Virtual skills training: the role of presence and agency

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**Abstract**

Virtual reality (VR) simulations provide increased feelings of presence and agency that could allow increased skill improvement during VR training. Direct relationships between active agency in VR and skill improvement have previously not been investigated. This study examined the relationship between (a) presence and agency, and (b) presence and skills improvement, via active and passive VR simulations and through measuring real-world golf-putting skill. Participants (n = 23) completed baseline putting skill assessment before using an Oculus Rift VR head-mounted display to complete active (putting with a virtual golf club) and passive (watching a game of golf) VR simulations. Measures of presence and agency were administered after each simulation, followed by a final putting skill assessment. The active simulation induced higher feelings of general presence and agency. However, no relationship was identified between presence and either agency or skill improvement. No skill improvement was evident in either the active or passive simulations, potentially due to the short training period applied, as well as a lack of realism in the VR simulations inhibiting a transfer of skills to a real environment. These findings reinforce previous literature that shows active VR to increase feelings of presence and agency. This study generates a number of fruitful research questions about the relationship between presence and skills training.

1. Introduction

Virtual Reality (VR) involves the computer-generated simulation of a three dimensional image, environment or scenario that can be interacted with in a seemingly real or physical way through the use of multiple sensory channels, including visual, auditory and tactile stimuli (Adamo-ovich et al., 2009; Henneberg, 2017). VR platforms allow virtual environments to become interactive and engaging for users as they are more immersive than in past experiments with earlier technologies such as the use of computerized games or television sets (Gorini et al., 2011; Lee, 2004; Slater and Wilbur, 1997).

Immersion in VR constitutes the extent to which the sensory cues of a VR platform replicate real life (Slater, 2003). Continental presence improvement has led to increases in the accessibility and number of practical applications of VR (Juan and Pérez, 2009; Tussyadiah et al., 2018). Originally VR was used primarily for entertainment purposes, however, it is now applied in the field of psychology (Ke and Im, 2013; Peperkorn et al., 2015; Wiederhold and Wiederhold, 2005) for usability testing (Bowman and McMahan, 2007), as well as skills training in a variety of areas including medical, industrial and sporting settings (Chao et al., 2017; Gurusamy et al., 2008; Munz et al., 2007).

When examining VR, user experience can be captured by the construct of presence. The definition of presence is frequently debated, however common themes can be identified within the literature. Presence is the subjective feeling of “being there” within a constructed virtual environment and behaving and feeling as if this mediated environment was the real world (Brade et al., 2017; Sanchez-Vives and Slater, 2005; Slater et al., 2007). High presence in VR enhances user experience in a VR simulation (Cheng et al., 2014). Prior research indicates that task engagement and performance is generally greater when a higher level of presence is experienced (Ogbangwo et al., 2014; Slater et al., 2007), although the specific assessment of use of VR to entrain skills has not been adequately examined with modern technologies. As laboratory studies in VR tend to attract small samples, with few studies incorporating a longitudinal design, our understanding of presence has been limited to short-term post-experience reports.

Numerous variables influence the experience of presence. The fidelity of a virtual environment, that is, how similar the content of the simulation is to the real world, allows for increased believability of the virtual environment, contributing to presence (Schuemie et al., 2001; Slater et al., 1994; Yu et al., 2012). The user’s ability to participate in and modify the virtual environment, or their level of interactivity, can also influence presence (Schuemie et al., 2001). Similarly, user engagement, referring to involvement and interest in the virtual environmental

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content, also contributes to presence (Diemer et al., 2015; Lessiter et al.,
2001). Variations in the technical specifications of VR software and
hardware also exerts a large impact on the experience of presence.
Technical factors include the objective properties of the display, navi-
gation methods, and user interfaces (Lorenz et al., 2015; Witmer and
Singer, 1998), as well as visual and audio quality (Bowman and McMa-
han, 2007). The technical specifications of VR equipment can therefore
have an overarching effect on the fidelity, interactivity, and level of
engagement of the virtual environment.

