Digital LOTCA
How to Evaluate Acquired Brain Injury using Technology

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Abstract: In this article, we are going to describe the solution proposed to help people with acquired brain damage, consisting of a service-oriented application, which provides a platform in which different tests are used that are used in the test battery of cognitive evaluations of occupational therapy of Loewenstein. This platform allows the patient to perform the tests on a touch screen, while the therapist can observe the results of the test in real time on a monitor.

1 INTRODUCTION

First, we are going to define what is the Brain Damage Injury, and what is the current situation of this type of brain injuries in the world. Acquired Brain Injury (ABI) is the involvement of brain structures in people who, having been born without any type of brain injury, suffer at a later time in their lives, brain injuries that cause an impairment of cognitive, emotional, behavioral and/or physical functioning. This injury is a major health problem, due to the high number of people affected (more than 400,000 in Spain), the duration, severity and variety of sequelae. The ABI represents the main cause of disability in adults in developed countries (Cerebral Injury Association of Navarra, 2014).

The causes by which this type of injury can be generated are very varied, and include (Cerebral Injury Association of Navarra, 2014):

- Cranioencephalic trauma: is the brain injury from a trauma or blow. The most frequent causes are traffic accidents (in 80 % of cases), work accidents and sports accidents.
- Stroke: cerebrovascular accidents are injuries resulting from an interruption of the cerebral blood flow system, such as embolisms and thrombosis, or cerebral hemorrhages, including ruptured aneurysms, or malformations of the veins and arteries that irrigate the brain.
- Anoxies or hypoxia: it is the absence or poor oxygenation of the brain during a certain time, which causes the neuronal death of part of the brain tissue.
- Brain tumors: both the tumor itself and the procedures aimed at its elimination (surgery, radiation) cause important damage to the surrounding brain tissue.
- Other causes: iencephalitis of various etiologies, which may be a consequence of infectious, viral, or toxic poisoning processes.

In the Figure 1 we can see a graphic overview of the incidence and prevalence of ABI in Spain.

The ABI can affect all areas of human functioning. The affected area and therefore the deficits presented by the affected person will depend on the type of injury, the initial location and severity of the injury; as well as the characteristics of each affected person such as age, personality or abilities prior to the injury. The sequels are grouped into four dimensions that may or may not be present in the same person (Red Menni of Cerebral Injury, 2015):

- Physical-motor deficits: There may be alterations in balance, inability to stand, inability to walk, limitations in the movement of one or more limbs, or even control of the trunk and head at rest.
- Cognitive deficits: for example, deficits in learning and memory, attentional deficits, language alterations, alterations in formal thinking (logical-deductive reasoning, problem solving, abstraction) and alterations in the regulation of proactive or targeted behavior (planning, initiation and behavioral self-regulation).

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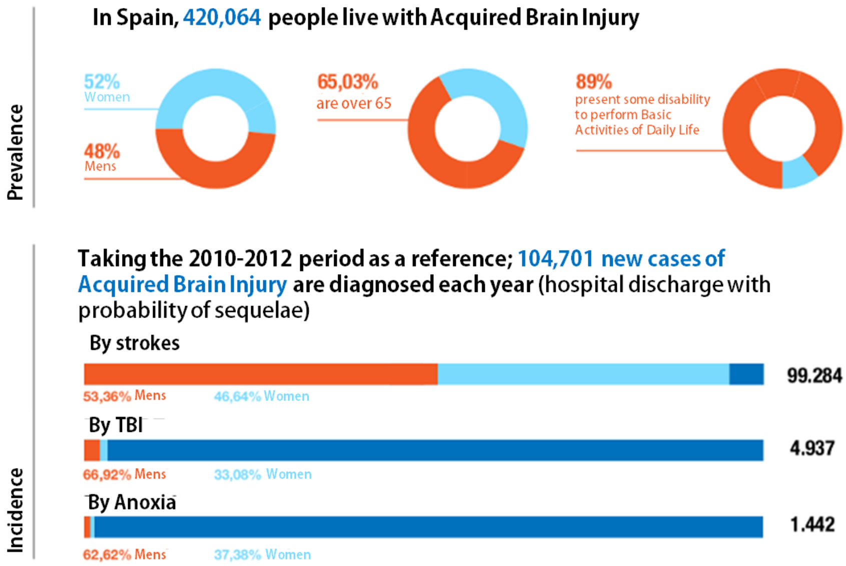

Figure 1: Incidence and prevalence of ABI in Spain.

