Do safety attitudes improve after VR-Based training? – It depends

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Abstract: Workers' characteristics are not often studied in virtual reality safety training, especially for work at heights. Hence, our study evaluated the effects of age and experience on training effectiveness using virtualized serious games. We conducted a pretest-posttest control design with virtual- and lecture-based training. Safety attitudes were assessed among 102 construction workers in Colombia. We found that participants improved their commitment and motivation after the virtual-safety training. However, workers with more experience showed a decrease in self-efficacy. We recommend considering the demographic context when designing training.

Keywords: Safety training, construction industry, virtual reality

1. Introduction

Lack or inadequate training is often cited as one of the root causes of many accidents in construction industry (Gónzalez et al. 2016). Even if there have been efforts to promote safety training to reduce work-related events, its effectiveness relies on two factors: those that are related to organizational practices, and those that are related to the instructional process (Colligan & Cohen 2004). In other words, training might not be effective, mainly because companies do not invest in the best training to save costs, or training is poorly designed (Albert & Routh 2021).

This last aspect is of our interest, since researchers have shown that the use of conventional techniques (e.g. lecture-based), although effective for improving safety outcomes (Gao et al. 2019), are least engaging methods (Burke et al. 2006), leading workers to have a negative attitude towards safety programs (Namian et al. 2016). Serious games within virtual environments emerges as a learning option that allows users to interact in scenarios that simulate reality free of real risks (Gao et al. 2017). Virtual reality (VR) training has shown an improvement in workers' attitudes, impacting their safety performance (Nykänen et al. 2019, 2020). However, a robust assessment is still needed to confirm its benefits (Checa & Bustillo 2020).

To address this research gap, this study evaluated the effectiveness of VR-training, and explored if there were differences with conventional training. In both, we focused on improving safety attitudes, because it is not often assessed in safety training (Rey-Becerra et al. 2021). In particular, we are interested in work at heights (WaH), because it is one of the riskiest activities in construction due to its high mortality rate (ARL-sura

2020), and the difference between participants' characteristics, because it has not often been studied (Yu et al. 2022). Then, this study focused on the question to what extent VR-based training participants can improve safety attitudes as compared to lecture-based training participants, and how it differs between age or experience.

2. Theoretical background

2.1 Safety attitudes

There are many definitions regarding attitudes. Gagné (1984, pp. 383) described attitudes as internal states of human being that affects behavior. Kraiger et al. (1993, pp. 318) broadened this concept, including affective outcomes (i.e., commitment) and motivational outcomes (i.e., motivational disposition and self-efficacy). Moreover, Eagly & Chaiken (1993, pp. 1) explained that reporting an attitude is the expression of a judgment about a specific issue, object, or person. Traducing this to a work environment, Salas & Cannon-bowers (1997) explained that attitudes refer to what workers "feel" or judge. Finally, Christian et al. (2009) explained that job attitudes are an individual factor related to workers' commitment to safety, and it is an antecedent of safety performance because the higher the attitudes, the higher the motivation to behave safely. Altogether, the concept of safety attitudes can be seen as a construct with many facets. Hence, for this study, motivation, self-efficacy, and commitment have been considered as safety attitudes because they are internal states that influence the choice of an action (Kraiger et al. 1993).

Safety motivation is the employees' willingness to act safely (Neal & Griffin 2006, pp. 947). According to a meta-analysis done by Christian et al. (2009), the higher the safety motivation, the higher the participation in safety activities, and therefore the fewer accidents. More recently, Casey et al. (2018) evaluated the impact of safety training showing that participants' safety motivation was not improved after intervention. On the contrary, Nykänen et al. (2019) have shown a small effect of Attitude to Work intervention program on participants' safety motivation depending on their internal safety locus of control (to control consequences of owns behavior). Same authors later showed a greater increase in safety motivation for participants in VR-based safety training compared to traditional one (Nykänen et al. 2020).

Safety self-efficacy is the one's confidence to perform safety-related activities in order to prevent accidents and injuries (Nykänen et al. 2018, pp. 46). Self-efficacy is a motivational driver to proactive safety behavior (Curcuruto et al. 2016). Nykänen et al. (2019) found that participation in safety training increased self-efficacy, and later same authors showed that VR-based training had a stronger impact on self-efficacy than lecture-based training, but more evidence is needed (Nykänen et al. 2020).

