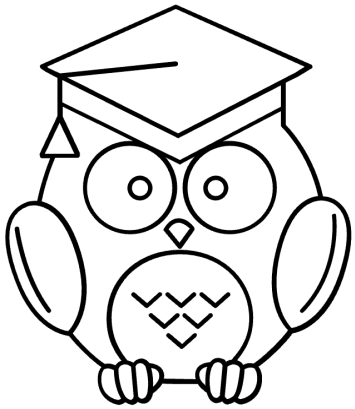

TLDR

Virtual and augmented reality for biomedical applications

Cell Reports Medicine

Mythreye Venkatesan, Harini Mohan, Justin R Ryan, Christian M Schürch, Garry P Nolan, David H Frakes, Ahmet F Coskun

Contributors:

Nitya Sriharshita Gaddamanugu - Writer
Bryan Zhang - Editor

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The Big Idea:

3D visualization techniques such as virtual reality, (or VR) and augmented reality (AR) are beginning to be used in medical procedures because of their versatility. Though, there are some setbacks such as the cost and other factors.

Key Terms and Concepts:

Virtual Reality (VR):
Virtual reality is visual interaction with a computer generated environment that consists of software and hardware. VR systems collect data from the user such as head tracking, controller movement, and hand tracking to facilitate proper interaction with the environment.

Mixed Reality (MR):
Mixed reality is a combination of both the digital and physical worlds. MR allows the physical and digital worlds to interact with each other.

Augmented Reality (AR):
Augmented reality can be related to a hologram, in the sense that it is a projection that the user can interact with. AR overlays images onto the real world.

Extended Reality (XR):
XR is defined as a combination between the real and virtual world using computers and wearable devices, and encompasses VR, AR, and MR technologies as well.

Immersion:
Nature of user experience facilitated by technology (how connected the user is with the digital world). For instance:

- VR provides complete immersion
- AR provides partial immersion since the digital images are overlayed.
- MR is partial as well because it allows for interaction between physical and digital objects

Information:
Type of data handled during visualization.

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Methodology:

- Summarized current biomedical trends in XR
- Demonstrated use of VR and AR in classrooms for education
- Cost, complexity and challenges are discussed
- Used external data from surveys and experiments to support claims
- Analyzed case studies

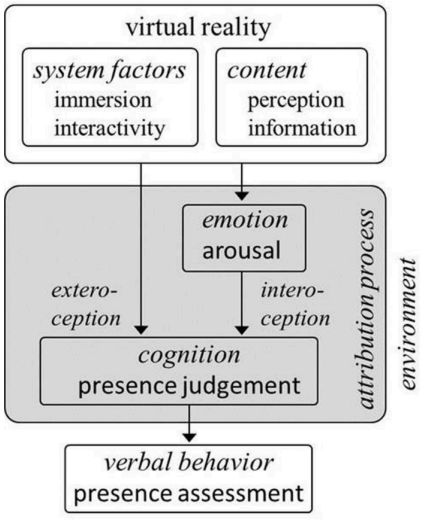
Key Findings:

- XR platforms have been shown to improve learning and emotional engagement in students.
    - This aids the understanding of new concepts
    - Virtual memory places increase effectiveness of memorizing due to more spatial organization
    - Measuring participant's responses to a VR experience showed that there was greater emotional engagement

- Studies explored the effects of perceptual (visual and auditory) and conceptual (related to fear) information on fear/anxiety in a VR environment
    - People with phobias are more sensitive to perceptive cues, helping further knowledge on phobias and anxiety in general
    - More involvement in the VR experience leads to more emotional responses
    - Certain arousing emotions (such as fear or excitement) are stronger in VR

- Users made decisions based on the degree of excitement (emotional arousal) and immersion

- Studies explored the effect of VR on non-cognitive factors and cognitive factors.
    - The results indicated that the usage of VR provides an ideal learning environment compared to a normal desktop.