- Alterations in communication: occur due to the alteration of physical and cognitive abilities or the combination thereof. In the case of physical alterations, oral, written or comprehension expression is affected. There are also language alterations that produce the inability for oral expression or comprehension, despite the fact that the physical-motor system remains intact.

- Behavioral and/or Emotional Alterations: At the same time that the cognitive alterations appear behavioral and/or emotional alterations associated with changes of character or personality. The origin of behavioral alterations could be considered in two ways: lack of inhibition, sometimes causing physically or verbally aggressive behaviors or excessive inhibition or poor behavioral initiative, in which the affected shows apathy not initiating activities if not explicitly asked , he does not enjoy the things that he used to enjoy so much, he has a feeling of exhaustion and lethargy, and on the emotional level he hardly expresses emotions. When an ABI occurs, there is a sudden break with the occupational roles that the person played until the time of injury. This usually causes that suddenly, the person suffering a brain injury moves from a balanced and active occupational reality to a situation in which he becomes a passive recipient of care. Then, as he recovers capacities, he finds himself in a situation of significant decrease in the level of participation, being unable or depending on help to perform a large number of activities.

As indicated by (Spanish Federation of Cerebral Injury, 2014), in the process of rehabilitation of Acquired Brain Injury it has five objectives:

- Evaluate the sequelae of brain damage and the difficulties they cause.
- Reeducate and compensate for the sequelae of brain damage to reduce disability.
- Prevent future complications of the sequelae of the ABI or of the brain injury itself.
- Enhance conserved skills.
- Promote social and family integration.

Our solution focuses on this first stage of the rehabilitation of brain injury, the evaluation of the sequels produced and the difficulties or deficits that these cause. For this, we have started from a traditional methodology in this area called LOTCA, and we have created a digital platform that makes it easier to diagnose and assess the therapist.

2 OCCUPATIONAL THERAPY IN ACQUIRED BRAIN INJURY

Loewenstein's Occupational Therapy Cognitive Assessment (LOTCA) (Katz N., 1989) battery of evaluation was developed as a technique used to measure basic cognitive abilities and visual perception in adults with neurological disabilities. It provides an in-depth evaluation of basic cognitive skills and it can be used for treatment planning and review of treatment progress (McDermott, 2011). The LOTCA battery measures the basic cognitive abilities required for daily functions including orientation, visual perception and psychomotor skills, problem solving abilities and thought operations. The development of this battery is based on information obtained from clinical and neuropsychological experience and development theories.

Usually, LOTCA is used in the initial stage of the evaluation of patients, but it can be used to establish therapeutic goals and review the cognitive status over time (Annes G., 1996) (Zwecker M, 2002) The original version of LOTCA (Katz N., 1989) was developed to be used by individuals under 70 with neurological dysfunction and was made up of 20 items grouped into 4 areas: Orientation, (2 items), perception (6 items), visual-motor organization (7 items) and thought operations (5 items).

Next, we will proceed to describe the characteristics of the specific measurement of each one of the aforementioned areas:

- Orientation: the tests in the area of orientation evaluate the orientation of the individual in space and time.
- Visual perception: tests in the area of visual perception evaluate the individual's ability to identify images of everyday objects, objects photographed from unusual angles, distinguish between superimposed figures and recognize spatial relationships between objects.
- Spatial perception: the tests related to spatial perception evaluate the ability of the individual to differentiate between right and left, to determine the spatial relationships between objects and himself.
- Motor praxis: the tests related to motor praxis evaluate the ability of individuals to imitate motor actions, use objects and perform symbolic actions.
- Visuomotor organization: the tests related to the visual-motor organization evaluate the ability of the individual to copy geometric figures, reproduce a two-dimensional model, copy a design of a colored block and a clean block design, reproduce a puzzle, a complete task of a peg board and draw a clock.
- Thought operations: thinking operations evaluate the individual's ability to complete tasks that include: ordering, categorizing and drawing geometric sequences (Annes G., 1996).

