An Informatics Training Environment for the Integrated Study of Major Depressive Disorder

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Abstract. The complex brain alterations in major depressive disorder are difficult to address in training contexts. The increase in available evidence obtained through medical imaging studies and the latest information and communication technology developments offer favorable conditions to face this challenge. The objective of this paper is to generate a computer application that allows us to integrate and present, visually and interactively, the relevant contents to this clinical condition in training contexts. The implications of this digital resource are discussed in the teaching and learning process within the framework of the cognitive load theory.

Key words. Three-dimensional visualization; educational software; major depressive disorder; medical training

I. INTRODUCTION

Major Depressive Disorder represents a social problem due to its prevalence in today's society and because of its treatment difficulty [1]. In recent years, it has become one of the most studied neuropsychiatric disorders in neuroscience, especially from a medical imaging perspective. In particular, numerous studies have used techniques like Magnetic Resonance Imaging (MRI) and Single-photon Emission Computed Tomography (SPECT) for the study of morphological [2][3] and brain metabolic [4-7] alterations associated to this clinical condition.

However, the complexity of the results obtained regarding anatomical and functional alterations hinders its presentation and understanding in training contexts. Some authors have documented this problem and coined the term 'neurophobia' referring to it [8].

Recent developments in information and communication technologies (ICTs) offer new opportunities to develop informatics environments capable of integrating large amounts of information with teaching purposes. Therefore, they can provide tools which facilitate the integration of neuroanatomical content, such as the morphology of brain structures and their spatial relationships.

Traditionally, students must perform complex mental reconstructions of multiple three-dimensional brain structures. According to the cognitive load theory, these cognitive demands associated to the mental reconstruction process, especially related to short term memory consumption, negatively influence the performance in learning tasks.

The use of three-dimensional digital models in training contexts will contribute to the reduction of these cognitive demands. At the same time, several authors have proposed recommendations directed towards improving the informatics teaching application design that can be grouped in three categories: use of multimedia learning environments, integration of different content levels and use of graphic elements which favor the active student implication in the learning process [9-13].

The graphical user interface constitutes a key element in any computer application, especially with teaching purposes that regulate the student content interaction. Its design must consider, in addition to the aforementioned guidelines, pedagogical aspects on content organization and design regarding the use and layout of graphic or visual elements for information access [14]. An adequate graphical interface will reduce and facilitate user navigation, while increasing the sense of control and independence over the graphical environment and the contents within it. For example, the use of icons contributes to this function, simplifying and clarifying the user application interaction [15].

The objectives of this paper were two: first, apply the advances made in ICTs to develop an informatics environment that visually and interactively integrates contents regarding major depressive disorder, paying special attention to the findings obtained from diagnostic imaging techniques concerning brain alterations; second, empirically evaluate the satisfaction and perception level of the developed application use in a medical training setting.

II. Material and Methods

The development of this educational informatics tool and evaluation of satisfaction and level of perceived usefulness in the learning and teaching process included the following phases and stages:

A. *Image Acquisition*

First, MRI and SPECT images were acquired from a male 45 year old patient, diagnosed with unipolar major depressive disorder, one year duration, with no psychiatric or neurological history and no referred psychopharmacological treatment. The patient gave his informed consent to participate in the study, which was approved by the local ethics committee following the principles established in the Declaration of Helsinki.

B. *Creation of three-dimensional models*

Then, the volumetric generation of brain structures contained in previously obtained neuroimaging, was done using the Amira Version 5.3® Visage Imaging GmbH software for advanced imaging visualization and manipulation.

This process required, in turn, two steps: first, the region of interest (ROIs) segmentation for each structure, consistent with the bilateral identification and delimitation of the previously acquired MRI sections; second, the final rendering from the mesh model creations, from the union of the previously segmented ROIs. The intermediate surface representation of the 3D models was formed earlier from multiple polygons, in our case, triangles.

