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Remote Monitoring Technologies for Mental Health in Rwanda

Marc Uwiragiye[1*] & Dr. Djuma Sumbiri[2]
[1,2]Department of Information Technology, University of Lay Adventists of Kigali, Rwanda
Corresponding Author Emails: umarcotec@yahoo.fr; sumbirdj@gmail.com

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Abstract

Nowadays people are more concerned about their health as diseases are increasing day by day and more. Hence this is very important to daily monitor health to minimize death caused by complications and diseases. The integration of the Internet of Things (IoT) in healthcare presents transformative opportunities for managing neuropsychiatric diseases. In Rwanda, where mental health care faces challenges such as limited accessibility and resource constraints, IoT-driven solutions offer innovative pathways to improve remote monitoring, diagnosis, and treatment. The study introduces smart wearable integration with IoT, where customized devices such as wristbands, smart rings, and patches with EEG, ECG, and stress level sensors enable continuous patient health tracking and mood detection. Additionally, IoT-based geofencing for emergency alerts is incorporated to track patient location using RFID and GPS, ensuring immediate intervention if a patient wanders outside a designated safe zone. These innovations enhance real-time monitoring, improve treatment adherence, and strengthen mental healthcare accessibility. In an Internet of Things setting, it suggests a smart health remote monitor system that can track a patient's current location and basic health indicators in real-time. Sensors such as a heartbeat sensor, body temperature sensor, ECG, EEG, and RFID with GPS sensors connected to a microcontroller to control hardware modules and a GSM module, as well as a communication network that connects to the servers, will be utilized in this system to collect data from the patient's body. The medical staff will get the patients' condition through a portal, where they may process and evaluate the patient's current state. The family members will receive the information instantly. The study seeks to bridge healthcare accessibility gaps, improve patient outcomes, and contribute to the advancement of digital mental healthcare systems in Rwanda.

Keywords: *Remote Monitoring Technologies, Mental Health*, *Internet of Things*, *Electrocardiogram, electroencephalogram, Radio Frequency Identification*

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1. Introduction

Years ago, Rwanda started the project of Telemedicine as the remote delivery of healthcare services through the use of technologies, and some of them have been developed and gained significant prominence [1].

A growing number of patients is making Remote Monitoring Technologies for Mental Health becoming popular due to the emergence of highly infectious diseases, the demographic shift toward the aging population, and the rise in health complications.

Neuropsychiatric diseases, including depression, schizophrenia, and bipolar disorder, pose significant public health concerns worldwide. In Rwanda, limited healthcare infrastructure, a shortage of mental health professionals, and the stigma surrounding mental illness present challenges in delivering effective neuropsychiatric care. Traditional healthcare models often require in-person consultations, which can be difficult for patients in remote or underserved areas.

The advent of the Internet of Things (IoT) presents an opportunity to revolutionize mental healthcare by enabling real-time, remote monitoring of patients. IoT-driven solutions integrate wearable biometric sensors, and geolocation tracking to enhance diagnosis, treatment adherence, and timely medical interventions. This study proposes an IoT-based health remote monitoring system to bridge accessibility gaps and improve the quality of mental healthcare in Rwanda. By leveraging smart wearable devices and geofencing technologies, healthcare providers can track patient vitals, detect mood changes, and respond promptly to emergencies, ensuring better patient outcomes.

This research explores the integration of IoT in neuropsychiatric disease management, focusing on its implementation, benefits, and challenges that ensure a safe and efficient healthcare monitoring system for Rwanda.

A Remote Monitoring Technology for Mental Health in Rwanda (RMTMH) here proposed by using IoT, through sensors, the RMTMH, a personalized healthcare system, tracks patients' blood pressure, body temperature, pulse, electrocardiogram (ECG), and electroencephalogram (EEG). The data is transmitted via Wi-Fi, allowing medical staff to access patient data. In this system, a tracking location with a RFID and GPS locator option will be integrated into the proposed model to identify and trace the patient's location in case of emergency intervention.

2. Literature Review

Internet of Things (IoT) powered health monitoring systems have shown promise in improving patient outcomes, managing long-term illnesses, and facilitating prompt intervention. Applications of IoT technology to neuropsychiatric diseases are especially beneficial since they enable ongoing monitoring of physiological and cognitive factors. With a focus on the management of neuropsychiatric disorders, this section provides an extensive overview of relevant research in the field of IoT-based healthcare monitoring.[1]

The Internet of Medical Things (IoMT), sometimes referred to as IoT in healthcare, involves the use of networked sensors and devices that gather and send health data in real-time. Wearable sensors, cloud-based platforms, data analytics, and decision support systems are frequently used in these investigations.

