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Agile Development of a Mobile Application for Remote Monitoring of Neurological Patients

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ABSTRACT
This research aims to address the issues of limited accessibility and efficiency in monitoring neurological patients by developing an Agile Development-based Remote Monitoring application. The development method includes identifying user needs through interviews and questionnaires, designing initial prototypes using Adobe XD, piloting testing with target users, and evaluating users using the System Usability Scale (SUS) and in-depth interviews. This research indicates that the application successfully enhances treatment accessibility, user satisfaction, and the effectiveness of neurological patient monitoring. The primary contribution of this research lies in providing user-oriented technological solutions in health monitoring, with the potential for further development to enhance overall remote healthcare service quality.

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INTRODUCTION

Monitoring neurological patients has become a crucial aspect of managing diseases related to the nervous system. Alongside technological advancements, remote monitoring approaches have become increasingly relevant and necessary. This context underscores the pivotal role of technology in facilitating neurological patient monitoring without the need for physical presence in the patient's exact location. Neurological conditions encompass a range of disorders and diseases requiring routine monitoring to ensure treatment response and prevent potential complications. Neurological conditions such as epilepsy, stroke, Parkinson's disease, and multiple sclerosis necessitate continuous monitoring of symptoms, drug responses, and patient condition changes over time(Bhushan et al., 2024; Gramkow et al., 2024; Hinault et al., 2023; Karagianni et al., 2024; O'Horo et al., 2021).

However, remote monitoring for neurological patients also faces several challenges that must be addressed. Key challenges include limitations in obtaining accurate and real-time data, the need for adequate technological infrastructure to support fast and secure data transmission, and a thorough understanding of patients' clinical needs to ensure that information obtained from remote monitoring is genuinely beneficial in managing their neurological conditions. Conventional monitoring for neurological patients often faces several issues that can impede its effectiveness. One of these is the limited accessibility of patients to care due to physical mobility or geographical distance. Patients living in remote areas or

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with mobility limitations often struggle to access necessary care regularly, thus disrupting the optimal management of their neurological conditions(Chen et al., 2023; Ferreira et al., 2023; Waerzeggers et al., 2010; Wischmann et al., 2024).

Furthermore, there is a risk of losing vital information during the monitoring process in the context of conventional monitoring. For instance, during routine visits to hospitals or clinics, not all data can be captured in real-time or comprehensively, mainly if significant medical events occur between two visits. This can disrupt accurate assessments of patients' conditions and hinder quick responses to changes requiring immediate medical attention. However, with the development of mobile technology in healthcare, there is significant potential to address some of these issues. Mobile applications are crucial in facilitating remote healthcare services by providing platforms enabling patients to connect with healthcare providers remotely. This opens up opportunities for virtual medical consultations, routine condition monitoring, and real-time delivery of essential information.

Another advantage is wearable sensors that can collect real-time data from neurological patients. These sensors, such as smartwatches or other gadgets, can be worn on the patient's body or everyday devices. Data collected by these wearable sensors can provide more accurate and continuous information about patients' physical activity, heart rate, sleep patterns, and other parameters relevant to their neurological conditions. This allows medical teams to monitor patients' conditions more effectively and rapidly respond to changes. The development of mobile technology in the healthcare sector has paved the way for significant innovation in patient monitoring, particularly for those with neurological conditions requiring special attention. Mobile applications and wearable sensors are two technological aspects that greatly enrich how we manage and monitor remote health(Cronin, 2023; Demaerschalk et al., 2023; Kolabas et al., 2023; Waddell et al., 2023).

Mobile applications have played a crucial role in facilitating remote healthcare services. These applications allow patients to connect with their medical teams without physically attending clinics or hospitals. This enables virtual medical consultations, regular patient condition monitoring, and rapid and efficient exchange of information between patients and healthcare providers. These applications also often come with notification and reminder features, helping ensure that patients adhere to their treatment schedules diligently. Another advantage comes from wearable sensors transforming how we collect health data(Matías-Guiu et al., 2010; Moreno, 2010; Savill et al., 2024). These sensors, attached to the patient's body or everyday devices like smartwatches, can collect real-time data on various health parameters such as heart rate, levels of physical activity, sleep patterns, and even medication responses. Information gathered by these sensors provides a more comprehensive and accurate picture of the patient's condition, enabling medical teams to make more precise decisions and respond to condition changes more quickly.

