Mobile Computing System for Neuropsychological Evaluation

Enrique Alfonso Carmona García[1], Elena Fabiola Ruiz Ledesma[1],
Laura Ivoone Garay Jiménez[2], Mario Eduardo Rivero Ángeles[3]

[1] Instituto Politécnico Nacional, ESCOM, CDMX, México
`eacarmona860920@gmail.com,efruiz@ipn.mx`
[2] Instituto Politécnico Nacional, UPIITA, CDMX, México
`lgaray@ipn.mx`
[3] Instituto Politécnico Nacional, CIC, CDMX, México
`mriveroa@ipn.mx`

Abstract. The cognitive process evaluation requires the application of a neuropsychological test such as the *Evaluación Neuropsicológica Breve en Español (Neuropsi ©)*. It is a standardized and validated test in Mexico. This test consists of a battery of activities aimed at measuring the memory, attention, motor, language, and vision-space skills, considering the age and education level. Nowadays, the application is performed by a specialist and he must observe, measure and take note of the process for the final evaluation, this procedure takes more than one hour per subject. Considering this test as a possible evaluation for the student cognitive skills, this period is too long for application in a class in real time. So, it was proposed a software that implemented the Neuropsi © test, it could to be carried out simultaneously by different users on its own mobile devices. The information is concentrated in a server and the system sends quantitative and qualitative automated evaluation to the specialist and he can obtain individual and group profiles. In the present paper, we report the modular architecture of the system according software engineering, the diagnostic and results modules and its functionality is described.

Keywords: neuropsychological test, automated cognitive skill evaluation.

1 Introduction

A current goal for the educational technology is to standardize the performance evaluation into the teaching-learning process but because of its complexity, it must be analyzed from an interdisciplinary perspective. In the present work, the main interest was to develop a modular architecture of a computer system according the software engineering. This system measures and promotes the attention and concentration simultaneously in a group of students, with the purpose of reporting the improvements for each student or for an entire class to a specialist.

There are several factors that cause low academic achievement, some of these factors are lack of understanding of the involved concepts of the studied topic, lack of good study habits or strategies, lack of attention in classes among others [1,2]. Implementation of pedagogical solutions that allow raising the quality of learning

Enrique Alfonso Carmona García, Elena Fabiola Ruiz Ledesma, et al.

processes through the reinforcement of cognitive abilities requires monitoring these processes and reinforce these basic abilities.

One of the most important elements is the attention, which is regulated by neurological centers [3-9]. Any biological or physical abnormal behaviors of them, alters the final result: to attend effectively to the respective task. Attention, as a psychological process, is characterized by the transformation of its basic reflected nature, such as the case of attention due to an imminent danger, by acquiring a voluntary character from the interaction with the medium [10], [11]. Concentration is considered as a prolonged process of attention and occurs when there is a strong motivation towards the tasks, activities or demands of the environment [11], [12]. The study of the attention and concentration characteristics by specialists has allowed to establish different levels of attention [10], [11]. The levels of attention are: focused, held, selective, alternating, and divided attention. They are measured by specially through a designed test for this purpose. It has been possible to establish the hierarchy that exists in these different kinds of attention. Noting that to be successful in complex tasks which requires high attention levels, such as alternating and divided attention, firstly, it is necessary to train the held and focused attention [10], [13]. In general, for the evaluation and measurement of attention, direct observation can be used [11], [12] and questionnaires such as the Conners scale [13]. In neuropsychology clinic, the accepted instruments of measurement are the neuropsychological tests, that evaluate a determined cognitive domain or skill, defined as a sample of conduct under specific conditions [14]. In the present study, we selected the neuropsychological brief evaluation battery in Spanish, Neuropsi ©. This neuropsychological battery is a standard collection of several tests for specific cognitive skills. The administration of the battery and obtaining the results usually takes a period which varies between days and weeks because the application of the battery is done in a personalized interview and the specialist is taking note of the relevant qualitative and quantitative characteristics in each test as well as the registration of the specific times associated to the performance of the subject during each test.

However, in a classroom where the students in the group have already been over certain academic requirements for admission, and they already are considered as typical healthy condition, it is important to evaluate, in a fast and reliable way, the present conditions of their attention capacities. This test could be used to have feedback into the teaching-learning process and to alert about a dangerous diminish of students' performance.

