XoveTIC: Impulsando el talento científico

Editorial Office

Servizo de Publicacións (SPU)
Universidade da Coruña
Maestranza 9, 15001 A Coruña, Spain

Handle: 2183/40661
DOI: 10.17979/spudc.9788497498913

Cover image courtesy of CITIC—Research Center of Information and Communication Technologies, University of A Coruna, Spain
CITIC, as a center accredited for excellence within the Galician University System and a member of the CIGUS Network, receives subsidies from the Department of Education, Science, Universities, and Vocational Training of the Xunta de Galicia. Additionally, it is co-financed by the EU through the FEDER Galicia 2021-27 operational program (Ref. ED431G 2023/01)

Proceedings XoveTIC 2024. Impulsando el talento científico.

This volume was typeset in LaTeX by the editors using *varianTeX* — a reusable template for journals in the Humanities, developed by Wout Dillen. *varianTeX* is open source, available on GitHub, and deposited in the Zenodo Open Science Repository. DOI: 10.5281/zenodo.3484651.

Extended Reality Tools for Medical Training and Education

Mariana Pinto, Adélio Vilaça, Luís Coelho, Renato Magalhães, and Rita Veloso

1 ISEP, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4249-015 Porto, Portugal
2 CAC ICBAS-CHP { Centro Académico Clínico Instituto de Ciências Biomédicas Abel Salazar { Centro Hospitalar Universitário de Santo António, Porto, Portugal
3 LabRP-CIR, ESS, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 4200-072 Porto, Portugal
4 Executive Board Member, Centro Hospitalar Universitário Santo António, Porto, Portugal
Correspondence: rita.veloso@chporto.min-saude.pt

DOI: *https://doi.org/10.17979/spudc.9788497498913.13*

Abstract: The integration of extended reality (XR) in medical education represents a cutting-edge approach to simulation-based training. This study critically assesses XR software for medical teaching, with a focus on compatibility, medical specialization, and licensing requirements. The findings highlight the significant use in anatomy (44%) and surgical applications (26%). Virtual and mixed reality are the dominant technologies in this field, with the U.S. accounting for 62% of the companies involved. Specifically, HoloAnatomy, tested on HoloLens 2 and evaluated by seven healthcare professionals using NASA-TLX, was deemed intuitive and effective, though high device costs limit broader adoption. In conclusion, XR technologies hold substantial potential for advancing medical education, but the cost barriers must be overcome to enable wider implementation.

1 Introduction

The rapid evolution of medical knowledge has created a demand for innovative tools that enhance both education and clinical practice. Immersive technology, encompassing virtual reality (VR), augmented reality (AR), mixed reality (MR), and extended reality (XR), is emerging as a key solution to meet this need. Research across fields like healthcare, education, and crisis management demonstrates that immersive technology can improve learning experiences and foster collaboration and creativity in educational settings(Tang et al., 2022).

Existing studies indicate that VR is the most frequently discussed immersive technology, especially in simulation and training, while AR and MR are becoming more prominent, particularly in surgical training. The literature mainly focuses on medical students and surgeons, highlighting the relevance of these technologies for both educational and professional development. However, there is a gap in studies on specialties like orthopedics and neurosurgery, suggesting either a need for further research or a lower level of application in these areas.

This study provides a comprehensive evaluation of tools that integrate extended reality with medical applications, analysing their features and specifications. A subset of these tools was tested using Microsoft's HoloLens 2 and Meta's Quest 3 headsets. One software was selected by a physician for further testing by a group of healthcare professionals in a controlled environment, with the primary goal of assessing the effectiveness of these tools and their potential impact on medical education and practice.

2 Methods

Data was gathered through a search using terms like "Extended reality software for medical education in headsets", "Medical software for HMD Meta Quest", and "Medical software for HMD HoloLens". The research relied on two main digital resources: Google and OpenAI's ChatGPT. A detailed analysis was conducted by reviewing the official websites of the identified applications to confirm their relevance. The findings were organized into tables: the first table listed compatible devices, targeted medical fields, and the technology used, while the second table provided details on licensing, country of origin, release year, and the associated company.