In addition to factors that can increase the feeling of presence there
are also those that can decrease it. Distracting or low-quality technologies
and interfaces reduce feelings of presence (Held and Durlach, 1992).
Some VR simulations can also produce negative effects in users, such as
disorientation or nausea (LaViola, 2000; Lombard and Ditton, 1997).
These effects are more likely to be produced by more immersive tech-
nologies and can interfere with the experience of presence. Changes in
VR application and software available have also not adequately been
regarded in their role of sustaining presence. For example, it is not
totally clear to what extent hardware or software specific attributes are
relevant predictors of presence, and whether a straight correlation be-
 tween “modernity” of technology/software and quality of presence can
be presumed.

1.1. Agency and the skills-training connection

A specific aspect of a virtual environment, related to the user's level of
interactivity, is whether the simulation provides an active or passive
experience. Active VR experiences involve a greater level of participation
and interactivity with the virtual environment, allowing higher levels of
presence to be experienced as users feel more engaged (Sekhvat and
Nomani, 2017). Freeman, Lessiter, Pugh and Keogh (2005), highlighted
the difference between active and passive simulations, while demon-
strating their influence on presence.

Their study compared two groups of participants that could either
actively or passively navigate a virtual environment. The active condition
involved participants being able to control their own movements and
where they went, whilst those in the passive condition had no control
over their movements in the virtual environment.

The ability to actively engage in a virtual environment and control
one's actions relates to the concept of agency. Agency is defined as having
a sense of ownership and control over one's actions (Friston, 2012;
Haggard and Chambon, 2012; Pacherie, 2007). Being able to interact
with the environment and control one's movements in active VR sce-
narios allows this feeling to be developed, even though a person's body
is not physically in virtual space (Kong et al., 2017). Kokkinara, Kilteni,
Blom, and Slater (2016) found that certain factors assist in generating
agency in VR, including (i) viewing the world from a first-person perspective; (ii)
being able to move freely and do as one intends within the
virtual environment.

An immediately feasible way to invest a VR participant with a sense of
agency is to provide them with a goal and the possibility of achieving that
goal through self-directed physical movement. This allows for
the training of motor skills used in sport a suitable context in which to
examine agency in VR. Prior studies have investigated the efficacy of VR
in training motor skills such as bowling (Siemon et al., 2009), dart
throwing (Tirp et al., 2015) and basketball shooting (Wiemeyer and
Schneider, 2012). Using VR to train these skills provides an alternative to
in-vivo training potentially provides an enhanced, configurable learning
environment, allowing skills to be developed in shorter time periods
(Satava et al., 2000). Virtual training also offers other benefits including
increased flexibility regarding space or resources, as well as a safe
environment to train complex or dangerous tasks (Bowman and McMa-
han, 2007; Rauter et al., 2013). However, it can be difficult for VR
training to improve skills to the same degree as real life or allow these
skills to be transferred to a real environment (Tirp et al., 2015; Wiemeyer
and Schneider, 2012). Numerous reasons, such as the lack of visual
accuracy/realism in VR environments, as well as discrepancies in
sensorimotor control, have been mentioned earlier which relate to these
difficulties. Examining agency and presence in a training context may
identify factors that can improve the efficacy of VR skills training.

VR skills training has proven to be an effective supplement to real life
training methods. Studies by Gray (2017) and Lam fromm and Gopher
(2011) show that in training baseball batting and juggling, VR training
paired with real life training leads to greater skill improvement when
compared to real life training on its own. VR alone has not shown strong
effects in training real-world motor skills, so paired training programs
compensating for deficits in the fidelity of the virtual environment, or for
differences in the movements required to perform the targeted skill
(Kaber et al., 2014; Zhang et al., 2016). Comparing real-world and
VR-based rowing training programs, Rauter et al. (2013) demonstrated
that a VR simulation with minimal discrepancies to real life could facil-
itate skill development to an extent comparable to real life training and
transferable to a real environment.

