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Abstract

Healthcare service systems require care follow-up procedures using clinical practice guidelines targeting specific patient groups. Studies have introduced various methods for providing patient care, but system design for follow-up support remains limited to a few specific types of disease management. A general need is identified in a climate of increased demand on fewer doctors, for which mobile systems can provide solutions. In this paper, we present a post-treatment follow-up Decision Support framework for use by patients and physicians. The proposed care support is cloud-based and offers online and asynchronous Patient-Physician interaction, with a ratings system designed to ensure continuing improvement in outcomes. Using a design science research process the solution framework has been prototyped and evaluated with representative physicians and users. Our framework provides a model for extending care service systems to inform better follow-up decision-making.

Keywords Follow-up care, clinical decision support, healthcare systems, m-health, doctor ratings.

INTRODUCTION

Although in healthcare post-treatment service is generally important, patients often have limited access to physician interaction due to location, time or availability, and discussion or clarification of medical information or treatments in detail can be compromised. Lack of time during a visit to the doctor and the infrequency of subsequent visits to the doctor are perceived as important barriers to communication and effective healthcare outcomes, particularly regarding chronic diseases and satisfaction (Dugdale et al, 1999; Hinton et al. 2007) implying a need for more effective post-treatment follow-up services. Likewise, public health crises such as opioid addiction and antibiotic ineffectiveness can result from excessive or unnecessary repeat prescriptions and uninformed self-medication choices, resulting not just in poor healthcare outcomes, but in poor value from a cost-benefit perspective (Qaseem, 2016). In countries where treatments are not fully insured or covered by national policies, lower-income patients may also drop out of necessary treatment regimes, or be unaware of lower cost alternatives.

This situation is set against a global shortage of doctors and other healthcare workers, projected to be over 14 million by 2030 (WHO, 2016), particularly in Africa and SE Asia, but is also an issue in rural areas of Australia, which has an ongoing problem managing healthcare worker supply (Patty, 2017). According to the World Health Organization, 44% of member countries have less than 1 physician for every 1000 people. In Bangladesh, the ratio of doctors/population was 1:12690 in 2015 and both this figure and the doctor/nurse ratio are far below the WHO recommended Standard (http://www.theindependentbd.com/home/printnews/24301). Managing workload by reducing consultation time per patient is already compromising care in the UK (British Medical Association, 2016) who call for a new approach, such as primary care access hubs, adapted to local structures and geography, to increase capacity and support ongoing care. In this context, (mobile) health decision systems for follow-up care may provide an innovative support solution.

M-health (Mobile health) broadly refers to a mobile service or application for providing healthcare support to anyone, anytime, and anywhere (Chen et al. 2005). Utilising mobile phone, GPRS and Internet technologies, M-health provides health professionals, patients, clinicians and other relevant users with support services to manage, disseminate, collect, administer, control and monitor healthcare information and improve health service delivery and quality of care support. Follow-up decision support systems in the healthcare industry can be provided as real-time healthcare services via the Internet using smart devices after release from a hospital or clinic. In such systems, released patients can request information regarding ongoing problems from doctors authorized by the practice from which initial treatment was obtained, with identities managed via online systems or mobile apps.

The service provided by various m-health information systems (IS) applications, eliminates geographical and temporal constraints while enhancing coverage, quality, and cost savings (Varshney, 2014). As a sub-class of IS, clinical decision support systems (CDSS) are a type of specialised DSS application that directly aids in "clinical decision making in which characteristics of individuals are matched to a computerized knowledge base for the purpose of generating patient-specific recommendations (Hunt et al. 1998). Combining these, Mobile Decision Support Systems (MDSS) applications have been developed for supporting decision making in clinical and non-clinical settings. In the next section, we review the existing work in MDSS before describing the design of our solution.

