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Enhancing Seamless Nurses-Physician Communication After-Hours

The Design of the Care4Patience with Google Glass

Esyin Chew[1, 2]
[1]Monash University Malaysia
Jalan Lagoon Selatan,
47500 Bandar Sunway
Selangor Darul Ehsan,
Malaysia
chew.esyin@monash.edu

[2]Cardiff School of Management
Cardiff Metropolitan University
Western Avenue
Cardiff CF5 2YB, UK.
echew@cardiffmet.ac.uk

Pei Lee Lee
University of Malaya
Jalan Universiti, 50603 Kuala Lumpur, Wilayah
Persekutuan Kuala Lumpur, Malaysia
peilee@siswa.um.edu.my

Weng Han Ho
Monash University Malaysia
Jalan Lagoon Selatan,
47500 Bandar Sunway
Selangor Darul Ehsan,
Malaysia
whho14@student.monash.edu

Abstract—There is a major issue in medical centres in Malaysia: the shared responsibility and communication between nurses at the bedside care and conversation with the physicians after- hours. Inexperience nurses may, sometimes, overlook patients' critical symptoms that indicate immediate medical care and cause the circumstance deteriorate. Therefore, mutual blaming practices are common if there is a medical error. The design of hands-free assessment and feedback with wearable technologies is welcomed in healthcare sector. Hence, the paper presents a pilot design that investigates how a wearable technology can help in daily patient care in an innovative way that enhance the nurses and physicians' communication. The paper reviewed the current practices and technologies, followed by the design of the transformed flow, hardware and apps used with technical limitations, pilot evaluation and future work.

Keywords—Google Glass; assessment and feedback in healthcare; effective communication; wearables in healthcare

I. INTRODUCTION

With the advancement of technologies, innovation in smart healthcare and business intelligent sectors today has fostered the research in design and implementation of wearable technologies. Effective communication is crucial in the diverse and complex nature in healthcare environment that involves multiple stakeholders with parallel tasking and multiple interactions in making medical decision and judgment. Generally speaking, failure in communication may cause serious consequences to patient safety. There are challenges faced by both nurses and physicians with the current information flow between nurses and physicians, especially after-hours communication, where how nurses communicate patients' conditions and diagnosis to physicians, and vice versa [1, 2, 3].

Considering the issues above, seamless assessment and feedback such as coherent and hands-free process with the use of wearable technology is possibly welcomed. The emerging of such a wearable technological innovation fosters the interest in operational and business process reengineering that lead to transformation. The common manual assessment and feedback process, occasionally, fails to perceive and communicate the real circumstances and bring undesirable outcomes. Thus, there is a research area, namely "tele-ICU" or "e-ICU" that empower the care teams to include a "second set of eyes" to share real-time experiences and better collaboration in patient care. On the other hand, Bernstein's studies suggest that the current setting of tele-ICU deliver with heavy cameras systems over costly investment [4]. With the declining prices over years, introducing emerging lighter wearable technology in patient care can possibly deliver and resolve the problem statement without high capital investment and threatening intrusion to patients with heavy cameras microphones. Hence, the paper presents an innovative research and design that (1) investigate the current practices and technologies for nurses-physicians communication; (2) explore how wearable technology can help in daily patient care and be designed in an innovative way that transforms the agenda of nurses' and physicians' communication.

II. PROBLEM DEFINITION AND CURRENT PRACTICE

A. *Revisiting the Communication Challenges in General Healthcare Sector*

Literature asserts that communication between nurse and physician in patient management is one of the most common contributing factors to medical mishaps [5]. Failure in communication is resulted from poor transmission and exchange of information and also relate to other factors such as hierarchical differences and power distance; language barriers; difference in communication style where nurses tends to be more detailed whereas physicians prefer brief statements in communicating; and conflicting roles and relationship with healthcare team [5, 6, 7]. Nowadays with the pervasiveness of mobile technologies, considerable number of physicians and nurses sending patient related information such as sms, app-based messaging and picture messaging, e.g. sending a picture of an injury or a MRI Scan to a colleague for day-to-day clinical duties [8, 9]. Figure 1 depicts the usage of technologies for doctors (blue) and nurses (yellow) in the UK. On the other hand, study found that 78.1% of hospital nurses regularly use their mobile phones for non-work-related activities at work [9]. The negative implications of such a practice are the potential distraction of these mobile devices [8], patients' information confidentiality as the effective communication between healthcare professionals is centered for patient safety and quality of care [9, 10].