Gope et al. (2016), for instance, emphasize the use of body sensor networks to continually monitor physiological signals and send them across secure wireless networks to medical specialists.[2]. Heart rate, blood pressure, oxygen levels, and other data are gathered by these systems and sent to medical professionals for immediate assessment.

Majumder et al. (2017) highlight the increasing use of mobile apps and wearable biosensors to gather health data in real-time. Similar to this, Kumar et al. (2020) demonstrated the viability of a wristwatch-based RPMS in clinical settings by employing a wireless sensor platform to efficiently monitor heart rate and SpO2[3][4]

Healthy individuals typically have a heart rate between 60 and 100 beats per minute. Adult guys' resting heart rates typically range from 70 to 75 beats per minute [4]. Generally speaking, females aged 12 and up have higher heart rates than boys do. The sum of the heat that the body radiates is what scientists call the temperature of the human body.[5]

The average person's body temperature depends on a number of variables, including his eating habits, gender, and the outside temperature. It usually falls between 97.8 °F (36.5 °C) and 99 °F (37.2 °C) in healthy persons. Body temperature changes can be caused by a variety of conditions, including the flu, low-temperature hypothermia, or any other ailment. Fever is a common symptom of nearly every illness [5].

A wearable device that uses physiological complexity indexes to measure mental health remission was proposed by Lanata et al. (2015).[6] Their approach demonstrated how bio-signal analysis could be used by wearable technology to identify behavioral and emotional shifts.

Using smart textiles and smartphone apps, Pathinarupothi et al. (2016) created an Internet of Things-based RPMS for patients with bipolar disorder that includes speech tracking, sleep analysis, and medication adherence. These approaches emphasize the importance of behavioral and contextual information in the diagnosis and treatment of mental health issues.[7]

Prabhakar and Rajaguru (2018) used electroencephalogram (EEG) signals and machine learning to categorize epilepsy. To attain high accuracy, their system employed SVM classification and dimensionality reduction. To solve data privacy concerns[8],

Al-Janabi et al. (2017) talked about using secure wireless body area networks (WBANs) to transmit EEG/ECG data in real-time. The feasibility of employing EEG/ECG sensors in wearable technology for remote neuropsychiatric monitoring is demonstrated by these investigations.[8][9]

For individuals suffering from schizophrenia or dementia, fall detection, and geolocation technology improve patient safety. Pathinarupothi et al. (2016) added voice-responsive alarms via Amazon Echo and fall detection sensors to their RPMS[7].

Using motion sensors and GPS, Ishii et al. (2016) developed a dementia detection system that warned caregivers when patients strayed outside of approved safe zones. This research backs up the use of accelerometers and GPS in the Internet of Things health systems.[9]

Silva et al. (2019) suggested predictive modeling methods for identifying mental health conditions through the examination of digital footprints, such as communication and typing habits. These results support the use of behavioral analysis in neuropsychiatric IoT-based treatment.[10][11]

Rawat and Gochhait (2022) showed how textile-based sensors and cognitive behavioral models may be used to track mental health conditions. Future prospects for integrated neuropsychiatric treatment are presented by implantable technologies for heart and brain monitoring, as mentioned by Zhong et al. (2020). Although they are still in their infancy, these technologies offer a path toward completely immersive patient monitoring settings.[12][13]

Das, Alam, and Hoque in their study used an RPMS for heart rate and temperature. The temperature sensor reading, which is shown on an LCD panel, is managed by the microprocessor. Additionally, they used an RF transmitter to communicate data to an RF receiver, which then displays the data on an LCD screen using a microcontroller. The authors of [15] built a multi-vital monitoring system that tracks all five physiological indicators, while the systems in the earlier research were made to track just one or two.[5]

Pathinarupothi et al. described RPMS-based fall detection [8]. A webcam and an Amazon Echo speaker are combined with a fall-detection sensor to collect data. They used a Raspberry Pi model B+ as a controlling device, and the doctor received the data they collected over WI-FI. The hub uses speakers to communicate with the user when it detects a fall. Voice recognition and user confirmation of falls are features of Amazon Echo devices.

