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DEVELOPMENT OF A PROTOTYPE MULTI-TOUCH ECG DIAGNOSTIC DECISION SUPPORT SYSTEM USING MOBILE TECHNOLOGY FOR MONITORING CARDIAC PATIENTS AT A DISTANCE[1]

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Abstract

The aim of this paper is to describe the development of a multi-touch measuring tool for a mobile ECG telehealth decision support system (DSS) prototype, which will be capable of providing remote mobile communication to speed up diagnostic decision making. The prototype developed is able to display three dimensional multi-layers on a mobile device such as a smart phone extracting ECG information from a web server. Users will have access to the mobile ECG decision support system whether their hand-held device runs Android OS, iPhone iOS and Window Mobile OS or any other multi-touch screen smart phone. By adopting the theory of technology acceptance, data is analyzed using content analysis to understand what is important and desirable in an ECG decision support system. Managing ECG patient care with modern wireless devices is expected to improve the quality of care. This new development offers an ECG diagnostic DSS that has proven to be simple to use by healthcare professionals delivering a patient's ECG data recording on a smart phone device in a readable format. This paper provides an example of a DSS prototype to deliver an ECG signal to a multi-touch hand-held device that is acceptable to users.

Keywords: Mobile Electrocardiography (m-ECG), decision support system (DSS), multi-touch, Health Informatics, Telehealth, Medical Informatics.

[1] This is a research-in-progress paper. Contributions stated are predicted expectations but further insights may be revealed.

1 INTRODUCTION

Heart disease is the leading cause of death, causing nearly 36 percent of all deaths in Australia and estimated 785,000 Americans had a new coronary attack in 2010 (BetterHealth 2008; CDC 2011). Heart disease is rapidly becoming one of the most serious diseases that threaten human beings. With the increasing demand on health care services for cardiac disease, there will be a significant shortage of physicians trained in critical care. Kjell (2009) has estimated that by 2020, there will be a deficit of intensivist that is equal to 22% of demand, and by 2030, this deficit will approach 35%. To cover this deficit, information and communication technology (ICT) can be used to reduce the time taken for diagnosis and treatment, especially in the rapidly increasing area of cardiac disease. One of the rapidly growing areas of telemedicine is the application of ICT to long term and long-range cardiovascular disease patient monitoring at a distance from a hospital or clinic. This is made possible with emerging electrogram instruments, which are used to record arrhythmia events when they occur and allows ECG readings to be reviewed by a cardiac expert. An ECG is the primary tool used for diagnosis and to understand the severity of a myocardial infarction or heart attack. It is important for patient survival for a clinician to receive patient information pertaining to possible detrimental change of condition as quickly as possible.

Previous research has shown that reducing the time between assessment and hospital admission reduces treatment time by one-third (Cheng et al. 2006). Recent advances in the ICT domain, such as mobile technology, computing power and memory size of mobile devices have increased the application of technology to ECG monitoring (Fang et al. 2008). A wireless ECG instrument has the ability to work with mobile phone technology specifically by ameliorating patient monitoring and sharing details between GP and specialist physician in private and public hospitals, enhancing the speed of assessment and efficient decision making about the treatment required.

The use of smart phones in health care is reported to improve decision-making, reduce medication errors, and patient care, which indicates that such a device might be a useful as part of a medical decision support system (DSS) (Chiarugi et al. 2008). This study focuses on developing a mobile ECG diagnostic decision support system, a new representation of the ECG signal-measuring tool in smart phone devices such as iPhone, iPad and Android phone. With new generation mobile technologies, which are able to receive signals from ECG instruments, cardiovascular diseases and other existing heart diseases can be detected accurately and early. To help experts to better diagnose and make care decision this study has developed a prototype using the latest technology of multi-touch for a diagnostic measuring tool. This mobile ECG DSS device poses challenges in the way diagnosis and care practices are carried out in cardiac care medicine. Testing was performed in the prototype to assess its acceptability by physicians and care givers, using the technology acceptance factors (Nesaar & Jean-Paul 2009).

