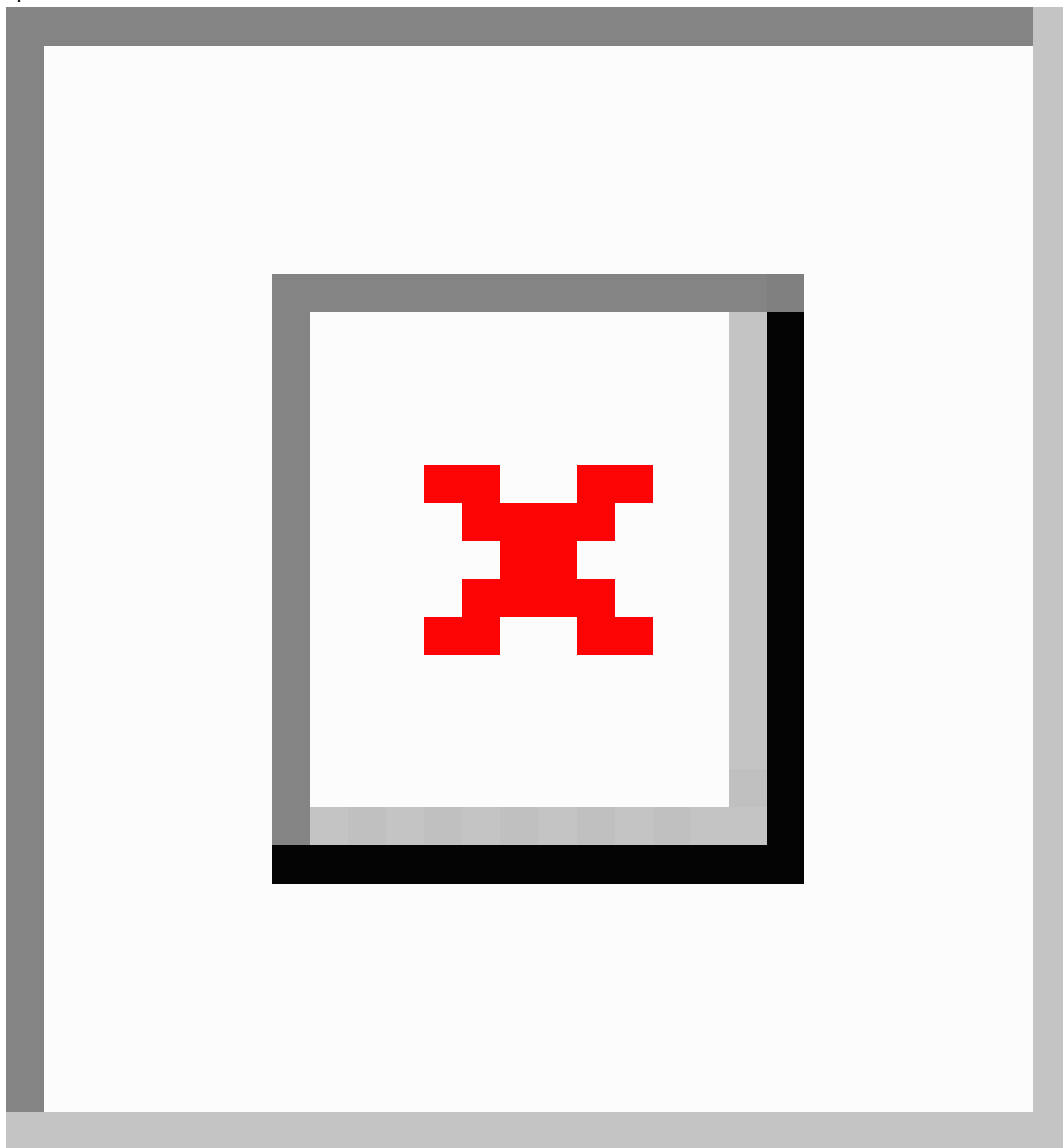
DistractMe App Content Management

The content available on DistractMe came from both the research team and the participants in this study. The researchers played an active role in adding content to the app, because previous studies of online support groups have shown that the majority of users prefer to read rather than contribute content [32], and we did not aim to attract the large population of users needed to generate large volumes of content. At the outset, we prepared 171 distractions and 179 tips. Some tips were labeled as being sourced from the smoking cessation website of Quit Victoria (the organization of the fourth author) and others were based on cessation research and practice. They included suggestions for coping, motivational information, and success stories written by ex-smokers. Distractions were sourced on the Internet and edited with Quit Victoria's smoking cessation counselors. They included interactive games and quizzes, funny pictures and videos, news, and infotainment websites. During the 6-week trial, the first author also added 37 comments on tips and distractions to engage with the study participants.

Participants could contribute distractions and tips directly through the iPhone app as well as through a Web form to simplify activities such as copy pasting or writing long texts. Each new item of content was immediately visible to the contributor, but required approval from a moderator to be visible to other users. The app was only available to users who consented to take part in the study.

Study Participants

Participants were recruited through Quit Victoria's telephone counseling service and their Facebook and Twitter channels as well as through the University of Melbourne's staff and student mailing lists. We sought participants who owned an iPhone and would use the DistractMe app in the first weeks of their quit attempt because this is the period when relapse often occurs [3]. All participants had to have quit no more than 1 week before the first interview of the study or be planning to quit smoking in the next month.

In all, 27 participants were recruited but only 14 provided the data for this paper. Five were excluded because they did not make a quit attempt, 4 because they were not available for a second interview, and 4 because they did not use the app at all. The 14 participants who did make a genuine quit attempt were diverse in terms of age (ranging from 20 to 53 years, average 33 years), gender (11 female, 3 male), and nicotine dependence (ranging from very low dependence to high dependence according to the Fagerström test [33]). Success in quitting during the study was also variable. At the second interview 6-12 weeks into the study, 7 participants described themselves as nonsmokers, 2 as social smokers who had significantly reduced their smoking, and 5 as smoking at previous levels.

Data Collection

Observations of quitting behavior with the DistractMe app were made over 6 weeks (Table 1). The study was timed to occur over the New Year holiday season in Australia because it is known that many people attempt to quit at this time. The first author interviewed each participant at the point of joining the study about plans to quit and general usage of iPhone apps (Multimedia Appendix 1). During this interview, participants downloaded and familiarized themselves with DistractMe. Interviews were conducted face-to-face (n=21) or via telephone (n=6) and lasted approximately 60 minutes. The participants received A$25 per interview to contribute toward travel expenses and phone data charges.

During the 6-week trial period, log data were collected for each participant. This included information about distractions and tips viewed or posted on the app. Participants were also asked to diarize their experiences with quitting and the app once a week. A second round of interviews was held after the 6-week trial focusing on the strategies and experiences of the quit attempts and the nature of engagement with the app (Multimedia Appendix 2). These lasted between 30 and 60 minutes, depending on the participant's quit attempt. Both rounds of interviews were semistructured based on a short list of questions.

**Table 1.** Methods used during the 6-week field study.

Timeline	Method	Aims
Week 1	Interview 1	Discuss plans for quitting and gather first impressions with DistractMe app
6-12 weeks following recruitment	Log data	Collect information on contents viewed, posted, and commented on via DistractMe
By respondents over the period of use	Diary	Gather feedback on quit attempt and DistractMe at the time of quitting
6-12 weeks after starting, depending on when quit attempt was made	Interview 2	Reflect on quit attempt and the engagement with DistractMe

Data Analysis

The aim of the analysis was to develop an understanding of patterns of engagement with the DistractMe app, including its deployment in the quit attempt and the uses made of distractions, tips, and comments on them. As customary in many forms of qualitative research [34], the analysis was carried out in parallel with the collection of data. From the first interview onward, we wrote analytic memos for each participant that described instances of engagement with the app together with the researchers' interpretations of the data [35]. These memos were used to code all forms of data (interview transcripts, diary entries, posts to the app) to develop an in-depth and broad picture of engagement with the app to cope with cravings and as a resource to later identify common themes across these instances [34]. The first author, using the software NVivo, conducted the coding and presented data and emerging themes in weekly meetings with the research team. Through ongoing discussions between all authors, observations were clustered into the 6 themes of engagement that are presented in this article [8]. As illustrated in Figure 3, themes were structured according to the content items of DistractMe (distractions and tips) and the stage of coping (anticipatory and immediate).

Qualitative analysis was complemented with data from the log files. These provided further evidence of the participants' personal engagement with the app during their quit attempt, including when and how often users logged into DistractMe, what distractions and tips they viewed, and what content they added themselves. This provided a valuable cross-check on information provided in interviews. It was the basis of excluding nonusers and provided an indication of the level engagement among the active users.

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Figure 3. Six quitting strategies used in association with the DistractMe app.
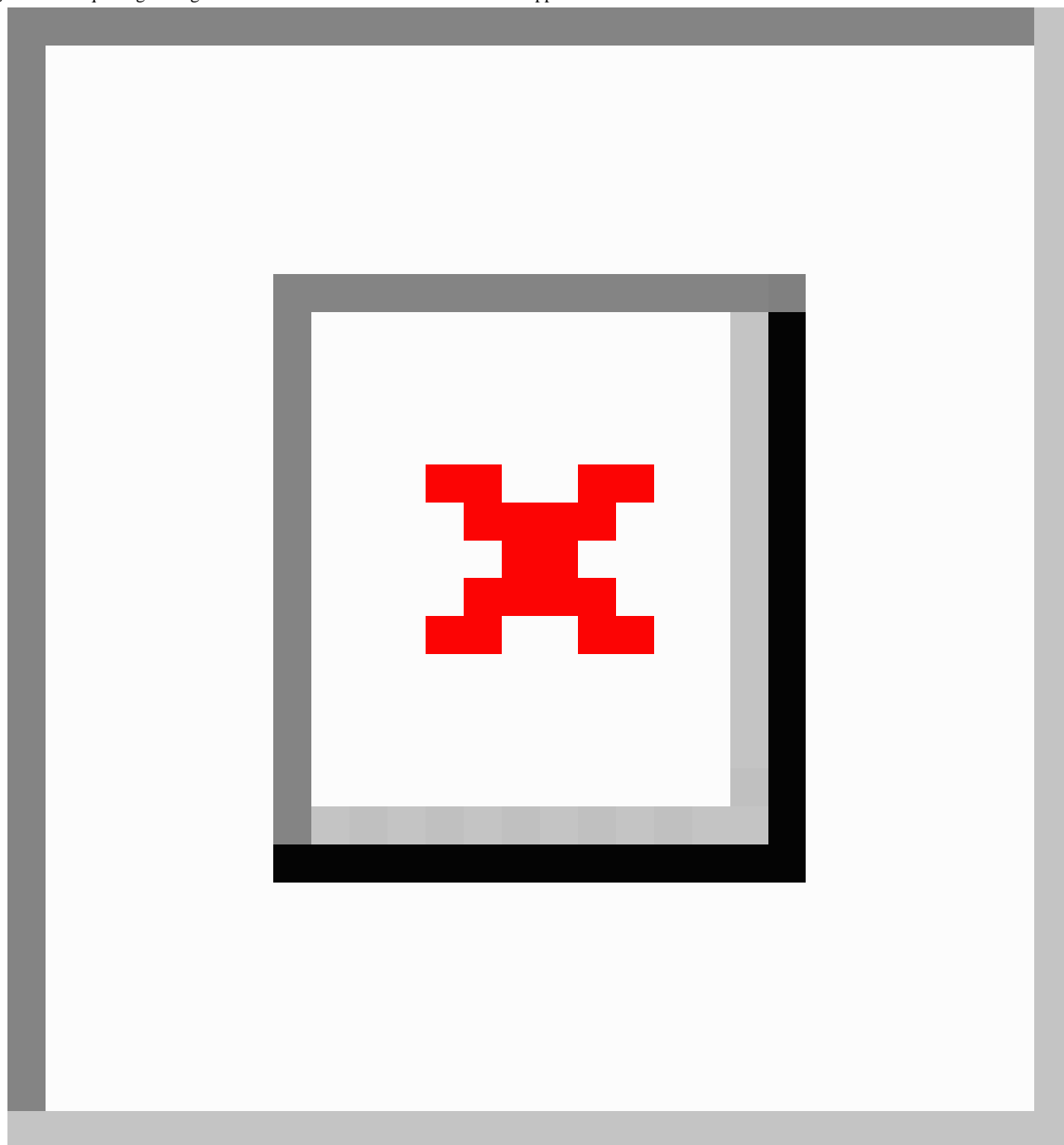
Results