Table 1: Compilation of Extended Reality Softwares for Medical Education

Name	Devices	Medical Area	Technology
3D Organon (3D Organon, 2024)	MetaQuest, VIVE FOCUS 3, VIVE XR Elite, Pico Neo 3 Pro, Pico 4 Enterprise	Anatomy	VR
AnatomyX (Medivis, 2024)	HoloLens, Magic Leap 1	Anatomy	AR
Body Map (Meta, 2024) (MAI, 2024)	Meta Quest	Anatomy	VR
Complete HeartX (App Store Preview, 2024)	Apple Vision Pro	Anatomy	MR
HoloAnatomy (Microsoft, 2024)	HoloLens	Anatomy	MR
HoloEyes XR (HoloEyes, 2024) (Sugimoto and Sueyoshi, 2023)	MetaQuest, Magic Leap, HoloLens	Anatomy	VR, MR
HoloHuman (GigXR, 2024)	HoloLens	Anatomy	MR
HoloPatient (GigXR, 2024)	HoloLens	Anatomy	MR
Human Anatomy VR (Meta, 2024)	Meta Quest, Apple Vision Pro	Anatomy	VR
Medicalholodeck (Medicalholodeck, 2024)	MetaQuest, Rift S, VIVE +, VIVE Pro, Magic Leap 2, HoloLens	Anatomy	VR, AR
Mimic Viewer XR (Microsoft, 2024)	HoloLens2, Magic Leap2, Meta Quest	Anatomy, Surgery	MR
Insight Heart (ANIMA RES, 2024)	HoloLens	Anatomy, Cardiology	MR
VisAR (Novard: Enterprise HealthCare Solutions, 2024)	HoloLens	Surgery	AR
VSI HoloMedicine (Microsoft, 2024)	HoloLens	Surgery	MR
SurgicalAR (Medivis, 2024)	HoloLens, Apple Vision Pro	Surgery	AR
OpenSight (NOVARAD, 2024)	HoloLens	Surgery	AR
Bone VR (App Store Preview, 2024)	Apple Vision Pro	Orthopedic surgery	VR
Precision OS (precisionOS, 2024)	MetaQuest	Orthopedic Surgery	VR
Oxford Medical Simulation (Oxford Medical Simulation, 2016-2024)	Meta Quest	Clinical Skills	VR
HoloSEEG (Microsoft, 2024)	HoloLens	Stereoelectroencephalography	MR
Vimedix (Medical Simulator, 2024)	HoloLens	Ultrasonography	AR

Table 2: Compilation of Extended Reality Softwares for Medical Education

Name	License Type	Country	Year of Release	Company
3D Organon (3D Organon, 2024)	€185.25 / year; a)	New York, USA	2019	Medis Media
AnatomyX (Medivis, 2024)	e)	New York, USA	2019	Medivis
Body Map (Meta, 2024) (MAI, 2024)	b)	Virginia, USA	2023	MAI
Complete HeartX (App Store Preview, 2024)	a); €46,69	USA	2024	Elsevier Health
HoloAnatomy (Microsoft, 2024)	a), b)	Ohio, USA	2019	Case Western Reserve University
HoloEyes XR (HoloEyes, 2024)	b)	Japan	2016	HoloEyes
HoloHuman (GigXR, 2024)	€8.90 to €9.24 / month	California, USA	2019	GigXR
HoloPatient (GigXR, 2024)	€8.90 to €9.24 / month	California, USA	2019	GigXR
Human Anatomy VR (Meta, 2024)	€269 to €529 / year	Bratislava	2017	Virtual Medicine
Medicalholodeck (Medicalholodeck, 2024)	€35.89 / month; 7-day free trial	Zurich, Switzerland	2017	Medicalholodeck
Mimic Viewer XR (Microsoft, 2024)	b)	Salt Lake City, USA	2017	NOVARAD
Insight Heart (ANIMA RES, 2024)	c)	Bonn, Germany	2016	ANIMA RES
VisAR (Novard: Enterprise HealthCare Solutions, 2024)	b)	Salt Lake City, USA	2017	NOVARAD
VSI HoloMedicine (Microsoft, 2024)	b)	Hamburg, Germany	2017	Aqpolar
SurgicalAR (Medivis, 2024)	c)	New York, USA	2019	Medivis
OpenSight (NOVARAD, 2024)	b)	Salt Lake City, USA	2017	NOVARAD
Osso VR (App Store Preview, 2024)	b)	San Francisco, USA	2016	Osso VR
Precision OS (precisionOS, 2024)	b)	Vancouver, Canada	2021	Precision OS
Oxford Medical Simulation (Oxford Medical Simulation, 2016-2024)	d)	London, UK	2022	Oxford Medical Simulation
HoloSEEG (Microsoft, 2024)	b)	Ohio, USA	2022	Case Western Reserve University
Vimedix (Medical Simulator, 2024)	b)	Canada	2020	CAE Healthcare

