Virtual reality training: Making construction work safer

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ABSTRACT

The Construction Industry damages over 60,000 underground services each year, a significant cost and risk to human life. Training is an established aspect of safety management, and research recognises the importance of interaction and engagement to enhance the training experience and increase knowledge retention. Despite this, often training sessions are delivered via traditional presentation – an approach lacking in the focus on engagement for a positive impact on learning outcomes. The use of virtual reality technologies within a safety context is becoming more commonplace, but there is limited evidence that this type of training intervention can improve safety performance with a reduction of accidents and incidents. The work presented evaluates the effectiveness of 360° film and virtual reality technology as a safety training intervention delivered to workers on construction projects.

This study has evaluated the impact of this safety intervention on the number of service strikes for one principal contractor organisation over a two-year period – a case study. Services strikes are when workers accidentally dig through underground utilities. The delivery of 85 training sessions was found to have a positive impact on safety outcomes, with a 32% reduction of services strikes following 12 months of training. It is concluded that the use of 360° film virtual reality technology as part of a safety training intervention can have a significant impact improving safety outcomes.

KEYWORDS

Safety, Virtual Reality, Construction Industry

Introduction

Damaging underground services is a significant problem for the Construction Industry with over 60,000 service strikes reported each year (USAG, 2016) resulting in damage to utility supplies and/or physical harm to the worker(s). USAG (2016) also stated that *"behavioural issues are showing increasing importance",* thus recognising the need to make improvements amongst the behaviours of those working around underground utilities to prevent such damages and harm occurring.

Health and safety legislation, such as the Health and Safety at Work Act 1974, recognises the importance of training as a component of good safety management. Therefore, it should be no surprise that training is one of the most commonly implemented interventions for companies seeking to improve safety. Clarke and Flitcroft (2013) recognise that whilst there is much research into the value of safety training, there is much less relating to the longer-term effectiveness as an intervention to improve safety.

The Kirkpatrick Evaluation Model (Kirkpatrick, 1998) is a widely accepted approach for the measurement of training effectiveness. This comprises four levels to determine the effectiveness of

a training programme: level 1 – reaction, level 2 – knowledge/learning, level 3 – behaviour, and level 4 – results. A review of training evaluations (Erskine, 2002) identified that most measurements are taken at level 1 only, with fewer evaluations conducted at levels 2, 3 and 4. This study seeks to measure the impact of virtual reality safety training at level 4 – the impact on safety performance outcomes. Evaluations of levels 1, 2 and 3 are included within another separate study.

Virtual reality (VR) describes an experience that is close to, but not completely reality. The majority of VR applications for training purposes are based on computer-generated training environments. However, this study uses 360° digital film rather than computer generated imagery, as this provides a more realistic user viewpoint and greater immersive experience, viewing 360°. Studies have found that the use of VR technologies are more realistic and involving; where involvement plays a key role in transmitting information effectively (Lanzotti et al., 2018). Lanzotti et al. (2018) also states technology that allows workers to experience a simulated hazardous environment in a safe scenario helps increase concentration and speed up the learning process. Research by Sacks et al. (2013) within the construction industry identified that VR training was more effective in terms of maintaining participants' attention and concentration, than traditional safety training approaches.

This study specifically evaluates the impact of a 360safeVR training module on safety outcomes within the construction industry. 360safeVR is unique partnership between industry leading safety experts and award-winning film makers. The aim of the study is to evaluate the use of VR technologies, as part of a wider safety training programme for the activity of working around underground utilities within the construction industry. The study objectives are to explore the effectiveness of 360° film viewed on VR headsets, and to establish whether delivery of VR safety training is effective at reducing the number of service strikes within a case study.

Methodology

Study design

The study design is in two parts: training delivery and evaluation of safety outcomes.

A 360safeVR training module 'working around buried services' has been delivered for one principal contractor organisation, in addition to the industry standard training. The content of the 360safeVR digital film was a reconstruction of a service strike accident in line with HSE guidance HSG 47: Avoiding danger from underground services. Each training session was delivered by a member of the principal contractor safety team who had been trained by 360safeVR in use of the technology and training delivery. Training was delivered in one-hour sessions to a maximum of eight individuals. Several sessions could be held on any given day. Projects where training was undertaken were chosen by the principal contractor due to the scope of construction work being undertaken and the relevance of the training module contents for the training delegates. A total of 85 of the same VR safety training interventions were held across the business, attended by a total of 619 individuals. This was around 60% of individuals working for the principal contractor undertaking digging around underground utilities.