2 METHOD

2.1 Users

Initially, a small number of users (13 users), having ECG experience in hospitals, were invited to participate in this research. The sample size was limited but mobile health technology development usually involves a small number of participants due to instruct and provide support to participants (Lindquist et al. 2008). This study interviewed doctors (9) and nurses (4) during the latter quarter of 2010 and they were a part of the demonstration of the

mobile ECG DSS prototype. Prior pilot testing was conducted to evaluate the appropriateness of selected mobile platforms and technical robustness of the system as well as the user interface (DSS). Twelve users met the criterion of having ECG experience and they tested the mobile ECG DSS prototype with a multi-touch measuring tool running under iOS (iPhone /iPad operating system) for two weeks. The interviewees answered a questionnaire before and after their use of the device running the DSS. There were no dropouts and only one doctor had no pre-hospital experience but is a high level of expert in mobile medical treatment relating to other diagnosis areas.

2.2 Materials

The mobile ECG DSS prototype is a web-based system where hand-held devices running Android OS, iOS (iPhone OS), Web OS or any other multi-touch supported smart phone, is able to retrieve ECG signals or readings using the built-in web browser.

In this mobile DSS, patients' data transmitted from a mobile ECG device are pre-analysed using multimodal analysis engine. The results extracted from different modalities are used to create a multimodal metadata repository along with a multimodal feature index for efficient search. The mobile ECG DSS interface uses Cascading Style Sheets 3 (CSS3) and HTML5 makeup language to perform a physician's examination of a patient's record. In this way, when a physician selects each ECG lead (up to 12 leads) recording, the current patient data is retrieved from the multimodal index and establishes a graph looking much like a line graph, composite inline, box plot or pie chart to support diagnosis, similar to what would appear on an ECG printout. The DSS report generation module pools diagnosis graphs associated with a patient's record to form statistical summaries to aid diagnosis. Sample output from the mobile ECG DSS as is displayed on a smart phone (iPhone) is shown in Figure 1.

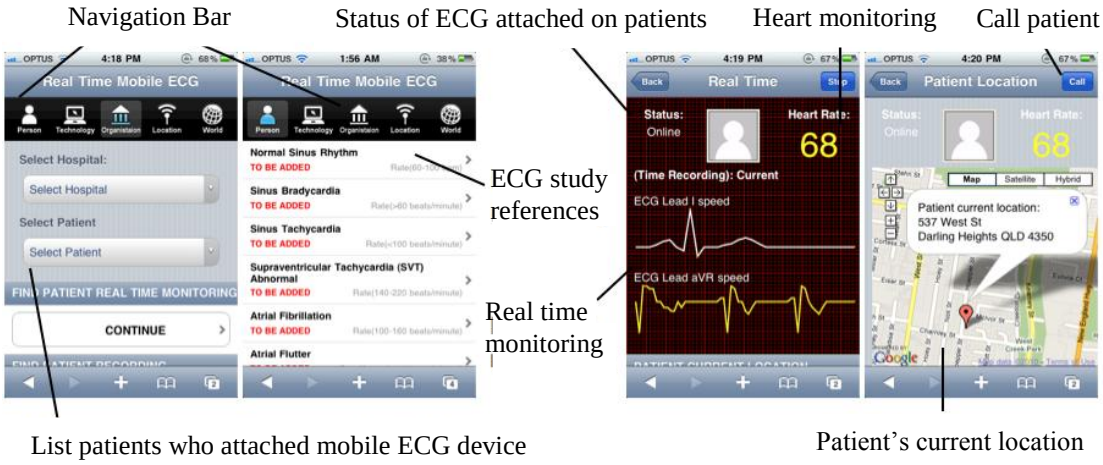

Figure 1. The mobile ECG decision support system in a smart phone device

Another main development of the prototype mobile ECG DSS involves a multi-touch measuring tool, which has the ability to reduce diagnosis time. The multi-finger interaction is a common experience that supports typing and executing key commands that are discrete serial actions (Tomer 2006). The goal of this multi-touch and multi-layer processing is to make it easy for a user to undertake a diagnosis using the simple 3D layers in HTML5/CSS being a necessary enabling technology to support the required levels of detail in the ECG waveform, and to support varying views of that waveform. Instead of using a normal scale, the multi-touch scale measuring tool object provides a transparent layer to look though this object and be able to measure the ECG waveform displayed underneath.

