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Jia, Z.,and Ho, J.C.(2025) Social Influences of Virtual Characters in Virtual Reality-Based Industrial Training: Sense of Being Watched, Social Pressure, and Complacency, in Chang, C.-Y., Chen, C.-H., & Hsu, Y. (eds.), *IASDR 2025: Design Next*, 02-05 December, Taipei, Taiwan. https://doi.org/10.21606/iasdr.2025.18

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International Association of Societies of Design Research Congress 2025
DESIGN NEXT
Taipei, Taiwan
2-4 December 2025

Social Influences of Virtual Characters in Virtual Reality-Based Industrial Training: Sense of Being Watched, Social Pressure, and Complacency

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The study reported in this paper examines the social influences caused by virtual characters in virtual-reality-based training. The adoption of virtual reality (VR) has becoming more common in professional and industrial training. In addition to simulating the workplace environments and task-related tools, virtual characters are often placed in the VR environment to make the environment more natural. However, virtual characters may have social influences on trainees (like real human does), which is one of the often overlooked aspects in VR-based industrial training. We conducted an exploratory study with 42 participants performing industrial tasks in VR while being observed by varying numbers of virtual characters within the VR environment. Our findings revealed that the presence of virtual characters, even though they were fake and not controlled by real humans, could influence participants' stress levels as the number of virtual characters increased. Interestingly, this influence could also indirectly enhance participants' perceived task performance with the perceived realism of the virtual environment as a moderator, however, this effect was not observed in the objective performance measure. These results suggest that virtual characters can activate a complacency mechanism in participants. These insights provide valuable guidance for future designs of VR-based training, emphasizing the importance of careful consideration of the placement of virtual characters in such environments.

Keywords: Social influence; Virtual gaze; Construction training; Self-awareness; Virtual reality

1 Introduction

The current study explores the potential social influence of virtual characters in virtual reality (VR)-based training in the construction industry. The motivation stems from the fact that while VR-based professional training has been studied in various professional contexts, the social aspects of virtual characters appearing in VR-based training do not receive significant attention from the research community.

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https://doi.org/10.21606/iasdr.2025.18

The increasing adoption of VR in professional training and education has led to the integration of virtual versions of task-related objects (e.g., hammers, nails, forklifts) and environments (e.g., highways, construction sites). Often, virtual characters (e.g., managers, colleagues, pedestrians) are included to enhance the realism of the virtual environment. These characters are typically added to decorate the virtual spaces and make them more natural. However, their potential social influences remain an under-explored aspect of VR-based training.

While the focus of VR-based training design often centers on task-related aspects, the role of virtual characters in the training process is rarely considered. The findings of this exploratory study aim to serve as a wake-up call or important reminders that while virtual characters can create a more natural and realistic scenario, their behaviors, relative positions, and presented attitudes can have side effects and should be carefully taken into account when designing VR-based training.

The study draws from social psychology concepts and literature on social influences and social pressure to inform its research. The next section delves into a comprehensive review of relevant literature.

2 Literature Review

Immersive media technologies, such as VR, have demonstrated significant potential in enhancing training and education by creating interactive, controlled, and engaging environments. These technologies offer unique opportunities to simulate realistic scenarios, allowing learners to experience social dynamics and decision-making processes in a safe yet impactful manner. The present study builds on a growing body of research that explores how psychological constructs like social influence, conformity, and peer pressure interact with immersive environments. These factors are crucial for understanding how VR environments impact stress, task performance, and perceived task performance, as explored in the study's methodology and results.

This literature review aims to provide a theoretical foundation for understanding the effects of social influence and peer pressure in immersive training contexts. By exploring existing research on conformity, group dynamics, and social norms, this review establishes the importance of these social aspects for designing effective VR-based training programs.

2.1 Social Influence and Immersive Media

Social influence is a key psychological phenomenon that shapes behavior in group settings. It encompasses two primary mechanisms: informational influence and normative influence (Henningsen & Henningsen, 2015; Toelch & Dolan, 2015). Informational influence occurs when individuals rely on others for accurate information, while normative influence drives behavior aimed at social acceptance. These mechanisms are particularly relevant in VR training, where interactions with virtual humans (VHs) can mimic real-world social dynamics.

In the context of immersive media, informational influence can enhance task performance by providing users with accurate, real-time feedback in simulated environments. This feedback mechanism not only improves task accuracy but also fosters active learning by reinforcing correct behaviors, as demonstrated by Jacobsen et al. (2022). Interestingly, even when normative influence is perceived as a weaker motivator, its impact on behavior remains significant (Nolan et al., 2008). This

highlights the importance of subtle design elements, such as the gaze behavior of VHs, in shaping users' experiences and stress levels.

2.2 Conformity and Group Dynamics in VR Environments

Theories of conformity provide a robust framework for understanding how individuals adapt their behavior in response to social pressures, making them highly applicable to VR-based training. For instance, Asch's (1951) classic experiments on group conformity revealed that individuals often align their decisions with group norms, even when doing so contradicts their own perceptions. The research on group polarization suggests that shared group identity and solidarity can amplify stress and conformity (Abrams et al., 1990). Moreover, studies have shown that depolarization can occur when diverse perspectives are introduced. The research by Mostajeran et al. (2020) found that smaller virtual audiences, rather than larger ones, heightened stress responses (particularly in HR) during public speaking tasks. Additionally, the transition from no audience to a single observer had a much greater social impact than increasing the audience from five to six people.