The Agile Development approach becomes highly relevant and practical in developing mobile applications for monitoring neurological patients. Agile principles such as flexibility in responding to changes in user needs and iterative improvements to enhance the application's quality form the main foundation of this development process(Altuwaijri & Ferrario, 2022; Leong et al., 2023; Sarhadi et al., 2022; Senabre Hidalgo, n.d.). The ad-

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vantages of the Agile approach in healthcare application development are particularly evident in the quick response to feedback from users and medical professionals. In monitoring neurological patients, where rapid response to condition changes is crucial, the flexibility and responsiveness offered by the Agile approach are vital to ensuring that the application can effectively meet the patient's needs.

Furthermore, another benefit of the Agile approach is its ability to ensure that the application complies with market needs and applicable health regulations. Through continuous iteration and testing, the application can be quickly adapted to meet healthcare data management's clinical and legal standards. In the context of research needs and goals, mobile applications for monitoring neurological patients are considered crucial, given the increasing demand for remote healthcare services and the limited accessibility of patients to quality neurological care. The development goals of these applications include improving patient monitoring access, enhancing the quality of remote healthcare services, and supporting more effective and efficient medical practices.

In research methodology, the Agile approach is applied from research design to application development stages. Collaboration with medical professionals and end-users is critical to ensuring the application meets users' needs and expectations. The results of this research have significant implications for improving accessibility and quality of care for neurological patients. Additionally, contributions to the development of mobile health technology and the application of Agile principles in healthcare and medical monitoring contexts provide essential added value to this research. Thus, mobile applications for monitoring neurological patients provide practical benefits and have broader implications for the future development of healthcare technology.

METHODS

This research consists of three main stages as shown in Figure 1. The first stage involves identifying stakeholder needs related to neurological patient monitoring, gathering data through interviews and surveys, and translating the results into requirement documents that serve as the basis for application development. Subsequently, the development stage implements Agile methodology to design and develop application prototypes with active collaboration from medical professionals and end-users. The final stage involves piloting application testing with target users to evaluate usability, reliability, and user satisfaction and analyzing the evaluation results to determine improvement or further development steps. With this approach, the research aims to enhance access to neurological patient monitoring, improve the quality of remote healthcare services, and support more effective and efficient medical practices through adaptive and responsive mobile application technology.

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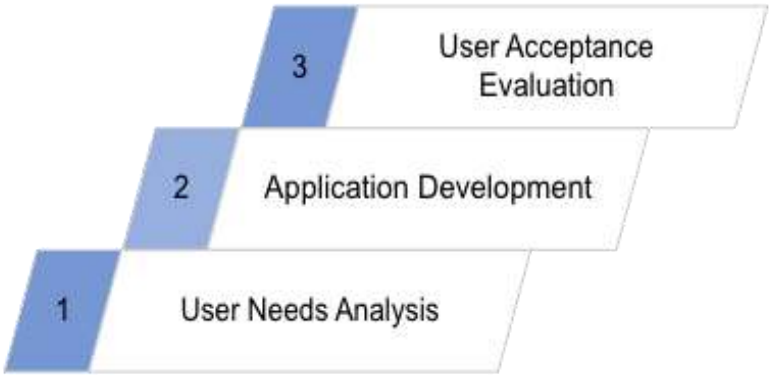

Figure 1. Research Stages

User Needs Analysis

The first stage of this research is the User Needs Analysis. The research team began by identifying all parties involved in neurological patient monitoring, including doctors, nurses, patients, and patients' families. Through interviews and surveys, they collected data on the needs and expectations of potential users regarding mobile applications for neurological patient monitoring. The needs analysis results were then documented in a requirement document that serves as a guide for further application development.

Application Development

Next, in the Application Development stage, the team designed initial prototypes based on the previously prepared requirement document. They utilized Agile Development methodology to initiate application development, set sprints, and assign tasks to the development team. Collaboration with medical professionals and end-users continued to gather feedback and make iterative improvements to the application. This process is iterated until an application is ready for testing.

User Acceptance Evaluation

In the final stage, User Acceptance Evaluation, the developed application was tested with a small number of target users in a piloting test. The team reviewed user experiences and received feedback on the application's usability, reliability, and user satisfaction. The evaluation results were comprehensively analyzed to assess the application's suitability for user needs and to determine improvement or further development steps based on the evaluation findings.

