

# An interactive program to conceptualize the anatomy of the internal brainstem in 3D.

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**Abstract.** Neuroanatomy is a complex sub-discipline of anatomy requiring abstract visualization and strong spatial reasoning. Traditional methods of learning neuroanatomy include investigation using dissection, light microscopy and histology. Often, this pedagogical approach requires students to formulate three-dimensional (3D) mental images from sequential two-dimensional (2D) cross-sections, which can be difficult for many students to conceptualize. The goal of this study is to develop an interactive 3D learning tool of the internal brainstem anatomy and assess its efficacy on student learning against the classical methods of learning neuroanatomy. Results reveal that students the amount of learning was equal between both experimental groups. Qualitative results show that students enjoyed interactive learning and warmly welcomed the 3D program. Future neuroanatomy laboratories may include a 3D component to aid in student conceptualization of internal brainstem anatomy.

**Keywords.** Neuroanatomy, 3D visualization, virtual reality, education

## Introduction

Neuroanatomy is a complex sub-discipline of anatomy that requires abstract thinking and strong spatial reasoning. The study of neuroanatomy has been around since the early 1900's, and its method of instruction has remained relatively unchanged. Classical neuroanatomy training based on dissection, histology and light microscopy. Specifically, the brain, brainstem and spinal cord are traditionally studied from two-dimensional (2D) cross-sections [1] and most structures are difficult to visualize even on the histology slices. Often, this pedagogical approach requires students to formulate three-dimensional (3D) mental images from 2D cross-sections [2], and to comprehend the spatial relationships between structures. This method depends on the student's spatial ability [2]. Brainstem anatomy is essential for medical students, as well as

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neurology/neurosurgery residents but is a difficult topic for students to conceptualize because of the close proximity of all structures (i.e. nuclei and tracts) [3].

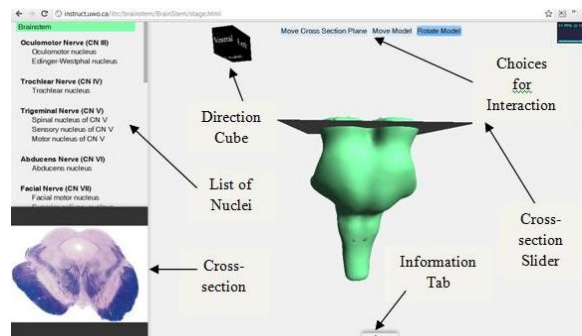
Studies have demonstrated that computer-assisted learning has a positive effect on student learning outcomes [4] and enhances understanding of neuroanatomical structures when combined with traditional methods [5]. There is however, an ongoing debate about whether 3D learning tools can successfully improve student learning and if they are better than classical methods, such as dissection.

The goals of the current study are to produce a an interactive 3D learning tool to aid in the conceptualization of 3D internal brainstem topography, and to measure its effect on student learning outcomes by comparing the 3D learning tool to traditional means of teaching and learning of neuroanatomy.

## 1. Methodology

### 1.1. Program Development

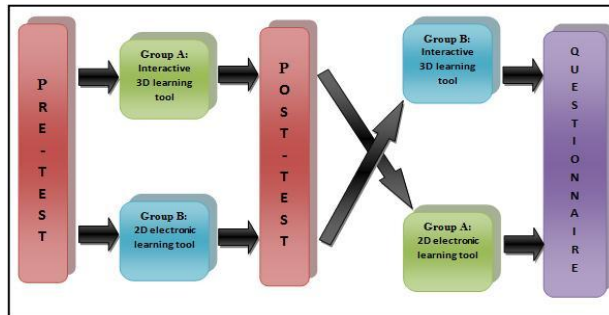
A magnetic resonance, T1 weighted dataset was acquired using the 3 Tesla magnet at Robarts Research Institute, that contained slices with the dimensions 0.86mm x 0.86mm x 1.0mm after REB approval. Manual segmentation of the image dataset was done in Amira 5.2 (Mercury Computer Systems Inc.) to develop the 3D model. To develop the 3D learning module, the Western University (UWO) Instructional Technology Resource Centre (ITRC) was approached to aid in the development of an interface in which the segmented structures of the aforementioned digital brainstem model could be stored and accessed. Further, the ITRC was involved in writing all of the HTML5 code required to provide functionality to the program (Figure 1).



**Figure 1.** Interface of 3D program immediately upon entering the program

Participants were split in 2 groups. A control group used the 2D learning module typical in a neuroanatomy laboratory setting. The 2D laboratory contained electronic, histological cross-sections of the brainstem, obtained from the University of Western Ontario, that were together incorporated into a module using Microsoft PowerPoint. Views contained in this 2D e-module approximated those seen under microscope but did not contain any of the spatial orientation components of the 3D e-learning module. The study group worked on the model we just described. Both 2D and 3D learning modules contained identical textual information such that students could complete laboratory objectives.

A randomized crossover study was developed to compare student-learning outcomes of the 3D learning tool with the 2D learning tool (Figure 2). The entire experiment took place on the computer through the University of Guelph teaching platform Courselink. Students in each experimental group had approximately 60 minutes to learn the material presented to them in the study guide.



