Play It by Ear: An Immersive Ear Anatomy Tutorial

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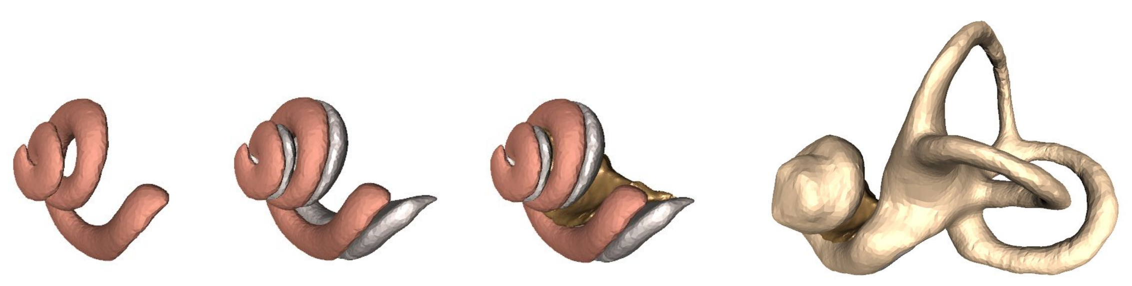
Purpose

The anatomy of the ear and the bones surrounding it are intricate yet critical for medical professionals to know. Current best practices teach ear anatomy through two-dimensional representations, which poorly characterize the three-dimensional (3D), spatial nature of the anatomy and make it difficult to learn and visualize. In this work, we describe an immersive, stereoscopic visualization tool for the anatomy of the ear based on real patient data [1]. And, in a preliminary evaluation, we compare how well medical students learn ear anatomy in virtual reality compared with more traditional learning methods.

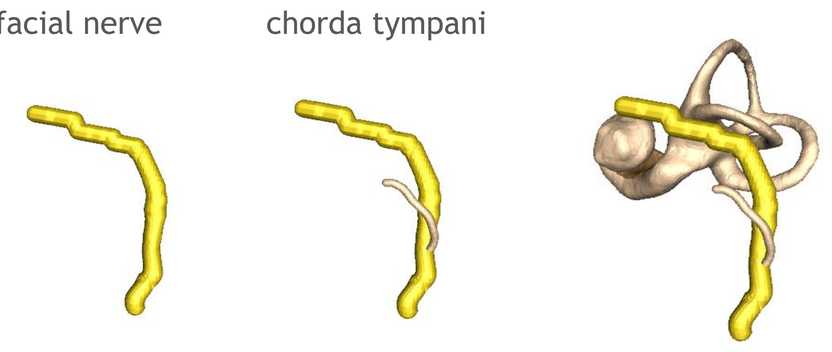
Individualized Models

Within our virtual environment, users interact with segmented ear structures inside of a skull model—all of which were generated in prior research [2]. Surface models are generated from the same **patient specific data** with a high resolution CT scan volume. And the segmented ear structures are extracted using automatic techniques:

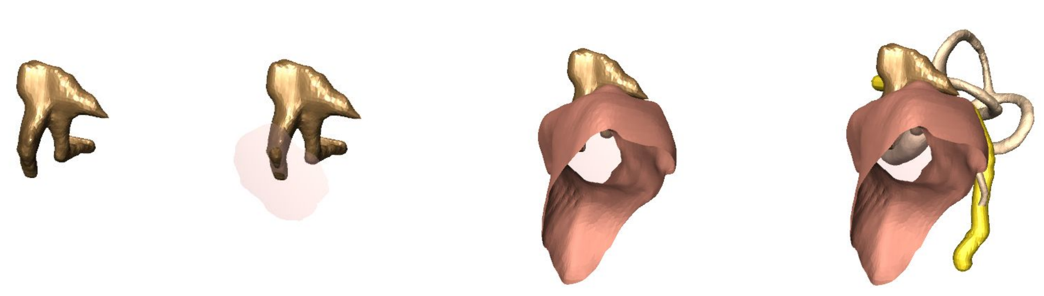
scala vestibuli | scala tympani | modiolus | cochlea & semicircular canals