RESULTS AND DISCUSSION

User Needs Analysis

The User Needs Analysis demonstrated significant achievements in understanding the needs and expectations of stakeholders related to neurological patient monitoring. The research team successfully identified all involved parties through meticulous stakeholder identification processes, including doctors, nurses, patients, and patients' families. In-depth interviews were conducted with stakeholders, accompanied by questionnaires and surveys, to obtain comprehensive feedback on the desired features and functionalities of the mobile

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application. Careful analysis of the needs data resulted in a profound understanding of the significant challenges in neurological patient monitoring and specific hopes and desires from users regarding the developed application. The requirement document clearly details all findings and analysis results, serving as the main guideline for further development. Thus, this stage provided a strong foundation for designing an application that could meet the real needs of stakeholders and provide practical solutions in neurological patient monitoring.

Table 1. Data Collection Results

Stakeholder	Main Needs	Challenges	Expectations and Desires
Doctor	- Real-time access to patient data	- Time and resource constraints	- Remote examination system
	- Tools for analyzing condition patterns	- Integration of data from various sources	- Integration with hospital electronic medical records system
Nurse	- Notification of patient condition changes	- Patient accessibility limitations	- Structured and easily accessible patient data
	- Sharing information with doctors	- Nurse resource constraints	- Clear and understandable notification features
Patient	- Easy and intuitive self-monitoring	- Mobility and time limitations	- User-friendly and easy-to-use application
	- Information about treatment and care	- Difficulty understanding medical information	- Notification features for reminding treatment schedules
Patient's Family	- Access to information about patient's condition	- Lack of understanding about the condition	- Monitoring and communication features with medical team

Table 1 provides an overview of each stakeholder's primary needs, challenges, and expectations related to neurological patient monitoring. This is the basis for designing an application that can meet real needs and provide practical solutions for managing patients' neurological conditions.

Application Development

The Application Development phase began by designing initial mobile application prototypes based on the previously compiled requirement document. The development team utilized design tools such as Adobe XD or Sketch to create intuitive and responsive user interfaces, aiming to facilitate the use of the application by doctors, nurses, and patients. The main focus was to arrange the design to ensure smooth navigation between application features and enable users to understand how to use various provided features quickly.

Once the prototype design was completed, the team adopted the Agile Development methodology in application development. They set sprints and assigned tasks to the devel-

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opment team according to the priorities and specifications outlined in the requirement document. Throughout the development process, collaboration with medical professionals and end-users continued to gather valuable feedback. By listening to input from potential users, the team iteratively improved the application to ensure that existing features met users' expectations and needs.

After the initial development stage was completed, internal testing of the application was conducted to ensure that basic functionality worked well and met the previously identified user needs. During testing, the team identified any bugs or issues that may arise and addressed them before proceeding to the next development stage. This was done to ensure the application runs smoothly and effectively and provides a positive user experience.