Safety commitment refers to the determination and belief to continuously participate in behaviors to prevent safety accidents (Park et al. 2021, pp. 8). In other words, it is the employees' engagement to participate in decision making about safety (Mullins et al. 2019). This term differs from the management commitment to safety, which relates to the organizational responsibility for employee well-being (level 4 of Kirkpatrick) (Kines et al. 2011). Though, both concepts have been studied within safety climate (Luo 2020), focusing on workers' perceptions of management commitment and not workers' safety commitment (Chen et al. 2021), which has not been evaluated for virtual-based interventions (Rey-Becerra et al. 2021).

In our previous literature review we found that only Nykänen et al. (2020) assessed attitude concerning a safe workplace after the use of virtual-based training. The authors found that training with VR was more effective than slide-show format regarding safety motivation (willingness) in the short term, and safety self-efficacy (confidence) in the long-term. However, safety commitment (engagement) is still missing.

2.2 Participants' characteristics as moderator of safety intervention

Worker's age and experience might have an impact on accident rates in construction (Muhammad & Marcham 2021). Young workers may be vulnerable in this industry because of their inexperience (International Labour Organization 2018). On the contrary, expert workers have more severe work-related events associated with an excess of confidence attributable to their experience (Min et al. 2012). Then, safety training may be promoted as a preventive measure to reduce safety outcomes on both novice (Holte & Kjestveit 2012) and experienced workers (Fang et al. 2021).

It is important to design training programs with instructional methods that involve workers´ perceptions and characteristics (Wilkins 2011). Virtual technologies afford opportunities for effectively training novice or experienced workers (Li et al. 2018). Nevertheless, conventional methods may be more suitable to ageing workforce (Fang et al. 2021). These demographic factors in construction workers have not been extensively studied for safety training (Yu et al. 2022), and authors have not studied the effect of experience level in its effectiveness, specific for WaH (Rey-Becerra et al. 2021). Therefore, we assumed that workers improved safety attitudes after intervention depending on their age and experience. Consequently, this study investigated whether younger and novice workers had more favorable results on safety motivation, safety self-efficacy, and safety commitment using virtual methods.

Hypothesis: *Younger or novice workers improve their safety attitudes more than aging or experienced workers in the Virtual training for WaH assessment.*

3. Methods

3.1 Participants

This study assessed safety outcomes among workers in the construction industry. We tested the two training methods with 102 workers from 6 different construction sites in Colombia. However, 5 participants did not answer all the attitudes questionnaires. 97% of the subjects were men, of which around 45% did not finish high school. To characterize workers in terms of age, we followed Colombian legislation with three groups: young (18-28 years old, 29.9%), adults (29-39 years old, 40.2%), and mature workers (>=40 years old, 29.9%). About experience, depending on the author, a novice can become an expert based on skills, job tenure years, or age (Ehsani & Ibrahim, 2008; Hoffman, 1996). Then, for our study, we categorize them into three groups: novice (less than 5 years' experience, 48.5%), experienced (between 5 and 10 years, 30.9%), and expert (more than 10 years, 20.6%).

3.2 Study design and interventions

We performed a quasi-experiment with pretest-posttest control group design (Cook & Campbell 1979). We measured training effectiveness following recommendations by Wang & Wilcox (2006, pp. 532): safety attitudes were evaluated before training (**T1**), and some days after the training (**T2**). We used three validated questionnaires: safety commitment questionnaire by Kim (2019) in Park et al. (2021), self-efficacy self-report by Nykänen et al. (2019), and the dimension of motivation in the Workplace Health & Safety by Neal et al. (2000). Some of the questionnaires were translated into Spanish following the cross-cultural translation technique (Sousa & Rojjanasrirat, 2011). All questionnaires had acceptable values of internal consistency.

We developed two types of interventions to prevent fall accidents: ViStra and LeStra. **ViStra** is a VR-based training with a serious game where participants do tasks at heights in a construction site in the safest way but in the shortest time. The virtual environment was designed by the Human-Computer Interaction Institute at the University of Trier, Germany (Kinkel 2021) specific for Pico Neo 3 (Pico Immersive Pte. Ltd. 2022). **LeStra** is a lecture-based safety training, a conventional seminar where participants watch videos of real cases with hazardous conditions using problem-based learning. The training goal of both ViStra and LeStra was to improve workers´ knowledge, behavior, and attitudes while working at heights, focused on the risk of falling from scaffolding, platforms, and roofs. They were designed as a complementary program to enhance the mandatory course by law.