The paper is organized as follows: Section II presents a review of the existing literature about attention and concentration and the actual tests and batteries that evaluate these processes. Section III presents the methodology proposed for the development of the modular architecture of the computer system. Finally, section IV presents the preliminary results and part of the future work.

2 Related Work

The first studies about attention and concentration appears at the end of the 19th century and the beginning of the 20th [15]. At present, many of the accepted concepts and ideas are dated from that beginning studies and others realized between the years 50s and 70s

of the last century [13], [16], [17], [18]. Attention is the ability to address some specific stimuli, inhibiting other simultaneous external or internal stimuli [19]. Attention and concentration have several parameters that let analyze their practical use in different contexts. These characteristics are: selectivity, volume, cyclicity, direction, intensity, and stability [11].

Evaluation of attention and concentration is often a complex process mainly due to the nature of the processes itself and its dependence of the context of the evaluation. In order to select the tests to be used into the proposed system, it should be considered the specific condition of application and it is necessary to meet psychometric criteria for reliability and validity into the description of the abilities and cognitive disabilities of an individual [20], [21]. It is important to pay attention on the educational level and the age of the subjects to make an adequate interpretation of the results. Also, it has been proven that the tests application to non-native speakers or people with different values or culture shows up significative difference in the obtained results [10], [22]. Because of this, although many functional tests and evaluation scales are available in English, it is not convenient to use them in Spanish-speaking and / or low-income and / or low-culture populations [20]. To solve this issue, several diagnostic tests for assessment of attention and concentration had been adapted so they can be used in several application cases. Some of these tests are: digit memorizing [22], [23], [24], *Corsi cubes* [18], *continuous cancellation or execution tests* [22], [25], symbolic *digit test* [26], *paced auditory serial Addition test* [27], *trace test* [25]. It is important mention that all these tests are independent of each other and they are specialized in assessing one or more specific levels of attention and concentration. Several batteries with specific purpose had been reported [22], some of these evaluation batteries are: *Halstead-Reitan, Luria-Nebraska, Ardila-Ostrosky, Dementia Rating Scale, Mental Status Check List, Blessed Orientation-Memory-Concentration test* [8], [9], [12]

A neuropsychological examination with a specific battery, like any type of clinical and paraclinical examination, has tests and applies procedures to achieve specific objectives [28]. Nowadays, there may be many reasons for conducting a neuropsychological evaluation such as determining work ability, following up on a psychological treatment and being able to determine the characteristics of its evolution or simply for exploratory or research purposes.

Specialist usually selects a neuropsychological battery to do the initial diagnosis of the patient and once the results have been analyzed and the diagnosis performed, a new specific test is selected to entrain the patient in specific skills. Nowadays these processes of selection, application of the neuropsychological battery, evaluation of the results and selection of complementary tests, are carried out by the specialists in a manual way. There are some specific tests that can be found in digital format for application or some basic evaluation tools, but they are not frequently used by the neurologists because administering and evaluating some tests in digital format and another in a manual way makes difficult to manage them in the cases of being include in a test battery. Besides, although in our days exist many different informatics solution who test some cognitive abilities like attention, visual perception, planning, reaction times, they are mainly oriented to children and to improving their general abilities. [29], [30], [31], [32]. In the case of Cognifit® [32], the system provides a complete computerized battery of tasks that allows the assessment of over 20 fundamental cognitive functions, clearly defined with objective measurement controls that provide

standardized age and demographic criteria based on the results of thousands of subjects. All the tests and tasks are validated by independent studies in representative populations, using the placebo system to measure and follow their effectiveness [33], [34]. In general, all this system present cognitive and neurological assessments. Unfortunately, the validation in Mexico is not reported and all these systems required to pay a license to be used, and in some cases their license is expensive.

For the implementation of the system, the brief Neuropsychologic battery in Spanish was selected, which it is validated for Spanish-speaking populations, it is ranked by level of education as 0, 5-10 and >10 years of education and age into a range 5 to 75 years old [19] [20]. This test battery measures important aspects related to the cognitive process, functions such as attention and concentration, spontaneous memory, visio-space functions, comprehension, executive and evocation functions.

