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Surveys and Experiments on the effectiveness of VR-based safety education

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Abstract

The present study examined the effectiveness of VR-based safety education compared to traditional text-based methods. A survey of VR content providers and users revealed that while various VR content is available, fall-related hazard experiences were the most commonly used, raising concerns about potential misalignment with educational goals. An experiment was conducted with university students to compare the impact of VR-based hazard learning, text-based learning, and a control group with no stimuli. Results showed that VR-based learning improved hazard detection, while text-based learning had less impact. Although the study suggests VR's potential in enhancing safety education, further research is needed due to the small sample size.

CCS Concepts

• ***General and reference*** → *Evaluation;* • ***Human-centered computing*** → *User studies;*

1. Introduction

VR technology is attracting attention as an effective alternative to existing workplace experiences and skill training. The development of VR learning content for hazard experiences is progressing, and its usage in the field of safety education is expanding [Kub19] [SMH23]. Behind these condition lies the promotion of digital transformation, such as national policies aimed at improving occupational safety and health, such as the 14th Occupational Accident Prevention Plan by the Ministry of Health, Labor and Welfare [Min23]. However, evaluation of the effectiveness of safety education using VR is not sufficient [HMEW20], so it is necessary to verify the effectiveness of VR-based safety education and quantitatively evaluate its effects.

The present study consisted of two parts: a questionnaire survey and an experiment. The questionnaire collected opinions on the effectiveness of VR educational content from both companies providing the content and users receiving it. In the experiment, we compared the results of hazard experience learning using VR content with those using textbooks to clarify the differences in effectiveness.

2. Questionnaire survey

The survey, developed using Microsoft Forms, was conducted over a three-month period from January 15 to April 17, 2024, targeting companies identified through online searches using keywords such as "VR" and "safety education". Cooperation was requested from 32 companies in Japan and overseas via e-mails and inquiry forms on their websites, resulting in responses from 10 companies. Additionally, 21 responses were received from users affiliated with Nagaoka University of Technology's Department of System Safety Engineering, the Japan Institute of Professional Engineers' Occupational Safety and Health Consultant Group, and others.

Regarding the types of content, providers had a wide range of content available, but users used "Fall" more than other content (Figure 1) . In terms of frequency of use, for example, both providers and users answered that they "repeatedly" and "only once" for the hazard experience education of "falling experiences".

3. Experiment

Participants were university students in their 20s, excluding those with prior hazardous experience, and were divided into three groups: Group A (VR-based learning, 4 participants), Group C (text-based learning, 3 participants), and Group E (no stimuli, 3 participants). The experiment involved three sessions, with the second held two weeks after the first and the third four weeks after the second.

Group A used the "RiMM Hazard Experience VR" system by

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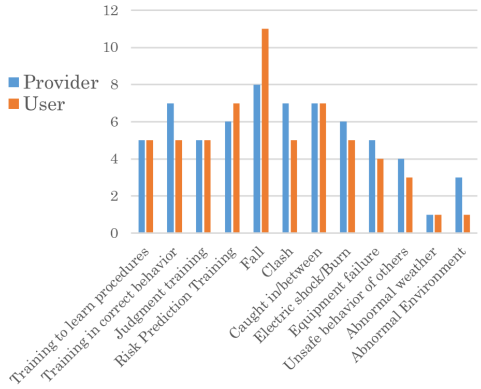

Figure 1: *The type of content provided by the provider or used by the user*

Santoku Corporation [San24]. Causes and preventive measures were presented via audio and text after the VR experiences, which lasted about 10 minutes in total. Group C used a video format, showing accident details, causes, and preventive measures in Japanese, with content sourced from Safety Staff [Rod24] and the Workplace Safety Site [Min24].

To measure effects, hazard perception and heart rate were analyzed. Hazard perception, the ability to identify hazards before incidents, was measured using Hirose et al.'s method [HTJ11], with the hazard detection rate, correct response rate for human/object-related accidents, and overall score evaluated. Heart rate was measured by the participants themselves using a 10-second counting video, with the value multiplied by six to get the rate per minute. All participants first underwent baseline testing (Test 0). After the stimuli for Groups A and C, Tests 1, 2, and 3 were conducted. Group E participated in Tests 2 and 3 without stimuli.

Statistical analysis was performed using repeated 2-way ANOVA to assess group (A, C, E) and repetition factors for hazard perception, and heart rate over 10 measurements. Significant results were followed by post-hoc comparisons with a significance level of $p < .05$. All analyses were conducted using HAD [Shi16]. In some of the results, Group A performed better, but Group C and E performed lower (Figure 2). This suggests that the VR stimulus may have contributed to the improvement in the hazard detection rate, one of the indicators of hazard perception.

4. Conclusion

Survey results showed that users frequently use "Fall", suggesting that users were particularly looking for stimulating hazard experiences. One of the benefits of VR is that it allows users to safely experience hazard experiences, but there are concerns that this becomes an attraction and is used in a way that is not intended or does not achieve the expected effect. In the present study, regarding the frequency of use, authors believe that the appropriate frequency of VR-based safety education differs between training-based training such as "learning correct procedures" and "hazard prediction training" and hazard-experience-based hazard-experience training such as "experiencing falls". Authors believe that hazard experiences should not be learned repeatedly. We would like to prove this and present the appropriate frequency of use.

In the present experiment, authors established the method for quantitatively evaluating and comparing the educational effects of VR-based hazard experience learning and text-based accident case learning, using hazard perception and vital signs as indicators. However, since the sample size was small, with only 10 participants, we aim to increase the number of participants in future studies to enhance the reliability of the results. Additionally, further investigation into the appropriate usage frequency and methods for different types of VR content is necessary.

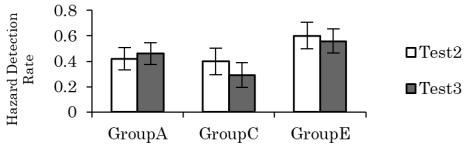

Figure 2: *Statistical Analysis Results of Hazard Detection Rate *Error bars represent standard error*

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