These analyzes have been standardized for the Israeli population (Annes G., 1996) (Cermak S. A., 1995) and suitable for use in the populations of the United States (Katz N., 1997). Regarding the evaluation time, LOTCA and LOTCA-II take approximately 45 minutes, with a range that ranges between 30 and 90 minutes (Annes G., 1996) (Zwecker M, 2002).

Regarding the suitability of individuals, LOTCA can be used with:

- Patients who have had a stroke, cardiovascular accident, stroke, stroke, cerebrovascular accident, etc. (Bar-Haim Erez A., 2003)
- Elderly individuals with dementia (Bar-Haim Erez A., 2003).
- Individuals with traumatic brain injuries (Annes G., 1996).
- Individuals with intellectual disabilities (Jang Y., 2009) and mental illness (Josman N., 2006) can also use it.
- An adapted version was developed for children with learning difficulties (Josman N., 2010).
- Patients with aphasia (Jang Y., 2009).

3 ARCHITECTURE OF THE SOLUTION

So far we have studied how technology can help diagnose and evaluate people with Acquired Brain Injury, and what are the most common techniques used today. Next, we will explain the solution we propose.

The proposed solution, briefly explained, consists of a client-server application, in which the therapist can create a personalized session for his patient, including data such as his name or the patient's own. This session contains a test of the battery proposed by LOTCA, belonging to the area of operations of thought.

If we performed this test in a traditional way, the therapist would provide the patient with a set of cards containing different geometrical shapes with different colors, and the patient should group them according to the pattern provided by the therapist.

To carry out this task, our solution proposes a distributed application, in which the patient will work on a touch screen solving the test, while the therapist observes the results in real time on another screen that will act as a monitor. In this test, the patient will be shown a set of cards with geometrical figures of different colors.

There are six different types of figures, and each of them is represented in three different colors, there being a total of eighteen different cards. The patient must group these cards according to the parameters indicated, which may be, for example, by colors, by shape, repeating a previously given pattern, etc.

The therapist will observe in real time on his monitor how the patient moves the different cards on the screen, allowing him to observe and analyze strange behaviors that indicate that the patient suffers some type of injury. In addition, he can also view statistical information such as the total time the session has been running.

To make this communication distributed between the screen of the therapist and the patient possible, it is necessary that there is a server that acts as an intermadiary and that collects all the data and processes them properly. This server, implemented using Node.js, has a REST services layer and is connected to a NoSQL database implemented in MongoDB, in which the data is stored in the session. The server is responsible for collecting the information that the therapist introduces about the session he want to create, processes them and generates the test, allowing the patient to connect to that session. Once the patient connects, it collects all the movements of cards that it makes, and making use of Web Sockets, sends them in real time to the therapist's monitor. In addition, the server is also responsible for storing all of this data in the database, so that the information of a certain session can be viewed at any time.

This can be done using the display module of the application results. This module allows, given a specific session that has already been carried out, to visualize which cards have been moved by the patient in a specific time slot, showing their position of origin, the path traveled and the final position. The therapist can modify that time frame to visualize which cards have moved in different lengths of time. Figure 2 shows the architecture of the application in a schematic way.

The reason for choosing Javascript and specifically, Node.js to implement the server, is the high performance provided by this technology in service-based applications. Node.js uses an event loop (Event Loop), which manages all asynchronous operations. In case of needing a blocking operation, an asynchronous request is sent to that Event Loop together with a callback, and the server continues with the request when it can. If we compare it with other technologies such as PHP and Java, in which every new connection to the server generates a new thread, with its corresponding memory consumption, Node.js for each new connection to the server, creates a new event inside the main engine of Node.js. This translates into great memory savings and therefore, support for a larger number of simultaneous requests using fewer resources. In addition, another of the great advantages is the ease and speed of implementation and execution