3   Methodology and Partial Results

The previous selection of the test battery was based on the need to develop an advance educational software that allows to administer and evaluate a neuropsychological battery for students in a website. Because the application of the selected neuropsychological evaluation starts with the selection of the battery to be used and ends with the final diagnosis generated by the specialist, the system is designed with the intention of reducing the time assigned to the administration of the battery helping to the specialist to manage an increasing amount of data.

The scores obtained in the different tests integrate the quantitative data considered by the specialist for the diagnosis. Each of these variables could have an independent effect or not [33], [34]. In the last case, there are some variables such as educational level, age, sex, culture, and laterality that should be considered [14]. The neuropsychological evaluation methodology has four stages: initial clinical evaluation, selection and application of the follow-up tests, analysis of results and generation of the report.

At present, there are a variety of software applications that are currently used in our daily lives, whether into our residence, traveling and working. In specific the mobile applications are used as a tool for a specific operation or complement a function in our modern life. One of the main reasons for creating a mobile application is the need to solve a problem or to simplify a complex operation in a ubiquitous way [35]. So an important concern in the software design is saving the generated information in an effective way so that it can be consulted or be analyzed at any time.

There are many database models, such as the relational models, non-relational models, hierarchical and object-oriented among others. The most significant challenge in implementing a database is the development of database structures [36], [37], [38]. It has been selected MongoDB for the storage of the generated data because MongoDB is a scalable, powerful, and flexible general-purpose database. It combines the ability to scale with features such as secondary indexes, rank queries, sorts, aggregations, and geospatial indexes. It is a database oriented to documents, replacing the concept of rows by another model of greater flexibility, documents; This means that, instead of storing the data in tables, MongoDB stores data structures with a specification called BSON, using a dynamic schema [39], [40].

In this case, two separate databases are used: User Database and Evaluation Database. In the database of users will be stored the information belonging to all people who use the system, regardless of its role in it. In addition, it will store the results obtained by the students when performing different batteries and tests. On the other hand, the Evaluation Database will contain all the information of the batteries and tests that the system has.

To successfully achieve the objectives of the system, it is necessary to use a development methodology capable of carry out the required processes efficiently. In this context, a process defines who is doing what, when, and how is performed a task. In software engineering, the aim is to build a software product or upgrade an existing one.

Following this methodology is guaranteed a high-quality software, reducing risk, and obtaining a predictable project [41]. The development process sets the needed activities to transform a user's requirements into a software system. The rational unified process (RUP) is a generic framework that can be adopted for a wide variety of software systems with different project sizes. RUP is based on software components interconnected through well-defined interfaces. The main aspects in RUP are: case-driven, centered into the architecture and iterative and incremental methodology [41], [42]. And it uses the Unified Modeling Language (UML) to prepare all schemas of a software system design for technical documentation [42], [43].

Because of the design of the system, the administration and evaluation of a single test or a tests battery can be carried out at any time and place so the student or the medical specialists do not need to be in the same place at the same time to applying the test, even it could be applied by a teacher in a classroom after a short training. Another important issue to be considered, it is the integrity, reliability, and security of all the information that is contained in the databases.

In Fig. 1 is presented the architecture of a modular system. It was designed to give independence between modules into the subsystems. It provides a solution considering an efficient maintenance. Another advantage is related to stability and availability of the final software because the administrator can disable a specific module and it does not affect the rest of the software so it continues available.

The Access Subsystem shown in Fig. 1 case (a) was composed by two modules: Login Module and the User Registration Module. In Login Module, it was implemented a role-based authentication to identify the potential users of the system. This module identifies the role of the user at the time he is login into the system, so all the not required system sections or information are maintained transparently and independently to the user. The administrator of the system directly supervises the User Registration Module because he is the person authorized to manage all user in the system so he adds, removes, or changes all the information regarding of the registered user in the system.