facial nerve | chorda tympani

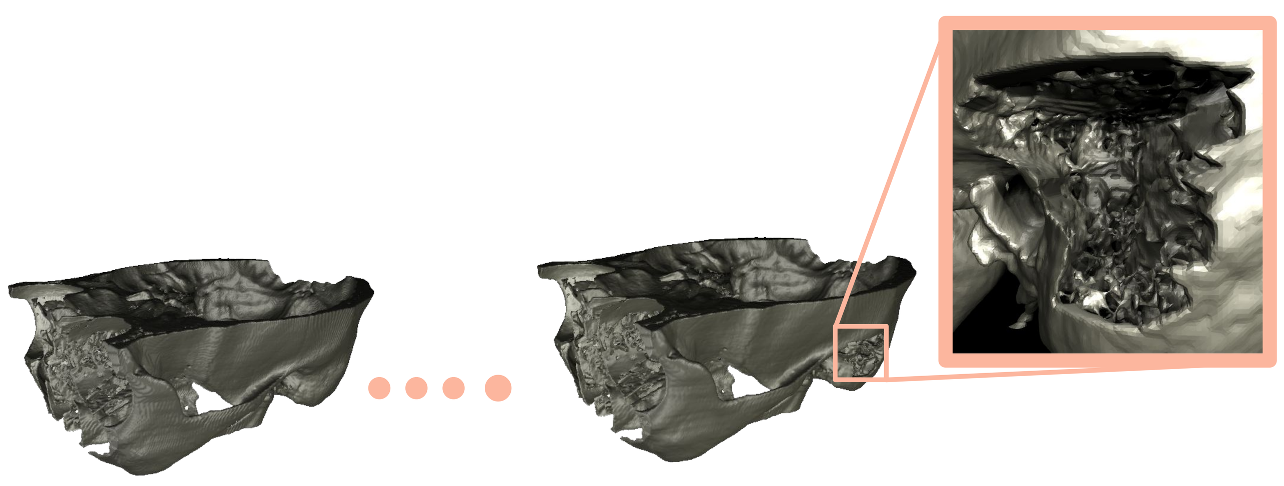


ossicles | tympanic membrane | external auditory canal



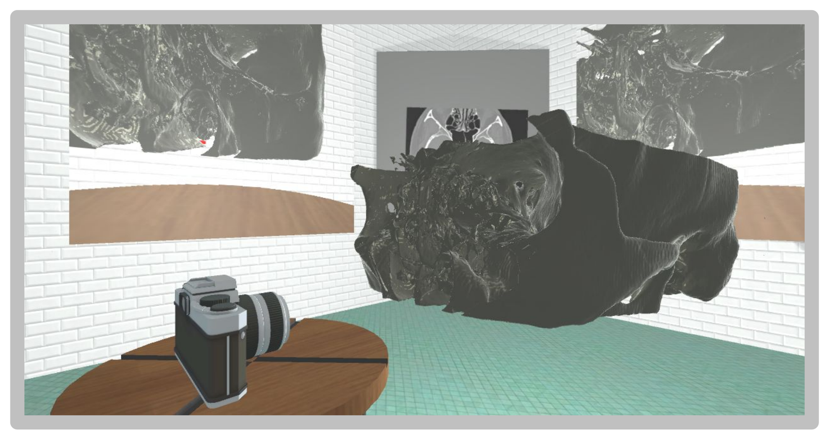
Simulated Mastoidectomy

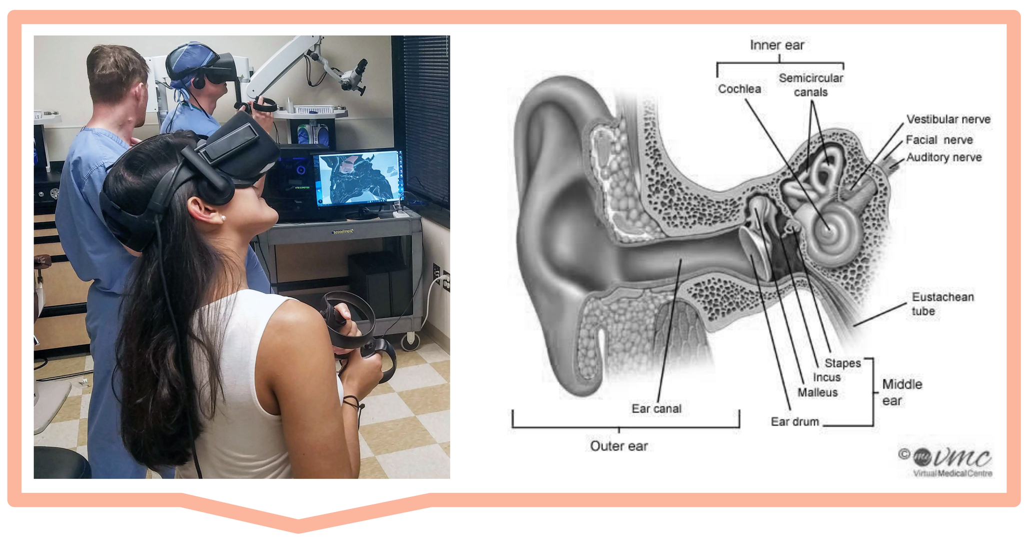
Users can also view 6 variant skull models that represent the shape of bony structures at sequential time points in a **mastoidectomy**—a common otological procedure performed to safely access critical structures of the middle and inner ear (e.g., for cochlear implants and aural atresia). This important resection procedure occurs in a small area of the skull behind the ear.



User Interface

The simulation is rendered by the Oculus Rift CV1 head-mounted display. Our system is networked to allow multiple users to interact with anatomy data synchronously. Within the virtual environment, users may freely