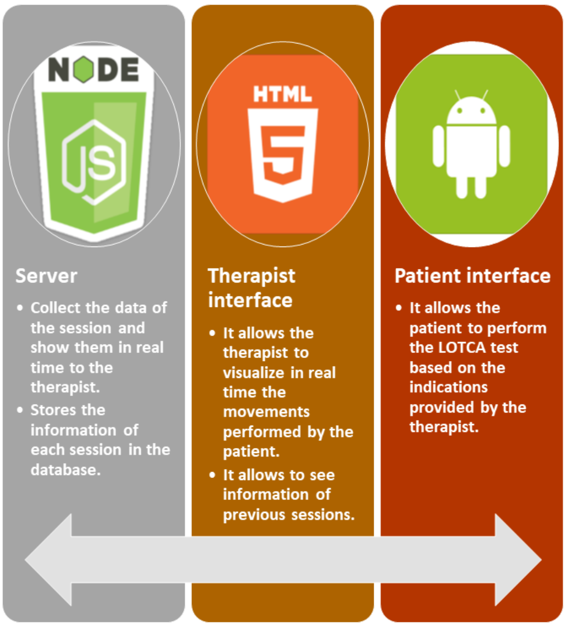

Figure 2: View of the architecture of the application.

of unit tests.

The fact of choosing a NoSQL database like MongoDB is fundamentally due to the advantages that this type of database provides in matters of performance and scalability with respect to a SQL database. In the developed application, we do not work with sensitive data about patients and, in particular, with data related to their medical file, which according to Spanish legislation are considered specially protected data. Therefore, the solution adopted does not require extremely restrictive measures regarding the storage and processing of data, although it does use encryption in those data that may lead to the theft of user information.

4 WORKING WITH THE DIGITAL LOTCA

To finish, we will show how the application we have developed works. First, we will show the functioning of the therapist's interface. To access it, the therapist must enter the application (see Figure 3) and select the option "I am the therapist". Once this is done, the therapist's interface will be displayed.

From this interface, the therapist can create a new session or can visualize information about a session that he has already done previously. If the therapist wishes to create a new session, he must enter an identifier for that session if he wish (although one is provided automatically), his name and that of the patient

Figure 3: Main user interface selection menu.

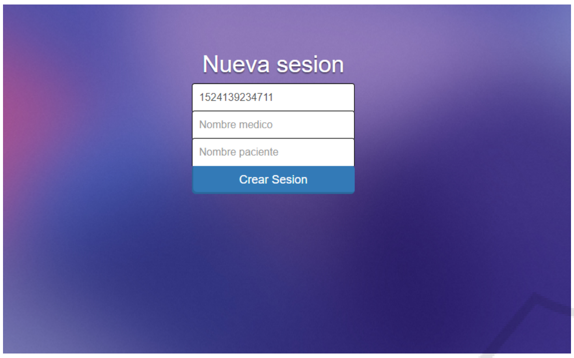

Figure 4: Menu to create a new session.

who is going to perform the session, as shown in the Figure 4. Once the session is created, an interface will be displayed in which the patient's screen is included, which will be shown empty until the patient enters the session, and a lateral menu in which the cards can be shuffled in case the order in the one that appears is not the right one, end the session, or handle the chronometer that measures the times of the session, as seen in the Figure5.

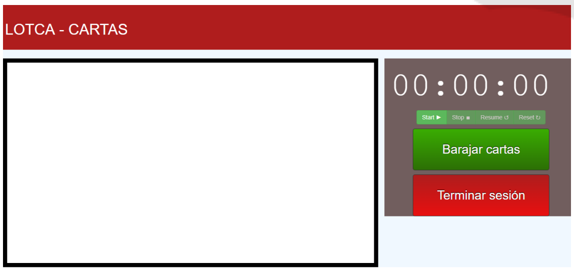

Figure 5: The therapist's interface before the patient enters.

Once this is done, the patient accesses the session that has been created. To do this, hr must select the option "I am the patient" in the main application menu (Figure 3). Then, he must enter the identifier of the session that the therapist chose when creating the session (Figure 6)

When the patient joins the session, only the set of cards necessary to complete the session will be shown on the screen. When working with a touch screen, he can freely drag those cards to group them following the pattern proposed by the therapist based on

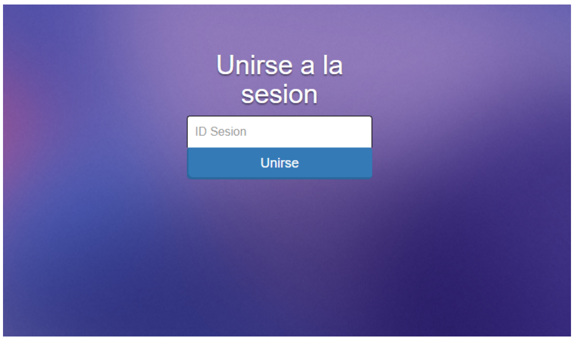

Figure 6: Menu to join a session.