Overview

The log data indicated that the 14 active participants engaged more with tips than distractions. They consumed on average 22.1 tips (range, 0-68) and 16.4 distractions (range, 1-69). Whereas they posted more distractions than tips (mean, 2.3; range, 0-12 distractions, and mean, 1.5; range, 0-5 tips), they posted more comments on tips (mean, 1.6; range, 0-5) than on distractions (mean, 1.0; range, 0-5). These results confirmed the rich accounts given in interviews and diaries, which allowed us to develop a picture of the quitting strategies devised and deployed through use of DistractMe.

Participants reported a variety of episodes in which the distractions and tips exchanged through the app helped them to deal with cravings. As shown in Figure 3, we clustered these into 6 distinct quitting strategies associated with the use of DistractMe. Strategies were further organized along two dimensions: those for coping with cravings when they occur versus those for preventing cravings from happening or creating situations in which their effects would be diminished; and strategies that draw attention away from smoking versus those that focus attention directly on it.

There were 2 strategies to cope with cravings when they occurred: diversion, implying the distraction of attention away from the craving; and confrontation, implying a direct focus on the craving with the resolve to beat it. On preventing cravings,

there were 4 distinguishable strategies. Two involved drawing attention away: avoidance of social or other situations in which temptations for smoking were high; and the displacement of cravings by embarking on other activities, such as gardening, that were less likely to lead to cravings or would diminish their effects. Two further strategies prevented craving by focusing directly on them: preparation, implying activities leading up to a quit date when supporting arrangements were put in place; and fortification, when quitters actively revisited their motivations and reaffirmed their commitment to quit. In the remainder of this section, we describe how DistractMe was appropriated by participants into these 6 strategies of quitting.

Coping With Cravings

Diversion

Diversion was a strategy that was fully intended in the design of the DistractMe app. As described, the app provided potential diversion away from cigarettes toward content available on the mobile phone such as news articles, quizzes, and YouTube videos, as well as behavioral diversions through games that kept the fingers of the participants busy.

The following example illustrates how participant 2 used her mobile phone to seek diversion in this way. She had experienced a stressful situation at work, and back home in the evening she craved a cigarette to help her relax. However, instead, she used the DistractMe app in concert with other apps to divert herself.

> I came home thinking, you know, I don't know what to do with myself; I don't know how to process all this. And after I'd sort of looked at a few newspapers online and had a bit of an interaction with some social media, I was sliding across the screen and went, Ooh, there we go, bingo! I logged on and all of a sudden 20 minutes later sort of went, Well, and the craving was gone. I didn't even think about cigarettes for the rest of the night and felt a great deal more settled. [Participant 2, interview 2]

At the outset of the trial, most participants were positive that distraction items could help in their quit attempt. In the second interview, however, although all of the 14 participants viewed distraction items for general interest, only 3 reported episodes where they had used them, or other content on their mobile phone, for diversion away from cravings. Many participants reported that DistractMe did not provide sufficient updates to effectively divert them.

> There's a lot of other applications that you can use and just like Pinterest. So if I want to just procrastinate or whatever I will use those applications because they have more content. [Participant 17, interview 2]

This suggests that although diversion sounded appealing to the participants, possibly because it offered a simple strategy for quitting, in practice they generally preferred other strategies.

Confrontation

Confrontation was the mirror opposite of diversion. Rather than taking one's mind off cravings for a cigarette, it consisted of concentrating on them to deliberately and actively resist.

Confronting a craving appeared to be the more challenging response, and only 4 participants reported it.

The participants characterized confrontation as an inner dialogue in which they examined the craving and explained to themselves that it was only a withdrawal symptom rather than a physical need and that nothing adverse would happen to them if they did not respond. Participant 14, whose cravings were triggered by the stress of unexpectedly losing her home, described this inner dialogue in detail.

> I was really stressed and I really wanted to buy a pack of cigarettes, and I knew it wasn't going to make me feel better, but I just really wanted to do it. I had a little bit of a rant and a tantrum, and then I was just like—I just had to talk myself out of it. I was just like, You feel shit now, like smoking a packet of cigarettes is not going to make you feel better about the house, it's not going to make you get the house anyway, like what difference does it make? It doesn't. And I feel like I have to consciously talk myself out of those situations. [Participant 14, interview 2]

The tips in DistractMe served as a means to support a confrontation strategy, which was consistent with our design intention for tips to be used to concentrate on smoking. For example, participant 17 used the videos in the tips section to remind herself of the negatives of smoking when she experienced cravings. Having experienced cancer in her family, she searched DistractMe for reminders about the health risks associated with smoking to withstand the temptation to give in and buy cigarettes.

> If I'm stressed and if I feel like I have to run to the 7-Eleven [and buy cigarettes], I just feel like OK, let's watch some creepy information about smoking on the app. [Participant 17, interview 2]

DistractMe also supported confrontation by allowing quitters to share information that highlight that cravings are merely a withdrawal symptom that will not be solved by giving in. For example, participant 20 found a website that explained the physiological process behind cravings. Inspired by this website, she shared her suggestions to confront cravings through the DistractMe app.

> Remind yourself, when you are experiencing a craving, your mind is sending messages that something bad will happen if you don't have a cigarette—messages similar to must eat or must drink for survival. When you are getting stressed about needing a cigarette, remind yourself that nothing bad will happen if you don't have a cigarette. The urgency, the craving itself, is a nicotine-induced fiction. And that uncomfortable desire will last about 3 minutes. Sit it out. [Participant 20, posted on DistractMe]

Prevention of Cravings

Preparation for Quitting

Preparing for quitting took many forms. Virtually all participants prepared themselves mentally for their quit attempt by reflecting on experiences from previous quit attempts, working out a

suitable time to quit, and looking up websites and reading books to get ready. For example, participant 14 posted a photo on the DistractMe app associated with the popular quitting guru Allen Carr as a motivator to stay a nonsmoker (Figure 4).

Only 6 of the 14 participants had set themselves an actual quit date at the time of the first interview. Three of these 6 people were planning to take quitting medication to reduce withdrawal symptoms, which required a prescription and so added a delay. The other 3 participants decided to quit in the days following the first interview and their preparation typically involved removing cigarettes from their environment.

> *Preparation is mainly just completely clearing the house of anything that reminds me of it, so everything I've used for smoking goes out.* [Participant 20, interview 2]

The remaining 8 participants were either continuously trying to quit or they were intending to quit in the near future and planned to quit ad-hoc, rather than on a chosen date.

Five participants reported that they used the DistractMe app for preparation before quitting. The most popular preparatory tip shared by the users of the app was to drink water, both to pre-empt cravings by staying hydrated as well as to cope with cravings by displacing the cigarette with a drink. Unlike other suggestions about medication and books, this tip could be applied instantaneously, and could continue after the quit date.

> *Well the drinking water tip—I started carrying a drink bottle with me everywhere, and I still do that, just always drinking lots of water.* [Participant 24, interview 2]

Figure 4. The participants used DistractMe to share resources to prepare for quitting.
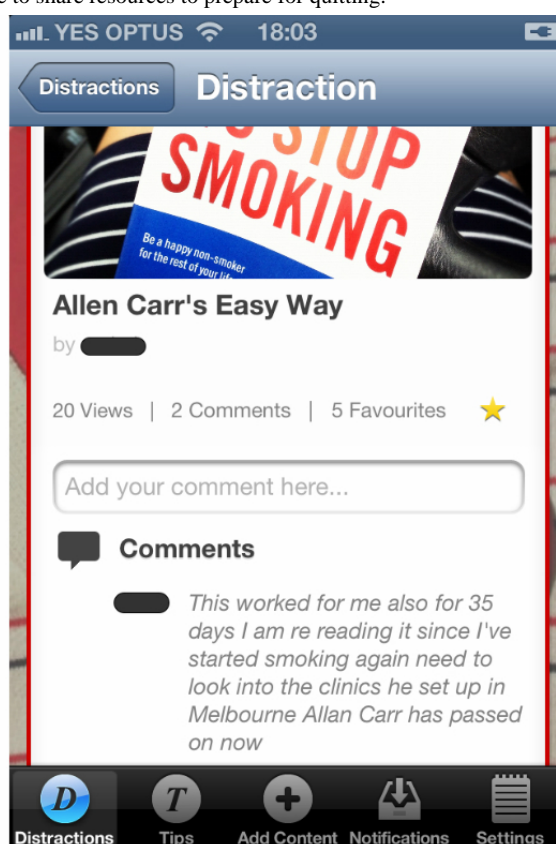
Fortification of the Quit Attempt

Eleven participants used DistractMe in their downtime to fortify their quit attempt. In particular, they used the tips to strengthen their motivation and dedication to stay a nonsmoker. Common strategies were to think about the negatives of smoking, highlight the positives for encouragement, and find inspiration and solidarity in reading about the experiences of others who were trying to quit.

For example, participant 7, a mother of 3, responded strongly to a video that showed how children would suffer if their parents were not there for them any more due a smoking-related premature death:

> *This ad really made me think how my three little ones would feel if I wasn't around and all because of such a silly habit. Time to quit!* [Participant 7, interview 2]

Participant 11 used a screenshot of one of the tips as a background image on her phone to remind herself about her decision to quit (Figure 5).

A key benefit for many participants was to read short personal stories written by others users. As shown in Figure 6, these stories typically provided tips on how to stay quit and they expressed the difficulties of coping with cravings and of resisting temptations to smoke again. These stories were reported as reassuring participants that they were not by themselves with

their difficulties, and thereby strengthened their commitment to stay on track.