Prabhakar and Rajaguru's most recent work and developed a remote patient monitoring system for epilepsy [10]. This work's main focus is on applying spatial reduction to acquired EEG data. FMI was used to do this. This study [11] introduces the Gaussian Kernel Support Vector Machine (G-SVM) as a classification technique and the Singular Value Decomposition Partial Transmit Scheme (SVD-PTS) as a data transfer mechanism. With a time delay of just 2.19 seconds, they report an accuracy percentage of 95.38% [11][8].

Healthcare is a key area for sensor and cloud-based integration, according to Gubbi et al. (2013), who presented a groundbreaking architecture for IoT applications. This project's layered architecture, which consists of application, network, and sensing layers, reflects their architectural features.[15]

The applications, security, design, and implementation problems of IoT in healthcare were all covered in a thorough survey by Islam et al. (2015). According to their findings, secure communication and real-time data access are crucial, and the suggested monitoring system places a high priority on these features.[16]

Martinez et al. (2018) examined mHealth applications for the most prevalent illnesses identified by the WHO, such as cardiovascular and neurological problems. Their data backs up the expanding trend of remote monitoring solutions that are mobile-based and designed for patients who are at risk.[15]

Darwish et al. (2017) investigated the wider effects of IoT in healthcare, emphasizing emergency applications, power management, and privacy. Their perspectives are essential to comprehending the operational factors that influenced this prototype's design, particularly in low-resource environments.[17]

Giulia Regalia and associates created with reliable seizure detection, continuous ambulatory monitoring, and prompt action messages; wearable automated seizure detection devices have enormous promise to improve seizure management. An accelerometer (ACC) and electrodermal activity (EDA) sensor bracelet that uses machine learning automatically recognizes an event based on symptoms of ongoing GTCS and sends an alarm to a mobile app

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that notifies designated caregivers via text and phone calls through a cloud-based system.[17][18]

Pranjal T. and associates suggested a method for epileptic patients that uses a sensor to measure sound, handshaking, temperature, and patient falls. IoT can be used to view the patient's condition on a PC. To detect atonic seizures, the following system was developed" The patient's temperature drops during this kind of seizure, which is indicative of a lack of muscular control". Myoclonic seizures are characterized by jerking motions all over the body.

Ming-Zher Poh et al. developed an algorithm for the automatic diagnosis of generalized tonic-clonic (GTC) seizures using accelerometry with a novel wrist-worn biosensor and sympathetically mediated electrodermal activity (EDA).

These studies collectively highlight how crucial it is to combine affordable sensors, safe cloud infrastructure, and real-time analytics to enable responsive and easily accessible healthcare. However, the majority of earlier systems did not integrate multi-sensors input (ECG, EEG, SpO2, mobility), location tracking (GPS/RFID), and emergency alarms into a single, cost-effective solution designed for low-resource environments like Rwanda. The proposed Remote Monitoring for Mental Health in Rwanda (RMTMH) fills this gap.

3. Hardware and Methodology

3.1 Methodology

Since severe problems necessitate ongoing care, monitoring neuropsychiatric diseases requires additional attention. In integrated multi-sensors input (ECG, EEG, SpO2, mobility, using an RFID/GPS locational tracker is essential to complete the system and other options may be added like Behavior tracking tools like Speech Tracker.

This HRMN model has an integrated geolocation RFID device that tracks the location of the patient inside the hospital or outside with a GPS tracker for further intervention in case of emergency. Figure 1 illustrates the block diagram of the proposed system.

3.2 Working principle

As a new patient enters and registers at the reception a unique card and tag are given to him, as usual when a nurse takes the Vital Sign Monitoring (VSM) standard examination that gauges basic physiological indicators such as blood pressure, heart rate, body temperature, blood oxygen saturation, and breathing rate all these data are recorded and stored on the card as well as on the central server database.

The tracking part includes the patient's condition and the help they receive when they are alone in their home. A temperature and heartbeat sensor continuously monitors the patient while they are in bed. A text message with the location is sent to the close relative if the temperature rises above the average body temperature or any abnormality is detected. However, a communication containing the location is sent to the centralized server hospital when the heartbeat exceeds the typical range.