C. *Co-registration and multimodal fusion*

The co-registration consisted of unifying information in data sets corresponding to different image modalities, namely MRI and SPECT. For this, craniometrical landmarks were used as parameters which allowed the image acquisition and alignment at the same angles.

Subsequently, the position and orientation of both images were compared and adjusted until the mutual information was maximized. As a result, the integration of three-dimensional models generated from morphological MRI imaging to functional SPECT imaging was possible.

D. *Animations*

Quality digital graphical animations were created with an attractive design and an optimum quality/weight archive value through Macromedia Flash©. At the same time, the level of interactivity improved by using ActionScript.

E. *Development of graphical user interface*

The development of graphical user interface was made using programming language intended for Visual C++ objects that allowed the development and depuration of the written code for Microsoft Windows APIs, DirectX and Microsoft.NET Framework technology. In particular, for the development of our project, Visual C++ generated two files: a workspace file (with .wsp extension) and a standard makefile (with extension .mak) that enabled the project use in a different environment.

F. *Development Evaluation*

Finally, an evaluation of satisfaction level and perceived usefulness was done to students in training with the developed informatics environment. The evaluation was anonymous, using a Likert type scale. The sample consisted of 65 university students in the last two years of medical school. The survey was comprised of 5 items and the answer format was the following: 1 ‘strongly disagree’, 2 ‘partially or somewhat agree’, 3 ‘neither agree nor disagree’, 4 ‘partially or somewhat disagree’, 5 ‘strongly agree’. Participants agreed on a voluntary basis and received no economic compensation for their participation.

III. Results

Our informatics tool is compatible with Microsoft Windows XP SP3, and 32 bit Windows Vista o Windows 7. The recommended hardware and software requirements for its visualization are a 1028 x 800 pixel screen with a 1GB or higher video card, a 1,2GHz or higher processor, 1GB of RAM memory, 2GB of free memory space in the hard drive and a CD-ROM.

The user interface of the developed educational application included an anatomical functional viewer of three-dimensional models and multiple graphic controls in charge of optimizing the user viewer interaction (Fig. 1).

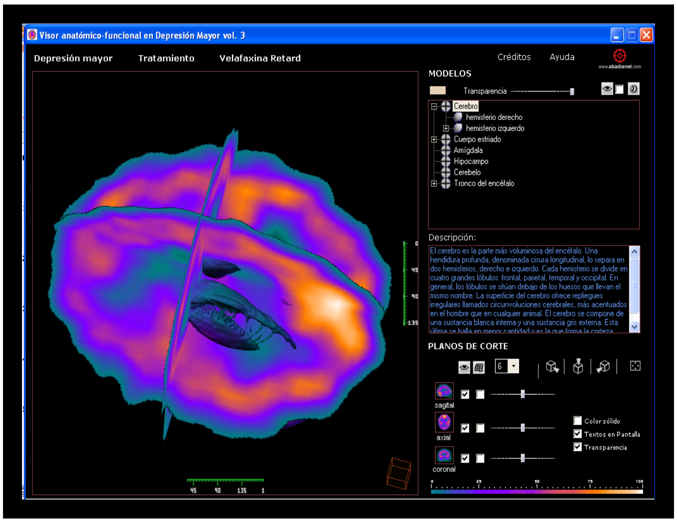

Figure 1. User interface capture which shows the different interaction options with the anatomical functional viewer.

A. Three-dimensional anatomical functional viewer models

The digital training environment was organized through a viewer that integrated information regarding anatomy and brain structure functioning in major depressive disorder and which allowed its study in an independent, interactive and visually attractive way.

The setting or main region on screen permitted the previously generated 3D model visualization embedded in SPECT sections, integrating in one display anatomical and functional information about the brain structures involved in major depressive disorder (Fig. 2).