STUDY BACKGROUND

MDSS studies developed over the past decade may be classed into three groups: A) mobile based CDSS for physicians and healthcare professionals (e.g. Martínez-Pérez et al. 2014; Anokwa et al. 2012; Karim and Bajwa, 2011); B) MDSS for outreach health workers (e.g. Praveen et al. 2014; Kuntagod and Mukherjee, 2011); C) and MDSS for public use or improving public healthcare (e.g. Ramesh et al. 2012; Fung et al. 2014).

Examples of the first type also include Krause et al. (2004), who introduced a MDSS for providing physicians with decision-relevant information on potential organ receivers, aiding assessment of forthcoming organ transplants and maintaining security of documentation. Michalowski et al. (2003) developed a mobile CDSS for emergency support of different acute pain presentations, while other studies in mobile based CDSS for medical emergency management have identified solution design requirements for emergency triage decision support (Peng et al. 2011).

Examples of MDSS solutions for outreach health professionals have also been designed, e.g. a tablet-based CDSS for cardiovascular disease management (Praveen et al. 2014) for use by non-physician health care workers and physicians in a rural Indian context. Others have been designed to enable consistent and quality primary healthcare delivery to rural populations and for ongoing pregnancy and

post-natal care (Maitra and Kuntagod, 2013). Such system solutions primarily support healthcare professionals or clinicians in their own practices rather than enhancing patients' self-management or monitoring of their medical conditions, through the exploration and utilisation of various online and offline data sources.

Helping to support decision making and planning by public healthcare professionals, Richard et al (2005) provide an example of web-based decision support relevant to the care of end-stage renal disease. This draws on a data warehouse of regional French data to visualize epidemiological information and relate e.g. dialysis unit location to geographical distribution of the disease.

In follow up care, systems addressing a number of other specific chronic diseases such as HIV and cancer have been developed. These have involved approaches such as virtual interviews (e.g. DeVault et al., 2014), and web based medical records analysis, along with specific systems for breast cancer follow-up (Abidi et al., 2007), cardiac conditions and HIV and tuberculosis management (Fraser et al., 2007). Piette et al (2001) investigated automated calls for diabetes monitoring whilst Singh et. al. (2009), and Green et al. (2010) focused on systems for cancer screening follow up. More widely, Epping-Jordan et al., (2004) introduced the Innovative Care for Chronic Conditions (ICCC) framework for designing healthcare systems at patient, organization and policy levels, and internationally effective models for ongoing management of pharmacotherapy are considered by Björkhem-Bergman et al., (2013), including tools for following up the use of medicines along with communication and education strategies.

Although there exists an abundance of m-Health tools available to increase the health literacy of users, there is a lack of theory-based m-Health tools to increase users' engagement (Voth et al. 2016). While the Internet as a platform is useful for altering the ways that people manage their health issues, the low health literacy of people becomes a barrier to understand the medical information given and subsequently follow instructions. Effective m-Health applications have great potential to improve users' health literacy and thus improve patient health. Studies show that using m-Health tools, additional communication and support for those who have low health literacy can enhance confidence and quality of life while improving their self-management ability for better health outcomes (Lyles et al. 2017).

Despite the individual value of specific tools, there is little evidence of attention to design of appropriate DSS, or of any framework to inform such a design. Design science research implies that an MDSS development design, if researched and reported as such, can suggest general principles to inform similar designs. To the extent that chronic diseases require ongoing management, albeit with the unique characteristics of each, there is a need for a solution framework that can guide rigorous development of effective MDSS that are relevant to real physician and patient needs. In the next section, we describe the design of such a solution framework.

RESEARCH METHODOLOGY

Our research process, outlined below follows the design science research paradigm described by Hevner et al. (2004). The framework balances both knowledge-based rigour and environmental relevance. We follow a cyclical iterative strategy for evaluation of our findings with health professionals (specifically, doctors). Furthermore, we engage in theory-building to develop a design model (Gregor and Jones, 2007) based on developed artefacts and the applied research process. In accordance with Gregor and Hevner's (2013) vision, we approach artefact and design theory as complementary outcomes of design science research. The design science research setting and its interrelated research cycles are depicted in Figure 1.