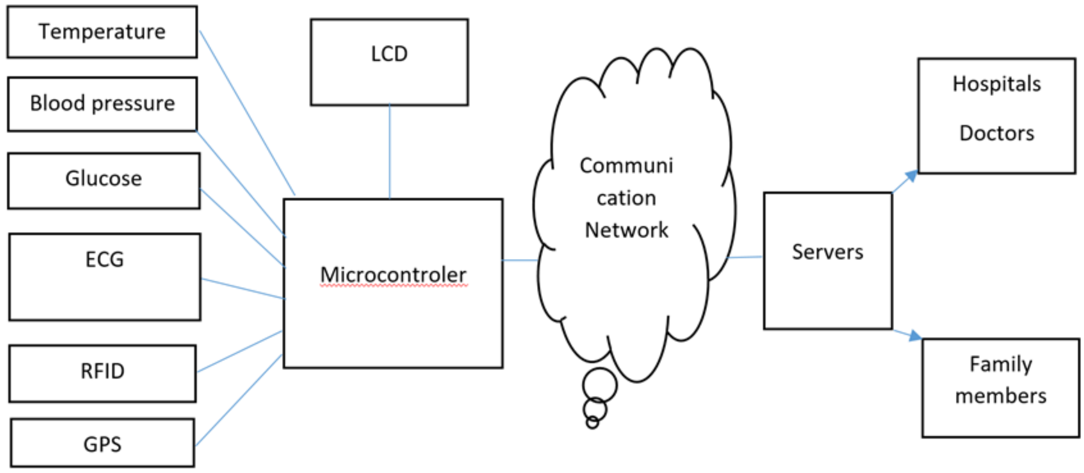

Figure 1: RMTMH Bloc diagram

Once more, if it stays high for the next minute, the closest hospital to the patient's location is determined, and the server of that specific hospital receives information along with an SMS to the relative stating "HELP." This allows the ambulance to enter the patient through the designated site, pick up the RFID tag, and travel to the hospital for treatment. The physician will use the RFID tag reader to check the patient's past medical history and treatments as the patient is being transported to the ward, and the prescriptions are then cleared appropriately.

3.3 Functionality

In order to guarantee real-time tracking and prompt medical intervention, the prototype system for Remote Monitoring Technologies for Mental Health in Rwanda integrates biological sensors, communication modules, and cloud services. The following phases (Figure 2) describe how the system operates.

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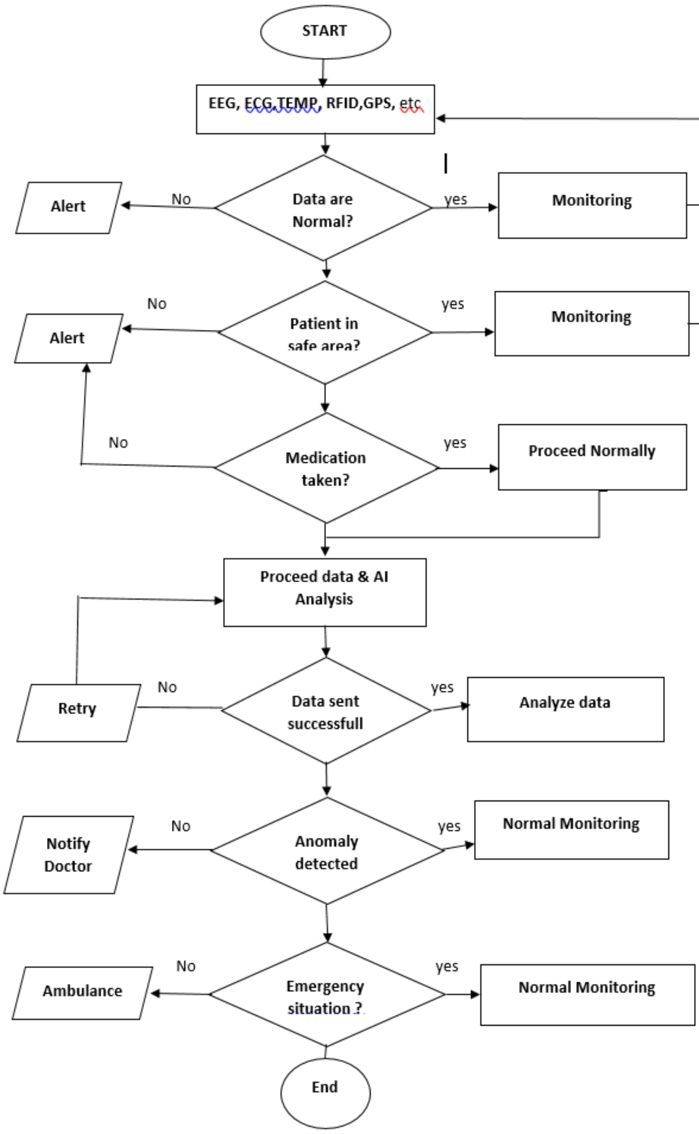