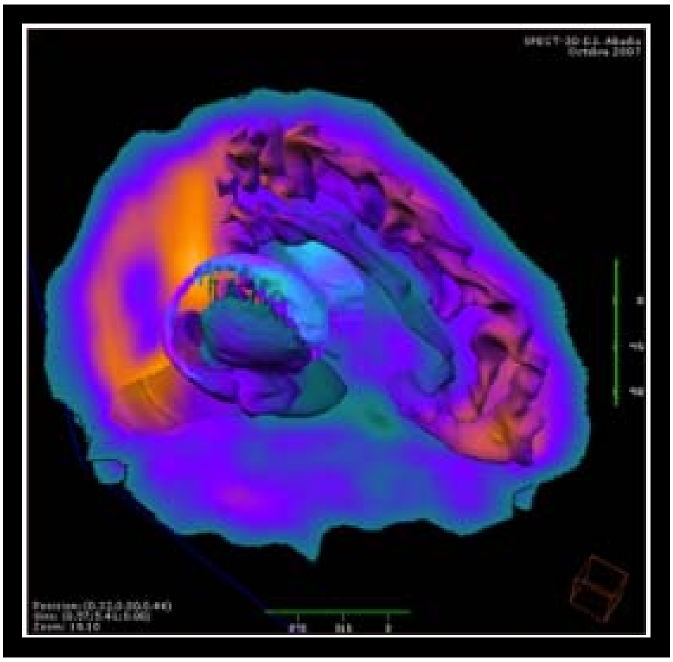

Figure 2. Anatomical functional viewer setting detail showing a representation of several brain structure 3D models embedded in SPECT sections. This integrated anatomical and functional visualization facilitates the comprehensive study of clinically relevant brain structures in major depressive disorder (hippocampus, amygdala, corpus striatum, cortical-medial region of a cerebral hemisphere).

B. Three-dimensional models

The graphic controls which regulate the 3D model interaction were located in the right upper quadrant of the screen.

The 3D models included anatomical details and real spatial characteristics of each generated structure. These models were organized according to a logical structure in a hierarchical tree**,** so that a simple click activated or made one model visible independently or several simultaneously (Fig. 3).

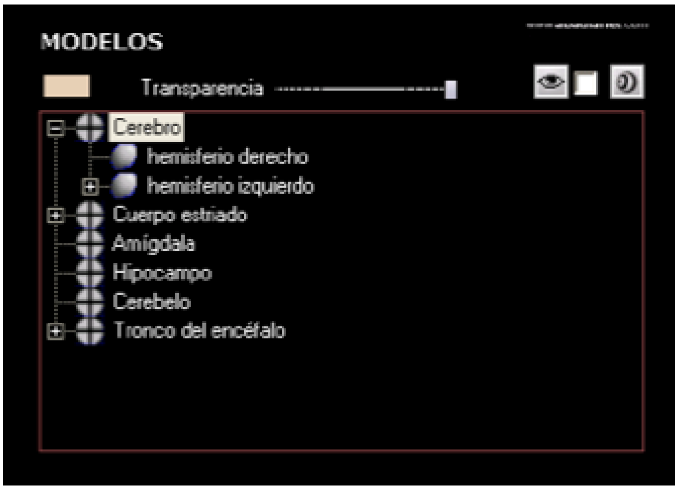

Figure 3. Visualization option control detail for 3D anatomical functional viewer models.

C. Plane cut

The controls and other graphic elements necessary for the reference plane interaction were situated in the right inferior quadrant of the interface. Three orthogonal planes were included: sagittal plane (lateral), axial plane (horizontal) and coronal plane (frontal). Each plane was accessible through an independent selection control that enabled the activation or deactivation of its visibility. Another control was included that incorporated a grating for calculating distance and a scrollbar for plane cut selection. A shift in plane position was possible by selecting and moving the cursor horizontally over the control (Fig. 4) o directly selecting the plane in the display while clicking "Mayúsculas", without pressing any mouse buttons. The last displaced plane will appear framed in blue.