2.3 Peer Pressure and Performance

Peer pressure, an important driver of behavior in both educational and workplace settings. As Falk & Ichino (2003) demonstrated, peer pressure can enhance productivity by motivating less productive individuals to increase their efforts. However, peer pressure is not universally beneficial. As Lahno & Serra-Garcia (2015) note, it can also lead to maladaptive behaviors, such as risk-taking or task errors, particularly when participants feel overwhelmed by social observation.

2.4 Social Norms and Immersive Training

Social norms play a crucial role in shaping behavior, particularly in immersive environments where users are exposed to simulated social dynamics. As Shi et al's experiment (2018), in virtual immersive environments, the behavior of virtual characters significantly influences users' actions and decision-making processes, even in domains involving risk-taking behavior (Fu et al., 2021). The effects of norm-violating behaviors are also relevant to immersive training. Research by van Kleef et al. (2015) highlights the interpersonal and intrapersonal consequences of breaking norms, which can be simulated in VR to teach conflict resolution and ethical decision-making.

2.5 Immersive Media and Social Identity

Social identity theories provide further insights into the role of group dynamics in immersive training. According to Hogg et al. (2004), group membership and self-categorization influence norm formation and conformity, which are critical for understanding participants' responses to groups of VHs in VR environments. As Herriot & Scott–Jackson (2002) observed, globalization and individualism have increased the complexity of maintaining social identities in workplace settings. Immersive media can address these challenges by simulating diverse group dynamics, allowing participants to practice navigating cultural and interpersonal conflicts.

2.6 Applications of VR in Industrial Education and Training

In recent years, VR technology has been applied to sports, virtual store, medical, industrial design, education and so on (Bernardo & Duarte, 2021; Lee et al., 2021; Rojas-Sánchez et al., 2023). VR technology as an innovative communication medium in the commercial and public sphere will be actively developed in the near future (Chemerys et al., 2021). For example, in the construction industry, VR technology can offer an immersive environment and simulated learning environment for users,

and results in better retention, task performance, learning speed, and engagement than the video training counterpart, maintaining system usability (Osti et al., 2021).

To improve situational realism, some VR training system involves virtual characters, for example, Guo et al.'s experiment (2012) support a Web-based multi-user operating machine in the same virtual environment, and the users can see other users or virtual character's behavior. Zhang et al. (2023) designed a VR platform which users can use gestures to guide other user's operation. Similarly, Xu & Zheng (2020) and Birt & Vasilevski (2021) also used virtual characters in the research of construction safety training to varying degrees.

However, the primary function of virtual characters in past research has been to enhance situational realism rather than to serve as active agents of social influence in training. As a result, the behavioral and social influence of virtual characters has often been overlooked, with less research focusing on their potential impact on trainee behavior and decision-making. This study hopes to fill this gap by exploring the social impact of virtual characters in VR training environments.

3 The current Study

The literature shows evidence that virtual characters, or virtual humans (VHs) can cause social influence on users, despite the users are well aware that the VHs are fake and there are no real human controlling the VHs. The current study is based on this backdrop to explore any social influence on users' perception and subjective experience in a VR-based professional training and education settings. The experiment was designed to investigate how the presence and behavior of VHs in a Virtual Reality Environment (VRE) influence participants' stress levels, task performance, and subjective experiences. One important aspect of VHs in a VRE is to what extent a user feels being watched (sense of being watched by VHs), despite the VHs are fake.

We developed the following hypotheses and a conceptual framework to illustrate the hypothesized relationships among the key constructs as illustrated in Figure 1.

- H1: Perceived being watched (PBW) positively influences trainees' Sensitivity of Stress Level to the number of VHs (SSL).

SSL refers to the extent to which the users' stress level is sensitive to the increasing number of VHs.

We further hypothesize that the influence of PBW on SSL would extend to the trainees' task performance (TP). Therefore, the following the hypothesis:

- H2: PBW indirectly influences trainees' TP, via its influence on SSL.

Furthermore, trainees' the indirect effect of PBW may lay on the trainees' perception level. Therefore, we hypothesize about the indirect effect on trainees' perceived task performance (PTP) as well.

- H3: PBW indirectly influences trainees' PTP, via its influence on SSL.

Trainees' perception of realism of VEs may vary across different trainees. Their perception of the realism of the VEs may affect the indirect effects hypothesized above. Therefore, we also hypothesize that perceived realism (PR) plays a moderator role in the proposed indirect effects. H4 corresponds to H2 while H5 corresponds to H3.

- H4: PBW indirectly influences trainees' TP, via its influence on SSL, with PR moderates the indirect influences.

- H5: PBW indirectly influences trainees' PTP, via its influence on SSL, with PR moderates the indirect influences.