Figure 2: Flowchart diagram

First step: Patient Registration & Identification, once arrives at the reception, the patient is registered and assigned a unique identification with an RFID tag and card which is used for identification verification and local tracking.

The second step concerns vital signal acquisition where multiple sensors measure and send data to the Arduino Uno R3 to continuously monitor the keys health metrics, specifically EEG sensor AD8232 monitors brain signals and stress levels, ECG sensor measures heart activity, temperature sensor LM35 records and track body temperature, Pulse oximeter MAX30100 monitors heart rate and oxygen saturation SpO2 and MPU6050 tracks fall risk and patient motion.

The third step is the microprocessor Arduino Uno R3 reads the sensor's data at defined intervals filters them and digitalizes them before being transmitted to the Google Cloud via Wifi module ESP8266.

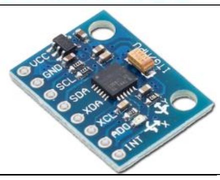
The following fourth step concerns the data link to the Google Cloud through WiFi and a GSM module SIM800L sends data via mobile networks and can trigger SMS alerts, the geolocation data captured by GPs are sent in the same packet,

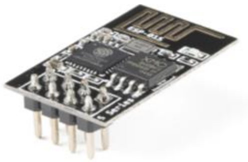
The next step is on the cloud where health data is stored in real-time database in Firebase format, this data is acceded by doctors or nurses via a dashboard or mobile web application. When vital signals cross predefined danger levels like high fever, irregular beat heart, or patient wandering out of a safe zone alert is automatically triggered vis cloud functions. If a critical condition is detected an emergency message is sent to the doctor's dashboard and phone member and an ambulance is dispatched for intervention referring to the patient's location. An LCD display attached to the Arduino shows live vitals for the patient or medical staff on site.

3.4 Hardware

To design our RMTMH in Rwanda hospitals system model we used the following hardwires that include microprocessors, sensors, and communication networks.

Table 1: Hardware modules

	Microcontroller: Arduino Uno R3) that controls all sensors and electronic devices connected for data process and communication system
	RFID RC 522 Reader, Active tag& card
	GPS Module Receiver, Navigation Satellite Positioning NEO-6M
	Pulse oximetry and Heart rate, SpO2 and Oxygen Saturation Sensors Track oxygen levels to assess respiratory function, which may correlate with stress or anxiety.
	Gyroscope with Accelerometer Module an incorporated 3-axis accelerometer and 3-axis gyroscope make up the MPU6050 to analyze movement patterns and detect irregular behaviors.
	The LM35 temperature measuring device. It displays the output voltage in Celsius.

	**WiFi Module ESP8266** Any microcontroller may connect to your WiFi network thanks to the ESP8266 WiFi Module, a self-contained SOC with an integrated TCP/IP protocol stack.
	**GSM module SIM800L** The SIM800L is a small cellular module that allows GPRS transmission, SMS sending and receiving, and phone calls.
	LCD Display, Due to the parallel interface of LCDs, controlling the display requires the microcontroller to concurrently manage a high number of interface pins
	The Buzzer The Grove Buzzer operates at both 3.3V and 5V with a sound output of 85 decibels that can be used to provide sound feedback to your application similar to the click sound of a button on a digital watch.
	Wire with pre-crimped terminals to connect different hardware.

3.5 Proposed block circuit

The hardware and sensors that make up the Remote Monitoring Technologies for Mental Health (RMTMH) system components work in tandem with software to enable healthcare professionals to track, report, and evaluate their patients' acute states both within and outside of the hospital or clinic. They allow for proactive clinical decision-making by the clinician by facilitating real-time understanding of the patient's disease status [18]. A prototype block circuit (Figure 3) was completed.