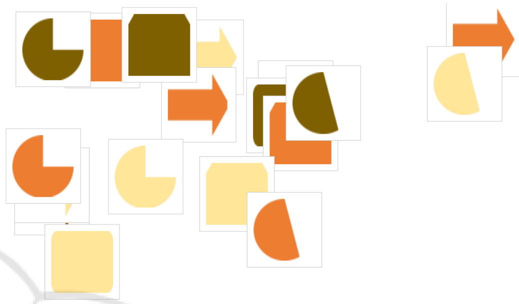

Figure 7: Patient interface when joining the session.

the LOTCA test (Figure 7).

In the therapist's interface, the patient's screen is now displayed, and each movement of cards that he makes can be seen in real time from the therapist's interface, as shown in the 8.

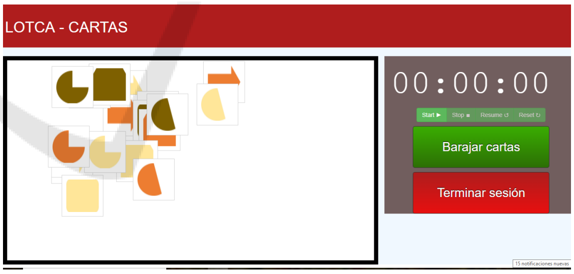

Figure 8: The therapist interface when the patient joins the session.

On the other hand, the therapist is offered the option of viewing information about previous sessions. To do this, he must first enter the identifier of the session he wants to view, as shown in the Figure 9.

When he has entered the identifier, a visualizer will be displayed where the therapist can scroll through the bar that appears at the bottom of the screen for the different moments of time the session has. On the right side, he can edit the time slot over which information is displayed, expressed in seconds. For example, if the therapist moves with the lower bar to position 20 and in the menu on the right, selects a

Figure 9: The therapist interface when the patient joins the session.

step of 5 seconds, the system will show information about the position occupied by the cards in the second 20 of the session, and about the changes that they have suffered in the last 5 seconds. For the id, the system shows highlighted the cards that have moved in that time slot, while the cards that have not moved, are shown with a weaker color. In addition, the trajectory followed by the cards displaced in that time slot, their original position (using a card with the grated contour) and their final position (using a card with the solid outline), as shown in the figure 10.

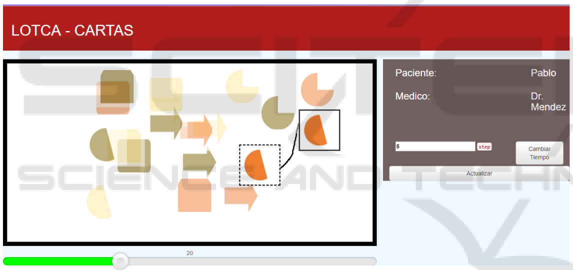

Figure 10: Session history viewer interface.

5 CONCLUSIONS

As a summary, we can say that our solution allows digitizing and computerizing a set of tests proposed in the LOTCA methodology for the diagnosis and evaluation of people with acquired brain damage.

Our solution allows the patient to work in a similar way to the one he would do if he worked in a traditional way, by providing him with a touch screen in which he can drag and move freely the cards used in the test.

In addition, our solution allows the therapist to visualize at all times what movements the patient is performing, without directly interfering with their task, since they can visualize these movements in a monitor that can be found anywhere. This allows that even other therapists can visualize that session in real time, even if they are not physically next to the patient.

The display module of old sessions allows the therapist to access at any time the information of the sessions, sharing this information with other colleagues who were not present at the time of the test, or returning to analyze the movements that the patient has made, in order to detect other anomalies that could not be detected in real time.

Finally, we believe that this platform can continue to grow, implementing all the tests included in LOTCA, and thus be able to replace the laborious traditional tests with these digitized tests.

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