VR technologies have been speculated to assist in learning and
training in various domains, from sports psychology to educational
contexts. From a behavioural stance, the mechanism of skills improve-
ment is traditionally measured as an increase in base-level scores.
However, a broader definition of skills development must also encompass
the application of environment-specific knowledge and psychological
predictors such as personal confidence. Whilst the primary aims of VR-
based intervention may be to improve one's results at a given task, it is
important to consider the role of presence and agency in VR in skills
habituation. For instance, a golf player immersed in a golf course simu-
lation may benefit from visuospatial presence of the environment (i.e., an
increased comfort with this scenario) prior to the implementation of any
scheduled skills-training. The former may have an important perfor-
mance priming that is not as easily discernible in less-immersive skills
training regimens (e.g., watching an expert golf player on a television
screen).

Multiple factors enable effective VR motor skills training. How
accurately the simulation replicates the real world is one factor, whilst
the capability to allow a motor skill to be performed identically in VR as it
is in a real environment is the other. These factors are comparable to
those shown to positively influence presence (Schuemie et al., 2001).
Therefore, facilitating agency and presence in a virtual environment
could improve motor skill training outcomes. It should be noted, how-
ever, that even if a VR simulation does not allow all motor demands of a
skill to be met cognitive aspects of that skill may still be improved, which
can contribute to increased performance (Lammfromm and Gopher,
2011). The continued identification of methods for improving VR skills
training will assist in this form of training becoming a practical stand-
alone method. Specifically, understanding the relationship between
presence, agency, and skills improvement could help shed light on the
discrepancies between skills refinement in VR and real-world skills
improvement.

This study examined the relationship between presence and motor
skills training by comparing active and passive VR scenarios. The motor
skill that was the focus of training was putting of a golf ball. The aim of
the present study was to examine the relationships between presence,
agency, and skill improvement, in both active and passive VR golf-
putting simulations. It was hypothesised that (i) the active simulation
would induce higher feelings of presence and agency than the passive
simulation; (ii) the active simulation would allow greater skill improve-
ment than the passive simulation; and (iii) higher feelings of
presence would be associated with higher feelings of agency, as well as
greater skill improvement across active and passive simulations.

2. Methods

2.1. Participants

The study comprised 23 volunteers recruited via social media
releases and advertisements posted at RMIT University in Melbourne, Australia. The sample consisted of 13 males and 10 females with ages ranging from 18 to 59 years ($M = 28.65$, $SD = 13.15$). Ethics approval to conduct this research project was granted by the RMIT University College of Science, Engineering and Health College Human Ethics Advisory Network.

3. Materials

3.1. Hardware

A first-generation Oculus Rift VR head-mounted display (HMD) was used to view the virtual environments. The Oculus Rift is comprised of an in-built screen display, headphones and optional hand-held controllers.

3.2. Application and video

The virtual reality application “Cloudlands VR Minigolf” (developed by Futuretown Inc.) was used to provide the active simulation. The application is geared towards entertainment rather than formal golf training. Despite this, the scenario was deemed suitable as it facilitated the visuospatial mechanics of putting well for the current proposed experiment. Furthermore, the Futuretown Inc. description of the simulation states “Cloudlands uses an intuitive control mapping between the virtual putter and your Samsung GearVR controller to make swinging feel natural, just like swinging a real putter. Expect real-life golf skills to translate into the virtual world” (from the Futuretown Inc. website), which made this simulation amenable to skills-related testing.

A 360° video (https://www.youtube.com/watch?v=J_TfvNIMwL4&feature=share) involving several adults putting on a golf course putting green was used to create the passive simulation. This video was recorded from a stationary tripod located at the centre of a putting green, allowing participants to observe the putting techniques of other individuals. This video was used to provide a passive VR experience and allow participants to passively experience the skill of putting being performed. Screenshot from “Cloudlands VR Minigolf” can be seen in Fig. 1.

3.3. Golf equipment

To assess the skill of putting before and after the VR simulations a 7-foot practice putting mat, several golf balls, and a two-way putter were used. The two-way putter allowed both left- and right-handed participants to use the same equipment.