> I really liked [the stories]—I said last time that I didn't really care about what other people said on the app, but there are stories, like people saying how long it's been. . . I think I commented on people's little stories, like when someone hasn't had a cigarette for 3 days and they were talking about how difficult that was and how good they felt after the first day, which is really true. If you are smoking every day and you can go a day without one, it's quite a big achievement. And then the second day again, you go through a similar sort of thing. So that helps. It was good to see that those early stages are very similar for those people. [Participant 8, interview 2]

Some participants further commented on the benefits of sharing their stories. While the research team seeded the majority of stories, 3 participants shared their quitting stories through the tips section of the app. As indicated by participant 2, being able to share one's experiences and reading in comments how these posts had helped others to remain nonsmokers, further fortified quitting.

> I felt enormously pleased when I saw that people had added some of my tips and things to their favorites – that made me feel really good. I'm thinking that's a funny response, but it was nice to know that no matter how small I was able to provide someone with something that might have helped them, even if it was only for five minutes. [Participant 2, interview 2]

Figure 5. Participant 11 commented that she used this tip as a reminder to remain a nonsmoker as wallpaper on her phone.
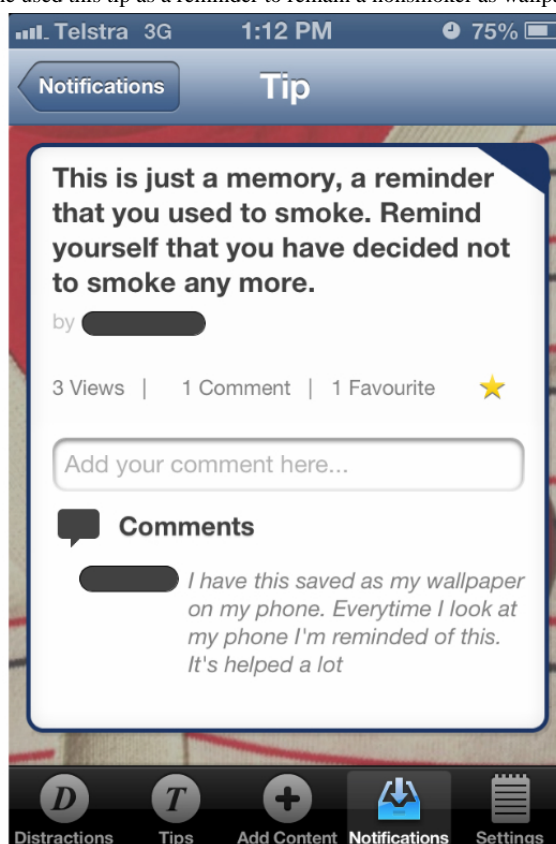
Figure 6. Personal stories written by others who were quitting smoking provided information and reassurance that participants were not alone with their difficulties in quitting.
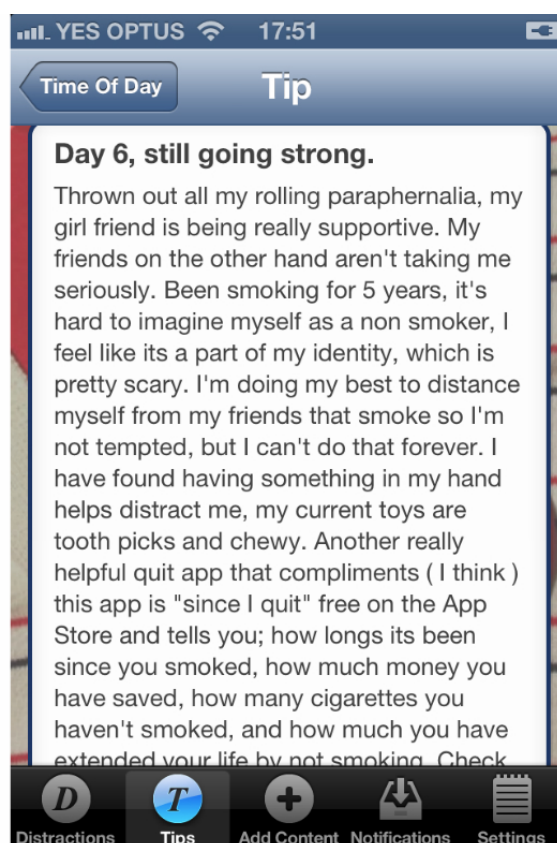
Avoidance of High-Risk Situations

Five participants reported that they used the DistractMe app to learn about ways of avoiding situations that may lead to cravings, or they shared their strategies with their peers. Similar to diversion, avoidance seeks to draw attention away from the desire for cigarettes, but does so in an anticipatory way.

A commonly used form of avoidance was to avoid alcohol for the first few weeks after quitting, because consuming alcohol was often associated with meeting other smokers and also because it diminished the control to resist temptations. The following comment on DistractMe is an example of an avoidance strategy shared with peers. Two participants commented on this tip, expressing that they found it useful but also that they were concerned that drinking alcohol again in the future may lead to a relapse.

> I've given up alcohol for a few weeks as I think it might help me with giving up. Alcohol and cigarettes have formed such a close bond in my head that I think this might be a way to break that bond. In a month I won't be a smoker anymore so don't think the alcohol will have the same connection then. [Participant 2, posted on DistractMe]

Other participants also highlighted the importance of avoiding particular places and routines. Three participants quit while they were traveling and thereby avoided any reminders through places or routines associated with smoking. Participant 11, on the other hand, temporarily moved in with her boyfriend to avoid temptations associated with her daily routines.

Displacement of Smoking With Other Activities

Displacement involves doing something else to prevent cravings. For example,

> I kept myself busy doing other stuff that I didn't even stop to think about needing a distraction. [Participant 1, interview 2]

Like avoidance, displacement was an anticipatory strategy that planned to draw attention away from smoking. In contrast to avoidance, however, displacement was about creating new situations in which smoking was not an issue at all. For example, participant 5 posted on DistractMe:

> Day one over Grandbaby was a good distraction now I hope I can make it the rest of my life :) [Participant 5, posted on DistractMe]

Nine participants mentioned displacement strategies in their posts on the app or in their feedback through the diaries and interviews. As indicated in the post above, spending time with nonsmokers was a common approach. Several people displaced cigarettes with other physical objects like sweets, chewing gums, and drinking straws, and shared these suggestions on the app. A further focus in the displacement activities was on keeping their hands busy through activities like knitting, cleaning, and painting. Several participants saw quitting as part of a larger attempt to develop a healthier lifestyle. They sought to exercise regurlarly, which served as a displacement activity. Beyond that, exercise helped the participants to lift their mood and to cope with other withdrawal symptoms, like feelings of restlessness, stress, and irritability.

Another thing I do to distract myself is I've been going to the gym a lot, which is another good benefit, like health benefit, but it's just also a lot of... it's an energy outlet as well, because I think I get real tense and a little bit hyperactive, because I've got all of this stress going on because I'm not smoking, even though I'm not that stressed, which is weird, I think it's just internal. [Participant 11, interview 2]

Discussion

Principal Results

In this study, we have explored how mobile phones might serve as tools to help people remain nonsmokers. Our approach has been to design and evaluate the DistractMe app, which was presented to quitters as a tool to distract themselves by viewing engaging nonsmoking-related content. This design was motivated by reports that self-distraction is a common quitting technique [23]. To provide a comparison in our observations, explicitly smoking-related quitting tips were added to DistractMe. Also included were standard social media functions for sharing comments on items, and viewing visits and favorite ratings. By observing 14 quitters using the DistractMe app, we have attempted to understand how this technological intervention is appropriated into real life quit attempts. Our aim has been to elucidate what forms distraction might take using a mobile app, and to understand this in relation to the use of smoking-related information as provided in the tips and social connectivity to a group of quitters.

Overall, the picture that has emerged through the interviews, diaries, and log data, provides support for the viability of distraction-related techniques in real life quitting using a mobile phone. However, it also reveals highly idiosyncratic use of the DistractMe app. Participants appropriated the app in distinct ways into their particular approach to quitting. We identified 6 quitting strategies deployed in concert with the use of DistractMe. Some of them were intended in the design of the app, whereas others were not. The primary intended strategy of diversion, using distraction items to take the mind off cravings, was reported by just 3 of the participants. In addition, 4 other participants used a strategy of confrontation, by watching or reading tips about smoking to confront cravings as they occurred. Four anticipatory strategies that attempted to prevent cravings or reduce their effects were also reported. Five participants used DistractMe as part of preparation for quitting; this involved reading tips and selecting distractions for later use. Once into the quit stage, 11 of the 14 participants followed a strategy of fortification of the quit attempt; typically this involved reading tips and comments on DistractMe to strengthen their motivations and resolve to remain nonsmokers. The other 2 anticipatory strategies shifted attention off smoking: avoidance strategies focused on staying away from places, people, activities, and situations associated with cigarettes; whereas displacement strategies were more proactively focused on shaping a new, smoke-free lifestyle, often in combination with increased exercise. Here, DistractMe served as a tool for participants to find out and share effective techniques, with 5 reporting valuable exchanges for avoidance and 9 for displacement.

The influence of social exchange between quitters, through posting distractions and tips and through comments on them, pervaded all 6 strategies. This is true even though the volume of exchange was slight relative to many social media applications. In this sense, the DistractMe app provided access to a community of peers that offered various forms of support. They offered informational support to prepare for quitting and to confront cravings. Furthermore, many tips were conveyed through short personal stories that offered emotional support and encouragement to fortify the quit attempt, similar to interactions on discussion forums, blogs, and Facebook pages dedicated to quitting smoking [36-38].

With both distractions and tips, the findings suggest that the main benefit was in consuming them rather than in contributing content. As in most online communities [32], particularly in sensitive settings such as health and behavior change [39], the participants in this study generally wished to remain private and preferred to consume content alone. Nevertheless, all of the 14 participants also contributed content through distractions, tips, and comments on the app. Some participants reported that being able to express themselves fortified their quit attempt, similar to how some quitters use blogs to express themselves and reflect on their progress [40]. More generally, writing one's story is recognized to have positive effects for health and well-being because it can be cathartic and helps individuals to gain analytical distance from their concerns [41].

While our initial design intention with DistractMe was to support coping through distraction (ie, diversion), the findings showed that the participants more commonly sought to cope with cravings through fortification and confrontation and by paying attention to smoking and cravings, rather than shifting attention away from them. This finding differs from previous research that suggests that distractions are the most frequently applied coping strategy to resist smoking [23]. One limitation pointed out by the participants was that DistractMe did not provide sufficient updates to offer an engaging experience, particularly when compared with the large number of updates on popular social media like YouTube and Facebook. However, the findings also showed that they rarely used these social media to distract themselves either.