Those who attended the training sessions were a mix of principal contractor employees, client representatives and those employed by supply chain organisations on the specific projects. The individuals undertook a variety of roles on the projects from management to plant operators. These were sourced by the project manager for each project, based on availability to attend on the date of training delivery.

Each project reported the number of 360safeVR training sessions delivered and the number of service strikes in an excel document. If there had been other interventions applied on a project to

reduce the number of service strikes, these were also recorded. This data was received by the central safety team and collated into spreadsheets over a twelve-month time period from June 2018 to May 2019. Service strike information was also available for the twelve months prior to the introduction of VR safety training from June 2017 to May 2018. The number of employees was also available for each time period. This information was collated by the central safety team, each project and the whole business using excel spreadsheets, which were shared with the researcher.

Analysis and results

The analysis was undertaken to establish the changes to the service strike incident rate following the delivery of VR training sessions. This involved a comparison of service strike data for two years (before and after VR training).

Safety performance is often measured using accident frequency rates (Cameron et al., 2007). This calculation is commonly used across the construction industry to compare safety performance. The number of accidents is the dependent variable, and the number of employees is the independent variable. This gives a measure of the safety performance normalised by the number of people employed. This study adapted this calculation to capture number of service strikes rather than reportable accidents (calculation 2) for the two-year period June 2017 to May 2018, and June 2018 to May 2019. Reportable accidents are as defined within RIDDOR 2013.

Table 1 shows two calculations:

- Calculation 1 is the standard equation for measuring safety performance (based on the number of reportable accidents). This is included for illustration purposes but not actually included within this study.
- Calculation 2 shows how calculation 1 has been updated to compare number of service strikes. The number of service strikes is the dependent variable, and the number of employees is the independent variable.

Table 1: Calculations used in analysis to determine accident/service strike frequency rate

Calculation 1 – Accident Frequency Rate	Calculation 2 – Service Strike Frequency Rate
$\frac{\text{Number of reportable accidents}}{\text{Number of employees}} \times 100{,}000$	$\frac{\text{Number of service strikes}}{\text{Number of employees}} \times 100{,}000$

During the time period June 2018 to May 2019 there were 31 service strikes in comparison with 45 strikes in the previous 12 months which is a 32% reduction in strikes. The results show a lower service strike frequency rate of 16.66 at the end of May 2019 after the VR training has been introduced compared with 25.49 for the twelve months prior to the VR training commencing.

Discussion

This study has found that the use of VR for the application of safety training can have a positive impact on safety outcomes, with a 32% reduction of service strikes following twelve months of training sessions delivered by a principal contractor across their construction projects: a service strike frequency rate of 16.66 at the end of May 2019 compared with 25.49 at the end of May 2018.

One factor in achieving such positive outcomes is attributed to the use of 360° film rather than computer-generated imagery, which enhances viewers' ability to transfer training content to day-to-day work activities, with the reality of the work environment being an important factor in delivering effective safety training. Salas et al. (1999) reports this is an advantage to using VR technologies for safety applications. A key factor in this, is that the viewer cannot be distracted, or disengage from the film whilst wearing the headset. With a conventional safety training, some distractions would be

expected (individuals checking their mobiles, looking away from the screen or presenter, talking amongst themselves, etc.), but with using VR headsets, participants are entirely immersed in the film, so are completely engaged for the whole duration.

Overall the sample size is good over a longitudinal study of twelve months with 85 VR training sessions attended by 619 individuals. However, this study was based on a case study for one principal contractor, therefore this organisation may not be representative of all other organisations working within the construction industry.

There may be other factors prevalent within this organisation that affected the number of service strikes, such as the prevailing safety climate or other safety interventions. These were excluded from the scope of this study due to the complex nature of studies involving safety interventions where obtaining reliable data is a challenge.

The aim of the study was to evaluate the use of VR technologies as part of a wider safety training programme for the activity of working around underground utilities within the construction industry. For a case study, the delivery of 360safeVR working around a buried services training module has been effective at improving safety performance and reducing occurrences of service strikes over a twelve-month period by 32%, supporting previous research findings by Lanzotti et al. (2018) and Sacks et al. (2013).

In further studies it would be worthwhile evaluating a combination of safety interventions as well as comparing data across a number of different organisations delivering 360safeVR training modules across a number of different principal contractor-led construction projects.

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