The heart of the architecture is based on the Student Subsystem and the Evaluator Subsystem, shown in Fig. 1 case (c) and case (d). The Student Subsystem is composed by two modules, the Initial Assessment Module, and Training Module. The main purpose of the Initial Assessment Module is provided the *Evaluación Neuropsicológica Breve en Español (Neuropsi ©)* to set the initial level of attention of the student and classify it as low, normal, or high according to the medical criteria. Afterward, the Training Module is activated. This module supplies tests to maintain or improve the level of attention. On the other hand, the Evaluator Subsystem manages all the test

offered by the system, the evaluation process and show the result to the specialist. Four modules compose the Evaluator Subsystem: General Results Module, Custom Results Module, Initial Evaluation Management Module and the Training Management Module.
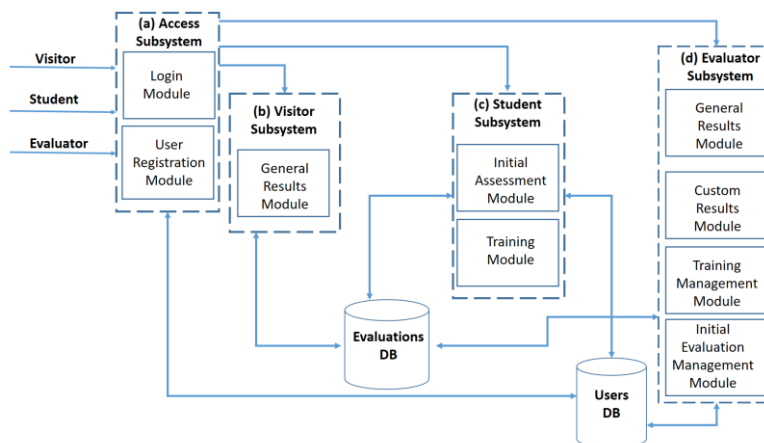
Fig. 1. Mobile System Architecture for Neuropsychological Evaluation. The subsystems are a, b, c and d. Modules are into the subsystems.

The General Results Module evaluates the results of the applied tests and determine the levels of attention as low, normal or high according the medical standard. The Training Module is called if a suggested action is required to improve the cognitive skills. The Custom Results Module allows to present the result obtained in several formats such as tables, graphic and provides files compatible to generic tools to facilitate the interpretation and analysis.

It important to point out that the General Results Module of the Evaluator Subsystem and the Visitor Subsystem are the same module, the difference is in the available results and its format that is offered to a visitor and an evaluator. The visitor only can access to the class information without identification information associated to the students but the Specialist, in the evaluator role, could access to every result obtained. The Initial Evaluation Module is responsible for generating and providing the complete validated neuropsychological test (*Neuropsi ©*) that is currently active in the system for the new student users.

Finally, in the Training Management Module, an evaluator could remove or edit any of the test in the system and he also has the possibility to add new test. It is worth mentioning how this module implemented the new offered test. All considered tests from the validated battery were analyzed offline, to identify their logic, then they were implemented, modifying the difficulty level according the clinical criteria. This methodology provides a greater number of test without need to introduce them by the specialist one by one. The advantage is that each test retains measured variables, clinical skills levels considered and the application of constant parameters, so into the new test the evaluation procedure is maintained. It is important to mention that the specialist can create as many tests as it is required. Also, the system provides to the

evaluator role the option of creating new entire neuropsychological batteries, customizing the tests that are already in the system for research or new studies validation.

This increase of available resources represents a significant improvement compared to the current application method because with this system it can be generated as many neuropsychological batteries with their respective standard evaluation forms in an easy way to make variations to them, the specialist could define the order of application and the tests can be printed for application in a traditional way or be applied into the system. Another important point to highlight is that this digital implementation of the neuropsychological tests batteries gives an auxiliary tool to the specialist to applied the test simultaneously through the web application assisted by a teacher previously trained. Moreover, the automatically measurement of the variables considered test and automated evaluation is an improvement with respect to the traditional way, where the specialist must annotate, observe and measure response times, completion times, which impacts on the number of people he can attend and the time taken to apply the test.