A further concern raised by some participants was that the content in DistractMe was mostly not interactive enough and this allowed them to smoke while using the app. Again, however, participants rarely used the highly interactive games that were available on their phones to seek distraction. Overall, we concluded that although the idea of playful diversion through an app appealed to the participants during the initial interviews, they typically did not seek to divert themselves when cravings actually occurred. An equal strategy to diversion was confrontation of the desire, sometimes by using the content of the app to focus on their reason to quit. However, more important than either of these strategies, greater reliance was placed on careful planning for avoidance and displacement. Hence, fortification of the quit attempt was the most widely reported strategy in this group of 14 smokers; chiefly reminding themselves of the negative effects of smoking and by exchanging stories with their peers that encouraged them to stay on track.

Although the findings showed that the DistractMe app offered important resources for immediate coping, the primary benefit for the participants, therefore, was to receive support before cravings even emerged. Typically, they used DistractMe in their downtime, browsing through items to help them prevent cravings, or looking to see if anyone has posted new content. For some participants, looking for new stories and comments on DistractMe became part of their digital routine, like checking emails and other social media. This helped to prepare for risk situations and reduce the risk of relapse at a later point [10,42].

Limitations

The findings presented here are based primarily on self-report. Although log data were used to verify that each participant presented in this study engaged with the app, it was mainly data from interviews and diaries that informed how DistractMe was used. Influences that occur from automated or operational processes [43] and those most readily forgotten will not be adequately reported. We used diaries to minimize reliance on retrospective accounts of coping from the interviews. Other techniques such as ecological momentary assessment [9] might overcome this limitation, but might also be counterproductive to the aim of distracting users from cigarettes, or might act as an intervention in its own right.

The study was based on a small qualitative study. This allowed us to study only with genuine quit attempts and to examine coping strategies in depth. Although the study allowed us to develop a conception of 6 quitting strategies, it does not offer reliable data on the effectiveness of DistractMe on smoking cessation. Furthermore, the small sample did not generate sufficient content updates for a self-sustaining support community. Relying on the research team to create some of the content introduced some artifice in this respect.

Recommendations for Practice

The findings of this study suggest several recommendations for the implementation of mobile app interventions to help people stay quit.

The first recommendation is that distractions delivered on a mobile app offer a viable technique for quitters, with the proviso that there are regular updates of content, if necessary, from moderators. Although only a few participants used distractions as a form of diversion from cravings, they provided a compelling reason for quitters to take up the app and explore its potential. Distractions were attractive to some potential users because they framed the app as a lightweight and playful resource to remain nonsmokers. They also facilitated a transition from consuming content to sharing content. Participants found it easier to share distractions than tips because they were easier to find and involved little personal information. This is important, because peer support groups in general relies on contributions from their members to be sustainable in the long term [32], and particularly in areas such as health behavior change many members are reluctant to contribute due to privacy concerns [39].

The second recommendation for smartphone apps to help quitting is to bolster tips conveyed through personal stories because these are attractive to many quitters who are drawn to personal information about the situations of other users. Reading how other people have experienced similar situations and acknowledging that quitting is challenging provided a sense of connectedness and solidarity among some participants that fortified their quit attempts. The high level of anonymity and the ability to comment and engage with stories encouraged some participants to share their experiences, despite concerns about failing to quit.

For an app like this to remain engaging for quitters, it needs to attract a large group of users to develop a self-sustainable online community. A larger group is more likely to generate a variety of distractions and tips, particularly the personal stories that many users desire. Moreover, a larger group is more likely to increase commentary on other people's posts, which provides recognition and further facilitates the sharing of distractions and tips [32]. This may also help to retain users who successfully quit to share their stories, similar to other online communities in the domain of smoking cessation [37,44].

Conclusions

This study shows that mobile apps designed around the techniques of distraction and quitting tips can be taken up and used by people attempting to quit smoking. The observations of 14 real life quit attempts revealed that uptake was idiosyncratic and was used as part of 6 distinct quitting strategies: diversion, avoidance, displacement, preparation, fortification, and confrontation. Social exchanges between quitters supported by the app played an important role in the way the app was appropriated. Users shared strategies for long-term distractions to avoid and displace activities, people, and places that may evoke cravings. Quitting tips, on the other hand, helped users to prepare coping strategies and to fortify their quit attempts.

In future work, we plan to expand this work from a small group to a larger community to explore the benefits of self-expression and interactivity among peers, to improve the diversity and depth of distractions and tips available on the application, and to work toward a self-sustainable community where quitters help one another resist smoking. We also plan to see whether there are benefits of integrating the next generation of this app with other online support such as tailored advice and the opportunity to explore the site material on a larger interface such as a tablet or computer screen.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Questions for interview 1.

[PDF File (Adobe PDF File), 27KB - mhealth_v2i2e23_app1.pdf]

Multimedia Appendix 2

Questions for interview 2.

[PDF File (Adobe PDF File), 28KB - mhealth_v2i2e23_app2.pdf]

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Short Paper

An Evaluation of Mobile Health Application Tools

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Abstract

Background: The rapid growth in the number of mobile health applications could have profound significance in the prevention of disease or in the treatment of patients with chronic disease such as diabetes.

Objective: The objective of this study was to describe the characteristics of the most common mobile health care applications available in the Apple iTunes marketplace.

Methods: We undertook a descriptive analysis of a sample of applications in the "health and wellness" category of the Apple iTunes Store. We characterized each application in terms of its health factor and primary method of user engagement. The main outcome measures of the analysis were price, health factors, and methods of user engagement.

Results: Among the 400 applications that met the inclusion criteria, the mean price of the most frequently downloaded paid applications was US $2.24 (SD $1.30), and the mean price of the most currently available paid applications was US $2.27 (SD $1.60). Fitness/training applications were the most popular (43.5%, 174/400). The next two most common categories were health resource (15.0%, 60/400) and diet/caloric intake (14.3%, 57/400). Applications in the health resource category constituted 5.5% (22/400) of the applications reviewed. Self-monitoring was the most common primary user engagement method (74.8%, 299/400). A total of 20.8% (83/400) of the applications used two or more user engagement approaches, with self-monitoring and progress tracking being the most frequent.

Conclusions: Most of the popular mobile health applications focus on fitness and self-monitoring. The approaches to user engagement utilized by these applications are limited and present an opportunity to improve the effectiveness of the technology.

Introduction

Mobile Devices and mHealth

The development of mobile communications devices such as smartphones and tablet computers has spurred rapid growth in the field of mobile health (mHealth), the use of mobile-enabled applications that collect or deliver health care information and data. These applications offer the potential for dynamic engagement of patients and providers in health care and a new means of improving health outcomes. This technology could have profound application in the prevention of cardiovascular disease or in the treatment of patients with chronic disease such as diabetes and congestive heart failure. The rapid growth in mHealth has outpaced the science needed to validate the clinical effectiveness (and safety) of health-related applications. Due to the proliferation of smartphones and health-centric mobile applications (app), the US Food and Drug Administration

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recently issued guidance that will apply a similar risk-based approach to assure the safety and effectiveness of mHealth apps as other medical devices [1].

mHealth offers a unique opportunity to tailor and customize care for individual patients on the basis of health needs and behavioral attributes. Self-monitoring tools and apps are growing faster than more traditional telemedicine interventions because of the ubiquity of smartphones and the minimal development cost of health-related apps in providing flexible, scalable, mobile, and interoperable platforms [2].

mHealth Patient Engagement

mHealth also promises greater patient engagement, given the technology's near instant and always-on functionality, and continual use for multiple tasks. This concept is critical to the behavior change required for improved patient outcomes. However, little is known about the health needs or health behaviors targeted by current mHealth offerings. Therefore, in this study, we set out to describe the most popular mHealth apps, both in purpose and engagement method, available in the Apple iTunes marketplace.

Methods

Health and Wellness Applications

We sampled a population of health apps that were well characterized with respect to intended use and download

statistics using the iTunes Store (Apple Inc). Apple screens apps submitted for distribution through the store for objectionable content and categorizes them based on functionality and developers' descriptions [3]. We analyzed apps in the "health and wellness" iTunes Store category, which Apple further grouped on the basis of popularity and other attributes.

We first reviewed each app for potential inclusion in the study. We required each app to have an English-language description, to offer its services and functionality in the United States, and to address a health factor or condition that was gender-neutral with regard to the user. We sought to identify 100 apps in each of the following 4 subcategories designated in the iTunes Store: (1) most popular free apps, (2) most popular paid apps, (3) most recently added free apps, and (4) most recently added paid apps. We obtained the sample of apps on March 21, 2012.

For each app that met the inclusion criteria, we reviewed the description in the iTunes Store to identify the price, the health factor or condition, and the method of user engagement. For paid apps, we identified the initial price, but did not consider the costs of optional or required paid services offered within the app. Table 1 lists the health factors and their corresponding definitions. A single app could have more than one health factor.

Table 1. Health factors and primary engagement methods of reviewed apps.

Health factor	Engagement method[a]				
	Changing personal environment	Goal setting	Reinforcement tracking	Self-monitoring	Other
Fitness/training	0	0	2	172	0
Health resource	0	0	0	27	31
Diet/caloric intake	0	5	0	52	0
Health education	0	3	1	30	2
Stress management	23	0	0	4	0
Sleep	6	0	0	9	0
Mental health	0	0	0	8	0
Smoking cessation	1	0	0	2	1
Pain management	0	0	0	1	1
All factors	30	8	3	305	35

[a]No reviewed apps were categorized into the engagement methods of facilitating social support, progress tracking, social presentation or announcement, and social referencing.

Categorizing the Applications

We also categorized the apps with respect to the type of behavioral strategy or method of user engagement employed. We defined user engagement as the psychological framework used by the app to promote the desired health outcome. We derived unique categories of user engagement based on the principles of the transtheoretical model of change and traditional

behavior modification models that consider both individual and social influences [4-11]. We characterized each app according to its primary engagement approach and, in some cases, a secondary engagement approach. The 9 categories of engagement were as follows: (1) changing personal environment, the app modifies the environment to encourage the desired behavior (eg, white or ambient noise, soothing sounds, or images for meditation); (2) facilitating social support,

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the app creates a group or uses existing groups online or in person and stresses camaraderie, problem solving, solidarity, etc; (3) goal setting, the app facilitates goal setting (eg, weight loss target, fitness goal); (4) progress tracking, the user identifies a goal and the app creates subsidiary goals or tasks based on the user-defined goal and logs the user's progress; (5) reinforcement tracking, the app allows a third party to assign reinforcements based on information collected by the app regarding the user's health or health behaviors; (6) self-monitoring, the user tracks his or her behavior in the app with no explicit reference to a goal, the app is simply a tracking tool (eg, pedometer); (7) social presentation or announcement, the app provides implicit social reinforcement, for example, by announcing an action, achievement, or process via social media or an app tool; (8) social referencing, the app facilitates indexing of the user's behavior in comparison with others, such as in an online community or social group that uses the same tool; and (9) other, the app does not fit the other categories.

All categorizations were made on the basis of the description of features and functionality in the app description in the iTunes Store. We used descriptive statistics (frequencies, means, and SDs) to describe characteristics of the apps according to price, health factors, and behavioral engagement.

