BrainGain: A Technological Approach for Increasing Consciousness in Coma Patients

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Abstract. Coma is a state of reduced consciousness that affects thousands of people each year. Despite advances in medicine, many patients remain in a coma for long periods of time, and many never fully recover consciousness.

This prototype is an initial version of the application, more simplified and will allow exploring and validating concepts, functionalities, and interfaces. The BrainGain application will be an innovative tool designed to help coma patients recover consciousness more quickly, through personalized stimuli and activities. The application allows the customization of the rehabilitation program for each patient, based on their needs. Patients can engage in cognitive stimulation exercises, physical activities, and therapies, all aimed at improving their quality of life. Initial results suggest that BrainGain may be a valuable tool in coma patient rehabilitation.

Keywords: awareness · coma · stimuli · activities · family · medical team

1 Introduction

Coma, or loss of consciousness, is a state of deep unconsciousness caused by various medical conditions. During a coma, the person does not respond to external stimuli and is unable to wake up or communicate consciously [1]. Treatment involves identifying and treating the underlying cause, carefully monitoring brain function, and rehabilitation. The duration of a coma can vary from a few hours to years, with varying prognosis [2–4].

Traumatic brain injury (TBI) is considered a current public health problem due to its contribution to global death and trauma-related disability [5]. Each year, 500–800 cases per 100,000 people are recorded according to multiple studies conducted in the United States and New Zealand [6]. Death occurs subsequently in 64.6% of total cases, with the most frequent cause being neurological disorders and unintentional injuries or trauma (such as falls) [7] [8] [4]. TBI is a brain injury resulting from impact or injury to the head, varying in severity and symptoms. Loss of consciousness is a frequent symptom associated with this diagnosis, which can have varying durations and result from the temporary interruption of normal brain activity due to the impact or injury. The

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need for immediate medical attention is evidenced by the loss of consciousness, which may indicate a severe brain injury and require urgent medical treatment. Treatment can include supportive care, such as rest and pain medication, or surgical intervention to treat serious complications [9–11].

To combat this symptom, the patient should be highly stimulated to regain consciousness, both by the medical team and family. The stimuli are diverse, but can be divided into two main branches, personal and mechanical. Personal stimuli are those directed to the patient's intimate sphere, such as familiar and friendly voices, favorite music, personal tastes, familiar smells, and sensory stimuli, in short, stimuli that appeal to the use of memory. Mechanical stimuli are more general, such as following orders, repeating orders, interacting with the environment, and requested movements. The stimuli vary depending on the patient's level of consciousness.

The *BrainGain* application serves as a valuable platform that collaborates with the patient, their family, and the medical team in the process of regaining consciousness. This application offers a wide range of resources and tools, such as personalized stimuli ideas, progress tracking and reporting features, informative articles explaining the medical condition and treatment processes, as well as communication tools to foster collaboration between the medical team and families. By addressing the issue of communication gaps between these parties, the application aims to enhance the overall support system for the patient's recovery.

Utilizing software to stimulate patients who have experienced head trauma and recently emerged from a coma brings numerous significant advantages to the rehabilitation and neurological recovery process [5]. The software can be tailored to cater to the specific needs of each individual, providing exercises and interactive activities that target the impaired cognitive and motor functions resulting from the coma period. Moreover, the digital approach ensures a safe and controlled environment, allowing healthcare professionals to closely monitor the patient's progress and adapt activities according to the evolving clinical condition. The incorporation of gamification and interactivity in the software makes the rehabilitation process more engaging and motivating for patients, encouraging active participation and dedication to treatment, thereby potentially expediting the recovery process and enhancing the post-head trauma quality of life.

The personalized stimuli provided by the *BrainGain* application are particularly important, as they can help to stimulate the patient's brain activity and encourage the return of consciousness. These stimuli can include familiar voices, music, and other sensory cues that are meaningful to the patient. By providing a range of personalized stimuli options, the *BrainGain* application can help caregivers to find the most effective stimuli for each individual patient. In addition to personalized stimuli, the *BrainGain* application provides a range of other valuable features to support patients and caregivers. These include progress tracking and reporting tools, which allow caregivers to track the patient's progress over time and adjust their care plan as needed. The application is intended for those responsible for patients when they are not conscious and for the initial gain of consciousness.