VR-based industrial training is ultimately a form of simulation. It is only a simulation of the real world. In VR training, trainees assume a role in the training (e.g., a worker or a colleague). They are like having a different body of the role in the VR. The degree which the trainees embody in the VEs may influence to what extent they perceive the VEs resemble with the real world. Therefore, we hypothesize:

- H6: Perceived embodiment (PE) influences resemblance with the real world (RW).

Furthermore, the influences may further extend to influence how much they stress levels are influenced by the number of VHs as well.

- H7: PE indirectly influences SSL, via its effect on RW.

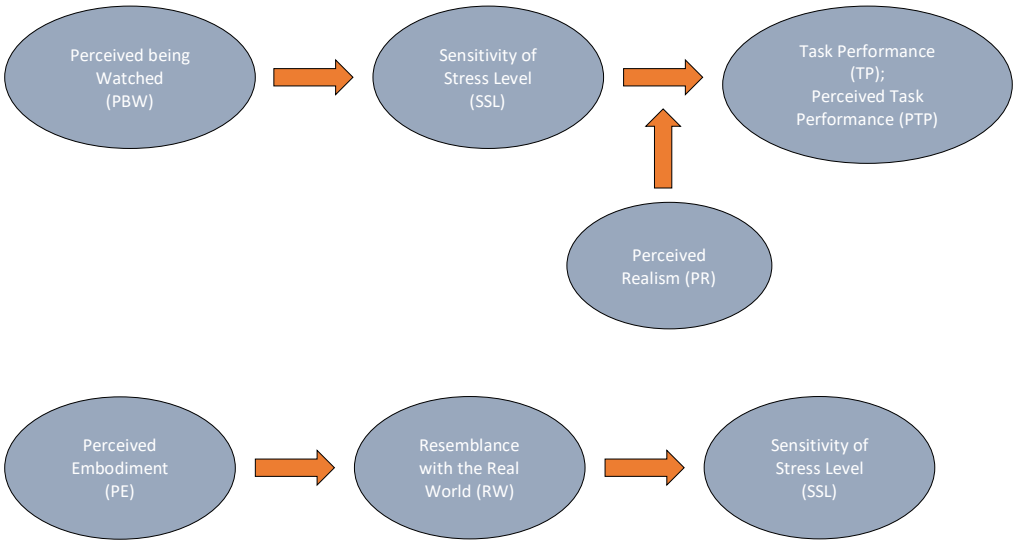


Figure 1. Conceptual Framework of Hypothesized Relationship

To test the hypotheses, the study employed a repeated measures experimental design and utilized quantitative data collection method.

A total of 51 participants, all students at The Hong Kong Polytechnic University (PolyU), were recruited for the experiment. After an initial pilot study with 8 participants to optimize task parameters, 42 participants completed the full experiment. Each participant was exposed to varying numbers of VHs (0, 3, 6, 9, and 12) across five randomized Task Rooms, where they performed a brick placement task while being observed by VHs with natural gaze behaviors.

4 Methodology

4.1 Participant

A total of 51 participants were recruited for this study, of which 26 were male and 25 were female, with an average age of 19 years old. All participants were students at a public university in Hong Kong who voluntarily enrolled in the experiment, and they were rewarded with corresponding course credits upon completion of the experiment. They were not majoring in design, architecture, or VR-related fields, and were largely inexperienced with VR-based industrial training, allowing us to

examine the responses of first-time users while minimising the influence of prior domain knowledge or VR experience.

Based on a pre-experiment questionnaire, participants were asked to report their past experiences with VR. 25 participants reported never having used a VR device, while 26 participants reported having been exposed to a VR device, e.g., by watching a VR video or participating in a VR game. All participants were explicitly informed that if they experience any kind of discomfort they can stop at any moment without any penalty. The participants signed an informed consent form before the start of the VR experiment.

Of the 51 participants, 8 were assigned to the pilot study, which was used to evaluate and adjust the experimental workflow and design. The main purpose of the pilot study was to optimize the experimental steps, including the task difficulty, the configuration of the number of VHs, and the reasonableness of the total duration of the VR experiment. Based on the feedback from the pilot study, the research team fine-tuned the design of the task, including reducing the number of bricks in the task, adjusting the gaze behavior of the VHs, adjusting the layout of the brick locations in the VRE, and adjusting the ambient sound settings to provide a more realistic and comfortable experience for the participants. After the pilot study, 43 participants took part in the experiment process, among which 1 participant did not complete the experiment due to motion sickness. In the end, 42 participants (22 males, 20 females; M = 19.167, SD = 1.513) who completed the experiment were included in the data analysis.

Participants were required to fulfil the following inclusion criteria: no contraindications to the use of VR equipment (e.g., history of severe vertigo). Participants were provided with professional safety protection and guidance by the research team to ensure their safety during the experiment. The study strictly followed the ethical principles of the Declaration of Helsinki and was reviewed and approved by the Ethics Committee of The Hong Kong Polytechnic University (Ref: HSEARS20230217009).

