Edward S. Rogers Sr. Department of Electrical & Computer Engineering
University of Toronto

ECE1778 - Creative Applications for Mobile Devices

Final Report	***MoniToddler*** – Android app for Continuous Real-time Monitoring of infant patients
Professor	Jonathan Rose
Team Members	Asad Siddiqui (996132616) - Specialist Hatif Sattar (997063387) - Programmer Yasser Khan (996835572) - Programmer
Date	April 7th, 2016
Word Count	2429

Introduction

Why MoniToddler?

In the Intensive Care Unit (ICU), the clinical status of pediatric patients is followed extremely closely through continuous monitoring of vital signs (i.e. heart rate, respiratory rate, blood pressure, oxygen saturation, etc.). In these settings, a trained healthcare provider (HCP) is at the bedside monitoring for trends indicative of clinical improvement or deterioration. When the clinical status of a patient improves, they are sent to a ward setting where they will have their vital signs monitored (at most) once every 2 hours, with the more likely situation being once every 4-6 hours. This can lead to missed signs of deterioration and the occurrence of critical events.

An In-Hospital Cardiac Arrest (IHCA) is an example of the most significant critical event. *Singh et al (2016)* found that the rate of survival to discharge after an IHCA was 7.1% with only 3.9% of patients showing good neurological outcome[1]. The group also found a positive correlation between response time and chance to survival. In addition, witnessed IHCA had a higher chance of survival than unwitnessed IHCA [2,3]. Furthermore, 38% of IHCA were found to be potentially preventable with respiratory insufficiency being the most common preventable cause of IHCA[2]. In addition to having preventable causes, clinical deterioration on the wards can be predicted earlier with higher accuracy using vital sign trends[4]. Based on the literature, it is evident that real-time notification of a critical event can lead to improved patient outcomes. For this reason, we chose to develop an app that monitors continuous vital signs and provides immediate warnings to HCPs when there are signs of deterioration.

What is MoniToddler?

MoniToddler is an important app because it fills the gap of monitoring pediatric patients by allowing proactive instead of reactive responses to clinical status changes. It does this by providing three key functions:

1. **Continuous Monitoring** - MoniToddler monitors continuous vital signs for pediatric patients on the ward that would otherwise be monitored less frequently (approx. once every 2-8 hours). Specifically, the prototype will monitor continuous respiratory rate and heart rate.

2. **Early Notifications** - The app is also important because it not only allows remote continuous monitoring, but also provides a means for HCPs to be notified of clinical changes in patients so that they can provide interventions to prevent delayed critical events and deterioration.

3. **Communication** - MoniToddler provides a centralized communication tool surrounding patients. This allows for manual entry of key clinical information that could not be monitored continuously and communication between HCPs through notes/chat.

Specialist Context

Asad is a third year resident trainee specializing in Anesthesiology with a special interest in Pediatric Critical Care. When pediatric patients are discharged from the ICU, a physician and a nurse from the ICU follow-up on the patients on the ward for several days. When this occurs, patients are dispersed throughout the hospital in different locations and are only intermittently followed by the ICU extension team. The MoniToddler app can help fill this gap. If the app were further developed to incorporate security/privacy and expand the vital signs being monitored, it could have a direct clinical impact through with the ICU follow-up team. Specifically, if the app continues to be developed to incorporate saturation, temperature and blood pressure, as well as be validated for accuracy, it can be used to implement the predictive algorithm (BedsidePEWS) remotely for at-risk patients[5]. However, it would take a significant amount of future work to develop these features and validate their accuracy for healthcare use.