This paper will present the development of the first prototype of the mobile application designed to assist coma patients in regaining consciousness.

2 Methodology

The development of the *BrainGain* mobile application prototype, aimed at assisting individuals in emerging from a comatose state, was carried out following a careful and rigorous methodological process. The work was divided into several phases, as shown in Fig. 1, allowing for a structured and efficient approach.

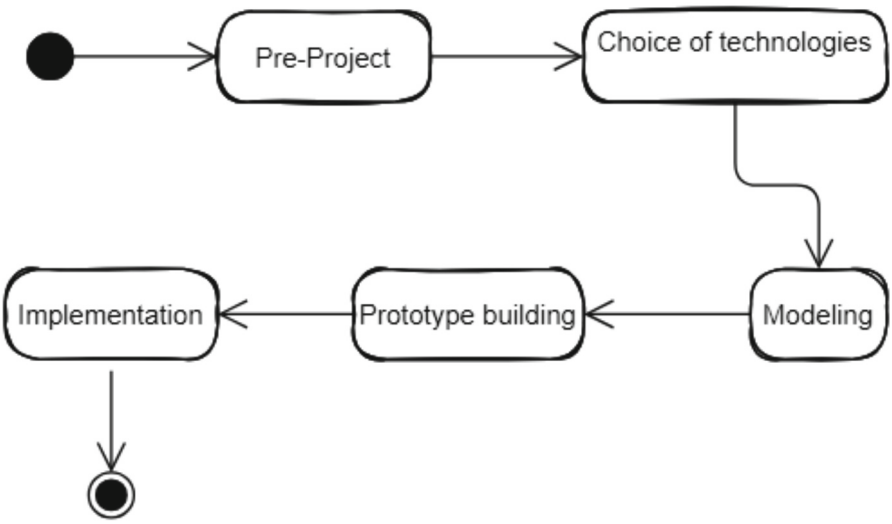

Fig. 1. Development pipeline

2.1 Pre-project

The pre-project phase is a fundamental step in the development process, whose main objectives are to deepen the understanding of the subject in question and obtain a comprehensive overview of the scope and activities that will be carried out. During this phase, we seek to collect relevant information, conduct research and analyze feasibility studies to identify needs and challenges related to the project. This preliminary exploration is crucial to defining clear goals and objectives, determining required resources, and establishing a solid strategy for project development. At the end of this phase, we are expected to be well grounded and prepared to move on to the next step in the process, with a solid understanding of what will be performed and what results to expect to achieve [12].

So, in the pre-project phase, an in-depth study of the technologies to be used was conducted. A thorough analysis of available options was performed, considering criteria such as performance, compatibility, and usability. Additionally, a detailed study of the most suitable programming language for the application development was conducted, ultimately opting for React Native and JavaScript. This choice was based on prior experience with these technologies and their ability to provide a smooth and intuitive user interface for both iOS and Android devices.

2.2 Choice of Technologies

The use of React Native presents itself as a strategic and advantageous choice in the development of mobile applications. By choosing this framework, it is possible to save time and resources, since it allows creating applications for iOS and Android from a single source code, avoiding the need to develop two different versions for each platform [13, 14]. In addition, React Native provides a fluid and fast user experience, as it can generate native interfaces, which results in performance and responsiveness similar to applications developed natively for each platform. Its wide community and the availability of pre-built components also facilitate the task of developers, accelerating the development process and allowing the creation of applications with the latest features and trends in the mobile market. One of the advantages of using JavaScript with React Native is language efficiency. JavaScript is an interpreted programming language, which means that the code is executed directly by the browser or by the interpreter, instead of being compiled before being executed. This makes the development process faster and more efficient, with less waiting time for compilation and debugging [15].