4.2 Procedure

The present study utilized a repeated measures experimental design intending to explore the effects of the number of VHs on participants' stress levels, task performance, and subjective experience. The task design was based on Jacobsen et al.'s (2022) study, which used a brick placement task as the core task, where participants were asked to place bricks in a specified location on an incomplete wall in a VRE. When the participant grasps a brick, the handle vibrates to give the participant haptic feedback.

With observation in the pilot study, the duration design of the VR experimental session was referred to Petri et al. (2020) and Guna et al.'s research (2020) to ensure that the total duration of the experimental tasks was controlled to be around 20 minutes. Each participant was exposed to different numbers of VHs (0, 3, 6, 9, and 12) gazing at the participants. The VR experiment presents 5 Task Rooms (corresponding to the five designated number of VHs) in a randomized order to avoid the interference of sequential effects. After completing each task in a Task Room, the participant was presented with a panel of questionnaire questions and the opportunity to select their answer. The experimental procedure was divided into three phases: the preparation phase, the VR experiment phase, and the post-experiment phase (see Figure 2).

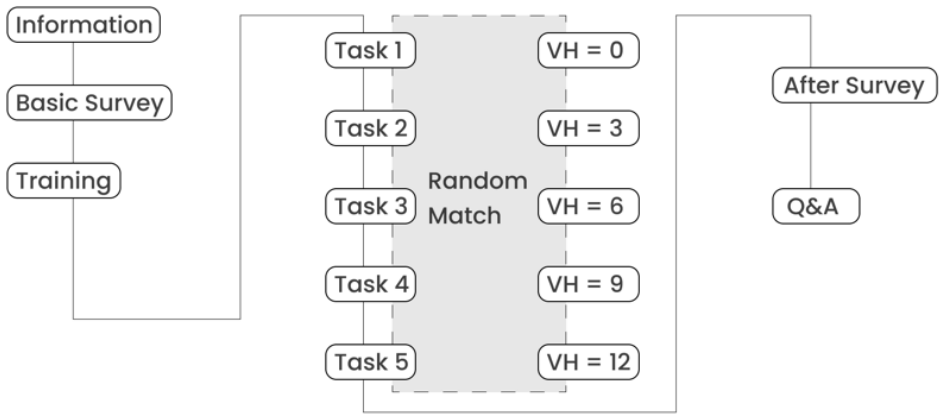


Figure 2. Experiment Procedure

4.3 Preparation Phase

Participants were first seated at Table A in the lab (see Figure 3). The experimenter introduced the participants to the experiment in detail, including the purpose of the study, task objectives, and basic operation of the VR equipment. Participants signed a consent form. Then, participants were asked to complete a questionnaire to collect their basic demographic information (e.g., gender, age, VR experience, etc.).

The lab layout was carefully designed to ensure the smoothness and safety of the experimental process. Table A was mainly used for the preparation of the experiment and questionnaire filling and interviews in the post-experiment phase, while Bench B area was the main place where the participants put on the Quest 2 headset and completed the VR tasks.



Figure 3. Lab Layout

4.4 VR Experiment Phase

The VR experimental phase was the core part of this study and consisted of one Training Room and five Task Rooms. After participants were seated in front of Bench B, the researcher assisted them in putting on the Quest 2 headset and ensured that the device was comfortable to wear and that the display was clear. The experimental tasks were run through a VR program developed with Unity, and

the Quest 2 headset was connected to a PC to run the VR program. The VR experiment was divided into the following two parts: Training Room and Task Rooms.

4.4.1 Training Room

In the training room, participants were required to complete a brick placement simulation task to familiarize themselves with the control of the VR equipment and task requirements (see Figure 4). The task was to carry each of the five bricks on a virtual table and accurately place at each of them to five designated locations on a half-completed virtual wall. The virtual table was at 90 degrees to the virtual incomplete wall and was replicated according to the dimensions of the lab, and the participants could complete the carrying and placing of the bricks by walking through a small range of the physical space in the real world (i.e. the lab). During the training task, a VH as a virtual manager provides real-time audio feedback in English, which is categorized into positive (e.g., “Well Done”), neutral (e.g., “Be Careful”), and negative (e.g., “What are you doing?"), and is accompanied by a hand-waving gesture. The role of the virtual manager was designed to help participants quickly understand the task criteria and to improve the accuracy and efficiency of the operation through the feedback mechanism. The design of the training tasks aims to ease the learning curve of the tasks and the adaptation needs of the participants when they first encounter the VR equipment. Participants can enter the Task Rooms only after they have completed the training tasks and reached the set accuracy standards.



Figure 4. Training task process within the VRE. (a) the participant’s hands in the environment; (b) task instructions in the training room; (c) clues to place bricks; (d) the button to proceed to the task rooms after completing the training

4.4.2 Task Rooms

After the training room, participants entered five Task Rooms in a randomized order, with the number of VHs (as co-workers) in each room being 0, 3, 6, 9, and 12 (see Figure 5). The VHs stood as observers behind the incomplete wall and watched the participants' operations with corresponding eye gaze behavior. The task required the participant to place five bricks in the specified location as in the Training Room, and after the task was completed, the VR system automatically recorded the completion time and the accuracy of the brick placement.