**Figure 2.** Study Design indicating a pre-test/post-test study design with a cross-over component and participant questionnaire

### 1.2. Qualitative and Quantitative Data

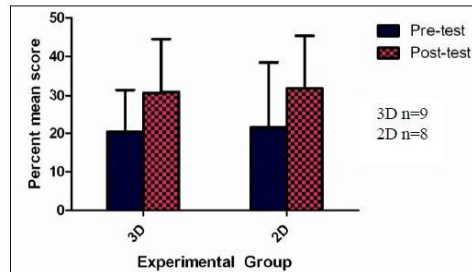
In order to assess the level of knowledge students possessed prior to using their respective lab tools, a knowledge pre-test was employed. This pre-test consisted of one quiz and was administered to the participants before their laboratory (Figure 1). The quiz consisted of 9 questions used to assess the level of prior neuroanatomy knowledge. Following the assigned laboratory, a 15 question post-test was administered to determine the amount of knowledge gained from the participant's laboratory experience. To analyze student learning as a direct result from the lab, 15 of 30 questions were identical to the pre-test questions. All of the questions used in the pre-test and post-test were consistent with the lower level thinking skills of Bloom's Taxonomy of Educational Objectives [6] and included knowledge-based questions, comprehension-style questions and application-style questions.

In addition to assessing knowledge translation, a qualitative user questionnaire served to gather information regarding the usability of the 3D and 2D labs, user preferences and opinions of participants. The survey contained 11 questions that consisted of a combination of Likert scale questions and short answer questions.

Seventeen participants were recruited from a third year undergraduate neuroanatomy course. Nine participants were assigned to the 3D laboratory and eight participants were assigned to the 2D assigned laboratory. Participants were both male and female, and their ages ranged between 18 and 25.

## 2. Results

The pre-test scores were similar between both experimental groups (Figure 3). The mean percent pre-test score for the 3D group was  $20.37 \pm 11.11$  and the mean percent score for the 2D group was  $21.53 \pm 16.91$ . The post-test scores showed a non-significant increase. The 3D group achieved an average of  $30.74 \pm 13.72$  and the 2D group achieved an average of  $31.67 \pm 13.69$ .



**Figure 3.** Percent Mean Change in Score on Spatial Relationship Questions

Both groups had similar MRT scores (average 10.25- 2D and 10.75 -3D groups), with a slight correlation between MRT scores and better post-test score results, independent of their groups.

Qualitative results show that students were very receptive to the online program (Table 1). It is evident that the 3D group enjoyed the interactive nature of the program and the ability to view spatial orientations of the brainstem structures. Moreover, students in the 2D laboratory also enjoyed the linear fashion of learning and liked that each cross-section was clearly labeled and colour coded. What students thought could have been improved on was more guidance in the utilization of the 3D module, such that sequential steps are provided for students to highlight the educational objectives.

**Table 1.** Representative Comments Regarding Participant Likes and Dislikes of the 3D and 2D Learning Modules

|                        | Participant Likes   | Participant Dislikes   |
|------------------------|---|--|
| 3D Assigned Laboratory | <p>Integration of the structures and being able to visualize the depth of the nuclei within the brainstem</p> <p>It was interactive, easy to use. Being able to rotate, pick out specific structures, moving from cross-section to the next, with an image of the real cross-section to reference</p> | <p>It was at times difficult to translate the 3D structure to the slide sections seen at the bottom left of the program screen</p> <p>As a student, I need a little more structure. I was not sure what exactly I needed to do and which information was required.</p> |
| 2D Assigned Laboratory | <p>I liked that it went layer by layer, and the structures were colour-coded</p> <p>I liked the logical flow to the presentation and how the cross-sections clearly circled the brain regions at that level</p>   | <p>It was hard to cross-reference the level of brainstem you were at</p> <p>It was hard to keep track of where particular structures were. Not interactive at all, boring, and very repetitive</p>   |

### 3. Discussion

Test answers demonstrated that student did learn in equally in each experimental group (Figure 3). A potential explanation for this outcome could be the limited number of spatial anatomy questions and the small sample size. Students with a better spatial ability tended to do better in the post test scores, in accordance to the literature [7].

Students reported a positive learning experience and displayed a positive attitude towards the learning module. The finding of user perception, positively relating to student learning is consistent with Koohang, 2004, who claims that well designed e-

learning tools will contribute to positive user perception and increases the probability for user satisfaction and successful learning experiences [8].

Additionally, our student feedback showed that students prefer guidance when using a learning module, especially for the first time. Possible additions to the learning module would be to include a step-by-step outline in which students can utilize the module to achieve the given learning objectives, with the option to by-pass certain steps to suit their own learning needs and objectives. This would likely decrease the cognitive load on the students and perhaps help them to use the module more efficiently, and thus learn more material.

## Conclusion

In summary, the current study has demonstrated, that student learning took place when exposed to a novel interactive 3D model of the internal brainstem anatomy. The results also illustrate that students who learn with 3D materials learn equally well as students who learn with traditionally based 2D materials. Additionally, students had a positive attitude towards the 3D learning module and found it to have great potential. Future neuroanatomy laboratories may implement 3D representations of the cranial nerve and brainstem nuclei complementary to the traditional methods of learning in order to create the most optimal learning environment for students learning neuroanatomy.

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