4. Results

Of the 97 participants, 52 trained with ViStra and the rest with LeStra. We fitted a linear mixed model to predict safety attitudes with *Time* and *Training* using *lme4* package in Rstudio (Bates et al. 2015). The model included *ID* (participant as repeated measured) as random effect only. The random effect of company was omitted because company-related variance was essentially zero for all safety attitudes. We added *experience* or *age* for the moderation analysis. We estimated eta-squared η^2 as the effect sizes of the interventions on workers´ safety outcomes to know its effectiveness (Richardson 2011). Values below 0.01 indicate small effect, values around 0.06 indicate medium effect, and values above 0.14 are considered large effect (Cohen 1973). All the statistical assumptions were checked and accomplished.

When including experience as moderator, the model's total explanatory power was moderate for commitment (conditional R^2=.25), and substantial for self-efficacy and for motivation (conditional R^2=.38 & R^2=0.34 respectively). The model's intercept, corresponding to *Time* at T1, *Training* as LeStra and experience equal zero was significant in all safety attitudes (at 3.79 for self-efficacy; at 4.18 for commitment; and at 4.34 for motivation). The interaction term between time (T2) and training (ViStra) was statistically significant and positive for commitment (β=.33, p=.03, η_p^2=.05) and moderate for motivation (β =.26, p=.07, η_p^2=.03), but not for self-efficacy. On the contrary, there was only a marginally significant and negative effect of the interaction between experience and training on self-efficacy (β=-.03, p=.01, η_p^2=.07). The effect of experience was statistically significant for self-efficacy (β=.03, p<.001, η_p^2=.05) and commitment (β=.02, p=.03, η_p^2=.04), but marginally for motivation (β=.02, p=.07, η_p^2=.07). When including a triple interaction between time, training and years of

experience, only the effect for motivation was negative and marginally significant (β=-.04, p=.07, η_p^2=.03). Similar results were obtained with age as it was strongly correlated with experience (r(95)=.61, p<.001). To understand the effect on safety outcomes, we created a categorical variable from experience. The analysis showed that experienced workers (β=-.55, p=.04, η_p^2=.04) and experts (β=-.64, p=.04, η_p^2=.04) had the strongest negative changes as a result of the intervention with ViStra in self-efficacy. Besides, there is a moderate positive effect of the triple interaction on self-efficacy and on motivation (β=-.69, p=.08, η_p^2=.03). There was no significant moderator effect for experience level on commitment. Therefore, we partially support our hypothesis.

5. Discussion

The aim of this study was to investigate whether younger and novice workers had more favorable results on safety attitudes using virtual-based training. We evaluate safety self-efficacy, safety commitment and safety motivation before and after the intervention with construction workers in Colombia. Contrary to the findings of Nykänen et al. (2020), we did not find a stronger impact of ViStra on self-efficacy, compared to LeStra. This may be due to a ceiling effect, where the average scores of workers' self-reported safety self-efficacy were above 4 out of a possible 5, leaving little room for improvement. Experience, however, played an important role: The more years of experience a worker has, the less improvement of self-efficacy with VR-based training. We may interpret our results as self-efficacy was lower among those more experienced in the group with ViStra, than among those more experienced in the group of LeStra.

According to our results, workers with ViStra improved their safety commitment and motivation more than workers with LeStra over time. In particular, the differences of virtual-based and lecture-based training in the change over time in safety motivation seems to be moderated by experience. Novice showed significantly higher results with ViStra after the intervention, than the experienced or experts. This may be a sign that the youngest are more motivated by new technologies than the older workers.

In summary, this paper argued that VR-based training can be more effective than lecture-based training for safety commitment and safety motivation, and it can be as effective as lecture-based training for safety self-efficacy. Nonetheless, experience affects the safety results of motivation and self-efficacy but in a small proportion. Future research should consider the potential effects of experience or age more carefully. We recommend safety practitioners to design training programs according to participants' characteristics (e.g., professional experience and age).

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