To begin, the relevance cycle connects the artefact development of the design cycle with its intended environment. It enables researchers to gather requirements in order to describe and later solve relevant problems and also to introduce artefacts to the environment. The rigour cycle relates the design cycle to the existing body of knowledge. Therefore, it informs the design activities and eventually enables the assimilation of the research findings by the knowledge base. Lastly, the design cycle is the central part of design science research and consists of the iteration of artefact development and evaluation. An artefact is iteratively constructed and evaluated, culminating with the output of a solution for the problem.

Our overall Design Science Research (DSR) process thus consisted of three design science research iterations as summarised in Table 1 below. These culminate in an evaluated and relevant IT artefact, and a rigorously documented theory, which becomes part of the body of knowledge and practice, potentially informing subsequent design /research projects. Details of these iterations now follow.
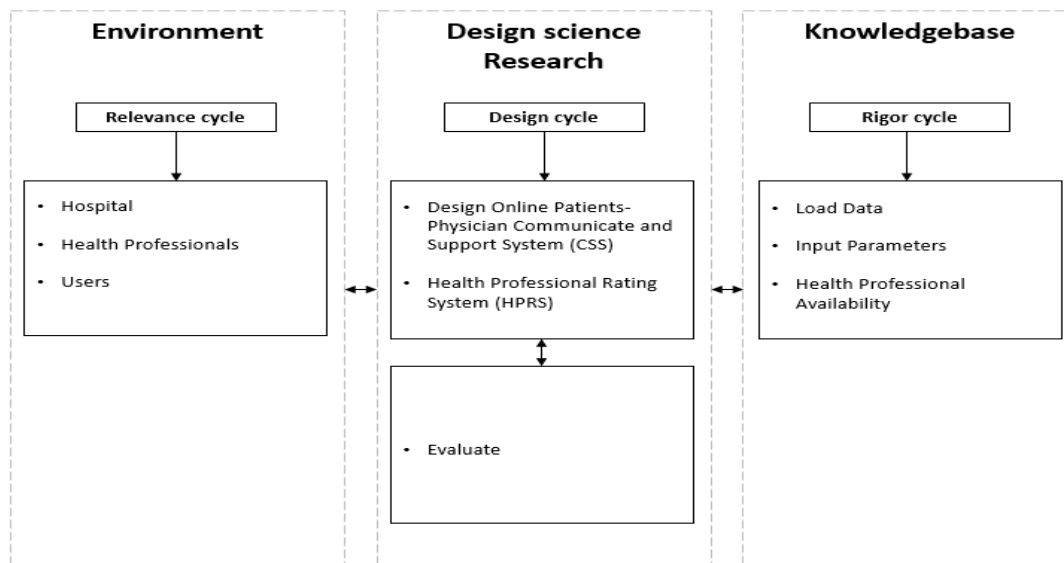
Figure 1: Design Science Research Setting

Iteration 1: Artefact Design

Relevance cycle: In several interviews with doctors and patients, we verified that the problem of having limited consultation time was as important and relevant as the literature had suggested. This directly impacted the possibility for patients to discuss or clarify medical information in any depth or to consider possible treatment options and outcomes in detail in post-treatment period. Interviewees also emphasised the lack of an online platform to manage communication and follow up patients in post-treatment period.

Rigour cycle: In the rigour cycle we identified knowledge relevant to the development of an innovative approach to communicate and follow up patients in post-treatment period. We identified that adoption and acceptance is a general issue and sought a solution approach that would address this. Literature reviewed in this cycle (Jha, 2015) suggested care quality improvement can be driven by publishing doctor ratings in user-friendly terms, and if done by (hospitals) themselves, helps build trust and obviate third party rating services whose methodology may neither be appropriately contextualised nor allow right of reply.