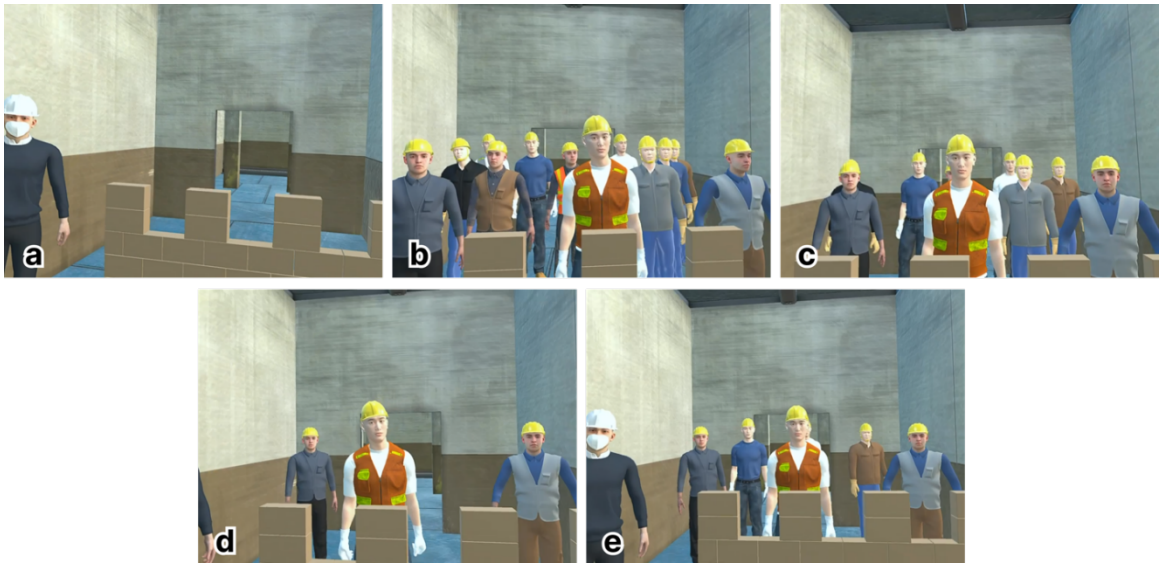


Figure 5. Task Room Setup. (a) the manager, 0 VHs; (b) 3 VHs with the manager; (c) 6 VHs with the manager; (d) 9 VHs with the manager; (e) 12 VHs with the manager

Participants were asked to complete a simple questionnaire in VR after they completed the current task and then switched to the next Task Room, asking their stress level and perceived resemblance with the real world, which was recorded through a 5-point Likert Scale from Strongly Disagree to Strongly Agree.

The research team monitored participants' performance in VR in real-time via an external view of the participants' view in VR via Quest Link. Throughout the experiment, participants were able to make small physical movements in the lab and combined the VR controller's tele-stick and grab buttons to complete brick placement task. The total duration of the experiment was about 20 minutes.

4.5 Stimulus

The VR program for this study was built using Unity (version 2022.3.51f1) and was run through a Meta Quest 2 device. The VR program consisted of one Training Room and five Task Rooms. The Training Room was designed to help participants familiarize themselves with the operations, with the Virtual Manager (a VH) guiding participants through the tasks via voice and visual feedback. The five Task Rooms simulated social observation situations with varying numbers of VHs, and the background sound effects (e.g., construction site noise) and visual design of each room were consistent to ensure comparable experimental conditions. To test only the effects of changes in number of VHs, the Manager will accompany the participants through all given Task Rooms and will be fixed next to the table in the VRE but will only provide feedback and assistance during the Training Room sessions. The five Task Rooms were presented to the participants in randomized orders.

4.6 Measures

In order to test the hypotheses, the constructs that appeared in the hypotheses were measured with corresponding items or measures. Most of the data were collected in a self-reported manner, with Likert scale questionnaire items. One exception is task performance, which was measured with accuracy of placing bricks on the depicted places of the incomplete wall. The task performance data was calculated and collected internally in the VR stimulus. Table 1 shows the measures.

Sensitivity of stress level (SSL) to the number of VHs was calculated with the following steps. Firstly, the slope of the change in SL between consecutive numbers of VHs (i.e., the change of SL between 0 and 3 VHs, the change of SL between 3 and 6 VHs, etc.) which results in four slope values. Then, the average value of the four slope values was calculated and was used as the value for SSL.

In the post-experiment phase, a post-VR survey was administered to measure PE, PR, PBW and PTP.