3.4. Questionnaires

Two questionnaire measures were administered to participants. These questionnaires were preceded by a brief series of demographic questions querying participant gender, age, experience with golf, and familiarity with VR technology.

3.4.1. Independent television commission sense of presence inventory (ITC-SOPI)

The shortened version of the Independent Television Commission Sense of Presence Inventory (ITC-SOPI) (Lessiter et al., 2001) is a 12-item measure of subjective presence and was developed from the original 44 item-ITC-SOPI. Participants were asked to respond to questions on a 5-point Likert scale ranging from (Strongly agree) to (Strongly disagree). The ICT-SOPI assesses presence as four factors: (i) spatial presence, a general measure of the participant’s sense of being located in a virtual environment; (ii) engagement, which measures participant level of involvement and interest in the virtual environment; (iii) ecological validity, measuring the believability and realism of the virtual environment; and (iv) negative effects, measuring participant’s adverse psychological or physiological reactions to VR technology use. The ITC-SOPI has shown adequate internal reliability on each of the four factors (Cronbach’s α ranging from .76 to .94), and validity has been established through comparison of scores across different media formats.

3.4.2. Sense of agency rating scale (SOARS)

The Sense of Agency Rating Scale (SOARS) (Polito et al., 2013) is a 10-item measure of the subjective sense of agency. Participants respond to questions on a 7-point Likert scale ranging from ranging from (Strongly agree) to (Strongly disagree). Agency is measured as two factors: (i) involuntariness, subjective experience of a reduction in control in one’s own actions; and (ii) effortlessness, subjective experience of the ease with which actions occur. Scores from each factor are combined to provide a total score for subjective agency. To facilitate intuitive comparison with other variables, traditional SOARS scoring was reversed for the present study, so that higher scores indicated greater feelings of agency. The SOARS demonstrates good internal consistency (Involuntariness Cronbach’s α = .91, Effortlessness Cronbach’s α = .73), and has been validated through comparison with other measures of agency and has been applied within VR contexts (Pritchard et al., 2016).

4. Experimental

A repeated measures design with counterbalancing was adopted, therefore participants completed both the passive and active VR simulations in randomised order.

Participants performed a baseline skill assessment of putting a golf ball, assessed by the number of puts out of 10 that were successfully hit into the hole using the practice putting mat. Each shot was taken 2 metres directly away from the hole. Following this skill assessment, participants used the Oculus Rift HMD to engage in both the “Cloudlands VR Minigolf” (the active condition), and 360° video (the passive condition) simulations. These simulations were completed in a random order. After each simulation the participants completed the questionnaires in the following order: demographic questions (baseline only), the ITC-SOPI and SOARS. Participants also completed the putting skill assessment after each simulation.

For the active simulation participants used the Oculus handheld controllers to practice their putting skills by interacting with the virtual environment. They were instructed to make their putting action as realistic as possible. Participants spent 10 min using the practice setting in the “Cloudlands VR Minigolf” application.

For the passive simulation, participants were instructed to watch the 360° video and observe the putting done by the individuals displayed. The video lasted 2 min and 50 s. After the first simulation was completed participants would wait 5 min before commencing the next simulation. Results from the putting skill assessments and questionnaires were recorded electronically with no identifiable information recorded.

Fig. 1. Screenshot from the “Cloudlands VR Minigolf” application.
5. Results and discussion

Table 1 shows the results of the paired samples t-tests comparing mean scores of the presence scales and total agency scores between the active and passive conditions. Assumptions of normality were tested and found to be satisfactory for all variables. Results from the paired sample t-tests showed significant differences in Engagement (p = .01), Ecological Validity (p < .01), Negative Effects (p = .01) and Total Agency (p = .01) between conditions. No significant difference was found between conditions for Spatial Presence. This same pattern of results was obtained from a series of Mann-Whitney U tests when using non-parametric testing (see in Table 2).