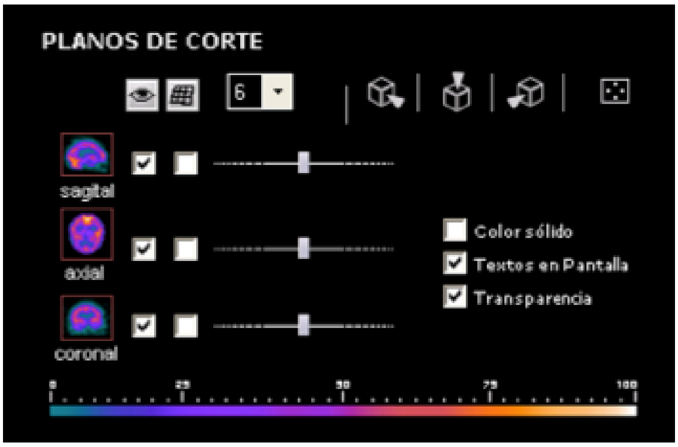

Figure 4. Plane cut control detail of the anatomical functional viewer. It includes access icons to predefined views (upper right region), that enable focusing on the scene orienting the camera and scrollbar for the selection of different plane cut levels and finally selecting the "rejilla" option for calculating distances within each SPECT section. Notice the numerical box which specifies the row and column number that will define the grating quadrants.

D. *Interactivity*

The anatomical functional viewer interface included four interactivity elements with 3D embedded models in SPECT sections within the display.

These elements were accessible through icons, such as meaning units that occupied less space within the interface. They were accompanied by tooltips, which are brief detailed text descriptions visible when placing the cursor over one of these icons.

The elements were the following:

- *Rotations:* Any visible viewer display can be rotated keeping the left mouse button pressed while moving the cursor on the screen.
- *Translation*: It requires keeping both mouse buttons pressed while moving the cursor.
- *Zoom*: It allows the image enlargement or reduction that the viewer shows, keeping the secondary mouse button pressed while moving the cursor up (enlarging) or down (reducing).
- *Selection:* It is possible to select a particular 3D model from the display corresponding to a specific brain structure by clicking on it, bearing in mind that the hierarchy level is open.

E. *Visualization options*

Other complementary visualization options included in our application were the following:

- *Predefined Views.* There are three predefined views on the models included in the display. A lateral right view, an upper and lateral left view (Fig. 4).
- *Texts.* It enables hiding the scientific and technical information by clicking the technical text option on screen (Fig. 4).
- *Color*. It is possible to modify or customize the 3D model color, for example, to maximize the contrast level with others (Fig. 3).
- *Transparency.* This model characteristic of the three-dimensional viewing can be activated or disabled and its opacity or transparency level can be changed for each model individually (Fig. 3 and 4).
- *Multimedia*. Animations that illustrate major depression characteristics and the current treatment action mechanisms are included (Fig. 5).

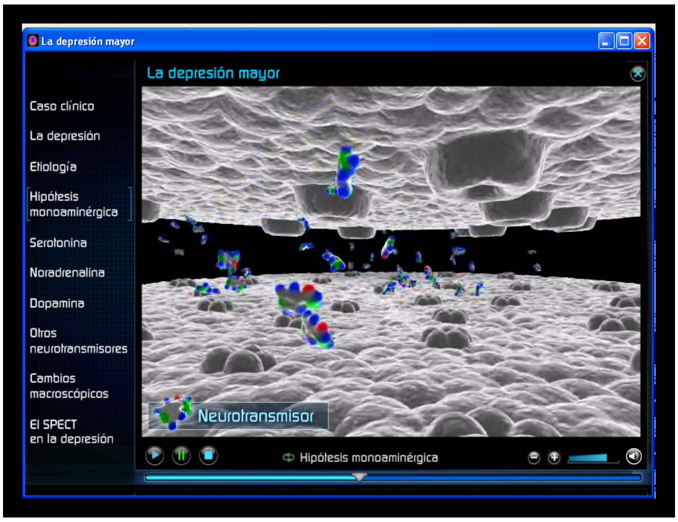

Figure 5. Schematic and animated representation of one of the most commonly used psychoactive drug action mechanisms in the treatment of depression. Regular reproduction and sound controls are seen, in addition to a reproductive line to move and find specific parts within the animation. The visible areas on screen can be captured and stored as a bitmap (.bmp extension) for teaching purposes.