Results

Reviewed Applications

We reviewed 550 apps, of which 150 did not meet the inclusion criteria. Figure 1 shows the number of apps excluded at each stage of review. The mean cost of the most frequently downloaded paid apps was US $2.24 (SD $1.30); the mean cost of the most recently available paid apps was US $2.27 (SD $1.60).

Figure 2 shows the number of apps that addressed each health factor. Among the 400 apps in the final cohort, fitness/training was the most popular health factor, accounting for 174 out of 400 apps surveyed (43.5%). These apps consisted mostly of predesigned exercise plans or a collection of exercises for the user to follow. The next two most common categories were health resource (ie, providing information about a health resource such as a gym, doctor's office, or health plan) and diet/caloric intake, accounting for 60 out of 400 apps (15.0%), and 57 out of 400 (14.3%) apps surveyed, respectively. The diet/caloric intake apps most commonly allowed users to track calories consumed and expended. All of the calorie apps had a preexisting database of calorie information, but allowed users to create their own items.

Figure 1. Assessment flowchart.
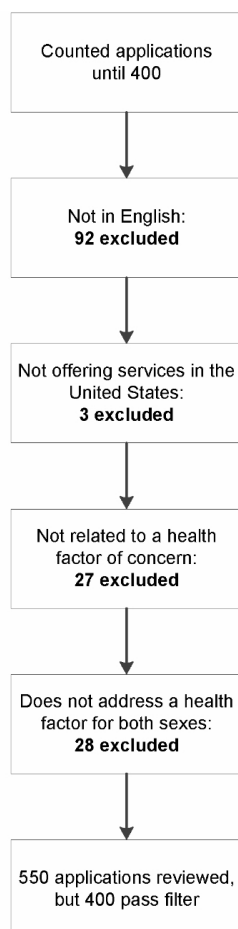
Figure 2. Frequency of health factors in reviewed applications. Note: Fitness/training applications are intended to help improve physical fitness, train for an event, or provide workout/gym plans. Health resource applications locate health resources like doctors, fitness centers, and wait times at medical providers. Diet/caloric intake applications help track calories, assist with making better dietary choices, and help with meal planning. Health education applications provide information about health conditions and wellness topics. Stress management applications inform users about ways to manage stress. Sleep applications inform users on ways to improve sleep patterns. Mental health applications deal with other mental health issues like depression and anxiety. Quit smoking applications inform users about smoking cessation strategies. Pain management applications inform users about pain management strategies.
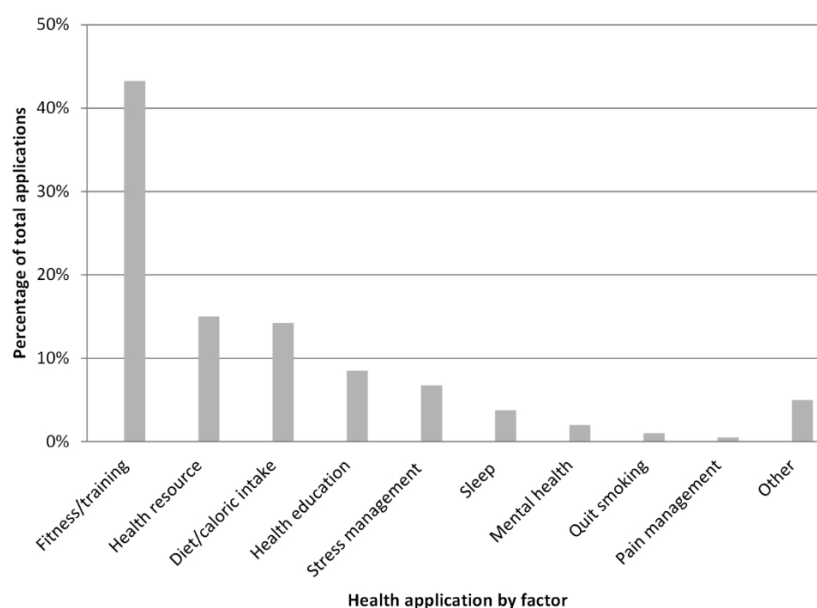
Engagement Approaches

Table 1 categorizes the reviewed apps by their primary engagement approaches. Self-monitoring was the most common method of engagement approach, as it was utilized in 299 apps out of 400 surveyed (74.8%). A total of 83 apps out of 400 (20.8%) used two or more approaches, with self-monitoring and progress tracking being the most frequent combination.

Discussion

Principal Findings

The results of our study provide a baseline for charting the evolution of mHealth apps in prevention and in disease management. Our review of the most frequently used health apps in the iTunes Store highlighted several trends that provide insights into the evolution of mHealth and where gaps and opportunities to improve health status of end users exist. The apps for monitoring exercise regimens and caloric intake (226 apps out of 400 surveyed) dominated the mHealth arena relative to apps addressing chronic issues such as sleep, mental health, and smoking (27 apps out of 400 surveyed). The health apps that deployed self-monitoring apps beyond fitness/exercising training were limited.

Although there is an extensive literature on approaches to behavior change [6-11], and tremendous interest in frameworks offered by the field of behavioral economics [12,13], we found only two major methods of engagement in our sample. The findings echo other recent publications (eg, Cowan et al, Azar et al) [14,15] in which mobile app developers minimally incorporate decades of health behavior theory into app design. These findings reinforce the grassroots entrepreneurial nature

of the market and a general lack of awareness of the literature among developers [14-16]. The findings may also reflect the limited insight of consumers into desirable and effective app features. Other possibilities include that the two major methods of engagement are the easiest methods from a programming standpoint and are the methods more likely to be downloaded, acting as a reinforcement mechanism for app developers. Finally, it is unknown whether mHealth approaches to behavior change improve self-monitoring, engagement, or have greater influence on outcomes than traditional models of intervention. The lack of data from these apps that can be analyzed for scientific outcomes further limits opportunities to guide developers in refining their offerings for maximal impact and increased market share.

Although the app market depends on national scale for its financial model, efforts to develop and test apps for specific health conditions and health behaviors may be another path toward popularizing effective apps. To improve customization according to patients' behaviors, several approaches can be considered including workshops to introduce and explain health behavior methodologies to app developers, grant programs tied to commercialization of behavioral approaches in mHealth, and efforts to assess the impact of mHealth in clinical practice.

Limitations

Our study has some limitations. We reviewed wellness apps as a potential model for future apps directed at disease management as the market progresses, although these later apps may have more sophisticated approaches to user engagement, and may not be as limited as the wellness apps we reviewed. We did not separately review apps in the Android marketplace due to common apps within the iTunes market, fragmentation in how software is delivered on the platform, and the lack of similar

indexing approaches in the Android market. Also, we limited our review to the most frequently downloaded apps. The less popular apps may address different health needs and use different approaches to behavior modification; however, this fact reinforces the notion that apps with scientific foundations may have difficulty differentiating themselves in a crowded marketplace of similar offerings. The market is dynamic and continuously evolving, and our assessment could be quickly outdated by new developments.

Conclusions

In conclusion, we found that the most popular mHealth apps focused on fitness and self-monitoring. The approaches to patient engagement were limited, presenting an opportunity to improve the effectiveness of the technology. Investments in scientific and developer communities together, and incentives to draw users into specific apps, could alter the dynamics of the market and have a significant impact on health outcomes. Further work will be required to develop this technology to the point where it is most likely to have an impact on patient outcomes.

Conflicts of Interest

Dr Shah reported serving as a consultant for Castlight Health, LLC. Dr Schulman reported receiving research support from Verizon.

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Abbreviations

app: application

Viewpoint

mHealth 2.0: Experiences, Possibilities, and Perspectives

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Abstract

With more than 1 billion users having access to mobile broadband Internet and a rapidly growing mobile app market, all stakeholders involved have high hopes that this technology may improve health care. Expectations range from overcoming structural barriers to access in low-income countries to more effective, interactive treatment of chronic conditions. Before medical health practice supported by mobile devices ("mHealth") can scale up, a number of challenges need to be adequately addressed. From a psychological perspective, high attrition rates, digital divide of society, and intellectual capabilities of the users are key issues when implementing such technologies. Furthermore, apps addressing behavior change often lack a comprehensive concept, which is essential for an ongoing impact. From a clinical point of view, there is insufficient evidence to allow scaling up of mHealth interventions. In addition, new concepts are required to assess the efficacy and efficiency of interventions. Regarding technology interoperability, open standards and low-energy wireless protocols appear to be vital for successful implementation. There is an ongoing discussion in how far health care-related apps require a conformity assessment and how to best communicate quality standards to consumers. "Apps Peer-Review" and standard reporting via an "App synopsis" appear to be promising approaches to increase transparency for end users. With respect to development, more emphasis must be placed on context analysis to identify what generic functions of mobile information technology best meet the needs of stakeholders involved. Hence, interdisciplinary alliances and collaborative strategies are vital to achieve sustainable growth for "mHealth 2.0," the next generation mobile technology to support patient care.

Introduction

With more than 6 billion mobile phone subscribers, it is estimated that 75% of the world population has access to mobile communication [1]. The number of devices with broadband capabilities increased to more than 1 billion worldwide [2]. Associated with the advances in hardware is the rapid evolution of a mobile app industry: with the promise "There's an app for that," Apple introduced its App Store in 2008. From conception, the number of mobile apps offered increased from 500 to 850,000, with more than 50 billion recent app downloads [3].

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New mobile technology offers novel system solutions for a variety of needs in daily life. Consumers, patients, providers of medical services, software developers, governments, and non-governmental organizations are excited about the opportunities mobile communication technology is likely to offer in terms of improving access to health care and delivery, engagement of patients, and clinical outcomes [4]. Whereas an estimated 63% of adults who own a mobile phone use their devices for Internet access, approximately 34% of them use their phones as their primary means for going online [5]. The availability of mobile Web access is allowing individuals who may not have broadband capabilities readily available in their home to access Internet content. With more than 97,000 health-related mobile applications and approximately 1000 new apps being published every month, there are high hopes in the market, which is expected to grow by more than 25% per year [6]. What is termed "mobile Health" or "mHealth," broadly defined as medical or public health practice supported by mobile devices [4], encompasses a variety of contexts: use of mobile phones to improve point of service data collection, care delivery, patient communication, use of alternative wireless devices for real-time medication monitoring, and adherence support [7]. These new services are developed within a colorful new industry, which brings together a variety of disciplines sometimes lacking understanding of each other's perspective. This viewpoint paper gathers experiences, evidence, and prognosis in the mHealth market from a psychological, medical, technological, and regulatory perspective (Figure 1). The idea of this paper was conceived at the Medicine 2.0 Conference 2013 in London, where 3 of the authors (TMS, UVA, and SB) met. They thought that a wider scope was required to fully understand the context of mHealth and started to write this paper, which evolved to be an interesting learning process for all contributors.