A between-subjects ANCOVA was conducted with spatial presence as the dependent variable and Engagement, Ecological Validity, Negative Effects and Total Agency as the covariates. The assumptions of independence between covariates and homogeneity of slopes were satisfied. The ANCOVA showed Spatial Presence scores were significantly higher in the active condition when controlling for the other presence and agency scales, Spatial Presence, F (1, 46) = 6.61, p = .01. Engagement, Ecological Validity and Total Agency were all significant covariates in predicting Spatial Presence. Engagement, F (1, 46) = 9.91, p < .01, Ecological Validity, F (1, 46) = 8.02, p < .01. Total Agency, F (1, 46) = 5.25, p = .03

Paired samples t-tests revealed no significant difference between the number of puts hit after completing the active (M = 3.13, SD = 2.24) or passive (M = 3.43, SD = 2.59) VR simulations, t(21) = -.68, p = .51. As well as between baseline putting scores (M = 2.57, SD = 2.12) and scores after the active simulation, t(21) = -1.23, p = .23, or passive simulation, t(21) = -.68, p = .51. However, assumptions of normality were violated for the baseline putting scores as well as the post passive and post active simulation putting score variables. To account for this Log10 transformations were applied to these variables. The paired samples t-tests using the transformed variables also revealed no significant difference between the number of puts hit after completing the active or passive VR simulations, t(21) = .28, p = .78. This was also done between baseline putting scores and scores after the active simulation, t(21) = -.48, p = .64 or passive simulation, t(21) = -.92, p = .37. The same pattern of results was obtained when using non-parametric testing.

Table 3 shows correlations between the ITC-SOPI presence scales, agency and post simulation putting scores within the passive VR condition. Table 4 shows the correlations within the active VR condition. No significant relationships were identified between Total Agency and any of the ITC-SOPI scales in either condition. There were also no significant differences identified for any variable between participants who completed the active condition first or second. There were also no significant differences identified for any variable between participants who completed the passive condition first or second. A series of Mann-Whitney U tests show this pattern of scores to be the same for non-parametric tests.

Our study examined the association between presence, agency, and skill improvement in both active and passive VR simulations. The results showed that the active simulation induced higher feelings of presence and agency than the passive simulation, supporting the first hypothesis. The second and third hypotheses were not supported, with no significant change occurring in skill improvement following the active simulation, and no significant correlation between presence, agency, and skill improvement in either condition.

Based on prior research, it was expected that Spatial Presence, Engagement and Ecological Validity, and Total Agency would have higher scores in the active condition (Kong et al., 2017; Lessiter et al., 2001). However, the results showed that only Engagement, Negative Effects and Total Agency were significantly higher in the active simulation. As Engagement is an important influence on the overall experience of presence, higher scores during the active condition support our first hypothesis. Higher interactivity in the active simulation would have increased engagement as participants felt more involved (Lessiter et al., 2001). The increase in total agency in the active condition is in accord with past literature that found individuals who had control over their actions in VR developed a sense of agency (Kokkinara et al., 2016; Kong et al., 2017). In the active simulation participants were able to control the actions they performed, allowing a greater sense of agency to be developed than in the passive simulation.

An important finding contradicting the first hypothesis was that Ecological Validity was higher in the passive simulation. Ecological Validity was expected to be higher in the active simulation, reflecting a closer approximation of the process of navigating the real-world environment (Yu et al., 2012). Interestingly, it appears that in the present study, Ecological Validity was more influenced by the photorealistic environment (Yu et al., 2012).

Table 1

| Scale  | Active condition | Passive condition | Paired samples t-test |
|--------|-----------------|-------------------|----------------------|
| M (SD) | M (SD) | t score | p score  |
| SP     | 4.19 (.37) | 3.93 (.56) | 1.95 | .06 |
| E      | 4.04 (.77) | 3.36 (.92) | 2.88 | .01 |
| EV     | 3.09 (1.01) | 3.96 (.60) | -3.98 | <.01 |
| NE     | 2.71 (.84) | 2.03 (.70) | 2.81 | .01 |
| TA     | 8.13 (.79) | 7.09 (1.59) | 2.92 | .01 |
| PUTT   | 3.13 (2.24) | 3.43 (2.59) | 0.28 | .78 |

Note. Degrees of freedom at 22 for all t-tests displayed. N = 23 for both active and passive conditions. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores.