Finally, JavaScript can provide a fluid and intuitive user interface for mobile applications. React Native being component-based allows developers to build a consistent, reusable UI across their entire app, resulting in a more consistent and easier-to-use user experience [16, 17].

2.3 Modelling

The modeling phase was divided into two parts, Functional and Data modeling.

During the functional modeling phase of the project, we conducted a survey of the essential requirements and the detailed specification of the application. In this context, we thoroughly studied the specific needs of comatose patients, as well as the requirements of health professionals and families engaged in their rehabilitation process. By employing Use Case diagrams (not included in this paper), we successfully developed a robust functional model tailored to the identified needs.

Requirements Gathering – Macro Functionalities

The quality of the produced software is closely tied to requirements gathering [18].

In this subsection, we present a list that outlines the specifications for everything that must be implemented. These requirements can be classified into two categories: functional and non-functional requirements. Functional requirements pertain to the services the system should provide, while non-functional requirements are associated with specific characteristics or limitations of the system.

In this paper we will present a listing of macro functionalities instead of individual requirements. This approach is justified by the search for a more comprehensive and results-oriented view of the software development process.

Rather than focusing on detailed requirements, identifying macro functionality allows us to group the high-level functionality of the system, highlighting its main capabilities and overall goals. This approach makes it easier for stakeholders to understand the breadth and complexity of the software, allowing for better prioritization and

decision-making throughout the development cycle. In addition, the list of macro functionalities promotes more efficient communication between the development team and stakeholders, facilitating the identification of critical areas and enabling a more precise allocation of resources and efforts throughout the project. In short, the macro functionality listing offers a strategic and integrated view of the software, providing a solid foundation for successful project planning and execution [19].

1. The *BrainGain* application must be able to manage several types of stimuli - visual, auditory, and tactile.
2. The *BrainGain* application must allow customizing the stimuli according to the individual characteristics of the patient.
3. The *BrainGain* application must allow the storage of monitoring and brain stimulation data - allowing the analysis of patterns and trends.
4. The *BrainGain* application must allow communication with the medical team responsible for treating the patient in a coma.
5. The *BrainGain* application must ensure safe and secure access to patient data.
6. The *BrainGain* application must allow multiple reports.
7. The *BrainGain* application should be multi-patient and multi-caregiver.

Data Modeling

Data modeling plays a crucial role in the field of data management and information systems as it serves as the basis for organizing and representing data in a structured and meaningful way. By defining the relationships between different data entities and attributes, data modeling helps to create a clear and standardized structure for databases, facilitating data integration, retrieval and analysis [20].

The Entity Relationship Diagram (ERD), as we can see in Fig. 2, enabled us to define the structure of the database required for efficiently storing and managing information essential to the recovery of comatose patients. Furthermore, we outlined the user interfaces for both the back-office and front-office through the creation of mockups. This approach ensures a cohesive and engaging user experience.

- ***Patient***: represents the patient in a coma, with information such as name, age, gender, medical history and level of consciousness.
- ***BrainStimuli***: represents the brain stimuli applied to the patient, including information such as type of stimulus, intensity, duration and frequency.
- ***Medical_Team***: represents the medical team responsible for the patient's treatment, including information such as name, specialization and position.
- ***Family***: represents the patient's relatives, with information such as name, relationship with the patient and contact data.
- ***User_Account***: represents the user accounts created for each member of the family, with information such as name, email and password.
- ***Reports***: represents the reports generated by the application, including information about the patient's progress, brain stimulation results and trends over time.
- ***Settings***: represents application settings, including information such as personalization of brain stimuli and security and privacy settings.