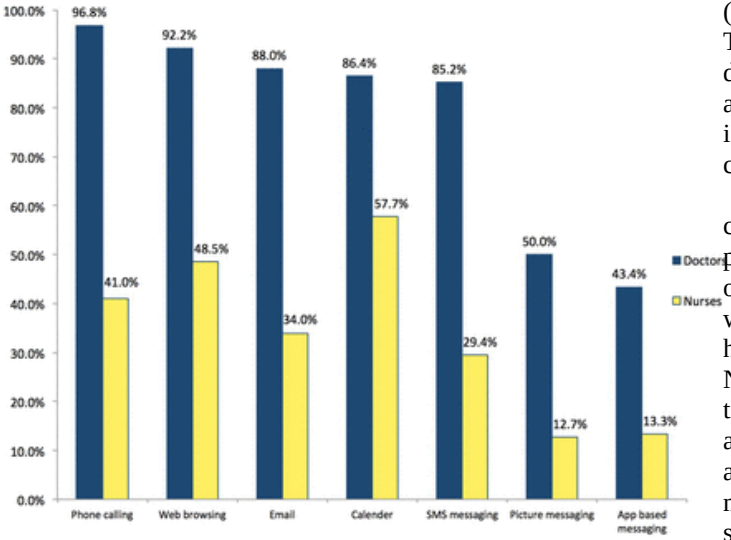

Figure 1. Staff using mobile phones features to perform their clinical duties [8]

Furthermore, there were barriers and difficulties in nurse-physician after-hours phone communication where nurses working under stress situation with scarce resources and fatigue whereas physician could be distracted in an inappropriate environment but ought to make prompt diagnosis and clinical decision over the phone [1]. These error prone situations may cause harm to patient and may result in serious adverse effect and even death. Joint Commission International (JCI), US based accreditation body for health care organizations reported that 2,455 sentinel events revealed that communication accounted 70% as the primary root cause of medical errors [4]. Agarwal et al. [11] developed a conceptual model for quantifying the economic burden on hospital due to poor communication estimated that total of $12.4 billion wasted in US hospital annually. The increase in length of stay is the major contributor to the loss which accounting for nearly 53% of the total waste. The magnitude of this is worrisome and how technological innovation helps in enhancing the communication is the centre of the research paper.

B. *Real Life Challenge in Healthcare in Malaysia*

Technology enhanced Malaysia healthcare initiatives are a growing research area [12, 13]. Many healthcare processes remain manual in the local hospitals. In the Asia region, HIS have been implemented in various hospitals such as South Korea, Singapore and Malaysia [14, 15]. Selayang Hospital is one of the pioneers in Malaysia in the implementation of Total Hospital Information System (THIS) as an integrated care delivery system [15, 16]. The implementation including Electronic Health Record, Radiology Information System and Pharmacy Information System and etc, to replace manual processes such as medication kardex sheet and handwritten prescription and [14]. Nevertheless, the THIS is only the very first initiatives of the clinical information system in the whole healthcare technological according to the Chronic Care Model (CCM) [17] that encourages high-quality chronic disease care. The component for the decision support and delivery system design are yet to be developed. However, this initiative only aimed to improve the healthcare data flow and management. It is limited to deal with the day-to-day nurses-physicians communication especially after-hours.

In the healthcare delivery in Malaysia, the admitting consultant will be solely responsible for the patient treatment plan in the hospital. The admitting consultant relies heavily on the information transpired by nurses in the ward during ward round and telephone calls when physician is outside the hospital and making decision on the patient treatment plan. Nurse-physician communication failures may occurs at any time, however the risk is higher after-hours especially at night and weekends through phone communication. One of the authors is a professional senior medical staff serve in local medical centers for more than 20 years and in a typical clinical scenario, nurse in-charge calls admitting physician using landlines or mobile phones informing of patient change of condition, describing patient clinical presentation and attempting in relating patient laboratory results and vital signs information. Consequently, admitting physician make clinical decision based on the information gathered and prescribing treatment and medication over the phone. Besides, transferring of care between physicians further complicate the scenario which the consulted physician covering the primary physician with brief clinical information during handover and the consulted physician may be totally unfamiliar with patient but require to make important clinical decision from the nurse

through phone conversation. Therefore, it is utmost important that pertinent, complete and accurate information is conveyed to the physician promptly in recognizing the clinical problem and in diagnosing patients.