a) *Free demo available*
b) *Contact with the company is necessary*
c) *A business license is required*
d) *A license agreement with the WHO must be obtained by the institution, and sub-licenses must be distributed to administrators and users*
e) *An annual subscription must be paid by users*

3 Results

3.1 Overview of Extended Reality Tools

A comprehensive evaluation of software applications revealed that the majority of tools support Microsoft HoloLens and Meta Quest devices, which together represent 62% of the market. In comparison, Apple Vision Pro and Magic Leap devices each hold 13%, suggesting lower compatibility with available applications. An analysis of the medical fields targeted showed a predominance of anatomy-focused tools (44%), followed by surgical applications (26%). This trend highlights the importance of anatomy education and the need for surgical simulation tools. Orthopedics accounted for 15% of applications, reflecting the benefits of 3D visualization in complex bone and joint cases. Other fields, such as clinical skills, ultrasonography, and cardiology, had limited representation. Technologically, VR and MR dominate, used in 37% and 36% of applications, respectively. AR makes up 27%, showing its value in simulations and education. The United States leads in software development (62%), followed by Germany (9%). Other countries contribute 4-5% each, indicating a global interest but with a smaller market impact. From 2016 to 2024, software launches peaked in 2019 (28%). The market saw a decline in 2020 and 2021, likely due to the pandemic, followed by a modest recovery in 2022, and a drop in 2023 and 2024.

3.2 Testing of the Studied Tools

Applications offering free trials on HoloLens 2 or Meta Quest 3 were selected for testing based on criteria like user interface, realism, and efficiency. Seven applications were tested, categorized into VR, AR, and MR.

In VR, three tools were assessed: Human Anatomy VR, Body Map, and Oxford Medical Simulation. Human Anatomy VR offers detailed anatomical manipulation but can cause user fatigue. Body Map has an intuitive interface and reduces fatigue with its realistic design. Oxford Medical Simulation excels in patient communication training but lacks realism, leading to fatigue with prolonged use.

For AR, OpenSight and Medicalholodeck were analyzed. OpenSight overlays holograms on patients for surgical planning, offering a realistic experience. Medicalholodeck allows detailed manipulation of medical scans, with Dissection Master XR serving as an anatomy atlas. In MR, Mimics Viewer XR and HoloAnatomy were explored. Mimics Viewer XR enhances surgical planning but lacks file import functionality. HoloAnatomy offers over 8,500 anatomical models, facilitating collaboration and effective educational use. Comparing HoloLens 2 and Meta Quest 3, Meta Quest39 motion controllers provided greater precision and responsiveness, making it easier to use. Future advancements in gesture recognition may influence this comparison (Kyaw et al., 2023).