The technique (Figure 2) extends the idea of area cursors by allowing a user to transform the tool object with one or two fingers. The user can scale, translate and rotate the object by moving their fingers on top of them, where the relative positions of associated contact points towards the object are preserved. The size of the activation area is proportional to the span of the fingers.

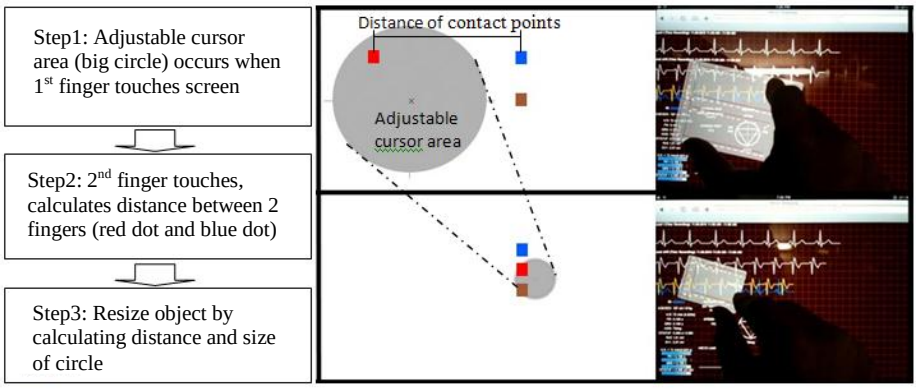

Figure 2. Adjustable cursor area makes it easy to select isolated targets (big circle with red dot) and calculates the distance with individual targets (blue dot) while allowing for resizing object

2.3 Process

Nesaar & Jean-Paul (2009) has identified mobile adoption factors to deliver telemedicine services (Table 1). These factors form part of a generalised technology acceptance theory for innovative technology in public healthcare sector. Users participated in acceptance aspect broken into seven acceptance factors. In order to complement the qualitative data collected of each factor, data collection included questionnaires and interviews. Data were collected between Nov and Dec 2010.Users practiced using the mobile ECG DSS together with a technical explanation from interviewer. During their use of the mobile ECG DSS, the user was asked questions about the capability of the DSS, diagnosis support provided using the multi-touch function, easy of viewing therapeutic records, and acceptance of the device for adoption in cardiac care. Interviews were digitally recorded and notes made of non-verbal behaviours during use of DSS.

2.4 Data analysis

Qualitative data were gathered during testing of mobile ECG DSS using focus groups and analysed using content analysis (Burnard 1995). Data was captured at a practitioner level in decision making, and on characteristics of technology acceptance to support or increase the use of the mobile ECG DSS (Table 1). Data analysis results have been presented in seven factors (Table 1) making up aspects of acceptance. Seven factors emerged from the content analysis, which represented the key contributing to the acceptance and the perception of mobile ECG DSS in the general practice. This method is used as a research tool to determine the presence of certain words, concepts and categories with a set of text (Arnit 2004). So that each factors was determined to play a role in the user acceptance of mobile health technology from this research.

3 RESULT

3.1 Demography

Of the practitioners (n=13) who had experience with ECG monitoring and pre-hospital ECG analysis, eight practitioners had more than eight years of work experience with cardiac care;

the other four had more than five years. They were asked about their involvement in medical instrument conferences in relation to new health care service as medium (n=5) to high attending (n=8), new mobile medical technology appetence as low (n=1) to high interested (n=12) and attitude forward mobile adoption as considered (n=9) to immediately (n=4). The majority of the participants (n=10) had used Far-End (wireless medical system) device in health recording, whereas only six participants had experience with remotely treatment for cardiac patients.