These challenges lead to inaccurate decision making in healthcare and mutual blaming culture between physicians and nurses. Can the use of wearable technology improve after-hours nurse-physician communication, and how? Selecting which wearable technology, Google Glass has gained considerable attention for intelligent health research [18, 19, 20, 21]. In Stanford, medical students begin to use Google Glass to improve patient-physician relationship [22]. Putting patient safety at the heart of excellent healthcare, the resolution with the integration of wearable technology is the priority to be investigated. Nevertheless, these studies have limited indications to resolve the problem between nurses and physician communication during chronic care after-hours.

III. Methods and Analytical Review of a Smart Healthcare Technological Choice

The above issues lead to the design and development of a healthcare solution using wearable technology. Agile approach [29] is adopted in the project by first revisiting the problem, previous studies and current practices / possible solutions in the healthcare sector from the lenses of nurses and physicians communication since this is a major issue in many medical centres in Malaysia: the shared responsibility and communication between nurses at the bedside care and the clinicians who are on call at home or other places. With two interviews (purposive sampling) with a senior nurse and a physician (one is from public medical centre and the other one is from a private medical centre). According to the interview, this is the current medical flow in a typical medical centre after-hours: if there is any concern or critical situation for patients, the common practices for nurses on duty are (1) make a phone call to the on-call doctor(s) at home or at other medical centre and describe patients' conditions; (2) doctor(s) and nurses will communicate over the phone for further details about the patients' conditions and necessary steps for further medical care; (3) Based on the nurses' description, decision will be made whether or not there is an urgent need for clinicians to physically attend immediately. However, inexperience nurses may, sometimes, overlook patients' critical symptoms that indicate immediate medical care and cause the circumstance deteriorate. The question here is that what is the best wearable technology to suit the design of the above communication flow, i.e Google Glass? Can Google Glass help to enhance the medical challenges at a feasible cost, and is there any other alternative technological choice?

Secondly, the authors performed an analytical review of the comparable products in the market, followed by the Agile design and development [29] for a seamless assessment and feedback process for an enhanced smart healthcare communication system, in response to the research gap. After each small development, the Glass solution is tested by the senior nurse and physician. Thirdly, the completed solution is piloted and evaluated to obtain the initial feedback for continued enhancement until commercialization. Figure 2 is the summary of the wearable devices in the market that maybe used in healthcare sector. It depicts an overall view for the comparable wearable technologies that are available in the market. Open Source Virtual Reality (OSVR) founded by Razer Corp [23]. OSVR is a fully open-source Virtual Reality device and every part of the hardware and software are not patented with open source and programmable solution. It has good partnership with many companies and organizations to develop the device. However, this OSVR is mainly focused on gaming purposes and may not be suitable for healthcare sector.

Name	OSVR	HTC VIVE	Oculus Rift	Sony Morpheus	Meta Pro	Google Glass
Shipment	June,2015	end of 2015	unavailable	mid of 2016	June,2014	April,2013
Price	$199.99	Upper end of price-range	$350.00	Unconfirmed	$2,985	$1,500
bluetooth	Yes	Yes	Yes	Yes	Yes	Yes
purpose	gaming focused	General use	General use	General use	General use	General use
Open-source	yes	no	no	no	no	no
accelerometer sensing	Yes	yes	Yes	Yes	Yes	Yes
gyroscope	Yes	MEMS gyroscope	Yes	Yes	Yes	Yes
Tracker	Yes	yes, with laser position senser	Yes,near infra-red CMOS Sensor	Yes	Yes	Yes
USB port	Yes	Not specified	Yes	Yes	unspecified	Yes
Voice recognition	unspecified	unspecified	Yes	unspecified	unspecified	Yes
Display Resolution	1080x1920	1200x1080	960x1080	1920x1080	1280x720	640x360
Screen size	5.5 inch	unspecified	unspecified	5.7inch	adjustable	adjustable
Field of View	100 degree diagonal	120 degree	100 degree(nominal)	90+ degree	2x40 degree	14 degree monocular
surround sound audio	Yes	Yes	Yes	Yes	Yes	no
Camera	Yes	Yes	Yes	Yes	Yes	Yes
Image						

Figure 2. Review of the Comparable Wearable Devices

Based on the specification comparison (see Figure 2), we observe that OSVR consists of extremely impressive 1080x1920 display resolutions compared to Google Glass's 640x360. It has all the common features, i.e. gyroscope, USB ports, trackers, camera, bluetooth 4.0, and accelerometer. In addition, it has a surround sounds audio, and a wide angle of 100 degree diagonal field of view. OSVR has a much higher specification but in cheaper price compared to Google Glass. However, since OSVR is focused solely on gaming, thus it is pretty impractical to carry out regular tasks due to its bulky 'threatening size' to patient if a nurse wears it. OSVR basically covered both eyes and the end users can only focus on the 5.5 inch screen. Conversely, Google Glass is able to assist the people to carry out regular tasks with its portability and being able to view the outside world and the displayed projections at the same time at the top right corner.