Table 2

| Scale  | Active condition | Passive condition | Mann-Whitney U test |
|--------|-----------------|-------------------|---------------------|
| M (SD) | M (SD) | U score | z score | p score  |
| SP     | 4.19 (.37) | 3.93 (.56) | 183.00 | -1.84 | .07 |
| E      | 4.04 (.77) | 3.36 (.92) | 146.00 | -2.63 | .01 |
| EV     | 3.09 (1.01) | 3.96 (.60) | 135.50 | -2.86 | <.01 |
| NE     | 2.71 (.84) | 2.03 (.70) | 128.00 | -3.04 | <.01 |
| TA     | 8.13 (.79) | 7.09 (1.59) | 158.00 | -2.35 | .02 |
| PUTT   | 3.13 (2.24) | 3.43 (2.59) | 250.50 | -0.31 | .76 |

Note. N = 23 for both active and passive conditions. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores.

Table 3

| Scale  | SP | E | EV | NE | TA | PUTT |
|--------|----|---|----|----|----|------|
| M (SD) | 4.19 | 3.99 | 3.76 | 3.93 | 4.04 | 3.09 |
| E      | 4.04 | 3.36 | 3.96 | 2.03 | 7.09 | 3.43 |
| EV     | 3.09 | 2.88 | -3.98 | 2.81 | 2.92 | 0.28 |
| NE     | 2.71 | 2.81 | 2.03 | 7.09 | 3.43 | 3.43 |
| TA     | 8.13 | 7.09 | 3.96 | 1.59 | -1.84 | -3.98 |
| PUTT   | 3.13 | 3.43 | 2.81 | 3.96 | -3.98 | 2.88 |

| Scale  | SP | E | EV | NE | TA | PUTT |
|--------|----|---|----|----|----|------|
| M (SD) | 4.19 | 3.99 | 3.76 | 3.93 | 4.04 | 3.09 |
| E      | 4.04 | 3.36 | 3.96 | 2.03 | 7.09 | 3.43 |
| EV     | 3.09 | 2.88 | -3.98 | 2.81 | 2.92 | 0.28 |
| NE     | 2.71 | 2.81 | 2.03 | 7.09 | 3.43 | 3.43 |
| TA     | 8.13 | 7.09 | 3.96 | 1.59 | -1.84 | -3.98 |
| PUTT   | 3.13 | 3.43 | 2.81 | 3.96 | -3.98 | 2.88 |

Note. N = 23. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores.

**p < .01.

Note. N = 23. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores.
environment of the passive condition, rather than the polygon-modelled environment of the active condition. This finding suggests that using recordings of real environments may contribute to greater feelings of presence and that animated simulations may restrict the experience of presence. Moving forward, a key challenge for VR technology will be to integrate higher photorealism into its polygonal environments. In these relatively early stages of VR processing power, mapping photographic textures onto the surface of polygons and environment backgrounds may have the capacity to increase presence without sacrificing interactivity.

Higher Negative Effects scores in the active simulation did not support the first hypothesis but were given precedent in existing literature. Prior research has shown negative effects in VR to decrease feelings of presence, presumably as participants are distracted from the virtual environment as their attention becomes focused on their discomfort (Lessiter et al., 2001; LaViola, 2000). This effect highlights the influence that condition alone can have on presence, supporting previous research showing that active VR simulations, with their higher levels of interactivity, allow greater feelings of presence (Freeman et al., 2005; Schuemie et al., 2001). The influence of the other variables on general presence was also noteworthy. Consistent with past research (Lessiter et al., 2001; Schuemie et al., 2001), participant engagement and perception of realism influenced their sense of presence. While increased engagement may have increased feelings of general presence in the active simulation, higher Ecological Validity scores are likely to have had a similar effect in the passive simulation.