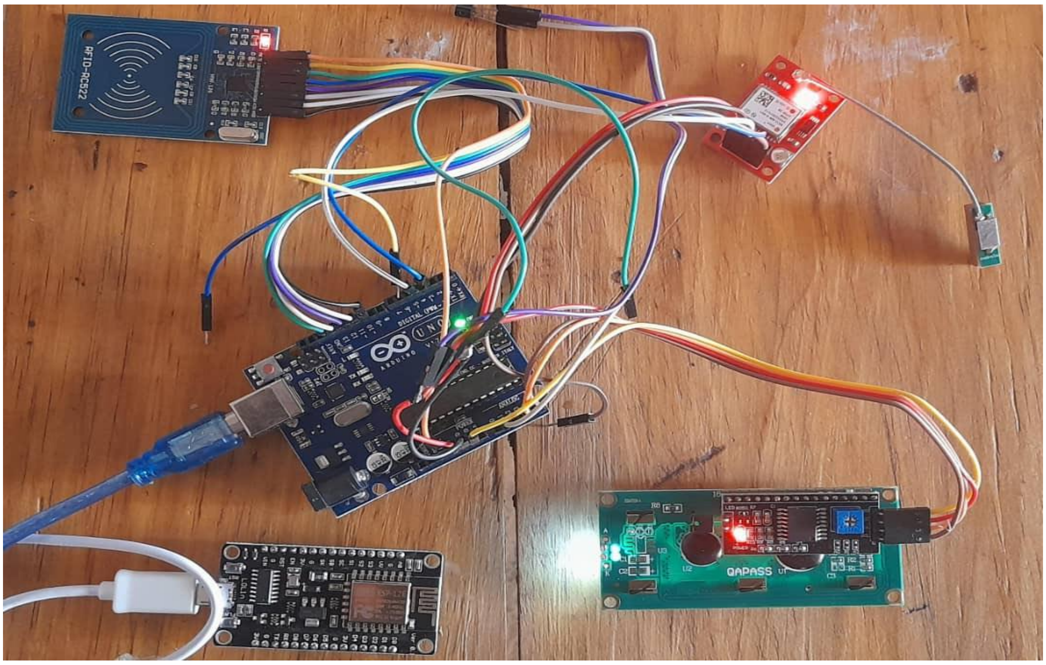


Figure 3: RMTMH Hardware assembled circuit

4. Results and Discussion

The suggested Remote Monitoring Technologies for Mental Health in Rwanda (RMTMH) was implemented using a hardware prototype based on an Arduino Uno R3, which combines a number of biomedical sensors, communication modules, and cloud services to collect, process, transmit, and show patient health data in real-time.

Table 2: Implementation results

Functionality	Status	Output Description
ECG Signal Monitoring	Successful	Real-time ECG waveform data is displayed locally and sent to Firebase
SpO_2 and Heart Rate Monitoring	Successful	SpO_2 and pulse rate recorded and transmitted every 5 seconds
Temperature Monitoring	Accurate	Consistent body temperature readings within the expected range
Motion/Fall Detection	Functional	Sudden movement triggers event logging
Patient Identification (RFID)	Functional	Tags read correctly and data matched with stored ID
GPS Geolocation	Accurate	Patient coordinates are uploaded and mapped via Google Maps
Real-Time Cloud Sync	Working	All data is sent to Firebase and accessed via dashboard/mobile
Alert Trigger (Abnormal values)	Working	Simulated emergency condition-generated SMS/email notification

Using the Arduino Uno R3 as the core processing unit and integrating a number of biomedical sensors and communication modules, the suggested Internet of Things-based Remote Monitoring Technologies for Mental Health (RMTMH) was successfully prototyped. A virtual environment that replicated characteristics common to outpatient neuropsychiatric monitoring such as changes in body temperature, heartbeat, and indoor/outdoor mobility was used to test the system.

5. Conclusion

The proposed Remote Monitoring Technologies for Mental Health (RMTMH) in Rwanda, offers a significant advancement in healthcare delivery by leveraging IoT technologies to address critical challenges in monitoring patients remotely. By integrating real-time vital sign monitoring, environmental sensing, secure data transmission, and geolocation tracking, the system provides a comprehensive solution for enhancing healthcare accessibility, particularly in underserved and remote areas. The study aligns with Rwanda's Digital Health Strategic Plan and global health goals, emphasizing its relevance and potential impact.

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Disclose statement

No potential conflict of interest was reported by the authors

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