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Editorial: Use of AR/MR/VR in the context of occupational safety and health

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Editorial on the Research Topic
Use of AR/MR/VR in the context of occupational safety and health

Extended Reality (XR), which encompasses virtual reality (VR), augmented reality (AR), and mixed reality (MR), is transforming various sectors in industry and services and thus shaping developments in occupational safety and health (OSH). The ability for humans to immerse and interact in simulated environments or enhance their real-world surroundings with digital information is affecting how to approach safety training, system design, hazard identification, and accident prevention. The adoption of XR in OSH is not just a technological advancement but a crucial investment in enhancing workers capacity, protecting workers, improving training efficacy, and reducing work-related accidents. In addition, XR techniques serve as tools and extensions to improve safety and health in system design and human-system interaction.

One of the most significant advantages of XR in OSH is the opportunity to create close-to-reality, controllable training environments. VR, for instance, allows employees to experience hazardous situations without real-world risks. One example is the mixed reality simulator for mobile elevating work platforms designed by Gasparello et al. which allows to train operators by confronting them with very risky situations while at the same time avoiding any real danger as a measure for accident prevention. Whether the application of high-risk environment is construction, manufacturing, chemical handling or different, VR simulation of potentially dangerous scenarios allows workers to safely practice safety procedures and emergency responses. For example, Ismael et al. created an AR system known as “SMARTLab” for safety training in hazardous material science laboratories to improve OSH and productivity. Hands-on, immersive experience has the potential to pave the way for better retention of safety protocols as compared to training methods like reading manuals or front-of-class teaching. Despite this, trainees may repeatedly engage in simulations until they master the necessary skills, ensuring they are well-prepared to prevent from real-life hazards.

In addition to training, XR technologies enhance hazard identification and risk assessment. Augmented reality, which overlays digital information onto the physical world, can assist workers in identifying hazards in real time. For instance, Feder et al.

assessed wearable displays for firefighters using VR with laypersons. Their findings indicate that users find the approach useful and that they would consider using such a system. Such AR technology could also be used to display safety guidelines, highlight dangerous areas, or provide warnings about equipment that requires maintenance. For example, Soyka and Simons (2022) used AR to display magnetic field measurements together with exposure evaluation data and necessary safety distances to facilitate risk assessment. Using a proactive approach can help workers to remain vigilant about potential risks, improving overall system safety. Moreover, AR-based tools could be especially designed to support supervisors in conducting more thorough inspections, identifying risks that might otherwise be overlooked.

Another crucial application of XR is in emergency preparedness and response. Workers can be trained through VR simulation scenarios to better handle emergencies, such as fires, equipment malfunctions, or chemical spills. These simulations can mimic real-world conditions, providing workers with the experience of making critical decisions under pressure. This preparedness not only enhances worker confidence but can also reduce response times and minimize the severity of accidents when emergencies occur if interfaces for human-system interaction are designed according to human factors and ergonomics requirements. Additionally, XR applications allow for detailed post-incident analysis, helping organizations refine human-machine interface design, safety protocols and training programs based on simulated outcomes.

XR also improves the accessibility of safety training. Workers from different geographic locations can participate in virtual safety workshops and training sessions without the need to be physically present at a training site. This reduces logistical challenges and makes it easier for organizations to provide consistent, high-quality safety training across all of their locations. Furthermore, adaptability of XR may also refer to that training programs can be tailored to individual workers' needs, ensuring that every employee receives the most relevant training for their specific job roles and risks.

The concept of the digital twin can also be seen as a MR application. A digital twin is a virtual model or digital replica of a physical object, system, or process, created using real-time data and advanced simulations. It mirrors the characteristics, functions, and performance of its real-world counterpart, allowing for analysis, monitoring, and optimization without directly interacting with the physical entity. Digital twins are commonly used in industries like manufacturing, healthcare, and smart cities to improve efficiency, predict failures, and optimize operations by providing insights based on simulated real-time data and predictive modelling. This concept enables more informed decision-making and enhances the ability to respond to changes dynamically. Casey et al. aimed at reducing the risk of material damage as well as improving OSH by creating a real-time digital twin for active safety in an aircraft hangar. They implemented an active safety system that uses the digital twin to perform real-time path planning, collision prediction, and safety alerts for tow truck drivers and hangar personnel.

An evaluation of XR technology including ecological validity of XR simulations is crucial for its effectiveness and real-world applicability. Technology evaluation helps assess whether XR tools meet the intended functional goals and usability requirements for human-system interaction, while ensuring tools function reliably and efficiently within specified contexts. Therefore, De Souza and Tartz investigated visual perception, visual quality, and user experience in video see-through head-mounted displays. Ecological validity, in addition, refers to how well XR simulations replicate real-world environments and user experiences, making them more empathetic for practical use. Without ecological validity, user experiences of XR may remain artificial or disconnected from real-world scenarios, which can limit their utility for design improvements and training. Personeni and Savescu conducted a systematic review assessing ecological validity of VR simulations in workstation health and safety assessment. Together, thorough technology evaluation and ecological validity ensure that XR simulations are both technically sound and meaningful for users, contributing to practical impact across education, healthcare, and industrial training.

In conclusion, XR technologies play an increasingly important role in advancing OSH. By providing immersive, hands-on training, suggesting improvements for redesign of interfaces for human-system interaction, enhancing real-time hazard awareness, and improving emergency preparedness, XR helps create safer work systems and measures for accident prevention to effectively protect workers from harm. As sectors in industries and services continue to adopt XR applications, this should have the potential to overall improvement of OSH and productivity.

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