# Enhancing Caregiver Training in Fall Prevention Through Extended Reality: A Mixed-Methods Study

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**Abstract.** We developed and evaluated a brief extended reality (XR) training to improve caregivers' hazard identification in home care settings using a user-centred process (needs assessment n = 195; expert workshop n = 5; pilot RCT n = 27). In the pilot RCT, the XR group outperformed controls on the primary outcome (hazard identification) and showed higher technology acceptance and learning support, with low cybersickness. XR appears feasible and promising for scalable caregiver education; larger trials should confirm efficacy and durability.

**Keywords:** nursing, virtual reality, training, education, fall prevention

## Introduction

Caregivers, especially informal caregivers, often lack access to practical training in essential skills such as fall prevention. Despite representing a substantial portion of the caregiving workforce in Austria and Europe, informal caregivers have limited opportunities for effective and scalable educational resources. With the growing demand for caregiving, innovative training solutions are urgently needed. Extended reality (XR), encompassing virtual reality (VR) and augmented reality (AR), offers realistic, risk-free environments that promote experiential learning in healthcare education (Ota et al., 2024; Shorey et al., 2020).

The immtaCARE project explored the feasibility and effectiveness of an XR-based fall prevention training module. Building on prior research highlighting VR's role in fall prevention (Piech & Czernicki, 2021), the project aimed to improve hazard recognition, user experience, and practical skill application compared to traditional methods. In addition to skill acquisition, the study assessed participants' acceptance and perceived usefulness of XR training.

*Terminology.* We use extended reality (XR) as an umbrella term for immersive technologies. In this study, the training was delivered on a virtual reality (VR) headset; therefore, we refer to an XR-based approach implemented via VR. Terminology is kept consistent throughout.

## Methods

A user-centered design (UCD) approach guided the development and evaluation of the training module. Across the programme, 195 caregivers took part in the needs assessment (157 professional; 38 informal), 5 experts contributed to the feasibility workshop, and 27 caregivers were enrolled in the RCT (XR n = 19; control n = 8).

A randomized controlled pilot trial (RCT) with 27 participants was conducted. All participants first watched a 5-minute instructional video on fall prevention. XR training (delivered via Meta Quest 2) consisted of a single ~15-minute immersive session simulating everyday home care environments (kitchen, bathroom, living room, hallway). Each scene contained multiple predefined fall hazards (e. g., loose cables, wet or cluttered floors, poor lighting, rugs without anti-slip mats). Participants freely explored the space and marked hazards using the controller by placing a virtual traffic cone at the respective location. At the end of the session, participants received corrective feedback summarizing each hazard, including why it represented a risk and how to mitigate it (visual confirmation and brief textual explanation). The control group received conventional materials (brief facilitator-led discussion plus printed fall prevention brochure) of comparable duration to control for time and attention. Subsequently, all participants undertook a practical assessment in a simulated caregiving environment containing 22 predefined fall hazards. The primary outcome was hazard identification performance, defined as the number of relevant fall hazards correctly identified in a simulated home care environment (score 0–22; higher = better). The task comprised 22 predefined hazards spanning obstacles, surface conditions, and layout (examples: loose cables, wet floors, inappropriate furniture placement). Each participant explored the environment and marked hazards by placing a traffic cone at the respective location while an assessor, blinded to group allocation, recorded whether each cone placement corresponded to the predefined hazards. Secondary outcomes were measured using: (i) Technology Acceptance Questionnaire, (ii) Quality of Learning Scale, and (iii) Virtual Reality Neuroscience Questionnaire.

Participants were randomly assigned to the XR training or control group using a computer-generated simple random sequence, prepared by an independent researcher not involved in recruitment or analysis. Allocation was concealed in sealed opaque envelopes. Due to the nature of the intervention, blinding of participants was not feasible; however, outcome assessors and data analysts were blinded to group allocation. The unequal group sizes (XR n = 19; control n = 8) resulted from the unrestricted simple randomization procedure combined with the small sample size, which by chance yielded more allocations to the XR group.