Design cycle: In the design cycle, we constructed the Patient-Physician CSS, and then constructed the Health Professional Rating System (HPRS) to incentivise physicians based on ratings, and aimed at motivating physicians to adopt. Although doctor rating systems are now beginning to emerge, (e.g. California's CPHI (Caqualityratings.org, 2017)), which helps patients to choose among doctors, we found no studies around incentivising physicians based on reputation ratings. Therefore, the idea of a user-based Health Professional Rating System (HPRS) emerged as a possible starting point to motivate physicians to provide better service, and patients actively to seek involvement in effective ongoing care.

Iteration 1: Artefact Design			
	Relevance Cycle	**Rigour Cycle**	**Design cycle**
Inputs	Support System/domain literature Health professionals Representative patients	Literature reviews	Online Health support model literature
Methods	Literature review Stakeholder interviews	Content analysis	Concept development
Steps	Search Literature Analyse relevant papers Discuss findings with health experts	Analyse publications Identify input knowledge	Design artefact Evaluate artefact

Results	Identification of need for online Communication and Support System for use in post-treatment period.	Communicate and Support System as a possible design starting point.	Patient-Physician CSS
Iteration 2: Implementation			
	Relevance Cycle	**Rigour Cycle**	**Design Cycle**
Inputs	Health professionals	Data analysis literature	Patient-Physician CSS, and HPRS
Methods	Workshop	Literature review	Prototyping
Steps	Formulate questions for workshop	Identify input knowledge for design process	Hold workshop to verify artefact
Results	Identify requirements	Patient-Physician CSS, and HPRS	Patient-Physician CSS
Iteration 3: Evaluation and Publication			
	Relevance Cycle	**Rigour Cycle**	**Design Cycle**
Inputs	Patient-Physician CSS Stakeholders	Development process	
Methods	Field-test	Publication writing	
Steps	Implement Patient-Physician CSS	Document DSR process and resulting artefact	
Results	Evaluated Patient-Physician CSS	Design theory This article	

Table 1: Overview of Relevance, Design and Rigour Cycle iterations

Iteration 2: Implementation

To evaluate the initial concept, we held a workshop as part of the relevance cycle. The participants of the workshop were two managing directors of a hospital, two employees of the IT department of the same hospital, two physicians, two patients/users and two of the authors. The workshop followed the general brainstorming method, consisting of two phases:

Generation phase: In this phase ideas about requirements are collected. Each participant formulated ideas and each of them was gathered without judgment.

Evaluation phase: The gathered ideas were discussed, categorized and merged when appropriate. Ultimately, the participants collectively came to an agreement on a finalized list of requirements.

The brainstorming process was applied using two different questions:

- What requirements for a Patient-Physician CSS could effectively solve the problem of limited time to discuss or clarify medical information in any depth in the post-treatment period?

- What Patient-Physician CSS requirements could motivate and incentivise physicians to provide better service?

In total, five general requirements were identified for the Patient-Physician CSS (see Table 2). Therefore, we started with a rigour cycle to identify input knowledge for Patient-Physician CSS development. We then analysed different data analysis methods for Health Professional Rating System (HPRS) to be implemented within the Patient-Physician CSS. To verify that requirements of the adapted concept and the Patient-Physician CSS were fulfilled, we held a second workshop with the same participants as the previous one. In due course, the concept and the Patient-Physician CSS were verified to have fulfilled all previously defined requirements, allowing for continued engagement of the third iteration of our DSR process. This design sequence is detailed further in section 4.