Table 1. Measurements of the current study

Construct	Item	Questionnaire Item	Measurement Timing	Answer Format
Resemblance with the Real World (RW)	RW	"My experience in the virtual environment was consistent with my real world experience."	During each task	5-Point Likert Scale (1 = Strongly Disagree, 5 = Strongly Agree)
Stress Level (SL)	SL	"I feel stress in the virtual environment."	During each task	5-Point Likert Scale (1 = Strongly Disagree, 5 = Strongly Agree)
Perceived Embodiment (PE)	PE	"To what extent did you identify yourself with the worker's body during the experience?"	After all tasks	7-Point Likert Scale (1 = Not at all, 7 = Very much)
Perceived Realism (PR)	PR	"Do you think the virtual environment can simulate the real environment on a psychological level?"	After all tasks	7-Point Likert Scale (1 = Not at all, 7 = Very much)
Perceived Being Watched (PBW)	PBW	"Did you feel that the virtual workers were watching you?"	After all tasks	7-Point Likert Scale (1 = Not at all, 7 = Very much)
Perceived Task Performance (PTP)	PTP	"Overall, how well do you think that you achieved your tasks?"	After all tasks	7-Point Likert Scale (1 = Not very well at all, 7 = Very well)
Task Performance (TP)	TP	"Average accuracy of placing the bricks in the designated location for tasks."	After all tasks	Numerical Score (0-100%)

5 Results

This study investigates the relationship between participants' task performance, self-reported stress level, and the variation in the number of VHs.

To test H1, a linear regression analysis was conducted to examine the influence of Perceived Being Watched (PBW) on Sensitivity of Stress Level (SSL). The mean SSL was 0.01 (SD = 0.09) and the mean PBW was 4.52 (SD = 1.95). A linear regression analysis was performed with PBW as the predictor variable and SSL as the dependent variable. The regression model was statistically significant, $F(1, 40) = 6.65$, $p = .01$. The model explained 14.3% of the variance in SSL ($R^2 = .14$). The coefficients indicated

that for each unit increase in PBW, SSL increased by 0.02 (B = 0.02, SE = 0.01), and this effect was significant (t(40) = 2.58, p = .01). H1 was supported.

To test H2, a mediation analysis was conducted using Model 4 of PROCESS macro (v4.2) for SPSS (Hayes, 2022) with 5,000 bootstrap samples, to evaluate whether the effect of PBW on trainee's TP was mediated by SSL. The indirect effect of PBW on TP through SSL was calculated, yielding an indirect effect of 0.0043 with a bootstrapped standard error of 0.0347. The 95% confidence interval for the indirect effect ranged from -0.0582 to 0.0841, indicating that the indirect effect was not statistically significant, as the confidence interval included zero. That is, the indirect effect of PBW on TP via SSL was not significant. Therefore, H2 was not supported.

To test H3, a mediation analysis with 5,000 bootstrap samples was conducted using Model 4 of PROCESS macro (v4.2) for SPSS, to evaluate whether the effect of PBW on trainee's PTP was mediated by SSL. The indirect effect of PBW on PTP through SSL was calculated, yielding an indirect effect of 0.0066 with a bootstrapped standard error of 0.0325. The 95% confidence interval for the indirect effect ranged from -0.0624 to 0.0721, indicating that the indirect effect was not statistically significant, as the confidence interval included zero. That is, the indirect effect of PBW on PTP via SSL was not significant. Therefore, H3 was not supported.

To test H4, a moderated mediation analysis was conducted using the PROCESS macro for SPSS (v 4.2, Model 14) to evaluate whether the effect of PBW on trainees' TP was mediated by SSL and moderated by PR. The analysis first examined the relationship between PBW and SSL. The regression model was significant, F(1,40)=6.65,p=.014, with an R2 of .14, indicating that PBW significantly predicted SSL (B = 0.02, SE = 0.01, p = .014). This suggests that higher perceptions of being watched are associated with increased sensitivity to stress levels.

Next, the direct effect of PBW on TP was assessed. The regression model was not significant, F(4,37)=1.19,p=.331, with an R2 of .11. The direct effect of PBW on TP was not significant (B = 0.12, SE = 0.08, p = .170), and neither SSL (B = -8.64, SE = 6.20, p = .172) nor PR (B = -0.04, SE = 0.12, p = .711) significantly predicted TP. The interaction term (SSL × PR) was also not significant (B = 1.88, SE = 1.26, p = .145).

In summary, the analysis did not support H4, as the indirect effect of PBW on TP via SSL was not significantly moderated by PR.

To test H5, a moderated mediation analysis was conducted using the PROCESS macro for SPSS (v 4.2, Model 14) to evaluate whether the effect of PBW on trainees' PTP was mediated by SSL and moderated by PR.

The analysis first examined the relationship between PBW and SSL. The regression model was significant, F(1,40)=6.65,p=.014, with an R2 of .14, indicating that PBW significantly predicted SSL (B = 0.02, SE = 0.01, p = .014). This suggests that higher perceptions of being watched are associated with increased sensitivity to stress levels.

Next, the direct effect of PBW on PTP was assessed. The regression model was not significant, F(4,37)=1.92,p=.127, with an R2 of .17. The direct effect of PBW on PTP was not significant (B = -0.0188, SE = 0.07, p = .787). However, SSL significantly predicted PTP (B = 12.68, SE = 5.04, p = .016), indicating a positive relationship between sensitivity to stress levels and perceived task performance. The

interaction term (SSL × PR) was significant (B = -2.54, SE = 1.03, p = .018), suggesting that the effect of SSL on PTP varied depending on the level of PR.