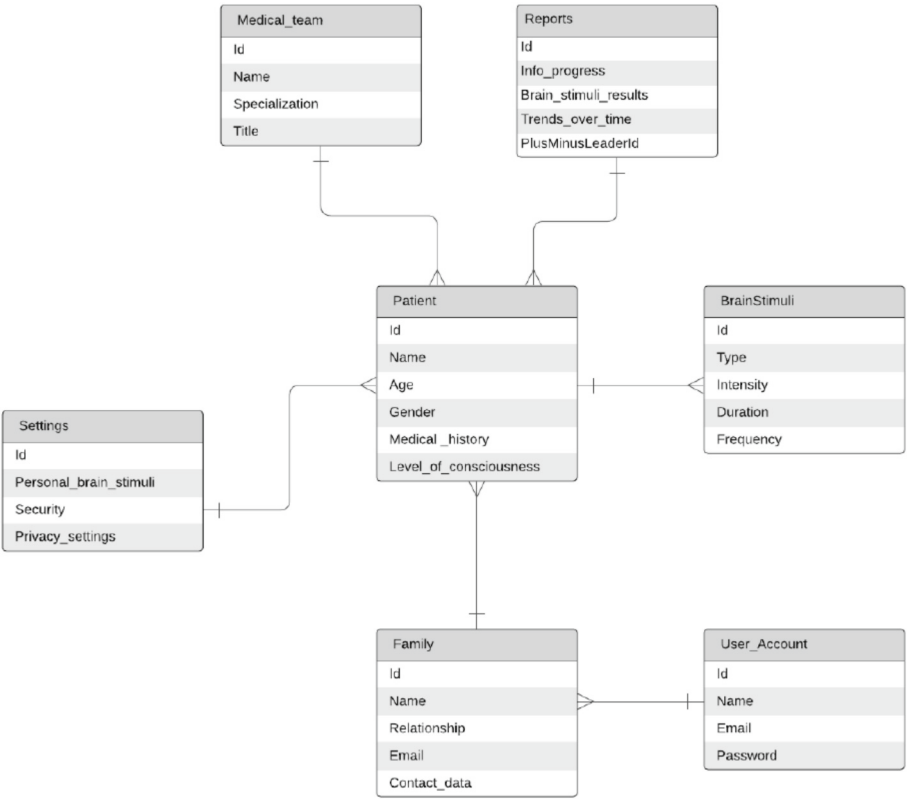

Fig. 2. Entity Relationship Diagram

3 Prototype Building and Implementation

The use of prototypes in software development offers numerous advantages that contribute significantly to the success of the project. First, a prototype allows developers and stakeholders to visualize a tangible representation of the proposed solution, facilitating communication and mutual understanding of expectations. In addition, prototypes allow for rapid iteration and validation of concepts, enabling early identification of failures and adjustment needs, which saves time and resources throughout the development cycle. Another advantage is the ability to get feedback from end users before full development, ensuring the final product best meets their needs and preferences. With the possibility of carrying out tests and simulations on prototypes, it is possible to mitigate risks and make more informed decisions, culminating in a more refined and satisfactory final delivery for all those involved in the project [21].

In the subsequent phase, focusing on prototyping, both the backend and frontend configurations of the application were meticulously developed, incorporating essential libraries to ensure smooth operation. The database's physical model was implemented using SQL light language, a crucial step that played a pivotal role in upholding the system's data integrity.

With the application's functional logic now in place, a seamless connection between interfaces and the database was established, ensuring efficient data management. Notably, the application underwent rigorous testing, albeit with a limited number of users due to the challenges in finding available comatose patients for participation.

The mobile application was purposefully designed to support both family members and healthcare professionals involved in the rehabilitation process of comatose patients. Recognizing the patients' inability to provide feedback, special emphasis was placed on safeguarding the security and privacy of the collected data.

It is important to acknowledge that, while the obtained results show promise, it would be premature to claim with absolute certainty that the mobile application can awaken patients from the coma state. The inherent complexity and variability of this medical condition present inherent limitations to studies in this domain.

Nevertheless, the mobile application represents a significant advancement in the rehabilitation of comatose patients, introducing an innovative and personalized approach. As we look to the future, further research and more comprehensive clinical trials hold the potential to deepen our understanding and validate the effectiveness of this tool in enhancing the quality of life for these patients.

4 Results and Discussion

This section aims to present the developed prototype, its functionalities, tests, and limitations.

4.1 BrainGain – Prototype

Three of the most relevant options made available by the prototype are the homepage, the menu, and the recovery diary.