4   Conclusions

As far as the authors knows, the Mexican psychologist do not have a validated mobile application that allows them to add existing neuropsychological tests batteries for their digital application. Neither they have digital evaluation tools that help them during the evaluation process so this automated system could significantly reduce the time needed for managing and evaluating the considered neuropsychological battery. This paper presents a modular architecture of a computer system for the application and evaluation of entire batteries or specific neuropsychological tests focused on attention and concentration so it was described how the system was structured and the functionality of the different modules that are into the system. The software engineering goals considered was to minimize as far as possible the application time of generating a test and the evaluation time required for test application, to give ubiquity and to increase the temporal availability of the system. The main contributions of the proposed computer system are:

1) Automated application and evaluation of neuropsychological tests batteries.

2) Creating new tests maintaining the skill level, evaluation variables and the original application parameters.

3) Obtaining new performance information, which are not currently measured in the traditional way of batteries application, such as an interval of time between each answer.

4) Easy generation of additional tests of attention and concentration but gradually ramping up the difficulty.

5) Storage of the obtained information in a centralized way and using a non-relational database, making possible its use in future knowledge discovered.

Because the easy way to create, visualize and test new forms of evaluation, it will possible to carry out new neuropsychological studies that will be concentrated, update and modified online providing an invaluable tool for research about the cognitive process into classrooms.

References

1. Ruiz Ledesma, E.F.: Sistema de evaluación de procesos cognitivos basado en estándares psicopedagógicos haciendo uso de tecnología educativa. Instituto Politécnico Nacional, Registro en la SIP 20164801 (2016)
2. Ruiz Ledesma, E.F.: Impacto del Cómputo Móvil en la enseñanza del concepto de variación. Instituto Politécnico Nacional, SIP 20131825 (2013)
3. Uriarte Bonilla, V.R.: Funciones cerebrales y psicopatología, México, D. F.: Alfil, S. A. de C. V. (2013)
4. Rao, S.: Integration of what and where in the primate prefrontal cortex. Science, Vol. 276, No. 821 (1997)
5. Miller, G.: Reflecting on another's mind. Science, Vol. 308, No. 945 (2005)
6. Gaddes, W.H., Edgell, D.: Learning Disabilities and Brain Function. New York: Springer-Verlag, (1994)
7. Cohen, R.A., Sparling-Cohen, Y.A., O´Donnell, B.F.: The Neuropsychology of Attention. New York: Plenum Press (1993)
8. Ostrosky-Solís, F., Gómez Pérez, E., Chayo-Dichy, R., Flores Lázaro, J.C.: ¿Problemas de atención? Un programa para su estimulación y rehabilitación, D. F. American Book Store (2004)
9. Téllez Olvera, H., Mendoza González, M.E., Butcher López, E.A., Pacheco Ralley, C.C., Tirado Medina, H.: Atención, aprendizaje y memoria. Aspectos psicobiológicos. México, Trillas (2002)
10. Kirby, E., Grimley, L.: Trastorno por déficit de atención. México, Limusa-Noriega (1992)
11. Conners, C.K.: Conners parents rating scale. Chicago, Abbott Laboratories (1979)
12. Ardila, A., Ostrosky, F.: Guía para el diagnóstico neuropsicológico, D.F, México (2012)
13. Stern, W.: Die Intelligenz der Kinder und Jugendlichen und die Methoden ihrer Untersuchung. Leipzig Verlag (1928)
14. Ervin, F., Mark, V.: Violence and the brain. New York, Harper & Row (1970)
15. Monroe, R.: Episodic behavioral disorders. Cambridge: Harvard University Press (1970)
16. Corsi, P.M.: Human memory and the medial temporal region of the brain. APA PsycNet, Dissertation Abstracts International (1972)
17. Ostrosky-Solís, F., Gutiérrez Vivó, J.: ¡Toc, Toc!, ¿hay alguien ahí?. Cerebro y conducta. Manual para usuarios inexpertos. México: Info Red (2000)
18. Ostrosky-Solís, F., Ardila, A., Roselli, M., López, G., Mendoza, V.: Neuropsychological test Performance in Illiterates. Clinical Neuropsychology 13(7), 645–660 (1998)
19. Ostrosky-Solis, F., Ardila, A., Roselli, M.: NEUROPSI. Evaluación Neuropsicológica Breve en español. Publingenio
20. Ostrosky, F., Gómez, E., Matute, E., Roselli, M., Ardila, A., Pineda, D.: Neuropsi, Atención y Memoria. Manual e instructivo, México, American Book Store (2007)
21. Ostrosky-Solís, F., Gómez, E., Matute, E., Roselli, M., Ardila, A., Pineda, D.: NeuroPsi, Atención y memoria. Manual, Protocolos, Láminas, Tablas Puntuaciones Totales y Perfiles, México, American Book Store & Teleton (2003)
22. Wechsler, D.: WMS-III Administration and Scoring Manual. San Antonio, Texas, The Psychological Corporation (1997)