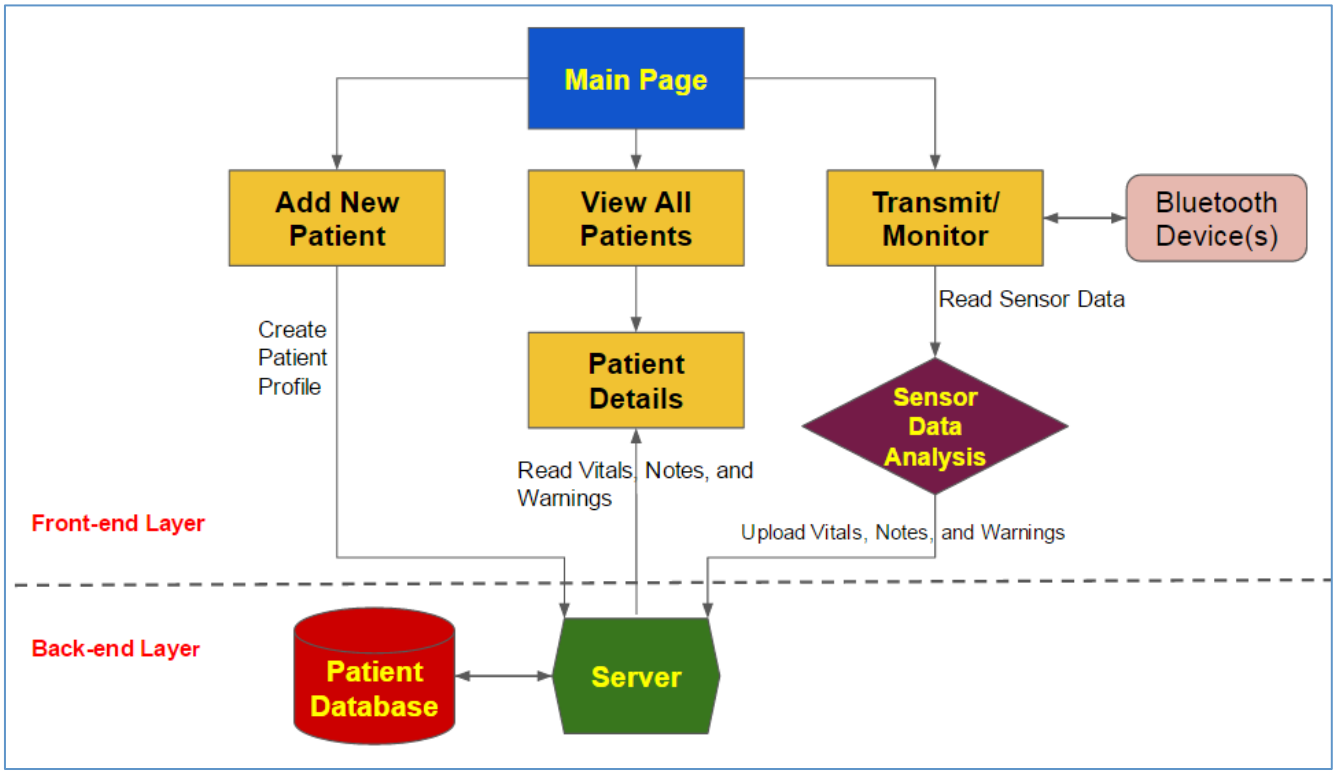
The product developed in the course will serve as a prototype for potentially attaining funding to further develop the app in the future. In this context, what we have achieved in the course can be used to conduct patient safety research to assess the impact of using continuous vital signs monitoring and early prediction algorithms to prevent critical events. Overall, if the app is further developed and validated, it can have an impact through (1) direct clinical application and (2) patient safety research regarding a novel tool to prevent critical events.

Overall Design

This section describes the overall design and descriptions of each of its components.

Block Diagram

The following diagram shows the block diagram.



Block Descriptions

In the block diagram, the “Main Page” consists of the following three options:

- **Add New Patient**: In this page, the HCP can create a new patient profile. This page requires standard patient demographic information to create a new file. This will be instantaneously uploaded and will be visible to all users using the Firebase server.

- **View All Patients**: This page shows a list of all the current patients being monitored. HCPs can click on any patient and view vitals in detail. Notifications can be enabled on “Main Page” under menu options “Enable Notifications”.