3.3 Evaluation of the software HoloAnatomy

To evaluate HoloAnatomy using HoloLens 2, seven healthcare professionals completed two questionnaires based on the NASA-TLX methodology and a custom survey. The NASA-TLX results showed low mental and physical demands, with 43% of participants rating mental demand as very low, and 85.8% rating physical demand as minimal. The custom questionnaire confirmed these findings, indicating that the software was intuitive, non-fatiguing, and efficient for anatomy-related tasks. This tool calculates an overall workload score based on a weighted average of six subscales: mental demand, physical demand, temporal demand, performance, effort, and frustration level(Cao et al., 2009). Participants rated their workload on a scale from 1 (very low) to 5 (very high).

Overall, HoloAnatomy was rated as effective and user-friendly, supporting its suitability for educational purposes in anatomy.

Figure 1 provides a comprehensive summary of the NASA-TLX questionnaire results, reinforcing the findings discussed earlier.

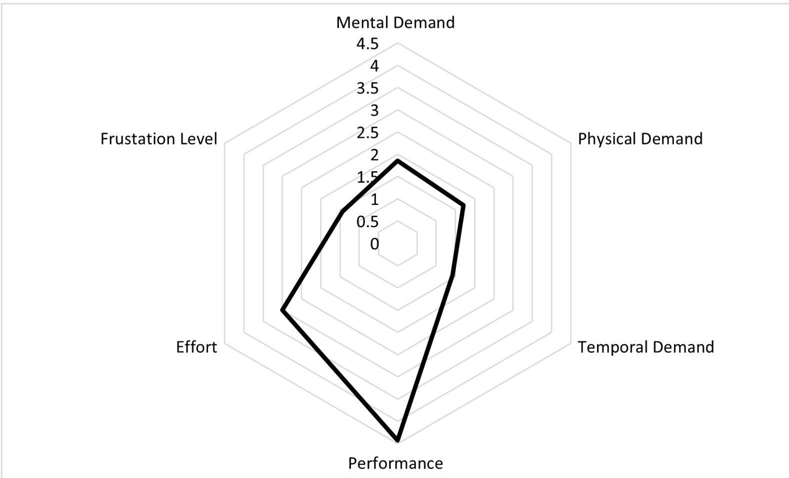

Figure 1: Radar chart summarizing NASA-TLX results.

4 Conclusions

The evaluation of the HoloAnatomy software, selected for testing by a group of healthcare professionals, revealed that the application features an intuitive interface, requiring minimal physical and mental effort from users. This design contributes to excellent performance in the study of anatomy. However, respondents reached a consensus that the software is more suitable for individual study rather than classroom applications, serving as a valuable complement to practical classes in anatomical theaters. On the other hand, the high cost of the HMD HoloLens 2 presents a significant barrier to their application in education.

The evaluation of the studied software and the distribution of the questionnaire to healthcare professionals, two key objectives of this final section, encountered notable challenges. The limited number of available professionals was a constraint, exacerbated by their busy work schedules, which imposed significant time restrictions. Additionally, the effectiveness of the evaluation was compromised by the expiration of the 7-day free trial period for the application licenses. The inability to renew these licenses without incurring additional costs hindered the ability to freely select from the applications analyzed in the exploratory review. Lastly, variability in users' technological proficiency was also considered a barrier.

To achieve a more comprehensive analysis, it would be advantageous to conduct further testing across a broader spectrum of applications and engage a larger group of physicians or medical students in the evaluation of these tools.

Acknowledgements

I extend my heartfelt gratitude to my mentors at CAC ICBAS-CHP, Professor Rita Veloso and Professor Renato Magalhães, for their invaluable support and guidance. I would also like to thank Dr. Adélio Vilaça and Professor Luís Coelho for making the completion of this work possible. Finally, I am grateful to my friends and family for their unwavering support throughout my academic journey.

Bibliography

3D Organon. 3d organon. *https://www.3dorganon.com/*, 2024. [Online; accessed 15-June-2024].

ANIMA RES. Anima res. *https://animares.com/portfolio/insight-heart*, 2024. [Online; accessed 20-June-2024].