All statistical analyses were conducted using Welch's two-sample t-tests (unequal variances) with $\alpha = .05$. To enhance interpretability, we additionally report effect sizes (Hedges' g for continuous outcomes) with 95 % confidence intervals. Effect sizes were calculated as Hedges' g using pooled standard deviations, corrected for small sample bias. Given unequal variances and sample sizes, effect size estimates should be interpreted with caution. The hazard identification task produced both an overall score (0–22) and item-level performance (22 predefined hazards). The overall score was analyzed as the primary outcome; item-level analyses are reported descriptively and with exploratory statistics. *Assumption checks.* We did not conduct formal normality or variance homogeneity tests due to the small sample size. Instead, we applied Welch's two-sample t-tests, which are robust to unequal variances and unequal group sizes and therefore more appropriate for our data. This choice provides conservative estimates while avoiding the inflated type I error risk associated with standard Student's t-tests under heteroscedasticity.

The study was reviewed by the institutional review board, which confirmed that formal ethical approval was not required due to the minimal-risk nature of the research. All procedures adhered to the ethical standards outlined in the Declaration of Helsinki (2013 revision), and written informed consent was obtained from all participants. No vulnerable populations (e. g., minors, cognitively impaired individuals, or patients in dependent relationships) were involved in the study.

## Outcomes

Overall hazard identification scores were higher in the XR group (XR M = 4.15 vs. Control M = 0.54), Welch's $t = -4.51$, $p < .001$, corresponding to a very large effect size (Hedges' $g = 1.71$, 95 % CI [0.76, 2.66]).

On item level, participants in the XR group more frequently identified hazards such as the wall-mounted shoehorn (XR M = 0.88 vs. Control M = 0.50), Welch's $t = -1.91$, $p = .044$, corresponding to a large effect size (Hedges' $g = 0.95$, 95 % CI [0.08, 1.82]). Participants in the XR group were substantially more likely to identify the open window hazard (XR M = 0.83 vs. Control M = 0.12), Welch's $t = -4.59$, $p < .001$, with a very large effect size (Hedges' $g = 1.88$, 95 % CI [0.90, 2.85]).

The XR group also reported significantly higher technology acceptance, with better understanding of fall prevention concepts (XR M = 4.35 vs. Control M = 3.00), Welch's t = –1.83, p = .045, corresponding to a large effect size (Hedges' g = 0.84, 95 % CI [–0.02, 1.69]). Similarly, perceived learning support was higher in the XR group (XR M = 4.45 vs. Control M = 3.00), Welch's t = –1.97, p = .035, with a large effect size (Hedges' g = 0.89, 95 % CI [0.03, 1.76]). Enjoyment of the training experience was also greater in the XR group (XR M = 6.20 vs. Control M = 4.27), Welch's t = –2.04, p = .031, corresponding to a large effect (Hedges' g = 0.91, 95 % CI [0.05, 1.78]).

All other predefined primary and secondary outcomes showed no statistically significant between-group differences (all p > .05). Corresponding effect sizes were small with confidence intervals including zero.

## Discussion

Our pilot RCT shows that a brief XR session can significantly improve caregivers' hazard identification and foster acceptance of innovative learning tools among caregivers. We pre-specified this primary outcome and controlled multiplicity by treating secondary outcomes as exploratory. Limitations include the small and imbalanced sample (XR n = 19; control n = 8) and short follow-up. Future work should replicate effects in larger, balanced samples and test durability and real-world transfer.

Nevertheless, these outcomes align with previous research on immersive learning, technology acceptance, and user experience in nursing education (Uymaz & Uymaz, 2022; Tewary et al., 2024; Mäkinen et al., 2023). The immersive nature of XR environments facilitates experiential learning, effectively bridging theoretical knowledge and practical application (Tewary et al., 2024).

While the observed trend toward increased self-efficacy did not achieve significance, longer training durations or larger sample sizes may yield clearer improvements. Similar studies have shown that XR-based education enhances both knowledge retention and practical skills (Ota et al., 2024).

Limitations include the small sample size, unequal group distribution, short intervention duration, and potential bias due to participants' prior technological experience. Future research should address these factors through expanded study designs and longitudinal assessments to evaluate sustained benefits. Despite these limitations, the immtaCARE project highlights XR's potential to transform caregiver education by providing scalable, engaging, and practice-oriented training solutions.

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