translate, rotate, and scale anatomy. A camera, which enabled users to capture still images of the data from various angles, is placed next to the skull. The camera serves as a metaphor for an endoscope. Screens along the walls capture both the camera feed and triaxial CT scans, which are selected using a cutting plane that intersects with the 3D model. The simulation also contains several different rendering modes.





The VR group was given an oral script | The standard group was given a written script

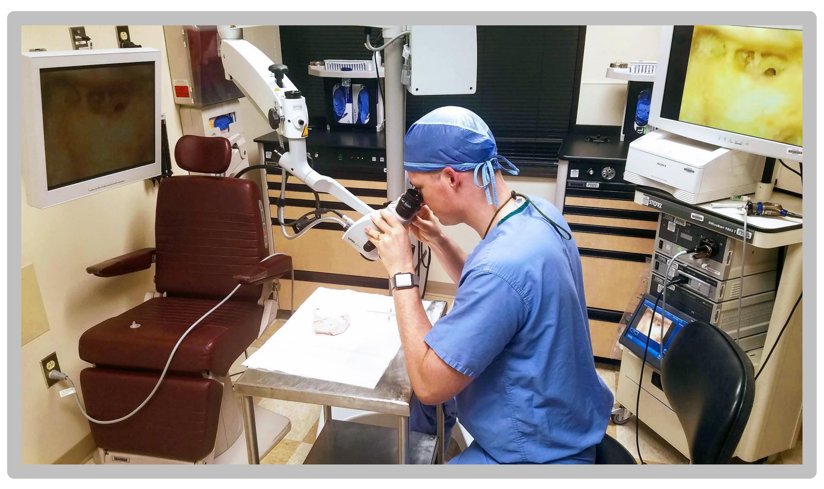
Learning Assessment

Ten medical students were recruited to evaluate learning effects between '**standard**' and '**virtual reality**' learning conditions in a between subjects design. The standard group learned with 2D representations of anatomy. The same script was given to each group.