Conditional effects of SSL on PTP at different levels of PR were examined. At PR = 3.00, the effect was significant (B = 5.06, SE = 2.31, p = .035), while at PR = 5.00, the effect was not significant (B = -0.0150, SE = 1.57, p = .993). At PR = 6.00, the effect was not significant (B = -2.55, SE = 2.05, p = .220).

The conditional indirect effects of PBW on PTP through SSL were calculated at different levels of PR. The indirect effect at PR = 3.00 was 0.0860 (BootLLCI = 0.0128, BootULCI = 0.1932), indicating a significant mediation effect. At PR = 5.00, the indirect effect was not significant (-0.0003, BootLLCI = -0.0621, BootULCI = 0.0660), while at PR = 6.00, the effect was -0.0434 (BootLLCI = -0.1419, BootULCI = 0.0426).

The index of moderated mediation was -0.0432 with a bootstrapped standard error of 0.0248 (BootLLCI = -0.0980, BootULCI = -0.0046), suggesting that the moderated mediation effect was significant. In summary, the analysis supported H5, indicating that PBW indirectly influences PTP through SSL, and this effect is moderated by PR. Figure 6 presents a visual illustration of the mechanism of the indirect effect.

To test H6, a linear regression analysis were conducted to examine the influence of PE on RW. The mean score for RW was 3.00 (SD = 0.06), while the mean score for PE was 5.14 (SD = 1.22). A linear regression analysis was performed to further investigate the predictive relationship between PE and RW. The model summary indicated that the model accounted for approximately 20.4% of the variance in RW, R2=0.204, F(1,40)=10.28,p=.003.

The regression coefficients indicated that PE significantly predicted RW (B = -0.020, SE = 0.006, β=−0.452, t(40)=−3.21,p=.003). The 95% confidence interval for the slope ranged from -0.033 to -0.008. These findings suggest that perceived embodiment negatively influences resemblance with the real world. H6 is supported.

To test H7, a mediation analysis was conducted using the PROCESS macro for SPSS (v 4.2, Model 4), with 5000 bootstrap samples, to examine whether PE indirectly influences SSL through RW. The model summary for the relationship between RW and PE indicated that the regression was significant, F(1,40)=10.28,p=.003, with R2=.204. PE significantly predicted RW (B = -0.0204, SE = 0.0064, t(40)=−3.21,p=.003), suggesting that higher levels of perceived embodiment are associated with lower resemblance to the real world.

In the subsequent analysis for SSL, the model was significant, F(2,39)=7.81,p=.001, with R2=.286. RW significantly predicted SSL (B = -0.9532, SE = 0.2415, t(39)=−3.95,p=.0003). The direct effect of PE on SSL was not significant (B = -0.0175, SE = 0.0109, t(39)=−1.61,p=.1163).

The analysis revealed that the indirect effect of PE on SSL through RW was significant (B = 0.0195, BootSE = 0.0076, BootLLCI = 0.0058, BootULCI = 0.0354).

In summary, the findings support H7, indicating that PE indirectly influences SSL via its effect on RW. With the indirect effect in place, the direct effect of PE on SSL was not significant, the mediated pathway through RW was confirmed. Figure 7 presents a visual illustration of the indirect effect.