No.	Requirement	Description
RQ1	Reduce time	Reduce the time of patients/users in post-post-treatment period
RQ2	Online	Keep the service online using mobile app
RQ3	On demand	Keep the service on demand with premium charge
RQ4	Adaptive	The Patient-Physician CSS adapted by health professions or physicians

RQ5	Incentive	Add Professional Rating System (HPRS) to motivate physicians to provide better service

Table 2: Requirements for Patient-Physician CSS

Iteration 3: Evaluation

For Patient-Physician CSS it is important to evaluate artefacts in a real-world environment, i.e. in their intended fields of application. Therefore, we carried out a field test in the relevance cycle. We implemented the Patient-Physician CSS and tested its information dissemination feature for patients/users. Overall, the Patient-Physician CSS showed improvements in time and effort by patients to discuss or clarify medical information in the post-treatment (follow-up) period. Subsequently, we addressed the iterative design theory building process within our overarching design science research process. We applied a theory-building process (Venable, 2006) where we first reviewed the current design theory and evaluated the need for refinement. Then, if refinement was deemed to be needed, we iteratively adjusted existing requirements until all new knowledge was incorporated.

Having outlined our methodology we now turn to the specific artefact details themselves.

SOLUTION FRAMEWORK: DESIGN, IMPLEMENTATION AND EVALUATION

Our artefact, an Online Patient-Physician Communication and Support System (CSS) is a particular class of DSS, i.e. a communication-driven DSS (Power, 2002), simultaneously providing direct advice and answers and incidentally increasing health literacy. There is, however, debate on how far m-Health apps conform with the requirements to provide the best communication experience to the users (Becker et al. 2014). In designing an m-Health platform, a two-way communication and personalised contents were found to be useful for improving user engagement (Sigler, 2017). Therefore we designed an m-Health tool aiming to increase the users' engagement and lead to increased health literacy through users' adherence to the artefact's use.

Based on the results of the first relevance cycle, we engaged in a rigour cycle, seeking input knowledge for the design cycle. We identified the Health Professional Rating System (HPRS) to be used by patients/users to motivate physicians to provide better service via incentives or bonuses as a key input.

In the design cycle, we used the HPRS concept within the Patient-Physician CDSS. The HPRS makes the Patient-Physician CDSS more reliable, as more ratings by patients/users provide more incentive to the physicians to cement their reputation and more validity to inform other patients' choices.

Next we performed another relevance cycle by evaluating the concept and gathering requirements in a workshop with the hospital. The general requirements emerging summarized in Table 2 were translated into the mobile app design framework shown in figure 3.

Regarding requirements 1 to 4, workshop participants agreed that the design concept might fulfil those requirements. For RQ5, concerning incentivisation, a rating system was identified as the best option to motivate physicians to provide better service. RQ5 guided us to specific methods such that the patients/users could choose the available physicians based on the Rating Points.

RQ1 and RQ2 are related to the main objective of the artefact to reduce the time of patients/users in post-post-treatment period and making the service available in distant geographical locations online using a mobile app. Stakeholder requirement RQ3 will motivate the CSS provider by generating revenue from the premium charge, whilst RQ4 will motivate the physicians to provide better service upon receiving a monetary incentive. The intangible benefit of increased reputation is also incentivising and could be monetized in various ways, such as bonuses, which is enabled by implementing RQ5.

We subsequently developed an initial CSS, based on the requirements and the previously identified method for CSS construction. Firstly, we developed a framework to guide implementation of the required functionality. It consists of three parts (figure 3): Patient-Physician CSS, Software coding and Health Professional Rating System (HPRS). Figure 4 shows screenshots from the prototype interface.

