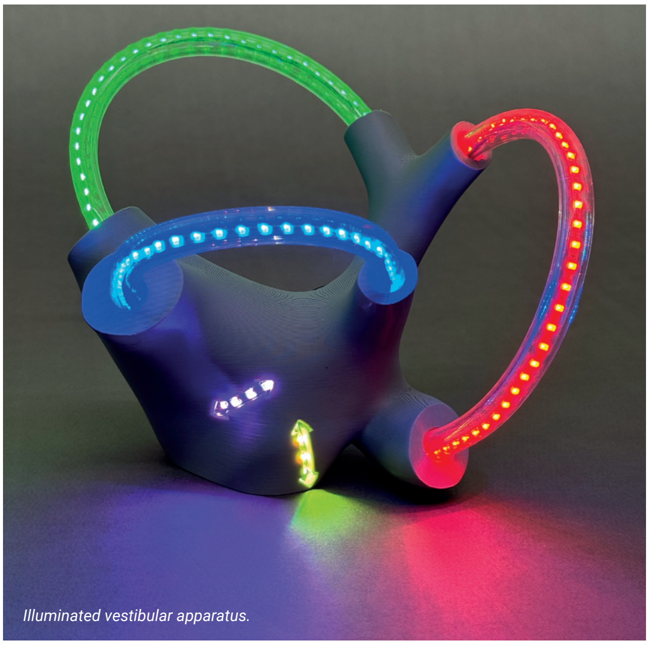
Illuminating ear education: building interactive models to enhance inner ear understanding

BY PATRICK ESMONDE AND HELENA ESMONDE


Illuminated cochlea model.


Illuminated vestibular apparatus.

Understanding the anatomy and function of the inner ear, particularly the vestibular apparatus and cochlea, is fundamental to audiology and otolaryngology education. However, the complex geometry and intricate functional relationships of these structures challenge us to find clear ways to demonstrate their essence. Standard 2D pictures, verbal explanations and videos often struggle to fully convey the three-dimensional structure and function of these organs. Luckily, recent advancements in 3D printing and electronic integration are offering exciting new ways to provide more illuminating and interactive learning experiences for inner ear education. Here, Patrick Esmonde provides insight into his journey to create 'Vestibular First' – a new model for teaching vestibular anatomy.

From a young age, I was fascinated by how things worked. Guided by my dad, I'd take apart toys, electronics, and old appliances – anything we could find. Fast forward to today, I've turned that curiosity into a rewarding career as an inventor in the vestibular space. I now blend my love for problem-solving with technology to bring solutions to life. My latest work has focused on visualising the electrophysiology of the inner ear's remarkable structures — particularly the vestibular apparatus and cochlea. As someone without formal medical or clinical training, I know firsthand how challenging the anatomy can be to grasp, which is why I've developed interactive tools, using 3D printing and electronics, to make them intuitive for students, clinicians, and even patients.

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A spark of inspiration

It all started with a clock. I had taken apart electronics before, but never built anything beyond simple circuits. That changed when I saw a mechanical clock that moved one degree per day, completing a full cycle in a year. Unable to afford the expensive version, I set out to build my own using off-the-shelf electronics and 3D printing. After lots of tutorials, sample projects and trial and error, I got it working! (If you'd like to make your own, you can find instructions at https://v1st.co/annualclock). While watching the clock slowly turn, I wondered, 'what else can I do with these little computers?' Better known as 'microcontrollers', these inexpensive, single-purpose computers, can detect inputs like motion and then control devices like lights or motors. Knowing the vestibular apparatus functions like a three-axis accelerometer and gyroscope, it became the perfect project to pair with a motion-sensing module.

How they work

The first model I made was of the vestibular apparatus. I used motion sensors to detect movement and light up the corresponding semicircular canals and otolith organs. For example, if you rotate the model along the horizontal canal axis, blue LED lights dim up and down in that canal, demonstrating how the cupula reacts to rotational acceleration. There's also a mode that shows how the vestibular sensors excite and inhibit with movement, which can be

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helpful for explaining conditions like benign paroxysmal positional vertigo (BPPV).

The cochlea model I made was inspired by chance and happened while I was upgrading the vestibular apparatus to be battery powered. As I laid the small strip of LED lights on my workbench, they formed a spiral shape and were pleasantly engaging when they illuminated together. Knowing the basics of the cochlea and the tonotopic mapping of the frequencies, I added a microphone to a new board and built a simple spectrum analyser that mapped the LEDs to the specific parts of the cochlea that respond to each frequency and amplitude. This model has been expanded to also be able to demonstrate how audiologic tests (e.g. otoacoustic emissions) work, visualise the bands of cochlear implants, and even show how tinnitus can impact hearing. You can see videos demonstrating these in action on our website: https://v1st.co/electronics

Why interactive models matter

While my initial goal was to create something entertaining and functional, I soon realised how beneficial these models could be in both education and patient care. A recent study found that first-year medical students using 3D vestibular models reported higher confidence in their understanding of vestibular anatomy compared to those learning with traditional 2D images [1]. It makes sense – having a hands-on tool with which you can interact promotes understanding of these complex structures, particularly for tactile and visual learners.

These benefits extend beyond student education, however. Patients with BPPV, for example, have reported a better grasp of their condition and a reduction in anxiety after learning with a 3D printed vestibular model compared to just verbal education [2]. By visually showing the movement of otoconia (tiny crystals in the vestibular apparatus) through fluid in a semicircular canal, these models help patients understand why they feel dizzy and how treatments like the canalith repositioning procedure work. This knowledge grows their confidence in their healthcare providers and plan of care as well.

Application in understanding and treating BPPV

Similar to the use of the fluid-filled vestibular model, one of the most valuable uses of the illuminated vestibular model that I built is in educating patients (and clinicians) about BPPV, a common cause of episodic vertigo. BPPV accounts for roughly 25% of all vertigo cases and 60% of peripheral vertigo cases [3]. The illuminated 3D vestibular model can visually show how inner ear crystals move through semicircular canals in response to gravity, clarifying how specific treatment manoeuvres would work to reposition otoconia in a given canal. The programmable and responsive nature of the illuminated model can make it easier for educators to bring vestibular pathology and treatment concepts to the next level.

Existing 3D models for educational use

In addition to these light-up 3D models which are still under development, I have created other vestibular models that are currently available for free download to those with access to a 3D printer. The instructions for building these models can be accessed on the Vestibular First website: https://v1st.co/3D. These models provide valuable options for educators and clinicians aiming to enhance their teaching and improve patient education outcomes.

Advice for budding entrepreneurs

1. **Diligently follow your curiosity.** Your ideas can transform the world, but only with the dedication and hard work to bring them to life – stay focused, and let your passion lead the way.
2. **You don't need to have all the answers right away.** Just start with what you know, use your academic and professional resources to network, learn more, and keep experimenting!
3. **Luck favours the prepared.** There's always a bit of luck involved when you're an entrepreneur – just make sure you're ready for it!

If you're interested in creating educational models or developing your own tech projects, I'd recommend using tools like 3D printers and microcontrollers to get started. Most academic institutions have connections with 3D-printing and engineering resources, so collaboration can be a great option.

The next steps

Interactive models like the ones that I built are helping to change how we teach and understand the inner ear. Whether you're a student, a patient, or a clinician, these tools make complex anatomy more approachable. I'm excited to keep exploring what's possible with this technology and hope that this work inspires others to follow their own inventive ideas. 3D printing and electronics open up endless possibilities, and who knows—maybe your next great contribution to science is just one project away.

References

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