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- XR and VR technologies can be used to diagnose illnesses, enlarge and analyze, and save time significantly.
    - In biomedical engineering, VR and AR have increased the ability to visualize and interact with microscopic images, molecular data, and anatomical datasets.
        - **Google's AR Microscope (ARM)** uses machine learning to diagnose certain cancers. It looks at whole slide microscopic images and employs deep learning algorithms.
        - **ExMicroVr**, a tool for nanoscale imaging (enlarging cell structures) allows for remote collaboration between scientists, and increases the tissue sample volume by 100 times. Using VR allowed the tissue sample to be seen in 3D and be interactive.
        - **ConfocalVR** uses VR to visualize 3D cellular images, allowing users to manipulate the displayed image by using controllers.
        - **Microsoft HoloLens** is used by engineers and doctors to look at 3D images and interact with them.

- VR and AR technologies can be used as training for surgeries and biomedical devices
    - VR gives medical students the opportunity to practice surgeries virtually before performing these surgeries on actual patients.
    - VR based simulators allow students to work on skills such as on the spot thinking, problem solving, and performing tasks regardless of stress levels.
    - Advanced simulators use scans from real patients to simulate reactions of certain tissues. This provides a realistic surgical experience.

    - AR tools facilitate collaboration between students and creates a hand-on environment. Tests and quizzes can also be administered by using VR and AR technologies, which reduces the risk of cheating.
    - Training software can adjust the difficulty of procedures to match the level of the student. This allows each student to work at their own pace, and allows students to target specific surgeries that they need help in.

- VR can be used to transfer knowledge of procedures in the biopharma industry
    - A study found that participants who trained using VR performed better than those who used traditional methods.

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- VR and AR can be used in *telemedicine* and *telehealth*
    - XR based telehealth can allow patients to remotely talk to medical professionals
    - These platforms utilize virtual environments, games, and exercises
    - These platforms allow people to receive consultations in their own homes. This could significantly aid people with mobility issues, such as people suffering from paralysis.

- Biomedical Case Studies:
    - Case Study #1: This study uses VR to visualize multiplexed protein imaging data, and uses highly multiplexed CODEX imaging data from people with chronic lymphocytic leukemia
    - Case Study #2: This study is an AR based visualization of a cerebral aneurysm.
    - Case Study #3: Using 3D software to create a model allowed cardiologists to help an 8 year old with his complex cardiac heterotaxy
    - Case Study #4: Google Cardboard is a cost effective solution that enables access to VR technology. It is vital for education.

- **Challenges associated with virtual and augmented reality platforms**
    - They are costly and typically exceed tens of thousands of dollars.
    - They are prone to facing technical issues. For example, applications using GPS technology might provide inaccurate locations.
    - Privacy, security, and ethical concerns are dire since devices may be susceptible to getting hacked, leading to leaked user data.