Figure 1. Development of health-related mobile applications and necessary viewpoints.
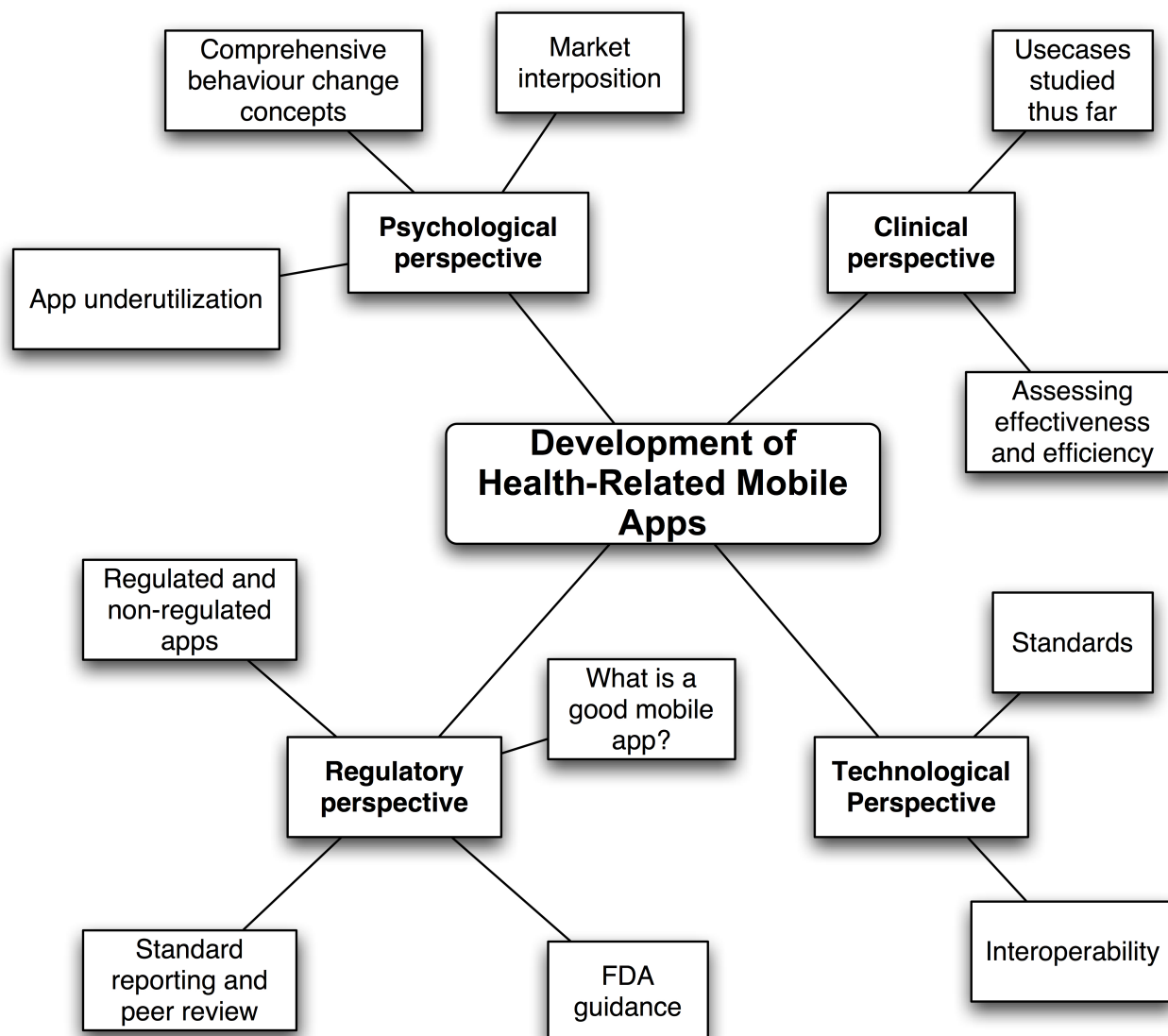
Psychological Perspective: What Are Consumers' Needs and Expectations?

Overview

An entire continuum of health care needs can be addressed via apps, broadly in two main areas: changing consumer/patient behavior in health-related areas (eg, diet and exercise) and improving the implementations of prescribed treatment regimens. As apps proliferate, psychological questions arise—to what degrees are apps not only downloaded but also used, and what can improve their uptake and effectiveness? This section will examine these questions in terms of consumers' needs and expectations about health-related apps.

App Underutilization

A study undertaken independently by the IMS Institute for Healthcare Informatics analyzed 43,689 mHealth apps, and suggested that despite an enormous number of health care apps available for download, most apps are underutilized [8]. The study found a significant skew in download volume for health care apps, with more than 50% of available apps achieving fewer than 500 downloads. Indeed, 5 apps account for 15% of all downloads in the health care category. The study clearly demonstrates that, to date, most efforts in app development have been in the overall wellness category with diet and exercise apps accounting for the majority of available apps. Despite the large number of health care apps developed so far, the majority has only simple functionality and does little more than provide information. In addition, studies show a high attrition rate for Internet interventions and mobile applications [9,10], which may be a reflection of an early interest in the novelty of the application, with a decline in eagerness as the novelty of the intervention wears off. Reasons for the limited number of downloads as well as hurdles for improved uptake can be found for all stakeholders. Patients currently face an overwhelming array of health care apps to choose from, with little guidance on quality or support from their doctors. A commendable effort was made by Happtique, a subsidiary of the Greater New York Hospital Association's for-profit arm GNYHA Ventures, to certify apps such as "amazing abs," "CalorieCounterPro," and "ControlMyWeight," providing some guidance through the app jungle. Yet the certification program was recently suspended because 2 certified apps were shown to threaten data privacy [11]. Data privacy and patients' ability to alert and defend themselves against privacy breaches have been discussed in the context of electronic health records [12]. These concerns are increasingly relevant as apps encourage consumers to pour potentially sensitive health data into them. Furthermore, apps developed to date do not completely cover the areas of health care responsible for the largest expenditures; for example, patients facing multiple chronic diseases and those typically over the age of 65. Elderly patients are likely to be among the top health care spenders but smartphone penetration is lowest among this group, with only 18% of the US population using them, compared to 55% of those aged 45-54 years.

How Apps Can Influence Behavior Change

A recent study that analyzed the written descriptions that developers provide with 3336 paid health and fitness apps in Apple's iTunes store identified 3 main psychological factors that can drive behavior change. These are (1) predisposing, which increase the user's capability; (2) enabling, which facilitates an authentic experience for users; and (3) reinforcing. These 3 factors assist the user in establishing and strengthening relationships and performing the required actions repeatedly [13].

Most of the apps were coded as either predisposing or enabling with only 6.65% of apps classed as reinforcing. Only 1.86% (62/3336) of apps included all 3 factors, which may help explain why health behaviors have not shifted dramatically since the emergence of apps. Another issue raised by the authors is that some health topics appear to have fewer apps associated with them. Examples of relatively neglected app topics include substance abuse, mental and emotional health, violence prevention and safety, and sexual and reproductive health. This lack of coverage of all health and well-being topics reduces the degree to which a person can take control of his or her health using apps alone. Interestingly, the more expensive apps (cost greater than $0.99) were identified as more credible or trustworthy, more recommendable to clients in a professional setting, and more likely designed to promote health and prevent disease. This reinforces the point that the more expensive apps are more likely to be based on theory leading to behavior change.

Market Interposition

In a review of apps and their potential [14], the authors marvel at the combination of phone and tracking systems, which years ago was considered science fiction. Yet even they acknowledge that apps "are so rapidly developed that they may or may not meet anyone's needs or expectations." Indeed, the fact that apps for taking care of various medical conditions are so readily available, and that this availability does not require the mediation of a health care professional, marks what Roth has dubbed "marketplace interposition" [15]. "Marketplace interposition" is where technological advancement encourages society to tacitly permit self-treatment and unauthorized practice of medicine through consumer access and actual use. What remains to be examined is whether and how people actually use this new right to self-treatment to take care of their health. Roth goes on to suggest that "marketplace interposition" means that it is the commercial marketplace that is effectively rejecting the federal prohibition against self-treatment and rejecting state prohibition of the unauthorized practice of law. "Marketplace interposition" is real and cannot be ignored if practical discussions are to be had regarding the appropriate level of regulation in mHealth. Society wants access and demands mobility. Some commentators argue for less regulation for certain diagnostic apps that presuppose a person is receiving medical attention. The reality is that the risk of injury is higher for lay people operating without physician oversight; some measure of regulation is necessary to ensure safety.

Potential Limitations of Apps From the Psychological Perspective

A recent review of social media interventions designed for health improvement has found that the effectiveness of such interventions is enhanced when they are combined with an off-line, not just virtual, social encounter [16]. This suggests that users of an app might also benefit from real-life support and interaction around the health issue they are managing digitally. Another limitation pertains to human cognition in general. Whenever information is presented, especially in probabilistic format, there is a chance that approximately half the people who read it will not be able to understand what it means. For example, women who received information about the BRCA 1/2 gene mutation, which is associated with a high prevalence of breast and ovarian cancer, misunderstood the risk magnitude associated with it [17]. Similarly, men who were asked about a gene that is associated with prostate cancer showed considerable difficulty in understanding the related risk probabilities [18], which may reflect a lack of tailoring to individuals with limited health literacy and numeracy. Probabilities are not the only issue to be taken into account when designing apps for optimum comprehension and effectiveness. Because approximately 90 million Americans read at or below the level of a sixth grader, it cannot be assumed that the entire population has sufficient literacy skills for coping with medical apps [19]. Comprehension issues may also arise among physicians when using apps, or when explaining/recommending them to patients. This can in part be tied in with the amount of information the patient/consumer/doctor has to read and assess. In an experiment that examined residents and medical students, the ability to choose the right course of action was diminished when participants were presented with 10 or 20 options as opposed to 3 [20]. Thus, even though digital media offers limitless possibilities for information presentation, the amount of information might be a liability, not an advantage. Even when no right answer exists, choice overload can be debilitating. This applies to the digital world, too. For example, "Switch to Health" was a company that offered incentives for physical behavior [21]. The company originally offered points that could be redeemed for an award from around 70 awards, ranging from an iTunes download to a Wii. However, the company later decided to categorize the awards so that consumers did not have to analyze all 70 of them, potentially being discouraged in the process. Comprehension is a key to the success of apps, but is not necessarily sufficient. For consumers to act upon information, they need to trust its source. Trust cannot merely be assumed, as has become apparent from parents' lack of adherence to the US Food and Drug Administration (FDA)/UK Medicines and Healthcare products Regulatory Agency warning regarding the administration of cough and cold medication for children. In a study examining parents' trust of the medical system and its representatives, parental trust was highest for their pediatricians, and then for the pharmacists. However, it was substantially lower for the health system [22-24]. Further research is required to assess to what degree people trust their app and its recommendation, and whether this drives health outcomes. So far, apps have been referred to as a homogenous entity. Yet not all apps, it appears, are created equal in terms of

potential effectiveness, or are as accessible to consumers in terms of cost. Higher quality apps, ones that are based more on theoretical content, most notably the health belief model, are more expensive [25]. This may be a barrier for successful uptake in a target population. It has been suggested that future collaborations between behavior change experts and app developers could foster apps that would possibly lead to better health outcomes.