    - Patient Details: This page shows details of all the real-time and non-real-time vitals collected from the patient. A graph displays the breathing pattern of the patient. “Add” button can be used to add Notes for the patient, which will send a notification to all individuals with the app.

- **Transmit/Monitor**: This page allows the patient to connect to Bluetooth devices (Sensortag and Tickr) and obtain vitals (Respiratory and Heart Rate). After sensors are turned on, the user presses “scan.” The app will connect to devices and start uploading vitals. A real-time graph will show respiratory pattern. The HCP can modify parameters that indicate the “critical” range on the “Main Page” under the menu option “Update Params.”

    - Sensor Data Analysis: This module collects accelerometer data obtained from Sensortag and analyzes the changes in acceleration after applying a Low-Pass Filter. It detects peaks for 10s and then multiplies the number of peaks by 6 to obtain respiratory rate “per minute.” Tickr directly provides the heart rate.

Functionality

Overall, the MoniToddler app fulfilled the three main goals that were outlined above – continuous monitoring, early notification, and communication. This section will provide an overview of end user functionality. Figures correspond to the Screenshots section.

Adding a Patient

Once the app opens, the main page (Fig 1a) with three options is shown: add a patient, view existing patients, and transmit data. The first step is to add a new patient to the database so that app owners can view their status. Clicking on "Add New Patient" will navigate the HCP to the Add Patient page (Fig 3a). Here the HCP can fill in all required information. The Hospital Filing Number is unique, so no two patients can have the same information in the database at the same time.

Transmitting Data

On the main page, the HCP can open the overflow menu (Fig 1b) and click on "Update Parameters". This will navigate them to the Update Parameters page (Fig 1c). Here the HCP can update the patient's normal Heart Rate and Respiratory Rate range for the specific patient they will be transmitting data for - if the rates go beyond the range specified then the patient will be considered critical.

The next page will allow the HCP to select which patient entry in the database will show the data to be transmitted (Fig 3b). This allows the transmitting Android device to be reused for different patients. The HCP will select the correct user, and that will lead them to the main transmit page (Fig 3c). The HCP will then attach all relevant hardware to the patient, such as the Wahoo Tickr and the Sensortag device. Once that is set the HCP can tap "Scan" which will start the Bluetooth connection. There exists a button for "Sensortag 1", which will change to "Sensortag 2" once pressed to allow for selectivity if two Sensortags are in the same area (Fig 3c). The HCP will leave the transmitting Android device near the patient so data can be collected by the Android device and transmitted to the database. A real-time graph is also provided to give the HCP immediate information. Leaving this page will disconnect the device from the patient hardware, and disable transmission from that patient entry.

View Patients

Now that the HCP has set up the transmission of a patient's status, anyone with the app that is not transmitting can view the data of any patient in the database. The supervising physician will open the MoniToddler app, will enter the overflow menu (Fig 1b), and will click on "Enable Notification" to allow the phone to vibrate and show a notification if a patient goes critical or a new note is added. The physician can then click on the "View Patients" button to be taken to the View Patients page (Fig 3b). Here the physician will see real-time general information about every patient in the database. They can tap on a patient to be taken to the Patient Details page (Fig 2a). This page gives more detailed information and additional vitals that would be manually added.

Scrolling down on the View Patient page, the physician will see a real-time graph of the respiratory rate of the patient, which is transmitted from the phone near the patient up to the database to be viewed by anyone with the app. In the Additional Vitals block on this page there is an “Add” button, which takes the physician to the Additional Vitals page (Fig 2c). Here they can enter a note with their name to specify they want information updated. A HCP (i.e. nurse) on the ward will receive a notification about this note (Fig 4a) and can navigate to the same page to manually enter this information for the physician to view remotely (i.e. Blood Pressure, Temperature, and Saturation).

At the top of the View Patient page is the critical status. If the patient’s monitored vitals go beyond the range specified by the HCP, this will change to “Patient Critical” and a notification will be sent to all users (Fig 4b) who have notifications enabled. This will allow HCPs to respond to emergencies quickly to prevent critical events.