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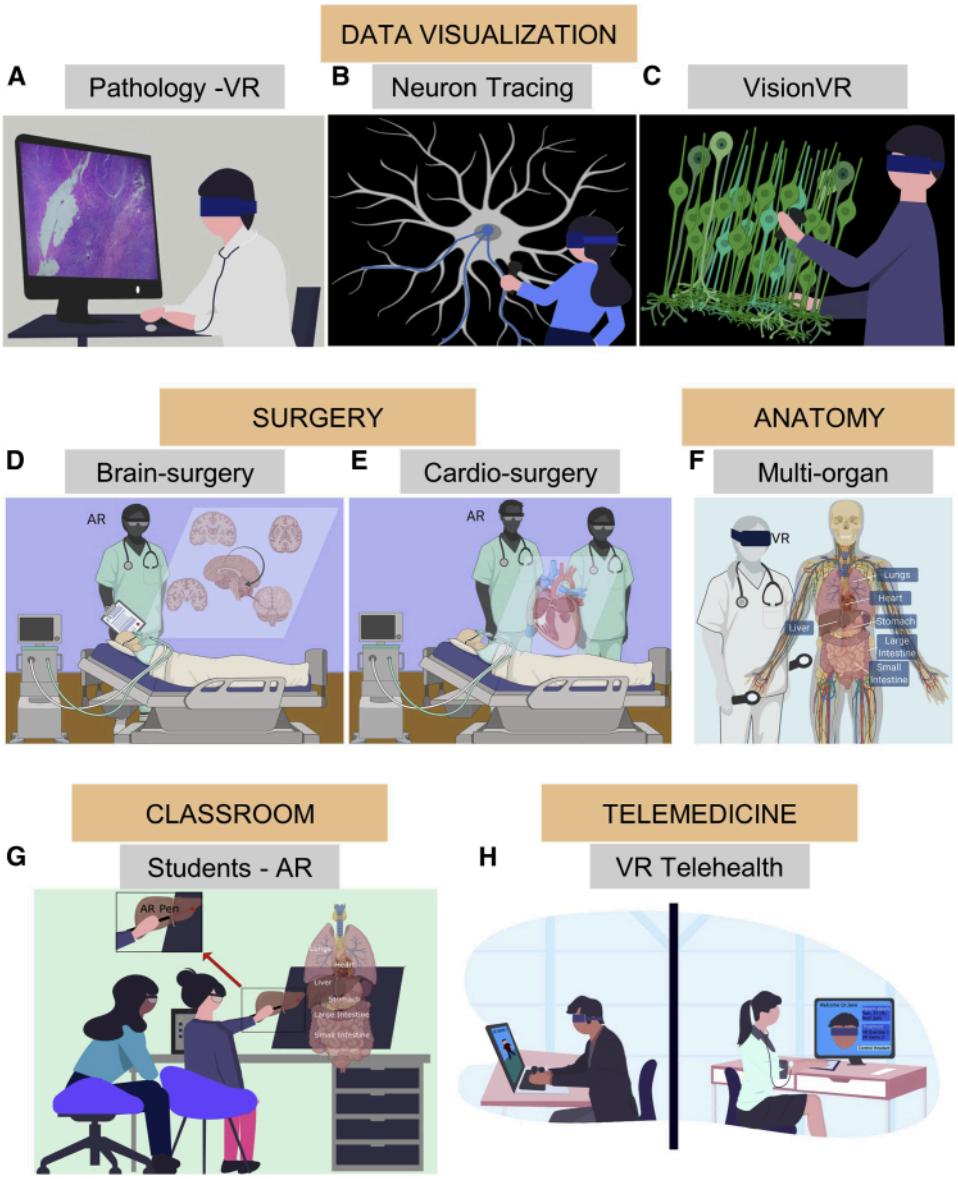

- The image above shows typical applications of VR and AR in medicine
  - A shows navigation and visualization of a digital whole slide using VR technology.
  - B shows a neuron tracing tool that can visualize whole brain imaging data in VR and virtually reconstruct neurons at different regions.
  - C shows a 3D scanning electron microscope
  - D and E shows physicians using AR to rotate and manipulate certain parts of anatomy during surgery to better visualize and perform surgeries
  - F shows the benefits of using AR and VR to study anatomy
  - G shows how AR pens can be used to get a 3D image to help students learn
  - H shows how VR can be used for clinical assessments

Implications:

- Doctors, researchers, and even patients can benefit immensely from the application of VR and AR technology to modern medicine. Doctors can use the technology to learn their craft, while researchers can use it to better visualize and analyze data and images. Patients can receive optimal care.
- The usage of VR and AR technology can significantly change modern medical procedures. One example is using an AR model during surgeries to look at organs that are not clearly visible. VR and AR technologies are versatile tools that can greatly improve medical education and procedures.

Sources:

Virtual and augmented reality for biomedical applications. (n.d.). PubMed Central. Retrieved May 28, 2025, from https://pmc.ncbi.nlm.nih.gov/articles/PMC8324499/

The impact of perception and presence on emotional reactions: a review of research in virtual reality - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/An-interoceptive-attribution-model-of-presence_fig4_272356362 [accessed 28 May 2025]