The initial input for the Patient-Physician CSS is an input screen (figure 4a) where the users ask question (input data) or start a communication. Based on the question category, an index of recommendations of health professionals or physicians is shown from where the users start a communication for decision support.
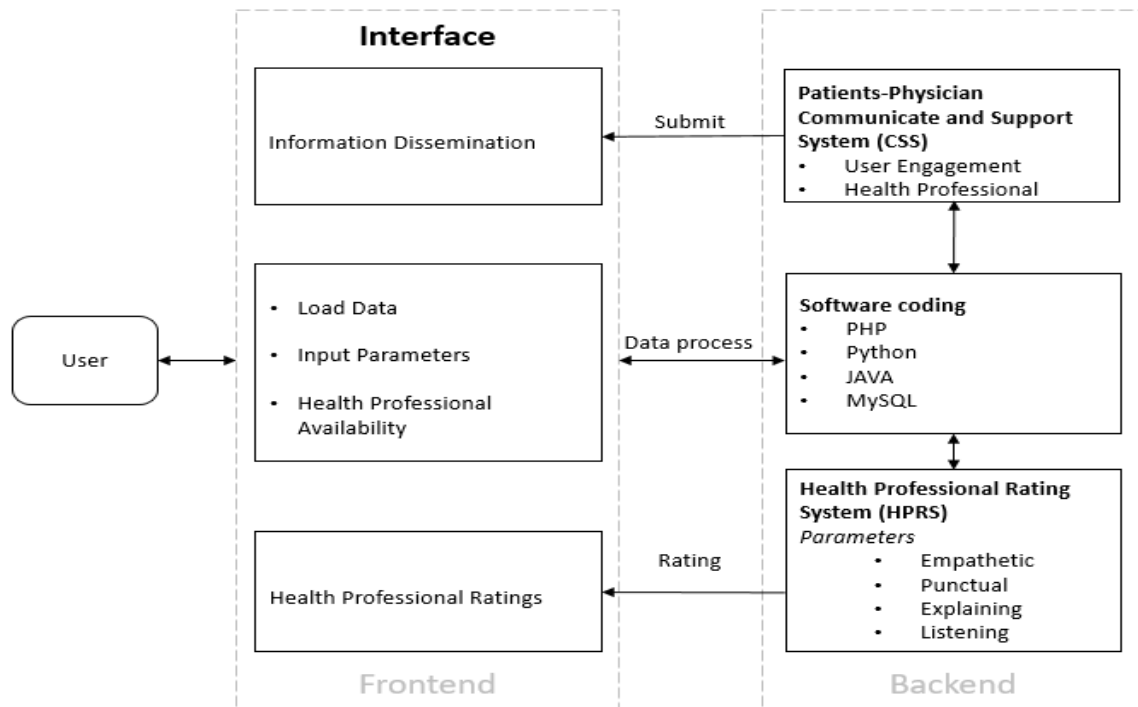
Figure 3: Patient-Physician CSS framework (frontend and backend) using in mobile app
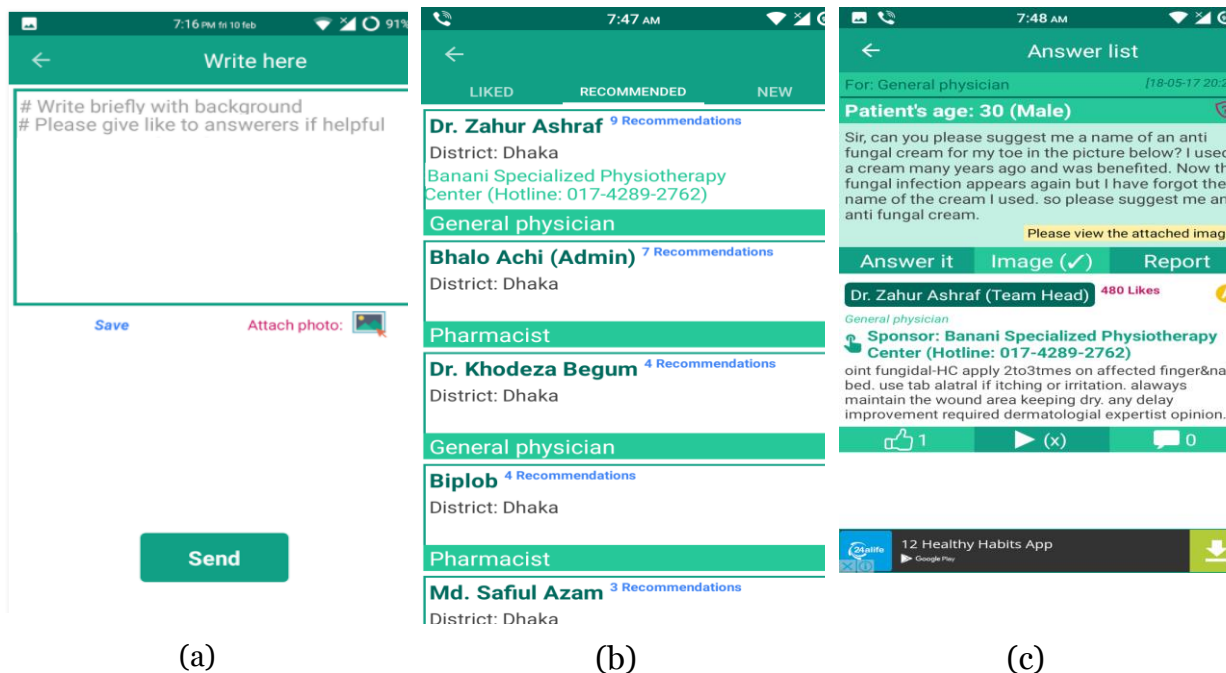