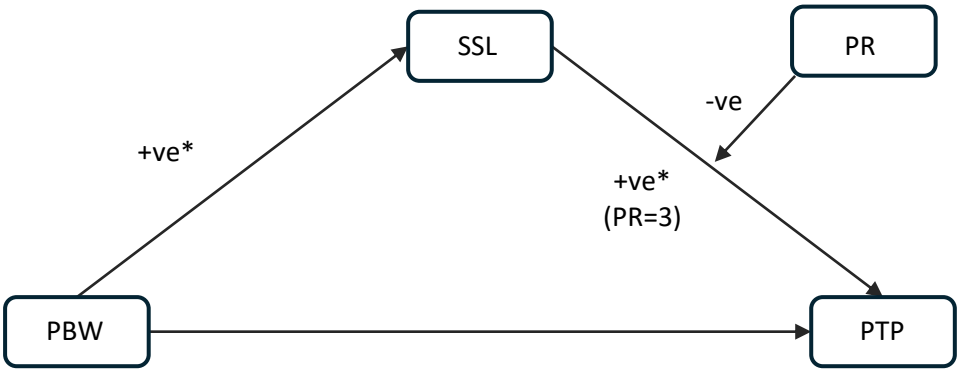


Figure 6. Visual Illustration of Indirect Effect of Perceived Being Watched

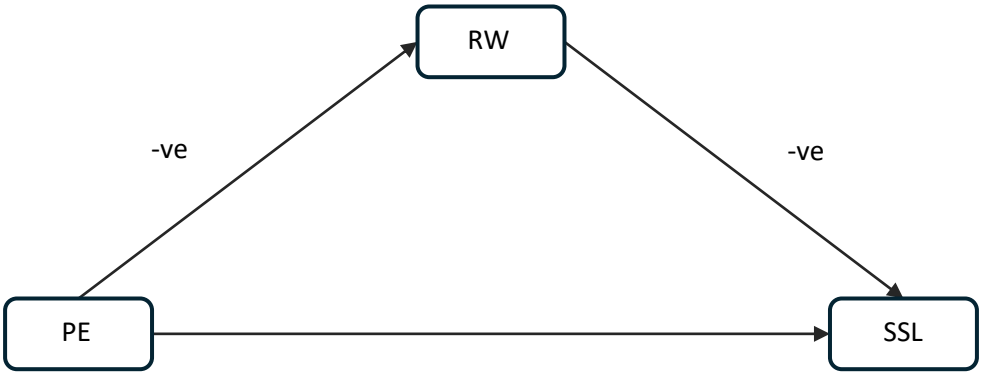


Figure 7. Visual illustration of Indirect Effect of Perceived Embodiment

6 Discussion

Virtual characters can "activate" a mechanism that makes participants' stress level more sensitive to the number of VHs.

Additionally, the indirect effect of the feeling of virtual characters watching oneself positively influences their perceived task performance by affecting their stress sensitivity to the number of VHs. This indirect effect is moderated by the perceived realism of the virtual environment.

As the perceived realism increases, the indirect effect becomes weaker and eventually insignificant. This indirect effect can be interpreted as that virtual witnesses create a mechanism similar to pride. The more a user feels the virtual witnesses are watching them, the higher their stress sensitivity to the number of virtual witnesses becomes. Consequently, the higher stress sensitivity leads to the perception that they are performing the tasks well. This indirect effect was found significant when the perceived realism of the environment is relatively low.

That is like a complacent mechanism: "Because people are watching me, I feel the pressure." But this is the kind of pressure that allows a person to show off, and they feel they are doing the task quite well, the pride can be seem to lead to complacent, This is further supported by the finding that when PTP is replaced with TP, the indirect effect was not found to be significant. This suggests that the PTP has a deviation from their actual performance (TP), reflecting a complacency is a dangerous effect.

However, this pride mechanism is moderated by the perceived realism of the virtual environment. One interpretation is that when the virtual environment is perceived as more realistic, the positive

indirect effect (that is, the pride) is reduced and becomes insignificant. Another interpretation is that as they feel the virtual environment is more realistic, the feeling of being watched affects stress and becomes overwhelming, weakening their perception of their task performance.

It becomes the kind of stress that reduces how one judges their own task performance. But the data shows that the stress moderating effect is not strong to a point that makes the indirect effect a negative one. It only reduces the significant positive effect to insignificant.

Our research indicates that virtual characters (presented as co-workers in the IVR scenario) can influence complacency. This suggests that while virtual characters may seem like a decorative element in IVR design and industrial training, their presence can activate complacency mechanisms. Literature suggests that complacency and overconfidence can lead to unsafe practices in the construction industry industry (Olatoye et al., 2024) and problematic risk acceptance (Harvey et al., 2018). Our findings emphasize the importance of considering the placement of virtual characters in IVR training environments beyond their aesthetic appeal. They could unintentionally cause side effects that lead to complacency, potentially contributing to risky perception and behavior. The design of IVR scenarios and environments involves various considerations, including realism, training instructions, and the appropriateness of the virtual space for trainees. While virtual characters can make environments more natural and realistic, our findings suggest that their placement should be carefully evaluated. We must consider whether their behaviors, despite being fake, could cause social influence on trainees' perceptions and behaviors.

7 Conclusion

This study aimed to explore how different numbers of virtual characters in a virtual reality environment affect trainees' stress levels and self-perceptions during industrial training. The results of the study emphasized the key role of perceived being watched (PBW) and perceived embodiment (PE) in shaping the user experience. It was found that PBW positively affects trainees' sensitivity of stress levels (SSL) and its indirect effect on performance is moderated by perceived realism (PR). In addition, PE affects perceived resemblance with the real-world (RW), affecting SSL indirectly. These insights provide valuable insights for designing VR environments and optimizing user comfort and performance.

Although this study provides a meaningful contribution to the design and application of VR training environments, there are still limitations that warrant further exploration. Firstly, the study mainly focuses on construction site training scenarios, and future studies could apply the focus and findings of this study in other areas, such as public speaking, virtual socializing, and transportation training scenarios. Secondly, this paper primarily focused on the number of virtual humans (VHs); future research could explore other avatar features, such as behavior, identity, or role.

In conclusion, this study highlights the importance of VHs in VR training and is worthy to be carefully designed, and complacency could motivate users to engage in risky behavior. Furthermore, realism serves as a moderating factor—while a more realistic environment is generally expected to enhance training effectiveness, its impact may vary among individuals. Some people perceive realism differently, and their expectations of a highly standardized environment could influence their risk perception. Therefore, carefully placing virtual characters within the VR environment is crucial to

balancing realism and training effectiveness, ensuring that users remain engaged without fostering dangerous complacency.

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Acknowledgement: This work was supported by the General Research Fund of the Research Grants Council, Hong Kong SAR Government (Project No. 15212223, titled "*Immersive-Virtual-Reality-Based Construction Safety Training Focusing on Safety-Related Social Aspects*"). The authors gratefully acknowledge the funding support that made this research possible.