HTC Vive [24]'s price is predicted to be of upper end of price-range compared to other products due to its higher end of technical specification with the standard built in functions such as accelerometer, gyroscope, tracker,

surrounded sound audio, camera and USB port. Morpheus by Sony [25] is considered at the higher end when compared to the other devices. It has all the common features such as USB port, tracker, gyroscope and accelerometer. Oculus Rift is one of the leading companies who started all these Virtual Reality concepts [26]. Some of the technology experts had stated that Oculus Rift produced one of the most consumer-friendly Virtual Reality Devices [27]. Oculus Rift Virtual Reality has surround sound and a standard camera. There is one feature that made Oculus and Google Glass stand out among the three products which is the voice recognition. Both Oculus and Glass are able to carry out voice command given from end user, for example, "Record Glass" command will instruct Google Glass to perform video recording function.

In summary, both OSVR and Oculus Rift have the lowest prices among all glass-like wearable devices that may be more feasible for a generalized implementation of healthcare solution. The price of Google Glass is positioned in the middle among all. The technical specifications of all OSVR, HTC Vive, Sony Morpheus and Oculus Rift are more attractive than Google Glass. However, it is found that they are less practical than Google Glass in healthcare application due to the bulky sizes yet with limited programmable functions. It seems to be extremely impractical to wear other devices to carry out regular tasks. OSVR, HTC Vive, Oculus Rift, Sony Morpheus and Metapro do not provide the portability and flexibility as Google Glass. Developers seem are constraint to use the built-in environment/pairing apps that may lead to patient data privacy issues. Comparing to Google Glass, Meta Pro Glass is priced at a much higher price. Its technical specification is slightly lower than all the comparable devices, but much higher than Google Glass. It features a 1280 x 720 display resolution, and a field of view of 40 degree. It does have a surround sound audio and a standard camera. Apart from that, it also has all the basic features such as tracker, gyroscope, and accelerometer and so on. MetaPro Glass is one of the devices that can possibly replace Google Glass as it does provide the portability, light and easy features of Google Glass. Moreover, it has a much higher specification than Google Glass. Due to its high price and lack of software support, nevertheless, Google Glass is the recommended device to the proposed design and solution for healthcare.

IV. DESIGN AND EVALUATION OF THE WEARABLE TECHNOLOGY FOR SEAMLESS ASSESSMENT AND FEEDBACK

Wearable technology such as Google glass is the latest and best technology to be adapted for healthcare smart application. The new assessment and feedback mechanism with the integration use of Glass and associated apps in care communication between nurses and clinicians provide novelty in transforming patient care after-hour. Figure 3 depicts the basic functionality of a Glass. The MyGlass [28] companion app is required to pair the users' phone with Glass in either Android or iOS platform. However, MyGlass app is developed by Google and is limited to manage Glass without customised facilities. It cannot fit the purposes of the research. Hence, the objective of the research is to design a Google Smart Healthcare Glass app with Google Glass that may transform nurses' and physicians' communication for medical centres in Malaysia, namely Care4Patient. Care4Patient is a design solution that is aimed to improve the communication and provide seamless assessment and feedback for both nurse and physicians after-hours. The innovation of Smart Healthcare Solution assessment and feedback in care communication using Google glass is depicted in the Figure 4-6.

Figure 5 indicates the functionality and flow of a Google Glass in patient care.