The homepage (see Fig. 3, middle image) provides access to a calendar, a board with future activities, and a mood board. The main objective of this page is to customize the application according to each patient's needs. The right image in Fig. 3 represents the recovery diary, where any relevant records that contribute to the patient's improvement can be daily inserted. Over time, these records can be evaluated and included in medical records, combating forgetfulness or lack of attention during critical moments. Finally, the menu (left image in Fig. 3) presents the user with various options available in the application, including activities, stimuli, and additional information on the subject.

Figure 4's left image showcases the "Learn more about it" page, offering a vast collection of articles to enhance users' knowledge about their prognosis. Selecting an article automatically opens a complete webpage, aiming to educate individuals and raise awareness on multiple levels.

The middle image of Fig. 4 represents the stimuli section, containing a huge list of stimuli to be performed for the patient. When selecting one of these stimuli, a brief explanatory note opens (image on the right in Fig. 4).

The prototype also provides an 'Activities' section (left image of Fig. 5). This section offers a selected list of exercises and stimulating therapies for coma patients, promoting sensory, cognitive, and emotional engagement. This feature empowers caregivers and

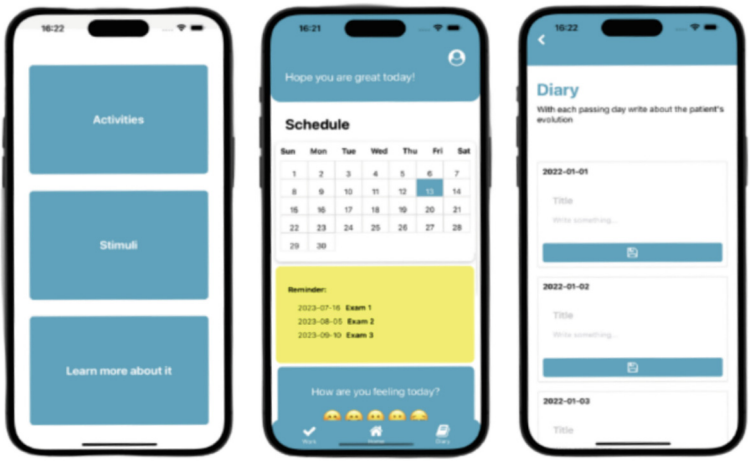

Fig. 3. Menu, homepage, and recovery diary

Fig. 4. Learn more about and stimuli pages.

enhances patient care, improving outcomes and aiding recovery from a coma. In the middle and right images of Fig. 5, we can see two examples of activities. The first activity consists of two circles, one green and one red, to stimulate the patient's perception and reasoning. In the second activity, we use music to stimulate the patient's auditory and emotional senses.

Thus, the prototype presented here aims to contribute significantly so that the future application represents a true advance in the field of technology, with a focus on increasing consciousness in coma patients. With an intuitive interface and innovative features, we are fully confident that it will become an indispensable tool for users and patients alike. We firmly believe that the prototype will contribute to every detail being meticulously

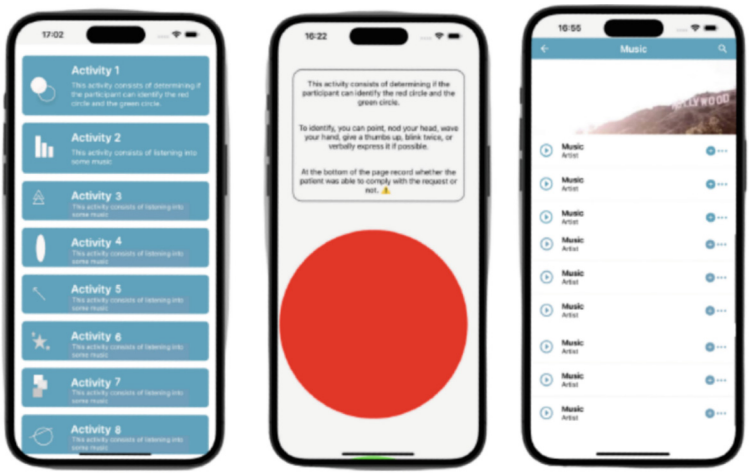

Fig. 5. Activities available example

planned to ensure the best possible experience. Our commitment is not only to meet the needs of patients and caregivers, but also to exceed their expectations.