| (a) | (b) | (c) |

Figure 4: Screenshot (a) shows the input field by patients/users. Screenshot (b) shows the index of recommendations of health professionals or physicians generated by HPRS, and screenshot (c) shows how medical information is disseminated in the mobile app interface.

The index of recommendations shows who has better ratings for providing post-treatment service. The rating was done by the patients/users once the physicians submit data for information dissemination for decision support. The user uses four parameters (empathetic, punctual, listening and explaining) to rate a response by a health professional or physician. Eventually, a user is able to choose available physicians based on total recommendations generated by Rating Points [figure 4 (b)].

For the HPRS, (similar to familiar social media platforms) to maintain and improve the quality of contents and service by health professionals or physicians, our platform used a 'Like' button function (figure 4c), since a 'Like' button function is both easy and useful for utilitarian and compliance motivation and ultimately for quality improvement of the health information content. The final prototype was tested and released as an app on google play, and is provided as a cloud based service. Although, according to the terms and conditions, the "data security" and "data integrity" are ensured by the cloud service provider, for "users' privacy", we added an encryption function into our system. Encryption is a reliable technology for protecting users' privacy and it guarantees the confidentiality of the communication process. This choice is considered further in the final discussion section.

In our last research cycle, the Patient-Physician CSS was evaluated within its intended field of application. Hence, we used the mobile application version of Patient-Physician CSS to evaluate its scope, usability, efficiency and adoptability. When implementing for targeted hospital patients, the following criteria were applied:

1. The patient/user is a member of that particular hospital.
2. The patient/user is a premium member.
3. The physician is available for providing on-demand service (e.g. consulting with patients)

To evaluate the impact of the Patient-Physician CSS two focus group meetings were conducted on issues of usefulness and adaptability, one with three representative users, and the other with four doctors. The following comment from one physician indicates the perceived value and possible use: *"...(this) system will be very effective for those children, who are just released from hospital and have some conditions to monitor"*. This was augmented by a short survey related to the requirements, voluntarily completed online both by patient (21) and professional (10) users. Space limitations preclude further description here: details are available from the first author.

To evaluate the fulfilment of RQ1, RQ2, RQ3 and RQ4, we analysed user feedback and monitored the number of users and health professionals using the mobile version of Patient-Physician CSS. Patients "would be happy" if they get useful feedback from the hospital management after receiving primary and/or major care. According to their feedback, the majority (67%) of respondents are happy to use the mobile based user interface in the latest released version. Additionally, the amount of queries by the users increased by 11% after making the interface more user friendly. While the level of adoption by users and physicians showed continuous increase, according to our survey, the addition of a real-time video consultation function "would make the CSS more useful". One respondent, a business man with little time to care for an aged parent suffering a chronic disease, stated that- *"treatment system via video call reduce time to obtain useful medical information and prescriptions of new medicine"*. He, like some others, would be willing to pay for such a type of service.