App Store Preview. Complete heartx. *https://apps.apple.com/us/app/complete-heartx/id6450795770*, 2024. [Online; accessed 20-June-2024].

App Store Preview. Osso health. *https://apps.apple.com/us/app/osso-health/id6475324153*, 2024. [Online; accessed 15-June-2024].

A. Cao, K. K. Chintamani, A. K. Pandya, and R. D. Ellis. NASA TLX: Software for assessing subjective mental workload. *Behavior Research Methods*, 41(1):113–117, 2009.

GigXR. Gigxr. *https://www.gigxr.com/*, 2024. [Online; accessed 5-June-2024].

HoloEyes. Holoeyes. *https://holoeyes.jp/en/*, 2024. [Online; accessed 20-June-2024].

N. Kyaw, M. Gu, E. Croft, and A. Cosgun. Comparing Usability of Augmented Reality and Virtual Reality for Creating Virtual Bounding Boxes of Real Objects. *Applied Sciences (Switzerland)*, 13(21), 2023.

MAI. Bodymap. *https://www.mai.ai/bodymap/*, 2024. [Online; accessed 25-June-2024].

Medical Simulator. Vimedix. *https://medical-simulator.com/vimedix/4226-cae-vimedix.html*, 2024. [Online; accessed 18-June-2024].

Medicalholodeck. Medicalholodeck. *https://www.medicalholodeck.com/en/*, 2024. [Online; accessed 19-June-2024].

Medivis. Medivis. *https://www.medivis.com/*, 2024. [Online; accessed 18-June-2024].

Meta. Experiences. *https://www.meta.com/pt-pt/experiences/5326454217425484/*, 2024. [Online; accessed 25-June-2024].

Meta. Human anatomy vr for institutions. *https://www.meta.com/en-gb/experiences/3662196457238336/*, 2024. [Online; accessed 18-June-2024].

Microsoft. Holoanatomy demo. *https://www.microsoft.com/en-us/p/holoanatomy-demo/9p51d9mb58bh?activetab=pivot:overviewtab*, 2024. [Online; accessed 20-June-2024].

Microsoft. Holoseeg. *https://www.microsoft.com/en-us/p/holoseeg/9nwqd4k401fg?activetab=pivot:overviewtab*, 2024. [Online; accessed 18-June-2024].

Microsoft. Mimics viewer xr. *https://www.microsoft.com/en-us/p/mimics-viewer-xr/9ns09sthtdn5?activetab=pivot:overviewtab*, 2024. [Online; accessed 20-June-2024].

Microsoft. Vsi holomedicine. *https://www.microsoft.com/en-us/p/vsi-holomedicine/9pnnp98lmfxk?activetab=pivot:overviewtab*, 2024. [Online; accessed 15-June-2024].

NOVARAD. Ar surgical navigation system opensight. *https://www.medicalexpo.com/prod/novarad/product-76942-1108313.html*, 2024. [Online; accessed 5-June-2024].

Novard: Enterprise HealthCare Solutions. Visar. *https://www.novarad.net/augmentedreality*, 2024. [Online; accessed 26-June-2024].

Oxford Medical Simulation. Oxford medical simulation. *https://oxfordmedicalsimulation.com/*, 2016-2024. [Online; accessed 26-June-2024].

precisionOS. precisionos. *https://www.precisionostech.com/*, 2024. [Online; accessed 18-June-2024].

M. Sugimoto and T. Sueyoshi. Development of Holoeyes Holographic Image-Guided Surgery and Telemedicine System: Clinical Benefits of Extended Reality (Virtual Reality, Augmented Reality, Mixed Reality), The Metaverse, and Artificial Intelligence in Surgery with a Systematic Review. *Medical Research Archives*, 11(7.1):1–12, 2023.

Y. M. Tang, K. Y. Chau, A. P. K. Kwok, T. Zhu, and X. Ma. A systematic review of immersive technology applications for medical practice and education - Trends, application areas, recipients, teaching contents, evaluation methods, and performance. *Educational Research Review*, 35(December 2021):100429, 2022.