F. *Evaluation*

The evaluation results show a high satisfaction level with the informatics environment, in terms of visual attraction, interactive capacity and content integration; and a high-perceived usefulness in relation to the presented application for teaching purposes (Table 1).

IV. Discussion

For several years now, our research group VisualMedSystem has been working on developing computer teaching programs, applying the most innovative technologies and evaluating their effectiveness in order to improve and enhance these resources in the teaching process [16-18].

This paper describes an innovative tool that facilitates training related with brain alterations in major depressive disorder. This is done by using an interactive visualization tool that allows the students to interact with different perspectives and volumes of brain structures affected by this disorder. Furthermore, this informatics environment also requires less cognitive demands than mental reconstructions of the structures necessary for its study.

The integration and representation of these contents in a visual and interactive way is suitable for training in these conditions and encourages independent student learning, one of the current problems due to the reduction of teaching hours in disciplines such as neuroanatomy [19].

The most relevant contributions of this paper for their use in training contexts are the following:

First, the three-dimensional models and images included represent real anatomical and spatial details. Therefore, they offer a more complete and realistic content than the traditional atlases and diagrams.

Second, the functional SPECT imaging incorporation adds an essential value, both for diffusion and current relevance of neuropsychiatric disorders through diagnostic imaging techniques, especially major depressive disorder [23], as well as for addressing one of the most complex issues in medical training [8][16][18].

Third, the integration of both anatomical and functional clinically relevant information, in a visually attractive and highly interactive informatics environment, stimulates the content assimilation and adaptation. Multiple 3D models, animations and text descriptions, navigation controls and other graphical elements are included, which enable an independent content exploration and maximize the content interaction possibilities.

Fourth, the evaluation results highlight the strong potential these types of informatics and multimedia tools have for students who are learning neuroanatomy [20-22]. It provides the student with the opportunity of having a more active role in the teaching-learning process by incorporating powerful multimedia elements that encourage the student interactivity and implication with the contents, overcoming the traditional and more restrictive ways of facing them [9-13].

Fifth, cognitively, the contents are presented according to the three organization systems of working memory: the phonological for processing acoustic information, the visuospatial for visual information processing and the episodic to organize information according to time references [25]. Hence avoiding a cognitive demand overload that interferes with the teaching and learning task, according to the cognitive load theory previously described [24].

Overall, these developments help broaden the action, decision and communication scopes amongst teachers and students through access to new digital media to explore, represent and process the knowledge regarding this clinical condition.

This paper contributes to the development and consolidation of current teaching-learning tendencies in terms of knowledge transfer, and the role of computers in educational settings. In the near future, we hope to continue developing this and other educational innovative tools that modern society imposes and that new students are used to handling. Over time, they are likely to become an essential and accessible part of the training curriculum, interested in a firsthand approach to the study of major depressive disorder.

Finally, we must define the usefulness of the developed application in training contexts, not the diagnostic decisions nor the treatment selection, which should be done with caution. Diagnostic imaging studies on major depressive disorder, as occurs with other psychiatric disorders, still need to overcome methodological difficulties associated with the heterogeneity in depression diagnosis [23][25].

V. CONCLUSIONS

This paper offers a teaching resource for the comprehensive study of major depressive disorder, of both anatomical and functional alterations through the brain structure three-dimensional representation and SPECT neuroimaging that can be interactively visualized and manipulated; multimedia animations and complementary descriptive texts.

It is a tool that provides a true digital learning environment where the user can interact with the contents independently through multiple visually attractive displays, and has a high educational value for medical training in depression.

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