Incomplete and Missing Features

Most of what the team planned to achieve was successfully implemented. Some ancillary features such as real time chat functionality was removed due to time constraints. Also, some pages (such as the transmit page) were not as user friendly as the team wanted. Time constraints prevented those pages from being overhauled, but it did allow for easier debugging.

Screenshots

Below are several screenshots, which are referred to in the above sections.

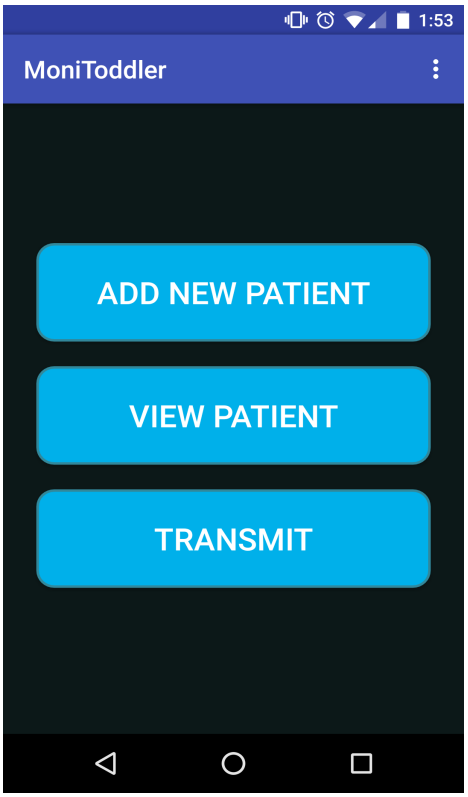
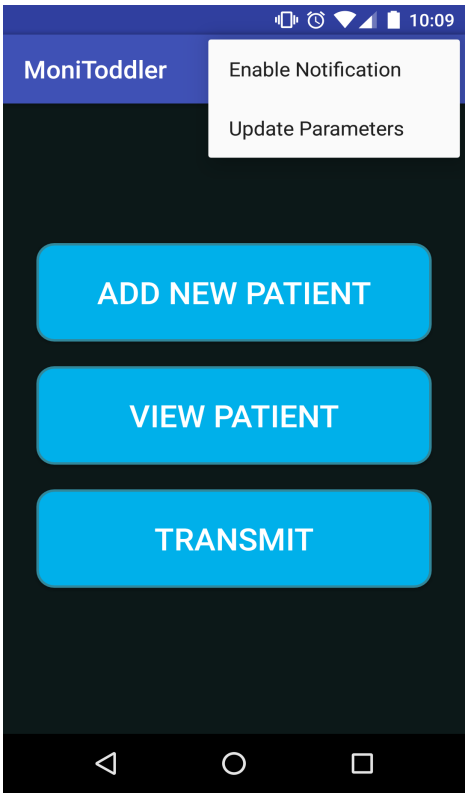
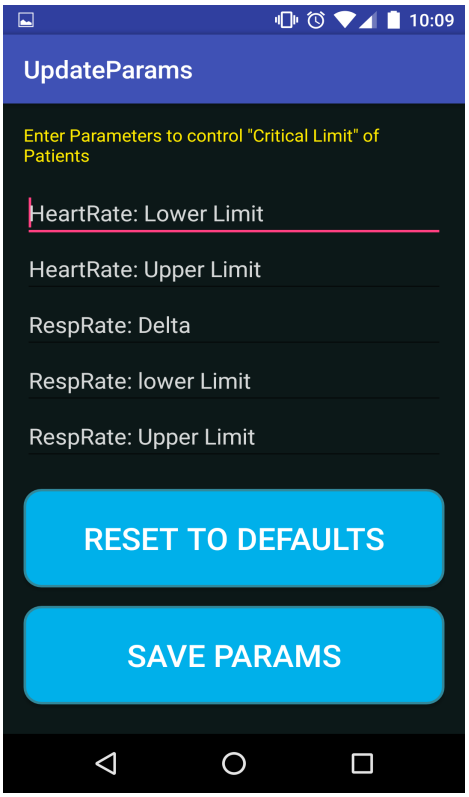