The second hypothesis, proposing that the active simulation would allow greater levels of skill improvement, was not supported, as no difference was found between post-simulation putting scores following the active and passive simulations. There was also no difference found between the baseline scores and post-simulation scores for either condition. As participants completed the putting assessment three times it is likely any improvements seen are due to practice effects. Although the active VR condition allowed participants to practice their putting in the virtual environment, skill improvement was not evident. This may be attributable to a lack of realism in the VR (Kaber et al., 2014; Zhang et al., 2016). Discrepancies that may have prevented skill transfer from virtual to real environment include the Oculus controllers not being the same weight as a golf club, and participants not receiving force feedback when they hit the virtual golf ball. As both conditions showed no skill improvement, these findings do not support the argument proposed by Lammfrood and Gopher (2011) stating that VR can improve cognitive aspects of a skill, and that this can be a sufficient precondition for skill improvement. One possibility is that more time was necessary for skill improvement to be demonstrated, as skill improvement becomes more evident when training and observation take place over an extended time period.

Aside from the technologies-specific issues that may have inhibited skills development, the fact that participants only came in for a single session was likely a considerate factor (Gray, 2017). Due to the expensive nature of VR, participants were not able to practice their skills for a longer period due to the methodological limitations of this research. Interestingly, many modern VR studies are limited to single-session exposure due to similar research limitations. However, as newer VR headsets offer more portable options for training and learning, it would be worthwhile to investigate whether participants experience a marked increase in skills development when VR training is applied in the longer term, and with greater consistency (e.g., daily training across several weeks). With the advent of portable technologies, researchers ought to consider the possible benefits of outside-the-laboratory VR training; although researchers will need to carefully monitor any confounding variables and ensure habitation occurs within VR if such an approach is taken in future work.

The third hypothesis proposed that presence would be associated with agency and skill improvement. This hypothesis was not supported. No significant correlations were found between any of the presence variables and agency in either the active or passive conditions. While the Spatial Presence scale and Total Agency tended to be higher in the active simulation, this relationship did not achieve statistical significance. Perhaps the link between presence and agency is not as plausible as may be assumed. Presence items focus on the individual perceiving himself within the virtual environment (Lessiter et al., 2001), while agency items focus on the perception of controlling one’s own actions, and how difficult those actions are to perform (Polito et al., 2013). With this distinction in mind, it is conceivable that a participant may feel engaged and present in the virtual environment, without necessarily experiencing a high sense of agency over their actions. Agency may also be reduced by the participant’s awareness that they are entering a manufactured environment.

| Table 4 | Correlations between ITC-SOPI scales, total agency and post simulation putting scores in the active VR condition. |
|---------|--------------------------------------------------------------------------------------------------|
|         | SP      | E       | EV      | NE      | TA       | PUTT     |
| SP      |         |         |         |         |          |          |
| E       | .24     |         |         |         |          |          |
| EV      | .41*    | .23     |         |         |          |          |
| NE      | .02     | .08     | .43*    | -       |          |          |
| TA      | .10     | .18     | .19     | .13     | -        |          |
| PUTT    | -.27    | -.24    | .001    | -.06    | .08      |          |
| Note: N = 23. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores. |
| *p < .05. |

| Table 5 | Spearman’s rho between ITC-SOPI scales, total agency and post simulation putting scores in the passive VR condition. |
|---------|-------------------------------------------------------------------------------------------------|
|         | SP      | E       | EV      | NE      | TA       | PUTT     |
| SP      |         |         |         |         |          |          |
| E       | .54**   |         |         |         |          |          |
| EV      | .49*    | .30     |         |         |          |          |
| NE      | .22     | -.001   | .43*    | -       |          |          |
| TA      | -.07    | -.29    | .29     | .24     | -        |          |
| PUTT    | .04     | .07     | -.06    | .04     | .03      | -        |
| Note: N = 23. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores. |
| *p < .05. **p < .01. |