Factors	Description
Perceived usefulness	Doctors perceived the mobile ECG DSS that is being able to provide them with relevant information either via the mobile network or software itself for the devices. They perceived the ECG DSS as a reference tool, patient information tool and even contemplated its use as a decision support tool that could help in diagnosis and medication prescription.
Social influences	Doctors display a professional maturity that does not allow factors like image or subjective norm to influence them.
Perceived user resources	Lack of resources to support their use of mobile ECG DSS by the hospitals, which did not negatively influence their intention to adapt. This could be attributed to the social circumstances where doctors have leant to cope with limited resources on a daily basis, despite their extremely pressurised work environments.
Task/technology fit	The medical profession is very information intensive one and doctors realised that the mobile health DSS would be able to help and keep abreast of the latest medical knowledge.
Result demonstrability	Doctors believed that the technology would be able to help them deliver better quality care to their patients
Fear of legal action	Underlying doctors' perceptions of the ECG DSS as an information tool was an unease in respect of malpractice legal suits. It was thought that the technology could aid the decision support. This could help reduce the possibility of incorrect diagnosis and treatment, perhaps legal action against the doctor.
Doctor-patient relationship	Where doctors do not interact with patients, a number of the above factors are not applicable. Thus this can be seen as a moderating variable or factor on the other factors.

Table 1. The acceptance factors that emerged from data analysis (Nesaar & Jean-Paul 2009)

3.2 Findings

Results from data collected using questionnaires showed that the majority of doctors and nurses had occasionally or often experienced ECG monitoring/ analysis (n=12), and routinely provided treatment for cardiac patients (n=12). Most practitioners said they had received sufficient information needed to accomplish ECG diagnosis on the mobile device by using multi-touch measuring tool (n=10) and adding diagnosis note (n=12). However, some practitioners (n=7) indicated that using the mobile device could be the main medical instrument for ECG reading but some disagreed with the idea of using a mobile screen to replace current paper read-out (n=6).

Acceptance

After using the mobile ECG DSS, the majority of the participants (n=13) found that it displays better ECG wave graphs than paper based print-out and provides more data completeness. Moreover, participants had different points of view as to whether the mobile ECG DSS application can reduce diagnosis time compare to other ECG devices; five doctors argued this issue, whereas all nurses totally agreed.

> *"Do not think it is time saving...almost all patients need to have a careful diagnosis and analysis".*
>
> *"Faster to make an assessment and avoid unnecessary suffering can be gained in this ECG mobile adoption but it is probably a matter of getting used to it".*
>
> *"Better control of DSS for real time monitoring when we are in situations that needs us to look at mobile device for immediacy."*

Participants reported that this is their first experience using a multi-touch function as a measuring tool in ECG diagnosis. Twelve participants found that it is suitable for emergency medical service (EMS) (Table 2).

> *"While I can use it in its entirety I think it is a very useful tool that can benefit much of our everyday work such as using measuring tool for quick diagnosis".*
>
> *"It has not been easy, but it's a beginning, before you have learnt the functions [….] then I would have indeed used it, I would change to a better smart phone and use in my daily work".*

Ten participants perceived that the mobile ECG DSS promoted realistic expectations of real-time monitoring and higher levels of treatment of cardiac care to patients. With easy access ECG information from the hand-held device, it could contribute to increasing confidence towards acceptance.

> *"If carried out properly, it can increase confidence".*
>
> *"It provides confidence for me when there is so much information …also includes the reference for reviewing ECG knowledge".*
>
> *"It won't be an issue for doctors to accept new mobile technology, as from my understanding, doctors love trying new methods to speed up all treatments".*

	Median	Range [a]
With the mobile ECG DSS, it has ability to		
print better ECG wave graphs	3.53	2-4
replace original ECG on paper read-out	2.69	1-4
analze a patient's data using multi-touch measuring scale tool	3.38	3-4
provide legible information and reliable output	3.53	1-4
increase the level of quality in comparison to a ECG paper printout	2.92	1-4
reduce diagnosis time	3.15	1-4
provide data completeness in presenting and recording	3.46	2-4
provide patient support than other ECG device	3.30	2-4
use in EMS routinely	3.38	1-4
The mobile ECG DSS might		
enhance the quality of treatment and diagnosis	3.00	2-4
enhance the delivery of treatment and diagnosis	3.30	2-4
have realistic expectations in cardiac care	3.07	2-4
have benefits to be gained by the application/ mobile adoption	3.30	2-4
have other potential uses in it with hardware and software	3.30	2-4
[a] Possible variations: 0 (totally disagree) to 4 (totally agree).		