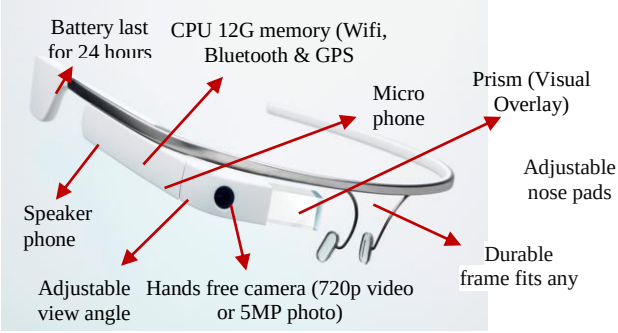

Figure 3. The Functionality of a Google Glass used in Care4Patient

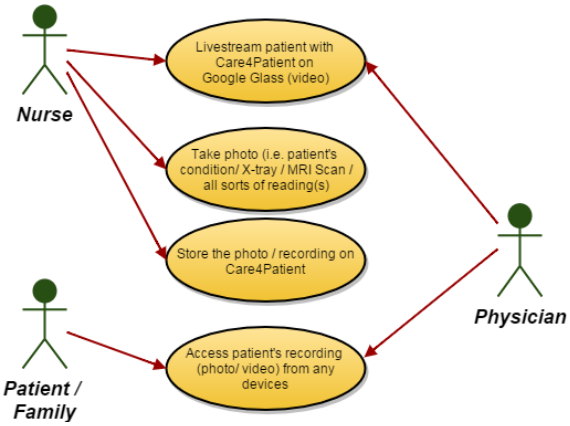

Figure 4. Care4Patient Use Case Scenario for Seamless Assessment and Feedback

Figure 4 shows the use case scenario of the Care4Patient, the interaction of the users (Nurses, Physicians and Patients / Family) with the Google Glass system to enhance the communication seamlessly. Figure 6 depicts the process from the nurse perspective after wearing a Care4Patients. Permission and consent will be taken from the patients during the point of admission. In order to allow the nurses to perform the functionalities implemented without using their hand during certain emergency where their hands may need to serve other medical care purposes, both voice command menu and finger-controlled commands are developed. There are three functions on the voice command, which is image capturing; video recording; and back to main menu (see Figure 6).

Furthermore, during the development phase, we constantly engaged with the end user (nurse and physician) and having discussions with them regarding the functionality and user interface. Care4Patient is developed with Agile using evaluated 'inspect and 'adapt' approach due to its simplicity and flexibility [29]. The solution is tested with expert sampling: a nurse and a physician; and further 6 researchers (play role) using walkthrough evaluation (survey with four simple first experience elicitations.

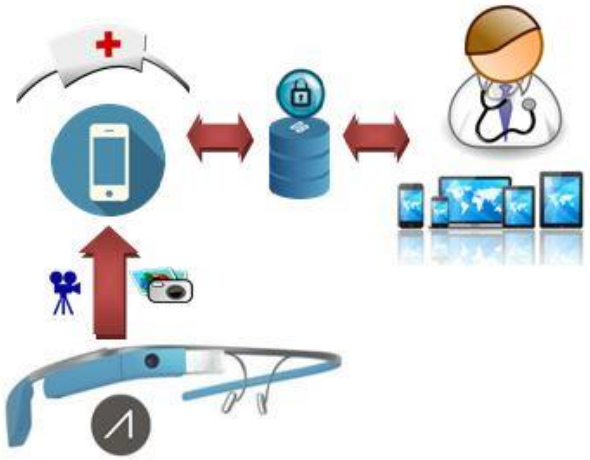

Figure 5. Care4Patient Smart Healthcare Solution for Nurses-Physicians Seamless Assessment and Feedback

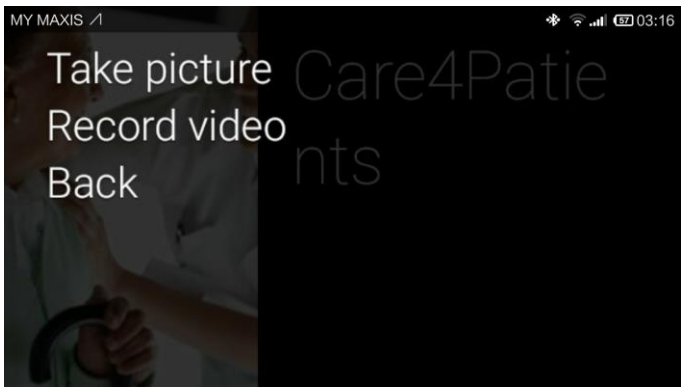

Figure 6. Screen Shot 2 of the Care4Patient

Based on the pilot test, users perceived Care4Patient is easy to use and can be revolutionary to the healthcare communication in Malaysia. The users suggest that the convenience and portability provided by the Care4Patient can save up a lot of time and stress for the medical staffs and to enhance their efficiency at work. They agree that the convenience provided for the nurses to contact physicians after-hours with immediate video and photos will provide a seamless assessment and feedback experience. The permanent accessible records to the patients' conditions on the intranet for the nurses' / doctor' communication and diagnosis can possibly increase the quality of healthcare for patients. However, the 26.6% of the users claimed that it will not be able to revolutionize the healthcare industry due to the hardware constraints of Google Glass. The main challenges of the Care4Patient solution remain in technicality limitation of Google Glass Explorer such as (1) the lag when using the applications; (2) Google Glass get overheated very quickly, and (3) the battery life is extremely bad. This issue is expected to be resolved when Google released the commercialized version, Glass 2 (enterprise edition) [29, 30].