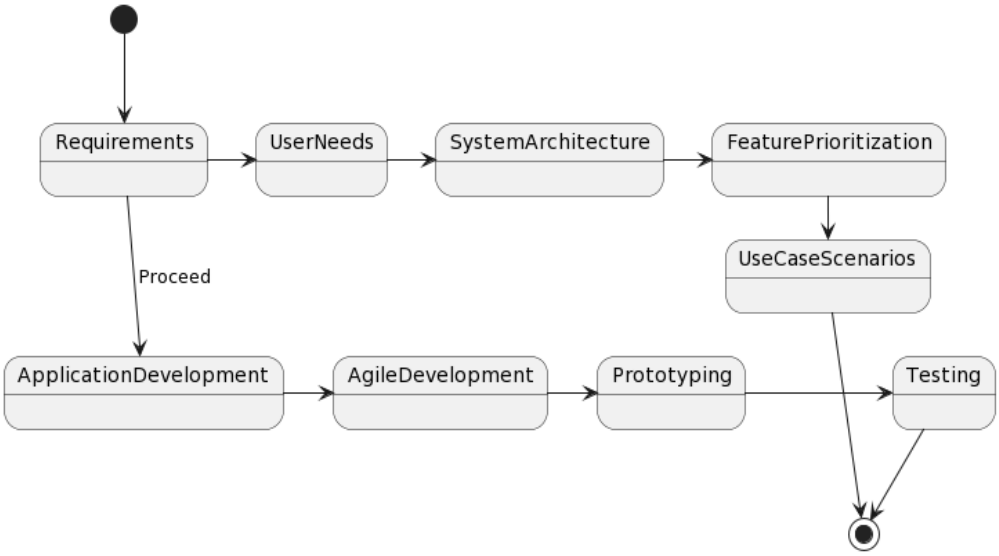

Figure 2. State Diagram

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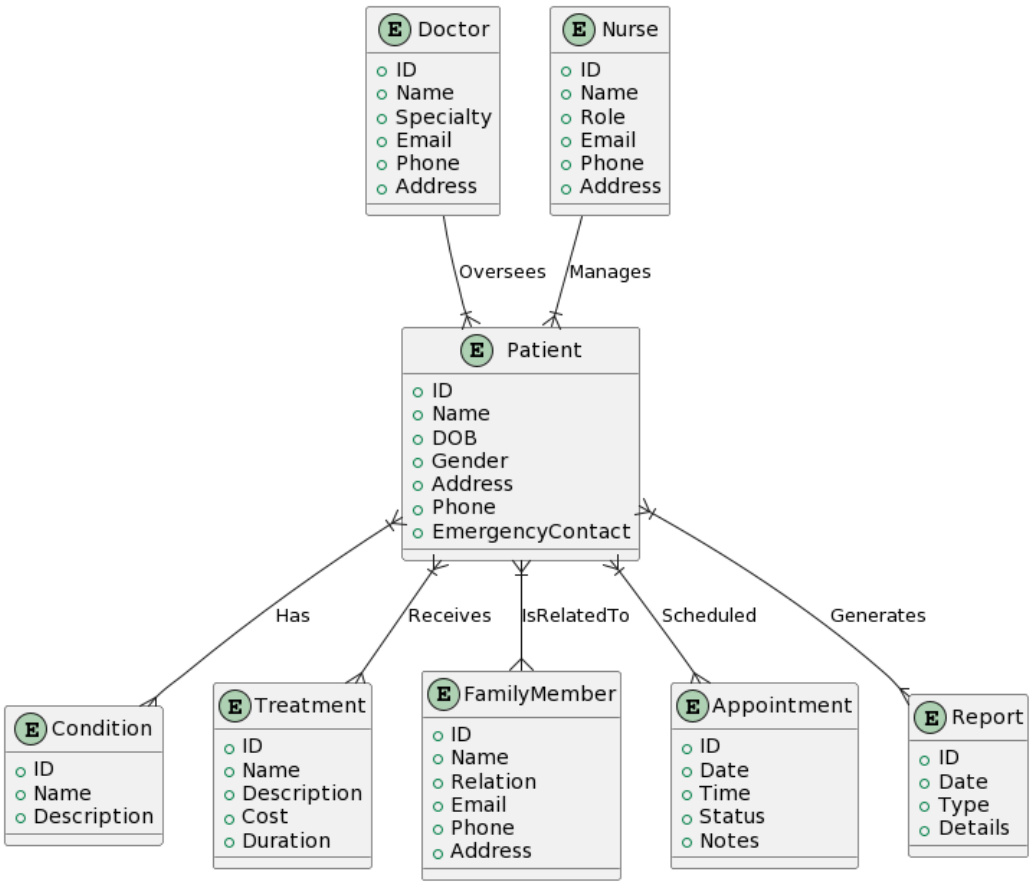

Figure 3. ERD

The Entity-Relationship Diagram (ERD) in Figure 3 displays the data structure for the Remote Monitoring of Neurological Patients application. It includes several main entities such as Doctor, Nurse, Patient, Condition, Treatment, family member, Appointment, and Report, each with relevant attributes to store critical patient information, treatments, appointments, and medical reports. The relationships between entities are also clearly defined; for example, the "Oversees" relationship between Doctor and Patient indicates the doctor's supervision of the patient, and the "Manages" relationship between Nurse and Patient indicates the care provided by the nurse to the patient, and so forth. The complexity of relationships between various entities in neurological patient monitoring is evident. For instance, medical information such as patient conditions and received treatments are represented through the "Has" and "Receives" relationships. Additionally, relationships with patient families and appointment schedules are also reflected in this ERD, underscoring the importance of involving all relevant parties in the remote care and monitoring process. With a well-organized data structure, as the ERD depicts, this application can efficiently manage information and facilitate optimal medical practices for neurological patient care.

