frontiers | Frontiers in Virtual Reality

TYPE Editorial
PUBLISHED 10 July 2025
DOI 10.3389/frvir.2025.1642586

OPEN ACCESS

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RECEIVED 06 June 2025
ACCEPTED 30 June 2025
PUBLISHED 10 July 2025

CITATION
Finseth T, Lubold N, Goel D, Alcañiz M and Lohre R (2025) Editorial: Adult acquisition, development, or maintenance of cognitive and emotional skills through virtual reality.
Front. Virtual Real. 6:1642586.
doi: 10.3389/frvir.2025.1642586

Editorial: Adult acquisition, development, or maintenance of cognitive and emotional skills through virtual reality

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KEYWORDS

cognitive skills, coping skills, behavioral skills, interpersonal skills, social skills, affective skills, extended reality, virtual reality

Editorial on the Research Topic
Adult acquisition, development, or maintenance of cognitive and emotional skills through virtual reality

Introduction

The escalating complexity of high-performance occupations, coupled with accelerating technological change, has heightened the need for continual adult learning and systematic skill refinement. Immersive simulation platforms—most prominently virtual reality (VR) and augmented reality (AR) modalities—now enable rigorous assessment and rehearsal of technical skills and task proficiency under conditions that can closely approximate operational demands. However, types of skills that are considered non-technical or non-task related, such as psychological skills, remain comparatively under-emphasized even though they are determinants of task performance in high-demand environments. Task, procedural, and motor-control skills commonly overshadow other psychological skills (e.g., emotion and cognitive skills). Similarly, complex cognitive skills in the presence of motor skills may be misidentified as psychomotor skills. Compounding this gap is the growing reliance on automation, potentially leading to automation complacency and skill degradation. To address these concerns, the present Research Topic investigates the capacity of immersive technologies to cultivate and sustain essential psychological skills (e.g., cognitive, emotional, coping, behavioral, interpersonal, and social) across diverse adult cohorts and professional contexts. These psychological skills are routinely implicated in occupational safety, resilience, and high-stakes performance. The five included contributions span specialized surgical instruction, non-specialist healthcare procedures, sports officiating, and cognitive-perceptual development, collectively demonstrating that well-designed VR interventions with attention to psychological skills can increase training efficiency, ecological validity, and skill transfer while simultaneously supporting learner motivation and safety.

Themes and content of the Research Topic

The selected contributions explore and address gaps pertaining to the training of psychological skills in VR and AR environments:

Güngör et al. offer a detailed methods article exploring a Head-Mounted Display (HMD)-based virtual reality (VR) training program for tasks associated with preparing for the intraoperative process among nursing students (e.g., surgical hand scrubbing, wearing surgical cap and surgical mask, gowning and gloving). They focus on maintaining psychological skills that are underrepresented in traditional curricula, such as procedural confidence, behavioral precision, and attentional control under simulated clinical conditions. As a result of the training, students reported a heightened sense of presence and improved comprehension, which supports the theoretical link between cognitive immersion and skill transference. However, while not necessarily surprising, the authors' overserved a motivational decay in students after repeated exposures to the same VR training content.

Kaiser et al. examine cognitive decision-making under pressure through the lens of softball umpire training using 360° VR. The authors illustrate the importance of ecological validity by comparing traditional 2D video and immersive VR. Although there was no significant difference observed between accuracy of calls made while using the 2D video and 360° VR footage, the study qualitative analysis and participant feedback supports that declarative-procedural integration (i.e., knowing rules and applying them in dynamic contexts) may be strengthened when learners are exposed to first-person perspectives in immersive simulations. This study contributes to broader theories of embodied cognition and situated learning and supports the concept that the fidelity of sensory input has potential to influence skill acquisition.

Pratap et al. extend the scope to technical cognition by reviewing VR training for intraoperative imaging in orthopedic surgery. A literature search provided insight into the role of VR role in training spatial awareness, task sequencing, and perceptual-motor skills. The findings from existing literature identified that there is a notable research gap in standardized training for intraoperative imaging. Moreover, this review supports the call for multimodal sensory inputs (e.g., haptic) and enhanced simulation realism to improve acquisition of VR-trained skills.

Clay et al. shift the focus from highly specialized training to non-specialized yet safety-critical medical procedures. The authors reviewed existing literature on immersive VR training with business-as-usual methods for tasks like personal protective equipment donning and cardiopulmonary resuscitation (CPR). Their findings suggest that psychological and procedural skills acquired in VR environments can be generalized to variable real-world settings, particularly when VR training is grounded in evidence-based learning theories such as andragogy and situated cognition.