Figure – 1 (a) Main Page



1(b)Main Page – Menu



1(c) Update Parameters

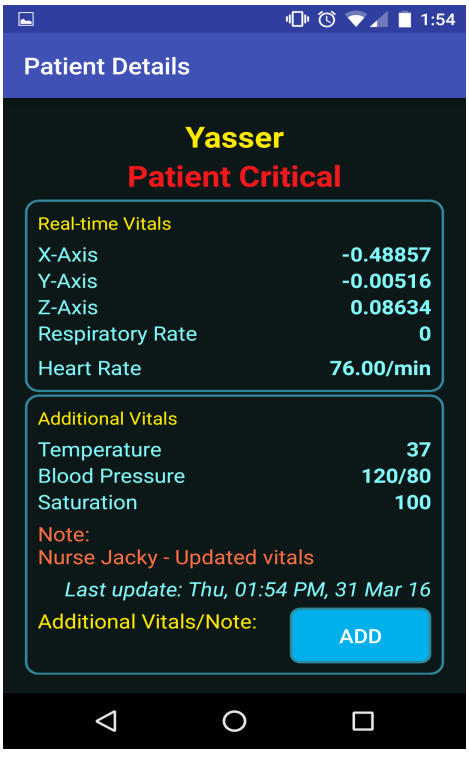
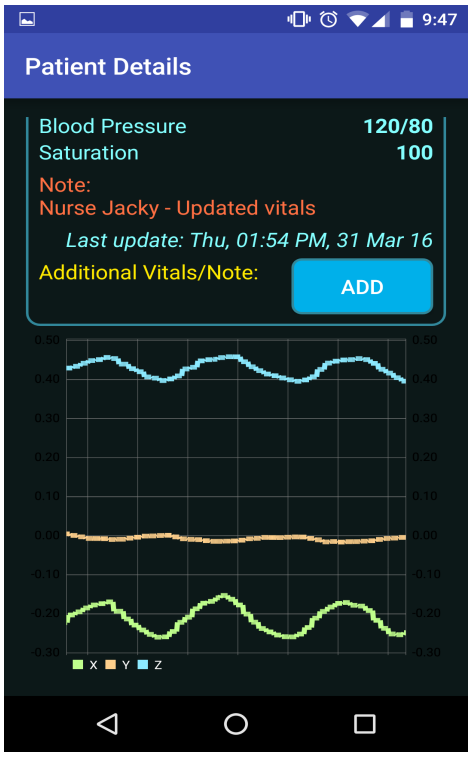
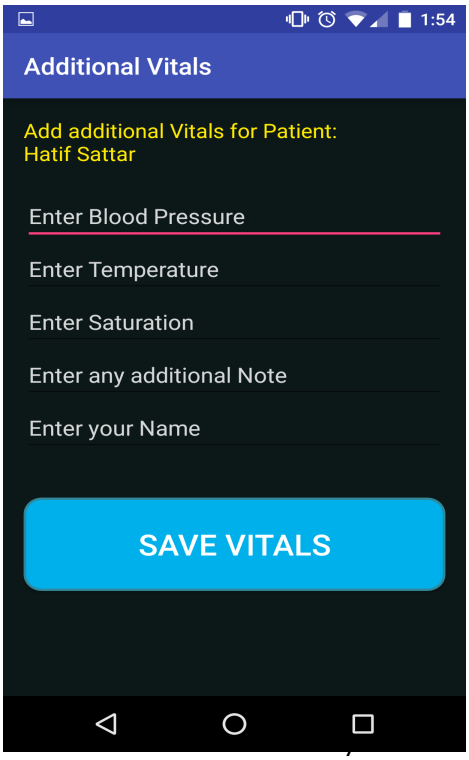