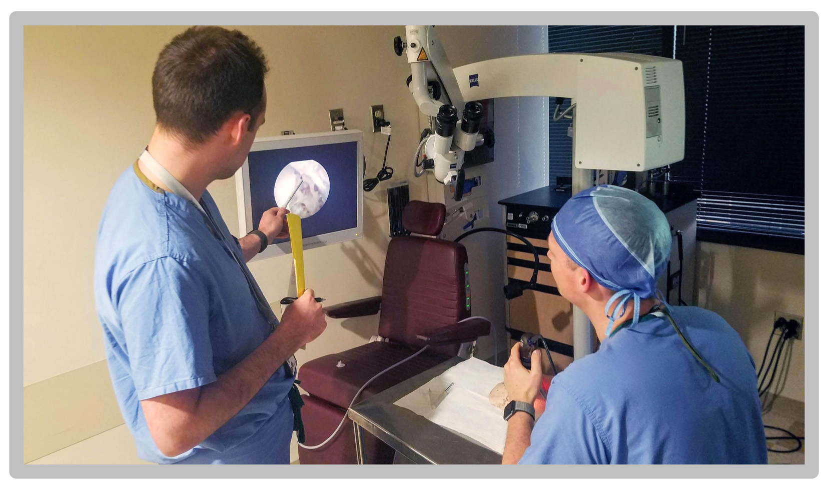
Participants were randomized into each group and allotted 17 minutes to learn anatomy.

Cadaveric Evaluation

Participants' understanding of anatomy was then tested on a **pre-drilled cadaveric temporal bone**. A single point was given to participants for each structure correctly identified. Fifteen structures were tested using binocular microscopy on a post-auricular, transmastoid view. Seven structures were tested via transcanal endoscopy.



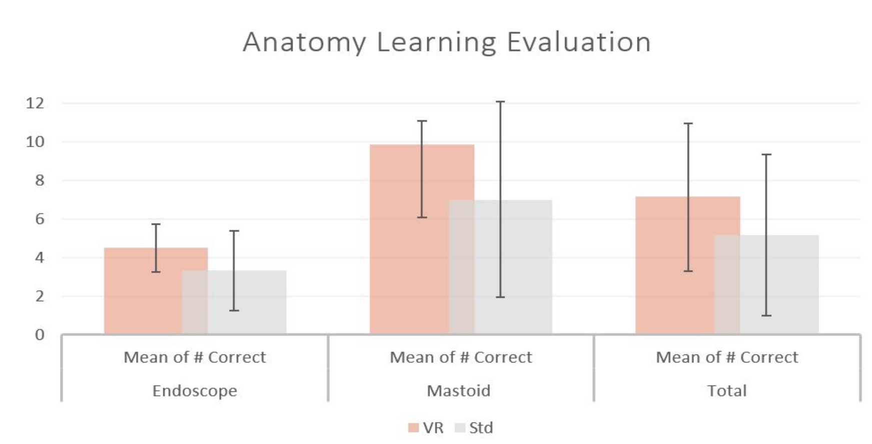
Mastoid structures tested via binocular microscopy



Endoscopic structures tested via transcanal endoscopy

Results

The VR group answered 60% (M=9, SD=3.54) of the structures correct compared with 37% (M=5.6, SD=4.16) in the standard learning group from the transmastoid view. And the VR group answered 60% correct (M=4.2, SD=1.10) compared with 40% (M=2.8, SD=1.79) in the standard learning group from the endoscopic view. In addition, we employed the System Usability Scale (SUS), which showed a significant (p=0.006) difference between the VR system (M=67, SD=10.1) and the standard learning arm (M=43, SD=10.2).



Conclusions

Our ongoing results reveal a trend in which the VR group outperforms the standard learning group, although this may change upon completion of the study. A complete evaluation of the system will be necessary to determine if there is truly a significant effect of learning condition. As the learning environment matures, next iterations of the system may provide additional learning functionalities like repeated practice, error correction, and feedback within the immersive tutorial.

References

[1] H. Adams, J. Shinn, W. G. Morrel, J. Noble, and B. Bodenheimer. Development and evaluation of an immersive virtual reality system for medical imaging of the ear, 2019. doi: 10.1117/12.2506178

[2] J. H. Noble and B. M. Dawant. An atlas-navigated optimal medial axis and deformable model algorithm (nomad) for the segmentation of the optic nerves and chiasm in mr and ct images. *Medical Image Analysis*, 15(6):877 – 884, 2011. doi: 10.1016/j.media.2011.05.001

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