4.2 Tests and Test Limitations

During the testing phase of the mobile application prototype, simulations and evaluations were carried out to assess its usability and functionality. Although health professionals or real patients were not involved in the tests, internal tests and evaluations were conducted by people close to the project.

The results of these preliminary tests showed that the application has an intuitive and user-friendly interface, facilitating user interaction. The features and activities available in the application were considered appropriate for stimulating the recovery of consciousness in coma patients.

Although the tests were not conducted with real patients, the preliminary results suggest that the mobile application may have a beneficial role in the rehabilitation process of coma patients. However, it is important to emphasize that further research and tests with real patients are needed to effectively validate the effectiveness and benefits of the application.

All procedures and techniques used were documented in detail to ensure reproducibility. However, given the limitations, exact replication of the tests may not be possible.

The Mobile application BrainGain project, which aims to help people recover from a coma, is a promising and important initiative in the healthcare field. By using technologies such as React Native and JavaScript, the application offers an intuitive and user-friendly interface for IOS and Android devices.

One of the main benefits of the Mobile application BrainGain is that it provides specific resources and activities to aid in the recovery of coma patients. By providing

visual and auditory stimuli, the application can help awaken consciousness and improve cognition in patients.

However, it is important to note that the effectiveness of the Mobile application BrainGain has not yet been fully validated through clinical trials on real patients. While preliminary tests conducted internally suggest that the user interface is intuitive and easy to use, it is essential that the application be tested on real patients to evaluate its effectiveness in helping them recover from a coma.

Additionally, it is important that the application be used in conjunction with other treatments and therapies, such as physiotherapy and occupational therapy, to ensure that patients receive the best possible care.

The Mobile application BrainGain can be a valuable tool to complement these treatments but should not be considered a sole solution for the treatment of coma patients.

In summary, the Mobile application BrainGain is a promising and important initiative in the healthcare field, but it is essential that it be subjected to clinical trials and used in conjunction with other treatments to ensure the best possible chance of helping people recover from a coma.

5 Conclusion

This study addressed the development and evaluation of the Mobile application with the aim of helping individuals in a coma state to regain consciousness. Although we faced significant limitations, such as the lack of a real sample of comatose patients, the results obtained through the simulations carried out by some people indicate a promising potential of the application.

Users highlighted the importance of the Mobile application as an innovative and personalized tool in the field of rehabilitation of comatose patients. Through the customization of stimuli and activities, the application proved to be capable of eliciting responses and stimulating brain activity in simulated patients. These results suggest that the application can play a significant role in the rehabilitation process, providing adequate stimuli for the recovery of consciousness.

It is important to emphasize that, due to the lack of a real sample of coma patients, we cannot fully generalize the results obtained. However, the insights and feedback from experts provide a solid foundation for future investigations and larger clinical studies.

Considering the limitations inherent to this field of research, including the complexity and variability of the coma state, the Mobile application represents a significant advance in the therapeutic approach and in improving the quality of life for patients. The customization of stimuli and activities offered by the application, combined with the intuitive and fluid interface, demonstrated the potential to stimulate the recovery of consciousness.

It is recommended that future studies be conducted with a real sample of comatose patients to validate and further deepen the results found. Additionally, the incorporation of specialized health professionals and careful consideration of the ethical aspects involved are essential for the development and proper implementation of the mobile app.

Overall, the mobile application prototype proved to be a promising tool for future application development. This application could be a strong ally in the rehabilitation of

comatose patients, paving the way for new therapeutic approaches and improving the understanding of this complex health condition. With the continuous advancement of technology and interdisciplinary collaboration, it is expected that the future mobile application can contribute to the recovery and quality of life of these patients, representing an important innovation in the field of medicine and intensive care.

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