Figure – 2 (a) Patient Details



2(b) Patient Details



2(c) Additional Vitals/Note

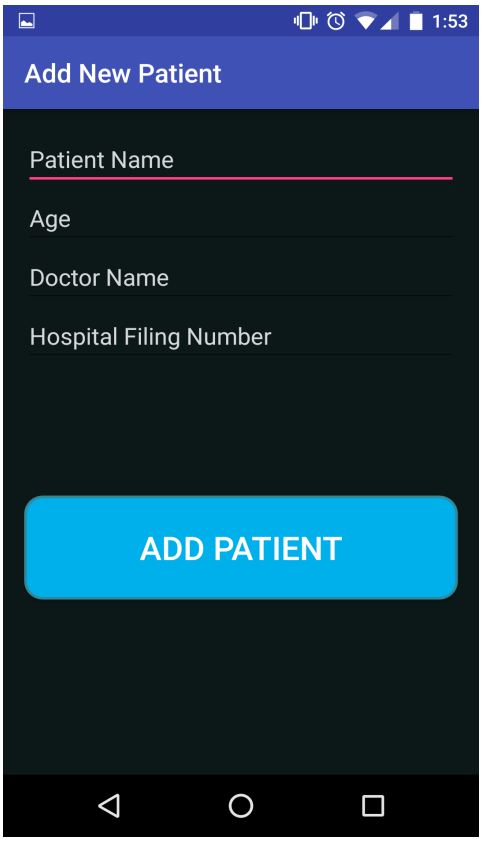
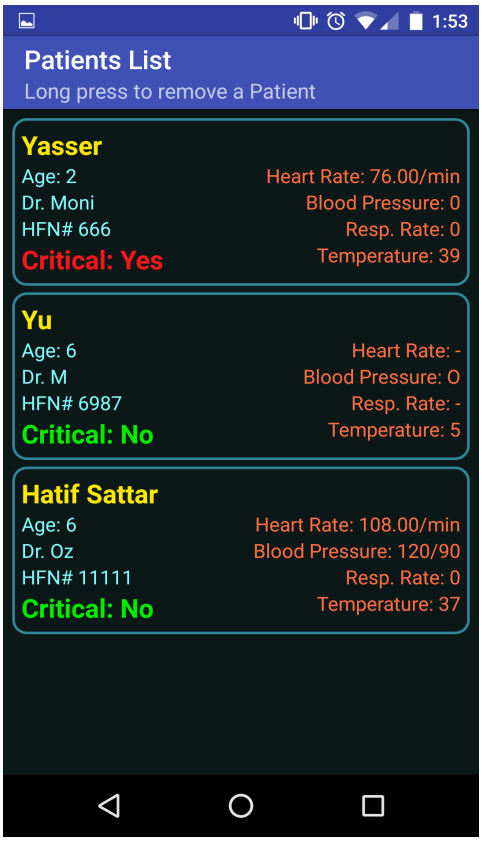
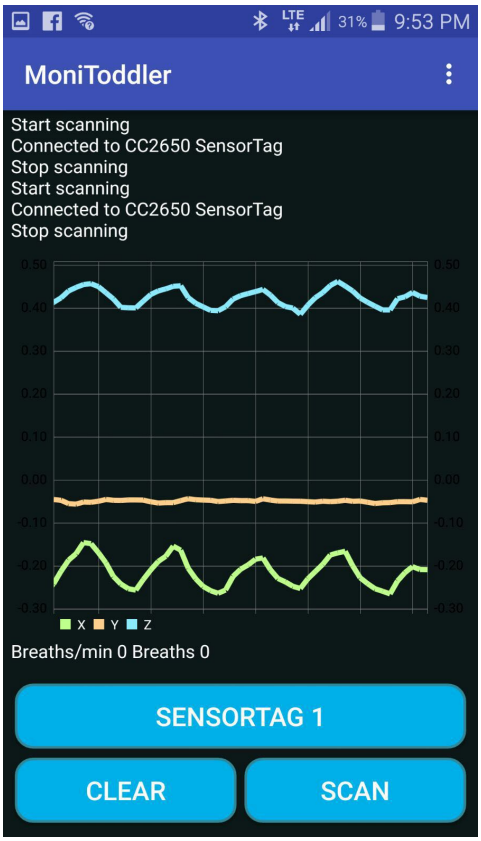