| Table 6 | Spearman’s rho between ITC-SOPI scales, total agency and post simulation putting scores in the active VR condition. |
|---------|-------------------------------------------------------------------------------------------------|
|         | SP      | E       | EV      | NE      | TA       | PUTT     |
| SP      |         |         |         |         |          |          |
| E       | .45*    |         |         |         |          |          |
| EV      | .42*    | .16     |         |         |          |          |
| NE      | .09     | .04     | .47*    | -       |          |          |
| TA      | -.04    | -.17    | -.23    | .06     | -        |          |
| PUTT    | .26     | .20     | .02     | -.07    | -.21     | -        |
| Note: N = 23. SP = Spatial Presence scale, E = Engagement scale, EV = Ecological Validity scale, NE = Negative Effect scale, TA = Total Agency Scale, PUTT = Post simulation putting scores. |
| *p < .05. |
environment, created with implicit expectations and parameters concerning participant actions and reactions. An emerging challenge for VR simulations in both entertainment and training will be to grow participant agency, perhaps by increasing the diversity of experiences and behaviours possible in the environment, even where these are tangential to the designers’ expectations for the VR simulation.

Whilst no difference was noted in skills improvement between VR environments, the boarder issue of learning and behavioural entrainment is worth re-emphasising here. As participants were immersed in a VR scenario (despite active v passive conditions), there may have been additional benefits gained from taking part in a VR simulation, which we did not measure here. For instance, we were not able to establish whether participants experienced an increase positive affect towards real-life experiences on a golf course after the VR experience, even though we would anticipate that VR immersion can facilitate increased self-confidence towards comparable real-world tasks (i.e., whether a tangible skills gain/loss is apparent). Such factors related to learning more broadly are worth investigating in future work that broadens the narrow band of investigation centred on quantitative skills acquisition and performance improvement.

In light of the findings here, limitations need to be considered. One limitation was that fundamental differences between the two VR simulations may have confounded results. The 360° video was a recording of a real golf course, while “Cloudlands VR Minigolf” was an animated simulation. The simulations also differed in length. These differences between the simulations likely affected participant perception of the two virtual experiences. In order to fully account for these variables, two parallel-form simulations with identical, or at least similar, appearance and duration would need to be created to avoid inconsistent outcomes and possible priming. An additional limitation results from the time participants could practice. Had participants been given an opportunity to take part in numerous trials across a period of weeks, the impact across conditions may have been more evident. On that point, some participants could have been experienced golfers prior to partaking in the experiment, which may have created unnecessary confounding of variables. The inverse is also possible, that participants had never attempted to play golf or minigolf in the past, which may have led to wide individual differences in the data. Future work can address these issues by examining standardised VR scenarios, by implementing a repeat-session design, and by screening participants for skill level during recruitment.

The ability to generalise the VR skills training results must also be considered. While this study's findings show that VR was unable to improve the skill of putting a golf ball, these same findings may not apply to all virtual skills training. Several things must be taken into account including the VR platform used, the skill trained, and length of the training period. Studies that use different VR interfaces or navigation methods or have training periods of a different length may find different results. VR may also be more suitable for training specific skills as these can be performed more realistically in a virtual environment. Due to these inconsistencies in can be difficult to compare VR skills training across studies, and with VR technology and research both in their infancy, it is possible that there are important parameters influencing presence, agency, and training that have yet to be identified.

The open-ended, generative findings of the present study make it clear that future research is necessary to further understand how presence and agency can enhance skill training within a VR environment. This study’s findings add to the existing knowledge base concerning factors influencing presence and agency in VR, and supports previous literature showing that eliciting active participation in VR has the capacity to increase these important elements of the virtual experience. Exploring the relationships between agency, presence, and skills acquisition will become ever more important as the complexity of VR software and hardware evolves to closer meet the demands of real-world performance-graded tasks found in sports psychology and beyond.

Declarations

Author contribution statement

J. Piccione: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

J. Collett: Analyzed and interpreted the data.

A. De Foe: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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