Table 1: Agile Evaluation for two sprints

A.	*B. Aspects\ Response*	*C. Yes*	*D. No*
E. 1	*F. **Easy to use***	*G. **60%***	*H. **40%***
I. 2	*J. **Can revolutionize the healthcare industry?***	*K. **73.4%***	*L. **26.6%***
M. 3	*N. **Best aspects for Care4Patient***	***(1) The convenience of capturing video and image without using the hands;*** ***(2) The accuracy of the patients' conditions and medicine dispatch.*** ***(3) Its potential impact in the after-hours healthcare.*** *O.*	
P. 4	*Q. **Key aspects for improvement?***	*R. **The hardware incapability e.g.*** ***(1) Overheating issues,*** ***(2) More powerful CPU is needed*** ***(3) The accuracy of voice recognition functionality.***	

Further Challenges and Limitations

Due to the fact that Google Glass voice recognition is still under development, there are some specific terms or words Google Glass cannot recognize. As a result, it keeping execute the wrong command from the users. Google Glass cannot detect a long sentence or commands; hence the developers have shortened the commands in order to improve the accuracy. Concerns on transferring sensitive data and patient confidentiality and safety issues repeatedly emphasized in many articles [31, 32, 33] and hence cautions and strict clinical governance must be in place in complying with Patient Data Protection Act that recently been enforced in Malaysia. This issue is raised by one senior nurse manager during the survey. Care4Patient data governance and patients' privacy must be complied with the Data Protection Act.

V. CONCLUSION AND FUTURE WORK

Telemedicine has been studied in the intensive care unit for several decades, but many questions remain unanswered regarding the costs and the benefits of its application [34].

Healthcare in the effort to improving patient care has taken an interest in adopting portable computing for mobility. Nurses-physicians communication barriers are one of the major challenges in day-to-day health practices, especially after-hours. Responding to the challenge, the research reviews the current wearable technologies and designs a solution with Google Glass that is portable, flexible and less threatening to the patients, namely Care4Patients. Since the data flow from nurses to physicians is in-house built, patients' information confidentiality and effective communication between healthcare professionals can enhance patient safety and quality of care. However, Glass introduced by Google Inc. in April 2012 is still in the beta phase. The released of commercial version of Google Glass 2 maybe be released soon [30, 31]. Glass represents a technology innovation and the design of Care4Patient can be re-coded on other latest and upcoming programmable Glass-like wearable.

Care4Patient enables the physicians to keep track of their patients at anytime from anywhere. Moreover, its live streaming feature will help the physicians and nurses to understand their patients' condition better and observe their patients symptoms properly in enhancing nurses–physicians communication. Previously, the only way a doctor can keep track of their patients is from the phone calls or Whatapps made by the nurses. However, there is miscommunication and privacy issues arise when the inexperienced nurses failed to describe the patients' condition or symptoms accurately and correctly. The design and development team is in the process of final touch up for the user interface design and of applying a design patent for Care4Patient with the following future impact: (1) **Humanity:** This development of the Google Glass apps can enhance critical patient care and reduce unexpected death through transforming after-hour communication between medical practitioners; (2) **Socio Economy:** Bernstein's studies suggest that the current setting of tele-ICU deliver over costly investment [4]. However, the design of the Care4Patient solution perform enhancement without high capital investment and threatening intrusion to patients with heavy cameras microphones. When the prices of Glass or other wearable technologies are affordable by everyone, it is worthwhile return on investment for medical centre to adopt the conceptual design in any appropriate wearable technologies. After obtaining the patent, the short-term future work will be a large scale of testing - the empirical evaluation in the real beds with nurses and physicians for a period of times for further real-time analysis and improvements. The long term future work for Care4Patient will be the development of Care4Patient in a cross platform environment to be installed in the major Glass-like wearable technologies.

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