Figure – 3(a) Add a Patient



3(b)View All Patients



3(c) Transmit Patient Vitals

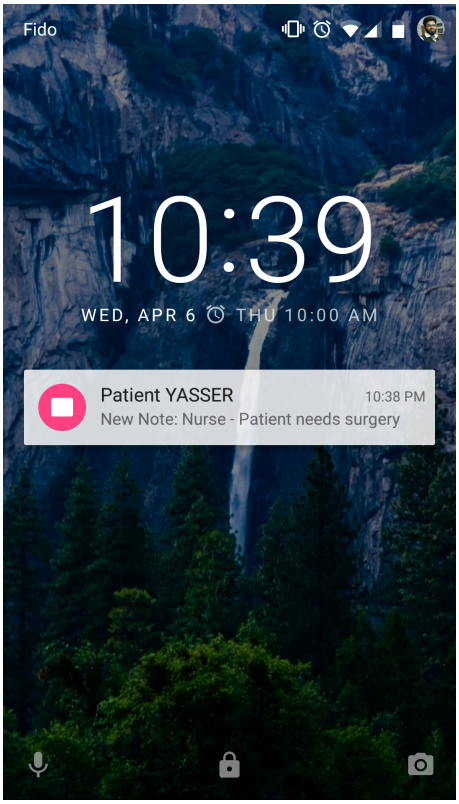
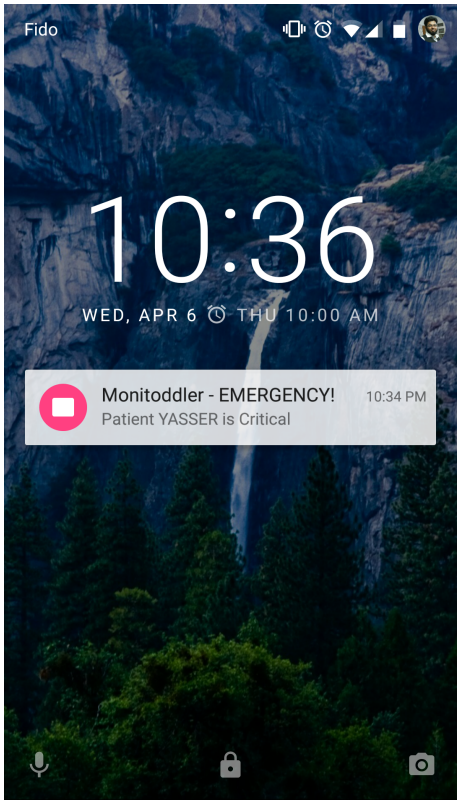


Figure – 4 (a) New Note



4(b) Critical Warning

Learning Points and Reflection

This section highlights what the team learned in the course of the project.

Learning Points

One area that the MoniToddler group realized was important in this type of project was in regards to Non-Technical Skills. Specifically, our group learned the value of strong communication and the barriers that can occur in a multidisciplinary team. One thing that we did well was have frequent meetings with centralized communication (i.e. through centralized MoniToddler e-mail account and WhatsApp group). Also, we learned to "speak the language" of one-another's specialties. For example, it was important for us to realize that Asad had no programming background and Yasser/Hatif had no medical background. This was initially a challenge as it was a common mistake to make the assumption that the others understood the jargon being used in conversation; however, we had to have constant reminders to ourselves about the importance of explaining all jargon. This helped us learn a great amount about one another's fields and the delicacy/difficulty surrounding effective communication of a specialty field to non-specialists.

