Morphology of Memory: Creating a web-based 3D interactive resource to teach the anatomy of the human hippocampus

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Abstract

The hippocampus is a critical region of the brain involved in memory and learning and is composed of layered, interconnected regions. Despite the importance of understanding normal hippocampal anatomy for studying its functions and disease processes that affect it, didactic educational visualizations are severely limited. To help graduate students and scientists better understand and visualize the human hippocampus, a web-based interactive resource was created that included a 3D animation and manipulatable 3D models of hippocampal regions. These resources allow users to expand their comprehension of this complex anatomy.

Introduction

The human hippocampus is located in the floor of the lateral ventricle in the medial temporal lobe (**Fig. 1**). It is critical for the generation of long-term declarative memory, learning, and aspects of emotional regulation[1]. Two major subdivisions, the cornu ammonis and the dentate gyrus, lie interlocked along the length of the hippocampus and are subdivided further into regions with distinct cellular characteristics[1].

The descriptive literature on this topic is extensive, but regions of the hippocampus are typically presented in 2D, as MRI slices or histological sections. During informal interviews, students and scientists revealed that they struggle to visualize hippocampal architecture in three dimensions.

The primary goal of this project was to provide a clear, accessible learning resource that includes a concise overview of the anatomy and the ability to interact with 3D models.

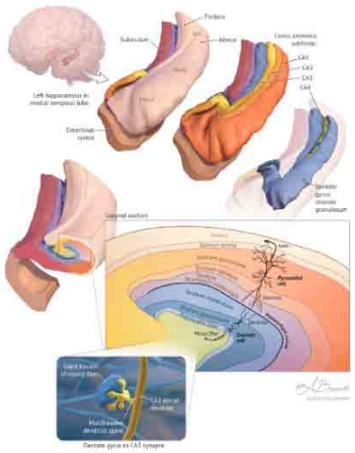

Figure 1. A visual summary of the adult human hippocampal formation.

Materials & Methods

Sources of Data
MRI segmentations of an anonymous human hippocampus were provided by the Center for Imaging Science (JHU) as the foundation for the creation of the main hippocampal model. Additional diffusion MRI data of the anterior half of an anonymous hippocampus was provided by the project preceptor, Dr. David Nauen, and Dr. Jiangyang Zhang (NYU). Two anonymized T2 MRI datasets from the Johns Hopkins Hospital were used to model the brain and ventricular system.

Segmentation & 3D Models
3D Slicer was used to view data and segment selected regions of interest (**Fig. 2**). ZBrush and Cinema 4D were used to repair artifacts, sculpt, and modify segmentations into educational 3D models (**Fig. 3**).

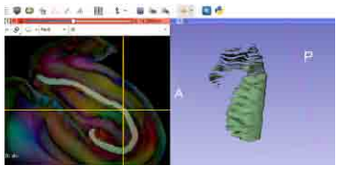

Figure 2. In-progress segmentation of diffusion data in 3D Slicer.

2D Assets & 3D Animation
Storyboards, illustrations, diagrams, and user interface elements were created in Draw.io, Adobe Illustrator, and Photoshop (**Fig. 4**). The 3D animation was created in Cinema 4D. Compositing with narration and labels was done in Adobe After Effects.

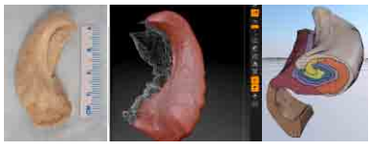

Figure 3. Sculpting and modifying with references in ZBrush and Cinema 4D.

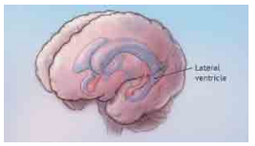

Figure 4. Sample animation storyboard.

3D Web-Based Interactive
Optimized 3D models were imported into Blender (**Fig. 5**). Rotation of models, visibility toggles, and other interactivity were coded using the toolkit Verge3D and its visual coding interface (**Fig. 6**).

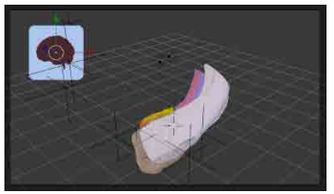

Figure 5. Screenshot of 3D scene in Blender.

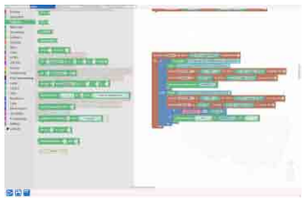

Figure 6. Screenshot of Verge3D visual coding interface.

Results

An online interactive application was created containing an introductory 3D animation (duration 3:50), interactive 3D models, and additional educational content (**Figs. 7-8**). 3D models included a brain, ventricular system, and a hippocampal model with 10 color-coded regions. Results are accessible online at ***alisabrandt.com***.

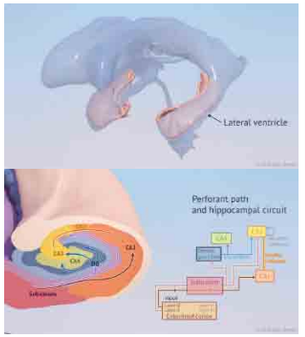

Figure 7. Final screenshots of introductory 3D animation.

Figure 8. Final screenshots of interactive with manipulable 3D models and additional content.

Conclusions

The results of this project address the needs of graduate students and scientists for an accessible 3D educational resource about hippocampal anatomy and connectivity involved in memory formation. The animation and interactive provide users with a new visual perspective that cannot be easily obtained from raw data and static 2D images. The freedom to dynamically view the anatomy from any angle contributes to better understanding of this structure. By opening the way for further learning and investigation, this project aimed to advance the communication and scientific study of hippocampus-related topics.

References

1. Duvernoy H, Cattin F, Risold P-Y. ***The Human Hippocampus: Functional Anatomy, Vascularization and Serial Sections with MRI.*** Springer, Heidelberg; 2013.