Liu et al. explore the application of augmented reality (AR) technology in anatomy teaching and surgical clinical teaching. Their study focused on clinical knowledge of spinal tumors and the surgical process of percutaneous vertebroplasty. Their results provide crucial insight into how complex anatomical and procedural knowledge can be conveyed through interactive spatial modeling. By comparing AR with traditional didactic methods, they provide support for immersive visualization fostering deeper anatomical understanding and demonstrate that engagement with digital 3D models can simulate preoperative reasoning and enhance surgical confidence. Further, findings showed that AR training enhanced student motivation, conceptual clarity, and procedural self-efficacy, which directly relates to emotional and interpersonal skills.

Synergistic insights and broader implications

Beyond their individual contributions, the contributions to this Research Topic reinforce the broader goals of XR-based skill acquisition, development, and maintenance in adult learners. A consistent finding across the studies is the impact of immersion and realism on learner engagement, presence, and the ecological validity of training. While technical competencies are known to benefit from heightened realism, it has been less clear whether psychological skills also benefit. Both Güngör et al. and Kaiser et al. suggest that immersive environments significantly heighten learner engagement and realism for psychological skills. This finding may support the theory that higher sensory and situational fidelity in extended reality environments leads to deeper cognitive and affective learning. Further, their work also suggests skills are more likely to transfer to real-world settings when the training environment mirrors the perceptual and cognitive demands of those settings. A similar finding by Liu et al. showed that realism of the AR simulation facilitated deeper spatial reasoning and anatomical understanding. Together, these results echo previous research showing increasing realism of physical and conceptual immersive elements subsequently increases the ability for mental models to transfer to simulated environments (Shirtcliff et al., 2024).

Another common theme is the challenge of long-term retention, skill decay, and long-term engagement. While short-term skill acquisition is well-documented, particularly in adolescent populations, less is known about long-term maintenance of psychological skills, particularly among adults. Pratap et al. suggest that dynamic and novel content is necessary for long-term maintenance. A potential aid for long-term maintenance may involve modular, scalable extended reality systems may allow for repeated practice without diminishing learner interest or efficacy. This sets the stage for future research exploring intelligent XR environments that adjust in complexity, modality, or pace using artificial intelligence.

There is also convergence around the need for personalized and adaptive learning systems. Clay et al. and Güngör et al. emphasize that training effectiveness may be influenced by learner variability (e.g., response style, tolerance for novelty) and user characteristics (e.g., technology acceptance, cognitive style, and prior experience). However, Güngör et al. observed motivational decline with repeated exposure, suggesting that static VR programs may exhaust their usefulness over time. This highlights a gap in current VR design that could be addressed through responsive content delivery. Such adaptive learning systems may use machine learning algorithms capable of tailoring difficulty, content pacing, or sensory stimuli to individual users. This idea can be further enhanced by Pratap et al. and Liu et al. suggestion to integrate neurophysiological sensors with extended reality systems to personalize experiences in real time, similar to recent adaptive training frameworks (Finseth T. et al., 2024).

Lastly, the manuscripts collectively call for a more defined conceptualization of what constitutes "psychological skills", with more research on identification and how individual skills can be assessed and monitored. Previous studies have attempted to address this challenge by controlling for confounding skills (e.g., motor and psychomotor skills) while breaking down cognitive skills into more fine-grained cognitive processes to study individual skill proficiency and transfer (Holder et al., 2024; Taatgen, 2013). Some support for fine-grained skill breakdown is provided by Clay et al., which suggests that less complex skills and processes trained in extended reality may be more likely to transfer across tasks and real-world contexts. However, rather than restricting focus on discrete cognitive skills and progress, future research should also consider the psychophysiological connection. For example, research where skills (e.g., cognitive, spatial judgment, emotional regulation, perceptual acuity) are assessed in parallel, since the skills often have interrelated responsivity despite being associated with differing areas within the brain (Finseth T. T. et al., 2024). The field stands to benefit from embracing refined terminology, concepts, multi-modal indicators, and standardized assessments.

Several limitations exist among the articles that may limit the generalizability of the findings. These include limited participant sample size, lack of experimental materials (i.e., quantity of audio-visual media) to carry out evaluations, limited amount of the training materials for the testing populations, and overly broad scope of what constitutes psychological skills within existing literature. It is recommended that future research focuses on expanding the participant pool, adopt more precise measurement methods for the skills they are testing, and control for other psychological confounds.

Conclusion

In sum, the studies featured in this Research Topic advance our understanding of how VR and AR technologies can facilitate the acquisition, development, and maintenance of psychological and procedural skills in adults. Immersive technologies emerge as robust adjuncts to established pedagogies, offering repeatable, low-risk, and data-rich practice opportunities. As such systems mature, they are poised to become foundational components of dynamic learning and training frameworks.

Author contributions

TF: Writing – review and editing, Writing – original draft, Conceptualization. NL: Writing – review and editing. DG: Writing – review and editing. MA: Writing – review and editing. RL: Writing – review and editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Conflict of interest

Authors TF, and NL were employed by the Honeywell Aerospace.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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