23. Lezak, M.D., Howieson, D. B., Loring, D. W.: Neuropsychological assessment. New York, Oxford University Press (2004)
24. Wechsler, D.: Wechsler Adult Intelligence Scale–Revised. New York, The Psychological Corporation (1981)
25. Gromwall, D.: Paced Auditory Serial Addition Task: A measure of recovery from concussion. Perceptual and Motor Skills, No. 44, pp. 367–373 (1977)
26. Reitan, R.M., Wolfson, D.: The Halstead-Reitan Neuropsychological Test Battery: Theory and interpretation. Tucson, Neuropsychology Press (1985)
27. Ardila, A., Rosselli, M.: Neuropsicología clínica. México, Manual Moderno (2007)
28. Ardila, A., Ostrosky-Solis, F., Rosselli, M., Gomez, C.: Age related cognitive decline during normal aging: The complex effect of education. Archives of Clinical Neuropsychology, No. 15, pp. 495–514 (2000)
29. Pixframe Studios: Towi: Desarrollo de habilidades del aprendizaje a través del juego, http://towi.com.mx/ [Last access: 20 06 2017]
30. Martínez Jiménez, M.Á., Hernández Mendo, A., Pastrana Brincones, J.L.: Programa informático para evaluación y entrenamiento de la atención. http://www.efdeportes.com/efd145/programa-informatico-para-evaluacion-de-la-atencion.htm [Last Access: 20 06 2017]
31. Unobrain: Entrenamiento cerebral, http://www.unobrain.com/entrenamiento-cerebral [Last access: 20 06 2017]
32. CogniFit: Test Neuropsicológicos y Estimulación Cognitiva, https://www.cognifit.com/es [Last access: 20 06 2017]
33. Preiss, M., Shatil, E., Cermakova, R., Cimermannova, D.: Personalized cognitive training in unipolar and bipolar disorder: a study of cognitive functioning. Frontiers in Human Neuroscience (2013)
34. Haimov, I., Shatil, E.: Cognitive Training Improves Sleep Quality and Cognitive Function among Older Adults with Insomnia. PLoS ONE (2013)
35. Merete, Ø., Bjørn Rishovd, R.: Neuropsychological Deficits in Adolescent-Onset Schizophrenia Compared with Attention Deficit Hyperactivity Disorder. Am J Psychiatry 156(388) (1999)
36. Wilens, T.E., Spencer, T.J.: Understanding Attention-Deficit/Hyperactivity Disorder from Childhood to Adulthood. JC Psychiat Suppl. 67(7), 8 (2006)
37. Pérez-Montoro Gutiérrez, M.: Arquitectura de la información en entornos web. Asturias, España: Ediciones Trea (2010)
38. Ezequiel Rozic, S.: Bases de datos. Buenos Aires, Argentina, MP Ediciones (2004)
39. Oppel, A.J.: Databases: A beginner's guide. McGraw-Hill (2009)
40. Silberschatz, A., Korth, H.F., Sudarshan, S.: Fundamentos de bases de datos. Madrid, España, McGraw-Hill (2002)
41. Chodorow, K.: MongoDB. The definitive guide. California, USA, O'Reilly Media (2013)
42. Wilson, M.: Building Node Applications with MongoDB and Backbone. California, USA, O'Reilly Media (2013)
43. Pollice, G., Augustine, L., Lowe, C., Madhur, J.: Software development for small teams: RUP-Centric approach. Pearson Education (2004)
44. Leffingwell, D., Widrig, D.: Managing software requirements. A use case approach. Pearson Education (2003)
45. Jacobson, I., Booch, G., Rumbaugh, J.: El proceso unificado de desarrollo de software. Madrid, España, Pearson Education (2000)