Changes for the Future

For the MoniToddler app, we used the Sensortag to measure respiratory rate. In order to do this, it was necessary for us to gather data from the Sensortag, parse the information, and determine what was meaningful information to deduce the respiratory rate. There are several devices currently available that can measure this and more vital signs. If we could do the project differently, we would focus on attaining sensors that were already calibrated for certain vital signs rather than figuring out a new algorithm for the Sensortag. This would have saved us time and allowed for us to focus more towards developing warning algorithms using the information rather than on gathering the information itself.

Contributions

This section lists the specific contributions each member made for the MoniToddler app.

Asad Siddiqui (specialist)

- Literature Review surrounding wearable tech in healthcare and outcomes from critical events
- Inception of MockUp for MoniToddler
- Data collection & analysis of Sensortag for respiratory rate using high-fidelity pediatric simulator + human participants
- Documentation, Presentation Creation/Editing
- Testing

Hatif Sattar (programmer)

- Setup Database and Backend
- Customized UI and Logo Design
- Low-Pass Filtering and Data Analysis
- Emergency Notifications
- Designed “additional vitals and notes” mechanism
- Implementation for Critical Limits for Individual Patients
- Testing

Yasser Khan (programmer)

- Connection to Bluetooth sensors (Tickr, Sensortag)
- Obtain and parse sensor data
- Low-Pass Filtering and Data Analysis
- Data logging into text file (for analysis)
- Data logging in Visual graphs
- Testing

Future Work

There are four features that we would continue to develop if we had the opportunity in the future:

1. **Expand Vital Signs Monitoring:** MoniToddler is currently capable of monitoring continuous Heart Rate and Respiratory Rate. The other vital signs that would be valuable to monitor continuously include: blood oxygen saturation, blood pressure and temperature. Of these vital signs, continuous, non-invasive blood pressure monitoring would be the most difficult to achieve as there is currently no wearable technology capable of doing this accurately.

2. **Validate Vital Signs:** The Sensortag was programmed for MoniToddler to monitor continuous respiratory rate. It would be important to validate the accuracy of the Sensortag for measuring respiratory rate in order to use it for clinical purposes.

3. **Implement Predictive Algorithm:** Vital signs trends are useful in predicting clinical deterioration in patients. Through continuous vital sign monitoring with MoniToddler, HCPs are more closely able to monitor vital sign trends in patients on the ward. The BedsidePEWS score is an algorithm currently being validated that incorporates vital signs trends in predicting patient deterioration[5]. The integration

of this predictive algorithm with MoniToddler is an important next step in helping prevent critical events.

4. **Security/Privacy:** The MoniToddler app stores vulnerable patient information. In order for the app to be used in a clinical scenario, it would be necessary to ensure that information entered in MoniToddler was private and secure.

Disclaimer for Source Code

Asad, Hatif and Yasser are in agreement with the posting of the video online. We would like the source code to not be reported on the web at this point; however we will contact Prof. Rose if anything changes.

Source Code

https://github.com/hatifsattar/MoniToddler.git

References

1. Singh S, Namrata, Grewal A, et al. Evaluation of Cardiopulmonary Resuscitation (CPR) for Patient Outcomes and their Predictors. J Clin Diagn Res 2016;10:UC01-4.
2. Chon GR, Lee J, Shin Y, et al. Clinical outcomes of witnessed and monitored cases of in-hospital cardiac arrest in the general ward of a university hospital in Korea. Respir Care 2013;58:1937-44.
3. Peberdy MA, Kaye W, Ornato JP, et al. Cardiopulmonary resuscitation of adults in the hospital: a report of 14720 cardiac arrests from the National Registry of Cardiopulmonary Resuscitation. Resuscitation 2003;58:297-308.
4. Churpek MM, Adhikari R, Edelson DP. The value of vital sign trends for detecting clinical deterioration on the wards. Resuscitation 2016;102:1-5.
5. Parshuram CS, Dryden-Palmer K, Farrell C, et al. Evaluating processes of care and outcomes of children in hospital (EPOCH): study protocol for a randomized controlled trial. Trials 2015;16:245.