Visualization of digital 3D models in anatomical teaching: main resources and a teaching experience of the nervous system

Gonzalo Arrondo¹, Javier Bernacer, Luis Díaz Robredo

Mind-Brain Group, Institute for Culture and Society, University of Navarra, Spain.

Faculty of Education and Psychology, University of Navarra, Spain.

Short title: Virtual 3D models and CNS anatomy

Key words: Emerging technologies; neuroscience; anatomy

This is an open access article under the CC BY-NC-ND 4.0 license (Attribution-NonCommercial-NoDerivatives 4.0 International; https://creativecommons.org/licenses/by-nc-nd/4.0/)

Abstract

The conformation of anatomical structures is complex in the 3 spatial planes. Historically, anatomy teaching has been carried out using 2-dimensional representation, 3-dimensional physical models, or real bodies. Only recently it has been possible to create digital 3-dimensional anatomical models that can be explored online or downloaded. The aim of this work is to critically describe two of the best-known online tools for anatomical visualization (Anatomography and Biodigital Human), and to present a teaching experience in the neuroscience domain. Animated images of brain structures were created and later used in class, and students were asked about their interest and usefulness. Results indicated that the use of this kind of resource is interesting due to its flexibility, attractiveness and cost.

¹ Corresponding author. Email address: garrondo@yahoo.es
Introduction
The conformation of anatomical structures is complex in the 3 spatial planes. Medical students and students of other health sciences degrees such as psychology, have to master the location and relationships between such structures by the end of their education. However, the fear of neurosciences, or neurophobia, has been described in students and medical professionals. Moreover, it is common that neurologists have to transmit their anatomical knowledge to patients and, similarly, in outreach talks.

Historically, anatomy teaching has been carried out using either 2-dimensional representation, 3-dimensional physical models, or real bodies. The visualization of spatial relationships between structures from 2-dimensional images is very hard and requires a high degree of mental representation. The other two teaching strategies are associated to a high economic cost. Therefore, the combination of teaching methods is the norm. Although there are early examples of the use of information and communication technologies in Spain for an better medical education, only recently it has been feasible to create 3-dimensional digital anatomical models that can be explored online through the World Wide Web or downloaded to other storage mediums. Price, but also interactivity and flexibility to adapt to different learning rates or contexts, are among the advantages of this approach. A recent metaanalysis of 36 studies that used this teaching methodology in anatomy courses showed that three-dimensional visualization technologies led to an improved learning of theoretical facts, of spatial relationships, and also to higher satisfaction among students. The aim of the our work is to compare the characteristics of two of the best known online tools for anatomical 3D visualization, and to present an usage experience in the neuroscience domain in a university in Spain.

Material and Methods
A recent work that compared the characteristics of 7 online tools for 3D anatomical visualization gave the two highest ratings to the programs Biodigital Human (www.biodigital.com) and Anatomography (www.http://lifesciencedb.jp/bp3d/) 5. We decided to create 3-dimensional digital models of brain structures for a biology introductory course within the psychology degree.

The characteristics of Anatomography and Biodigital were reviewed and compared in 2015. It was decided that the open license of the former added value to its use within the classroom, since the all other teaching requirements were similarly met through the functionalities of the two programs. Several animations of subcortical brain structures were created for a hands-on training session in neuroanatomy that supplemented the theory sessions and preceded a session with human post-mortem materials in the anatomy laboratory. Images were created with Anatomography and they were increasingly complex. We present here a Still example (figure 1) and all other animations, which have a free license, are included in supplementary material. Students answered a general evaluation questionnaire for the course at its where 2 questions on
the interest and degree to which the animations eased learning were asked. They had to be answered in a 5-point Likert-type scale.

**Results**

The basic functionality of both programs consists in selecting anatomical structures of different levels of complexity that the program combines into a single model afterwards. For example, the basal ganglia could be chosen, or alternatively only the putamen or caudate nucleus. Once the 3-dimensional model has been created, the user can virtually “navigate” around it, selecting the preferred rotation angle. However, programs differ in their usability, commercial license, data-interaction possibilities or graphical quality.

Biodigital Human is a commercial service launched in 2011 that stands out for its simplicity of use, impeccable anatomical details and fluid animations. Additionally, it has a virtual community space that permits users to share their visualizations. Among the previous uses of Biodigital, it helped plastic surgery students from Peru to improve their cleft palate surgery skills. Its biggest limitations are related to its license and business model. Basic visualization is free, but more advances capabilities, such as image downloading or the creation of complex animation are only available to premium members.

Anatomography appeared in 2009 and it is managed by a Japanese non-profit organization. Interface browsing is more complex than in the case of Biodigital, but the flexibility of the anatomical models obtained is also greater. Its Creative Commons license, which permits any use of the images created or their subjacent anatomical 3D models, is among its biggest advantages. For example, one of its leg models was recently combined with 3D-printing techniques to create an educational low-cost anatomy real model of blood flow. Final images are created from unique web addresses, hence permitting the saving of the work carried out. Moreover, they can be downloaded as animations where a camera moves around the structure or as still images.

Regarding our teaching experience, by the end of the term students judged images as being of high interest and greatly facilitating learning (mean 4.21 and standard deviation SD- 0.8; and mean 4.42 SD 0.8 respectively).

**Discussion**

We consider that the tools presented here can be a useful resource for those neurologists interested in effectively transmitting to patients, students or the general public, the anatomical localization of the different nervous system structures.

The two reviewed programs are the best rated currently, but they have very different characteristics regarding its ease of use, flexibility or license. Teachers should choose carefully which one they prefer taking into account their strengths and weaknesses.
The results of our educational experience, in line with the previous literature, indicate that the use of 3D visualization technology is a very useful resource to teach nervous system anatomy. In the future, we aim to prepare interactive exercises that take advantage of the easy use of the programs, to include virtual anatomical pinpoints for evaluation purposes and to integrate this kind of images in a virtual self-learning program.
**Figure 1:** image of the ventricular system created with Anatomography for the teaching of neuroanatomy within the degree of Psychology. Images were shown in color, animated (axis rotation), and with increasing complexity. License: Gonzalo Arrondo (University of Navarra, 2015), using the program Anatomography BodyParts3D, © The Database Center for Life Science licensed under CC Attribution-Share Alike 2.1 Japan.
References
5. Ramos da Mata TH. Acesso a conteúdos de repositórios biomédicos digitais através de uma Interface com boneco anatômico web 3D. Universidade de Brasília, 2013.