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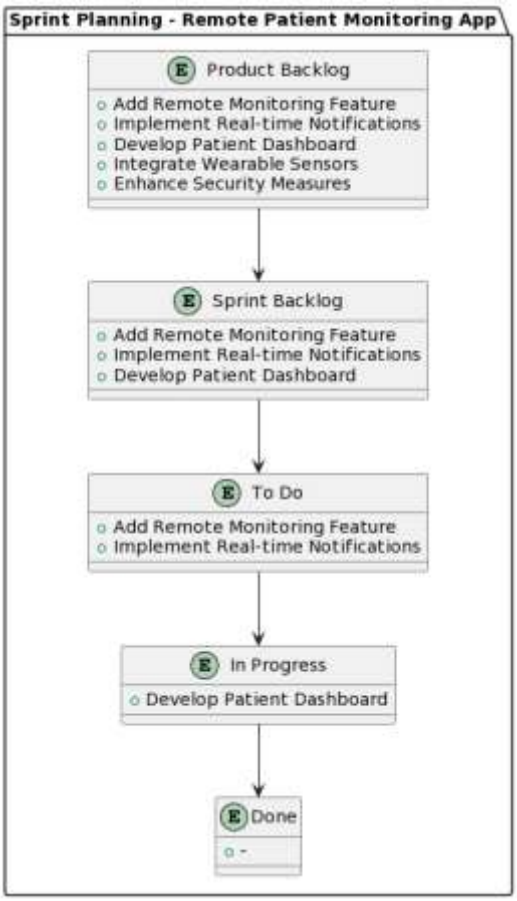

Figure 4. Sprint Planning

As shown in Figure 4, Sprint Planning in developing the Remote Monitoring of Neurological Patients application demonstrates a structured and focused approach to managing the project. The Sprint Planning analysis reveals several critical features prioritized for development, such as adding remote monitoring features, implementing real-time notifications, and developing patient dashboards. These features were chosen because they significantly impact the application's functionality and user experience. In this sprint, the selected features have been organized into a transparent workflow, starting from the "To Do" stage for features ready for implementation, then progressing to the "In Progress" stage for features under development, and finally to the "Done" stage after these features have been completed. This provides a clear overview of development progress and ensures the team can work efficiently to achieve the set development goals. Thus, Sprint Planning is a strong foundation for guiding the team to successfully develop the Remote Monitoring of Neurological Patients application according to user needs and expectations.

User Acceptance Evaluation

Various significant outcomes have been achieved upon completing the User Acceptance Evaluation stage in developing the Remote Monitoring of Neurological Patients application. Piloting tests were conducted with a small number of target users, including

doctors, nurses, and some patients, to evaluate the application's usability, reliability, and user satisfaction. Evaluation methods such as the System Usability Scale (SUS) were used to measure the application's usability from the user's perspective. At the same time, interviews and questionnaires were employed to obtain in-depth feedback. The evaluation results were then comprehensively analyzed to assess the application's suitability for user needs, user satisfaction levels, and potential areas for further improvement or development. A comprehensive evaluation report has been compiled, including recommendations for further improvement or development based on evaluation findings, which can be used as a guide in the subsequent development stage. The results of this User Acceptance Evaluation serve as a solid basis for ensuring that the developed application can provide a satisfying user experience and meet users' actual expectations and needs.

CONCLUSION

This research yields significant conclusions regarding developing the Remote Monitoring of Neurological Patients application using the Agile Development approach. In the neurological context, remote monitoring is crucial to enhance treatment accessibility, reduce the risk of vital information loss, and ensure real-time patient monitoring. Through the Agile Development approach, this application can adapt flexibly to changes in user needs, with iterative iterations allowing for continuous improvement and quality enhancement. The user evaluation conducted in the User Acceptance Evaluation stage also provides valuable input for refining the application, ensuring user satisfaction, and identifying potential further development. Thus, this research confirms the significant benefits of mobile technology in remote healthcare services and provides a solid foundation for further research and development in neurological patient monitoring.

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