Guided Drawing in Medical Education: Evaluating AR and MR Systems for Anatomy Learning

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Introduction

Anatomy education often relies on 2D drawings, posing challenges for students learning complex structures. Research shows that drawing enhances students' comprehension of complex anatomical structures [1,2]. With fewer teaching hours, modern students face greater difficulties acquiring foundational anatomical knowledge [3]. AR provides an interactive, real-time learning aid. This study evaluates three AR systems to improve anatomical understanding and drawing skills.

Key Findings

Learning outcomes, assessed through pre- and post-tests, showed no significant differences across groups. However, SAR and MR3D significantly reduced cognitive load compared to MR and the control group (Fig. 2a). Perceived usability varied, with SAR and control conditions reporting higher usability compared to MR without holograms, indicating usability challenges in the MR condition.

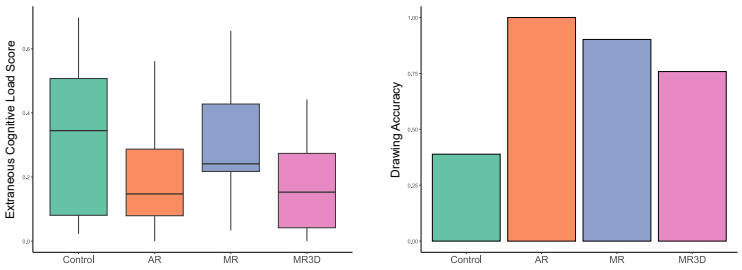

Figure 2 - a) Impact of conditions on extraneous cognitive load. AR and MR3D had the lowest levels. b) Drawing accuracy across all conditions, with AR showing the best results.

Drawing accuracy was significantly higher in assisted drawing conditions, with SAR outperforming MR3D (Fig. 2b). The complexity of MR3D, which required following instructions, drawing, and manipulating holograms simultaneously, contributed to the higher cognitive load. In contrast, SAR's simpler interface allowed for natural tracing, reducing cognitive load and enhancing accuracy

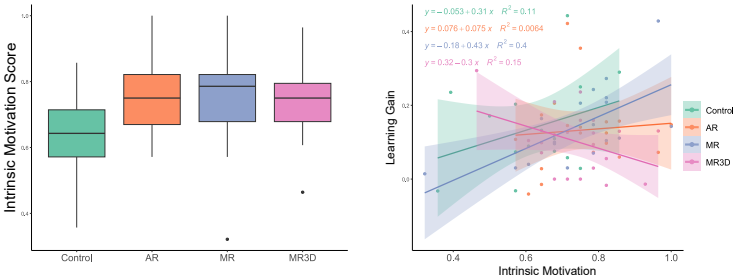

Figure 3 - Impact of conditions on intrinsic motivation. b) Intrinsic motivation and learning correlations by group. Trends vary across conditions.

Intrinsic motivation was higher in all intervention groups compared to the control (Fig. 3a). However, in the MR3D group, there was a negative correlation between motivation and learning gain (Fig. 3b), suggesting participants were more focused on interacting with holograms than on learning. This was supported by user reports highlighting MR3D's greater aesthetic appeal.

Methodology

This study involved 73 second-year medical students, randomly assigned to one of four experimental conditions (Figure 1). Participants followed a 20-minute neuroanatomy video lecture and simultaneously reproduced drawings with the instructor.

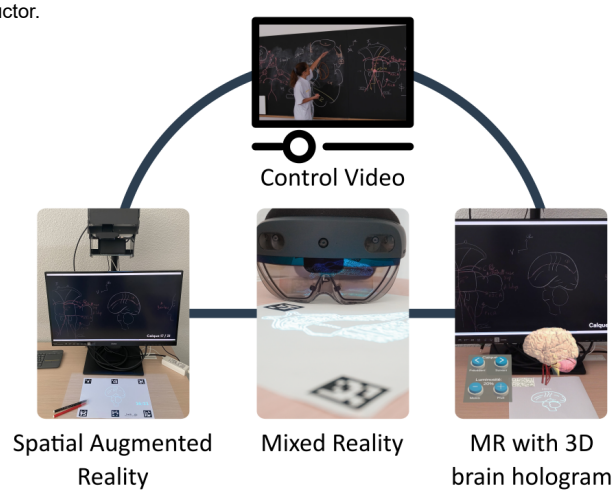

Figure 1 - Experimental conditions: **Spatial Augmented Reality (SAR):** A digital overlay was projected onto paper for students to trace the structure. **Mixed Reality (MR):** A HoloLens2 headset projected the overlay. **Mixed Reality with 3D Hologram:** In addition to the overlay, students could manipulate a 3D model. **Control:** No digital overlay was used.

Anatomical knowledge was assessed pre- and post-intervention. Learning experience (cognitive load, intrinsic motivation, engagement, and usability) was measured through self-reported questionnaires. Drawing quality was evaluated based on the presence (number of elements) and accuracy (1 point per correct drawing).

Conclusion

This study demonstrates that immersive technologies like AR and MR can enhance student engagement and drawing accuracy, especially in guided conditions such as SAR. However, increased motivation does not necessarily lead to improved learning outcomes, suggesting that these technologies may sometimes distract from the learning task [4]. Additionally, prior anatomical knowledge appears to play a key role in the effectiveness of these tools (Fig. 4).

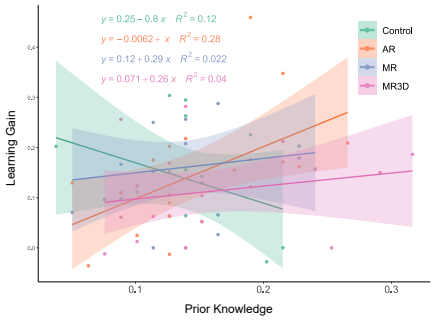

Figure 4 - Correlation trends between learning outcomes and prior anatomical knowledge. Learners with higher prior knowledge seem to benefit more from technological conditions.

References

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