One final point of limitation is that of "marketplace interposition," where the consumer is to assume responsibility over his or her health. However, the availability of a good, relevant, and efficient app does not guarantee that it will be used by patients, let alone by patients who need it the most. A hint of the potential issues and potential self-selectiveness of patients comes from a study showing that smokers are at an increased risk for prostate cancer, yet less likely than nonsmokers or previous smokers to seek testing [18]. The creation of effective apps alone is not sufficient for improving health; thus, app development requires the close involvement of public health and clinical professionals who can directly speak to the health problems to be addressed and the functional requirements.

Clinical Perspective: Is mHealth Technology Effective in Patient Care?

Use of mobile technology in patient care may be attractive for two reasons: One is its magical appeal for those interested in global public health to solve one of the most difficult problems facing global health efforts—that of structural barriers to access [26]. Another is its promise in better meeting patients' needs and offering more effective and efficient health care services. Particularly in chronic disease lifestyle changes, drug adherence and vital sign monitoring play essential roles in therapy management [27]. The intriguing question is whether mobile computing offers effective and efficient system solutions for these requirements. Currently, mHealth interventions do not have sufficient evidence, which would allow a scale up beyond pilot studies. Systematic reviews on the topic by Free and colleagues found that while multiple studies have been conducted, many are of poor quality and very few have found clinically significant benefits of the interventions [28,29]. It seems as though providers using mobile communication technology to connect with their patients achieve an improved overall patient-provider communication [30]. Authors studying short message service (SMS; text message)-based appointment reminders showed a statistically significant but modest increase in patient attendance compared to no reminders [28,31,32]. However, text message reminders were no more effective than postal or phone call reminders and texting reminders to patients who persistently missed appointments did not significantly change the number of cancelled appointments [28]. Particularly in chronic disease (eg, cardiovascular disease, chronic obstructive pulmonary disease, HIV infection, chronic kidney disease, and diabetes), lifestyle changes are a key component of the therapeutic management to reduce morbidity and mortality [33,34]. In their meta-analysis, Free et al identified 75 controlled trials (studies that compare the outcomes of people who do and do not receive an intervention) of mobile technology-based health interventions delivered to health care consumers that met their predefined criteria [29]. Twenty-six trials investigated the

use of mobile technologies to change health behaviors, 59 investigated their use in disease management, most were of low quality, and nearly all were undertaken in high-income countries [29]. In 1 high-quality trial that used text messages to improve adherence to antiretroviral therapy among HIV-positive patients in Kenya, the intervention significantly reduced the patients' viral load but did not significantly reduce mortality [35]. In 2 high-quality UK trials, a smoking intervention based on text messaging (txt2stop) more than doubled biochemically verified smoking cessation [36,37]. Other lower-quality trials indicated that using text messages to encourage physical activity improved diabetes control [38-41]. Combined diet and physical activity text messaging interventions also had no effect on weight, whereas interventions for other conditions showed suggestive benefits in some but not all cases [41].

Lessons Learned for Future Projects From the Clinical Perspective

On setting up a mobile communication intervention, one needs to bear in mind that next to the above-mentioned psychological factors, text messaging is more likely to work under a set of ideal parameters to include [26,42] the presence of follow-up; messages that are highly relevant in frequency, wording, and content; and personally tailored interventions.

The need for improved health is apparent. Chronic disease is on the rise, and some attribute it to factors that cannot easily be changed, certainly not with digital tools, such as increasingly busy lifestyles, unhealthy eating habits, and a highly competitive workplace [43]. On this theme, it has been proposed that collaboration between patients and physicians, one that takes into account limited time resources through a remote health-monitoring service, may provide an end-to-end solution. The goals for such a service, which would be operated via a mobile device, collect data, for example, blood pressure readings or weight from the patient through a mobile phone, provide these data to doctors through a Web interface, and enable doctors to manage the chronic condition by providing feedback to the patients remotely. Whether such systems will be effective and efficient is difficult to say. So far, evidence on telemonitoring (eg, hypertension and cardiac failure) is not allowing a general implementation for all patients [44-47]. It will be interesting to see whether mobile applications in the hands of patients will facilitate telemonitoring of chronic disease and allow a more widespread deployment. Finally, despite the aforementioned evidence, most mHealth interventions can be seen as the equivalent of black boxes [26]: The problem of pilot studies in text messaging is that a particular style of a black box application is compared to a situation without any black box application. The question for future trials is what generic functions of mobile technology are being deployed by users. In this context, further randomized controlled trials are necessary. Novel research designs such as data farming in cooperation with service providers may increase the evidence base and offer new insights regarding how to best implement such new tools.

Technological Perspective: Anything Goes?

Overview

Driven by the rapidly changing innovation cycles in the telehealth solution environment, it seems that everything can be solved relatively quickly. Many press releases give the unrealistic impression to the public audience that everything is possible. If there is the perception that an app is an "independent piece," this is wrong.

App Development

From a technological perspective, a mobile application is the result of an interweaving chain of many hardware and software components. The complexity is increasing with each additional hardware component and each new software release. The "Continua Healthcare Alliance" with their standardization and certification processes may help attenuate this phenomenon [48]. In addition to overall complexity, limited power supply remains an additional concern. For this reason, long-term mobile wireless monitoring is currently not feasible. In addition, software development and maintenance faces the problem of ever-increasing potential variations in end-customer apps. There is a cascade of at least 4 large operating systems for smart devices, nonstandardized drivers, and protocols customized by different mobile phone producers, and programming and design techniques, resulting in an exponential number of configurations for apps. When developing for telemonitoring, there is a choice of several new, partially mutually exclusive wireless-standards: Bluetooth Low Energy, ANT+, NFC, and ZigBee.

The level of support of these standards by mobile phone producers and operating systems is quite heterogeneous, reaching from "not at all" to "partially working" to "full support." The older and much better implemented standards such as Bluetooth 2.0 or WiFi have high energy consumption and are electromagnetically problematic in hospitals, airplanes, etc. Even within one operating system, pressure to update is high: Customers are urged ever increasingly to allow auto-update on their smart devices. Declining auto-updates often results in malfunctions of apps or even the basic functions of a mobile phone or tablet. Changes in operating system generations can be quite drastic, as Microsoft demonstrated with its change from Windows 7 to Windows 8. Even though Windows 7 apps still run on Windows 8 computers, they do not have the same look and feel as the new apps and have to be started from the old desktop, which Microsoft originally wanted to remove completely but had to re-introduce because of pressure from users groups. Furthermore, Windows 7 applications cannot access some of the new hardware such as Bluetooth Low Energy. Another example is the market leader for mobile devices, Android, where at least 5 layers of software affect the function on an app (eg, for heart rate-monitoring): the hardware drivers for phone components, the official Android version, the customized Android components, the wireless protocols, and design and software components.

Each of these layers can change independently and may force the others to follow, and for every new combination, an app

update may become necessary [49]. Apart from increasing costs, this poses a significant problem for the development of medical devices: According to regulations, any change in medical software automatically leads to a new certification process [50,51]. This is further aggravated by the installation of additional or new versions of apps on smart devices, sometimes not even voluntarily but rather caused by automatic updates running in the background. These newly installed apps may influence the medical app, so that a medical application running on a mobile phone would actually have to be recertified several times a week. Some producers have therefore branded their own versions of operating systems, albeit with relatively high costs, restricting automated updates and installation of foreign apps. Apart from the logistics effort this implies, it also frustrates end users because they either have to accept a separate device for their medical app or sacrifice the personal freedom of their mobile phone. If a producer decides to ignore regulatory requirements of recertification necessitated by updates, he does this at his own risk, with potentially unproportionally expensive lawsuits involved. In combination with rapid development cycles, the resulting maintenance and development costs have had a noticeable negative influence on business cases [52]. A positive aspect and hope for future products is the availability of new instruments for producers and developers to roll out and maintain their software products [51]. Nowadays, all mainstream operating systems feature their own app stores that include easy-to-use mechanisms for auto-updating. Software frameworks for apps support unit testing. Low-energy wireless protocols seem to reach a standard and are implemented on more and more devices. By conforming to these standards, and by prioritizing the opportune planning of test environments, many of the foreseeable problems resulting from updates can be mitigated.

Technological Challenges

So far, mHealth is evolving as a patchwork of incompatible applications that are not interoperable [53]. Mobile devices, medical hardware, and health information often cannot communicate with each other and share data. There is good evidence that improved therapeutic management can be achieved through an integrated health systems strengthening approach [54]. One may expect that enabling mHealth systems to share information with one another as well as with broader eHealth systems can increase efficacy and efficiency of patient care and reduce cost associated with data collection. International collaboration between industry and research institutions is vital for developing standards that are approved by all stakeholders. This demand for "interoperable systems" is going along hand in hand with the aspect of "open standards" [53]. The latter are crucial for equity in eHealth and mHealth. As discussed on the World Health Organization forum on data standards, there is a danger that closed standards may create a knowledge barrier for developers in low- and middle-income countries [55,56]. There are authors discussing the need for a governing body, for example, the World Health Organization, to certify such open standards and enable countries' access to standards that meet key criteria [57].

Legal and Regulatory Perspective: How Can We Make Medical Apps Trustworthy?

Overview

Transparency is a vital aspect for users and customers of a market that has low entry barriers and is flooded by mobile apps. Authorities are called on to develop regulatory instruments to ensure users' safety, which on the on the other hand may slow down technological and scientific developments.

A Good Mobile App

As mentioned before, being easily accessible and highly available makes smart devices, such as smartphones and tablet personal computers very attractive for both private and professional areas of application. Nevertheless, there are certain professions in which special care must be taken when making use of such devices and the medical field is one of them. In a medical context, when mobile smart devices are used in combination with add-ons that are connected either directly or via some wireless technology, for example containing additional sensors for fulfilling their purpose, such as for measuring blood glucose levels, manufacturers already have to conform to the usual laws and regulations that are in place for medical devices, although depending on the jurisdiction, they may or may not be well adapted to the specifics of mobile devices. Usually, regulation does not only encompass hardware-based add-ons but also extends to an app running on the smart device. When used in such a combination, the need for regulation may be easily obvious and once conformance has been proven, may indicate a certain level of trustworthiness for users. Still, standalone smart devices and the apps running on them may also pose a significant threat to a patient's safety and privacy if the necessary safety measures are not observed. A more casual user might not even notice flaws and shortcomings of the mobile device itself or its apps, although there are a number of potential problems to keep in mind. Among others, issues may range from not all promised functionality being available to outright miscalculations, erroneous or incomplete content, technical deficiencies, and other usage restrictions. In addition, because nonprofessional users of medical apps often do not have sufficient backgrounds, they may often be unable to judge whether the information they are being confronted with is correct. In a worst-case scenario, an app might give a user a false sense of security, thereby keeping him from seeking medical advice and help in a timely manner. One such example was shown in a study about apps that make use of the camera functionality of mobile devices to judge whether skin lesions are suspicious [58]. With the exception of 1 app that simply provided a means to upload the acquired image data to (remote) professionals for evaluation, all other apps (that were based on automatic image analysis) did not have an acceptable recognition rate. If such an app falsely gives an "all clear," a patient with a malignant lesion such as melanoma might not seek medical help in time and might thus have considerably lower chances of being cured. This is only one of many examples of why—despite all recent advances in the area of mHealth technology as well as health apps and medical apps—appropriate measures must be taken to ensure that such apps conform to necessary standards.