Table 2. Participants assessment of acceptance (n=13)

4 DISCUSSION

Interviewees also highlighted a number of challenges to accept new medical technology. These included usefulness, social influences, user resources, technology fit, result demonstrability, legal action and doctor-patient relationship (Table 3).

This paper found that a DSS mobile device as a reading instrument has the potential to be useful as an ECG analysing device for doctors and nurses in real-time monitoring. The majority of participants (n=9) regarded the mobile ECG as a useful DSS. In fact, 84% of participants (n=11) specific mentioned that a multi-touch measuring tool object helps to reduce diagnosis time and provides easily accessible information to the medical decision

support. All nurses were particular interested in ECG Reference (built into interface) because it can be useful tool in their future work as it is most frequently used during practice and they do not have higher level of knowledge of ECG diagnosis.

Attitude towards mobile ECG DSS	Advantage	Disadvantage
Usefulness of a mobile devices	Useful (n=9) Easy to access to the information they needed to accomplish their work Faster to make assessment User-friendly Possibility to make these tests A convenient way to analysis Confidence in work	Not useful (n=4) More functions and content are needed Require specific hand-hold device to operate the DSS A screen size has to be considered Required higher speed mobile Internet transmission It is only a good idea to use on monitoring 12 to 48 hours.
Social influences	Increased (n=5) A guideline for future electrogram analysis More control of the patients' diagnosis	Not increased (n=8)
User resources	Important (n=5) Intention to use new medical technology	Not important (n=8)
Technology fit	Easier (n=7) Good Easy to learn Better medication managing Comes with quick loading	Not easier (n=6) Took time to learn how to use More practice is needed
Result demonstrability	Time saving (n=11) Reduce diagnosis time when launching application from mobile	Not time saving (n=2) To make the ECG reading accruable, it is important to make sure leads have been attached in the right way and not all nurses would have good knowledge with it
Fear of legal action	Reduce (n=7) As an information tool and help to reduce the possibility of incorrect diagnosis	Not reduce (n=6) Double side effect between personal information and mobile security
Doctor-patient relationship	Increased (n=6) Always on interaction could increase relationship between us	Not increased (n=7) Comfortable to use on patients

Table 3. Summary of participants assessment by acceptance factors

Compared to doctors' and nurses' previous experiences, participants were very positive towards using the multi-touch measuring scale object as their primary ECG decision making tool. However, to enhance the quality of the health care using technology, it is important to look at all acceptance factors (Nesaar & Jean-Paul 2009). Participants believed that the mobile ECG DSS might increase the quality of treatment. This study shows an alternative way to think about using a mobile based decision support system to improve cardiac care by applying technology acceptance factors. In the process of carrying out this prototype development and study, it was able to determine not only what technology acceptance factors might occur in mobile health care, but also the reasons for those assessments.

5 CONCLUSIONS

Fundamentally, the multi-touch function on the smart phone was found to be useful and acceptable to doctors, nurses and cardiologists in real-time (simulated) monitoring of cardiac patients when obtaining a patient's ECG signal from a mobile transmission. The multi-touch measuring tool may support doctors in reducing inappropriate treatment. Based on feedback, the mobile ECG DSS has been modified to arrive at a better solution acceptable to users. However, to optimize the use and acceptability of this mobile ECG DSS, it is important to evaluate the system in doctors' everyday clinical practices. With the addition of more functions and content, the multi-touch mobile ECG diagnostic decision support system will become more acceptable and user-friendly for doctors and nurses for long distance real-time monitoring.

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