Regarding RQ5, the survey showed that health professionals are definitely interested in receiving incentives through achieving more ratings from the users. One respondent noted *"healthcare professionals will be motivated to get 'LIKEs' due to self-esteem"*, additionally, it was found that according to the health professionals, our CSS was considered useful by users to make them more informed and empowered. In the post-treatment period, the CSS provides the users (physicians and patients) a more efficient two-way relationship, which not only simplifies evaluating the clinical information but also enhances effective communication.

OVERALL DISCUSSION AND CONCLUSION

A need was identified to improve follow up care to patients in a climate of fewer doctors and reduced time for in depth consultations and advice. This need was verified as relevant to healthcare practitioners and patients, and operationalised into general requirements for a decision support system. This research was based on the premise that m-Health technology enables patients to become more informed, empowered and active participants in the process of clinical decision-making, thereby helping improve their health condition, and creating a stronger, more user-centred patient-doctor relationship. A mobile platform was seen as a basis for an innovative solution, involving an app designed to provide ongoing advice and education to patients on-demand, saving time for patients and doctors alike. An easy to use rating system was incorporated, designed to inform patient choice, and to incentivise adoption by practitioners. The system was prototyped, refined and released publicly before evaluation. The results confirmed increased efficiency in reducing the time of patients/users to start a consultation or communicate in post-post-treatment period, and positive evaluation by doctors for incentivisation provided by the ratings system. User friendliness was a guiding design principle, since patients may be low both in health literacy and skill in analysing ratings reports (Jha, 2015), and when the interface was refined to increase this aspect, usage increased by 11%.

Our user generated data are hosted in a rented cloud, which acts as a platform-as-a-Service (PaaS). This platform provides us the freedom of application design, application development, testing, deployment, hosting, application service integration, database integration, security, data scalability, storage, data backup, data conversion and persistence. Although to ensure the "data security", the cloud provider employs redundant servers and routine data backup processes, we also keep routine backup from our side. On the other hand, the cloud provider also ensures "data integrity" which means our data are protected from unauthorized deletion and modification and as well as misinterpretation. The data integrity ensures that the intended data is correctly retrieved by the intended users whenever required. Together with (hospital) policies on security and privacy of patient data the cloud platform ensures scalability and potentially global usage.

DSS design research have been explored in many application domains (e.g. supply chain management (Miah et al. 2013), agricultural management (Miah, 2012)). In this paper, we attempted to further apply our previous DSS design understanding into a public healthcare domain. There are some limitations to this work which suggest directions for further research. The prototype was developed and tested in Bangladesh, which has a critical shortage of doctors. Whilst many other regions have similar issues, cross-cultural testing and design adaptation could usefully be investigated. Although operational viability has been established, more systematic evaluation on a larger scale will suggest further refinements to the design, and useful functionality that may be added such as location analytics, video consultation and perhaps text mining to establish common questions, model responses and the like that can be partially automated or filter queries intelligently. The robustness of the ratings system and indeed its effectiveness requires a separate evaluation: reputation and recommender systems provide models, but rating doctors has proved controversial in the past, and might require careful management by the healthcare providers, as Jha (2015) has suggested. Our model assumes the service is not cost free, and both doctors and providers were concerned with the financial aspect. The cost around the services is therefore likewise a separate area for investigation: whilst some respondents were prepared to pay for an on-demand service issues of equity, ability to pay and the like must be considered if such solutions are to be adopted in public healthcare regimes. Similarly, tying bonuses to reputation may require a closer examination if adoption is contingent on such an aspect.

These are possible directions for the future however, and we hope that the general approach described in this paper suggests a design basis for particular models of follow up care and effective consultation.

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