Regardless of their purpose, apps used in a medical context need to be trustworthy, safe, and their user interface must allow efficient use. Especially when apps are used by health care professionals while working on patients, regulatory aspects become relevant because such apps might be subject to applicable medical product laws in the country where they are to be used. The aspect of an "app = medical device" is not trivial because using an uncertified application in a professional setting may lead to legal consequences for both the health care provider as well as his employee, for example, the health care professional who uses the app. Therefore, apps applied in this context also need to follow applicable laws and regulations. In fact, there is a lot of confusion about this topic because manufacturers are often unaware of the fact that their product might be required to undergo the same regulatory processes that are applicable for fever thermometers or cardiac catheters. Nevertheless, it depends on the manufacturer's declaration of the intended (medical) use of a product whether regulations are applied.

Regulation

Whether a smart device or app is classified as a medical device depends on its intended use described by the manufacturer. If the intended use matches certain criteria, the manufacturer has to ensure that all appropriate regulations are observed. For the European Market, manufacturers can refer to the MEDDEV Guideline 2.1.1/6 that was published by the European Commission in January 2012 [59]. Although it is legally not binding, it can be quite helpful in interpreting the appropriate European regulation. When it comes to software products, including mobile apps, an application is assigned the label "medical device" if it is intended for diagnostic or therapeutic purposes. Examples may include software that monitors specific parameters of the patient such as the heart rate or other physiological parameters in office settings or even in intensive care, but also software that allows measuring parameters such as the interpedicular or sagittal diameter of the spinal canal from previously acquired image data. It is always necessary for a manufacturer to obtain a CE label for a product falling under the medical device directive before he is allowed to put it on the market. This CE label can only be assigned after the product has successfully undergone appropriate conformity assessment procedures. The details of the regulatory processes vary depending on the risk category to which the product has been assigned. There are similar rules overseas: In the United States, if a device falls under regulation, manufacturers need a premarket notification; a letter of substantial equivalence must be obtained from the FDA. Without this, commercial distribution of such a device is prohibited. The FDA published a guideline aimed at developers of mobile medical apps on September 25, 2013 [49]. Its intent is comparable to the MEDDEV guideline published by the European Commission.

FDA Guidance on Mobile Medical Applications

The aforementioned guidance document published by the FDA is meant to provide clarification regarding the kinds of products that will warrant a closer look by the FDA in the future. Manufacturers as well as members of the US congress have eagerly awaited the finalized guidelines. In its final form, the guidance document only marginally differs from the draft version that the FDA put up for discussion in July 2011. According to the FDA, 130 comments were taken into account, most of which were affirmative of the draft's objectives [60].

For the time being, apps that can be classified as medical products but only pose limited risks for their users will not have to undergo regulatory procedures ("enforcement discretion"). The FDA describes this as a "risk-based approach." This is meant to alleviate concerns about discouraging innovation by putting up regulatory obstacles while still providing adequate protection for consumers. There was only little overt criticism of the guidance document, probably because the FDA refrained from also holding manufacturers of mobile phones and tablets or operators of app stores accountable. Instead, the FDA primarily focuses on apps that convert a conventional mobile device into a medical device or are meant as an accessory to an already regulated medical product. The FDA remains vague about which risk classes apply for apps and accessories and about which exceptions might apply—many interpretations are possible and some uncertainty remains. Because requirements posed on the products depend on the guidelines, the FDA will probably have to integrate clarifications into the guidance document in the near future.

Nonregulated Apps

Existing laws and regulations are only applicable for a rather small number of apps. The FDA counted only 140 medical apps with FDA approval to date. In addition, governmental regulations only apply to a limited number of apps. There are a number of private certification initiatives [61] for apps that do not have to undergo official regulatory processes, but these usually target professional developers or larger companies with sufficient financial background to pay for certification. Both official regulation processes as well as private certification are often not only expensive but also time-consuming and as such, they are not very attractive, even for those who are willing to conform to the necessary standards.

Although an advantage of private certification initiatives is that they often publish their results quickly, these initiatives often have their own test standards that are usually not disclosed; thus, it often remains unclear how they come to their conclusions. The same holds true for another popular source of information. Although many users rely on articles posted on blogs and other Web pages as well as user comments that can be found directly in the app stores to obtain basic information about an app, the presented information is often questionable because there is often only limited information about the authors' backgrounds.

Nevertheless, to not gamble away the large potential apps and accompanying mobile devices offer for all kinds of applications, including medicine, providing users with trustworthy apps that are well suited for their purpose is very important. If users were to lose trust in such apps, this might have a negative impact on future sales and hinder future innovations. In addition, one important question remains: How can users be provided with sufficient and trustable information to allow them to judge whether an app meets their needs and whether they can trust it

while still keeping cost and effort for distributors and developers at an acceptable level?

Standard Reporting and Peer Review

The rapid development and distribution processes that are common nowadays do not make it easy for users to assess the safety aspects of using apps in a medical context. One solution with good potential might be to implement a "standard reporting" mechanism for such apps. The idea behind this is to provide manufacturers, developers, and distributors with a comparatively cheap and easy to apply transparent solution for providing potential users with the information they need to form an opinion about an app. This "standard reporting" should encompass all information about an app in a standardized way, which in addition to aiding users, could also simplify comparisons between similar apps and further discussions about the apps whenever desired or could even serve to support peer review processes. The main intent of standard reporting remains to provide users with adequate information to let them easily judge whether an app is trustable and meets their needs. To promote the discussion about standard reporting, an app synopsis was developed that makes use of the idea of standardized reporting [62].

App Synopsis

The app synopsis we developed is meant to serve as a blueprint regarding the way necessary information may be provided. A number of existing projects and initiatives use criteria that are similar to those specified by the "Apps Peer-Review" project instigated by the *Journal of Medical Internet Research* (JMIR) that was launched in 2013 [63]. Many of the aspects included in the proposed app synopsis [62] are also already covered in the JMIR mHealth disclosure form [64]. Most of the existing projects make use of certification processes and/or review processes. Evaluation results are commonly published using specific channels, for example, a Web page provided by the project or in a scientific journal. For casual users who might not be informed about the existence of such projects, this approach has the disadvantage of low visibility of such evaluations. Also, those who are currently in the market of "app testing" come from many different—often commercial—backgrounds and their funding strategies as well as their areas of interest often differ, ranging from taking a look apps for only a single disease to targeting health apps in general. In some cases, it also remains unclear whether commercial interests might have undue influence on the results and which standards are applied while an app is being evaluated for certification. For example, only recently, the Health app certification program Happtique was halted [65] after an independent evaluation of 2 randomly selected apps out of 19 that had previously been certified by Happtique found serious deficits in these apps, for example, unencrypted personal health information and passwords. These diverse structures do not make it easy for consumers to find the information they need and to judge whether results obtained and published by such entities can be trusted.

The app synopsis on the other hand has a slightly different focus. It tries to integrate aspects from various initiatives that deal with Web-based medical content or medical apps, but there are also some notable differences. In contrast to other initiatives that were previously initiated for Web-based medical content (eg, HONcode [66]) and rely on providing users with evaluations of the content by experts or rating organizations (eg, medCERTAIN [67]), the information for the synopsis is being compiled by the manufacturers or developers themselves and is open for scrutiny and discussion by all interested parties, including experts, and patients. Although in parts, the predefined structure of the synopsis makes use of similar criteria for compiling the information, it keeps everything on a basic level that—in addition to answering questions customers commonly have—can also serve as a starting point for additional, independent testing, for example, by helping to identify appropriate test methods or to find suitable experts to help them with their assessment based on the available information. For users, this means that in addition to an expert's evaluation that may be valuable, but may also be biased, they can also access unfiltered information provided by the manufacturer to use in addition to any expert opinions they may find. Thus, altogether, they can use both kinds of information to form their opinion.

Another aspect in which the app synopsis differs from approaches that are available for Web content is that, with the progression of technology, new challenges arise and need to be addressed: users often entrust apps running on their personal devices with (potentially confidential) health information that they would hesitate to enter on a Web page. In addition, mobile devices go even further when collecting information: in addition to what users enter, they can also evaluate data acquired via integrated sensors or additional external sensors for diagnostic purposes and to support decision making on health aspects. One problematic example has already been illustrated above for apps that aim at diagnosing skin cancer [58]. This can also lead to a higher level of risk for users: not only do they have to be able to determine whether the information (diagnosis and resulting advice) they are presented with can be trusted, but also whether the app can be trusted with respect to data security and data protection. For apps, this is certainly also being addressed by other initiatives such as the JMIR Apps Peer-Review [63], but, instead of keeping the compiled information in places that might be "out of sight" for casual users, the results of the synopsis are meant to be published at places where users often first try to get information: the respective app stores as well as manufacturer's home pages. All in all, the provided information can also be used for an unofficial but collaborative evaluation process of all interested parties, for example, patients, doctors, but also competitors; this may also be an additional building block on the path toward informed patients in the information age.

Conclusions: Collaborative Strategies Vital to Help Sustain Growth in the mHealth Business

Undoubtedly, the use of mobile technologies in a medical context is highly attractive for patients, doctors, and administrative staff as well as researchers, but in part for different reasons. When using mobile devices and apps in a health context, patients usually have convenience in mind but

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would also like to stay in control of or be better informed about certain aspects, for example, by recording and evaluating data about their health. This is also emphasized by the continuing growth of the "quantified self" movement. On the other hand, on top of medical aspects, doctors, as well as administrators, hope for help with certain administrative headaches and cost savings [2]. Regardless of their backgrounds, all users want apps that they can trust, although what contributes to "trust" can be quite different depending on the user's perspective: this may range from an app being easy to understand from the user's point of view, providing sufficient background information, to studies that support an app's efficacy as appropriate measures being taken with respect to privacy, security, and data protection.

Legal and regulatory aspects must also be kept in mind [62], as well as data security. If mHealth technologies and applications are to be widely adopted, vendors must respect all these requirements. Concerning research, numerous studies have been published that are based on researchers' best guesses about optimal app-based implementations of specific interventions, yet only a few randomized controlled trials have been published that take a look at the overall situation. With respect to development, additional emphasis must be placed on context analysis to identify which generic functions of mobile information technology best meet the needs of involved stakeholders. Hence, interdisciplinary alliances and collaborative strategies are vital for achieving sustainable growth in the field.

Acknowledgments

Conflicts of Interest

None declared.

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