VIRTUAL REALITY
The New Pathway for Effective Safety Training

By Michael W. Norris, Kristen Spicer and Traci Byrd

WORKERS AROUND THE GLOBE share a common goal: to return home at the end of every workday. One of the many tools used to ensure that this goal is achieved is safety training. Effective training, especially that which gives workers the tools and skills to identify and assess job risk, is essential to worker safety. Many organizations use hands-on or on-the-job training to increase the effectiveness of safety training programs. When considering highly hazardous industries such as heavy industrial construction, power generation and petrochemical, the need for effective training is heightened.

Serious concerns regarding the effectiveness of training have haunted several industries but none more than the construction industry. Tam and Fung (2011) cite inadequate safety training as a contributing factor to the high number of incidents in the construction industry. Also, in 2011, Wilkins (as cited in Sacks, Perlman & Barak, 2013), having concerns for the quality of construction safety training, "surveyed 105 construction laborers who had taken the OSHA 10-hour construction safety training course and the results showed overall dissatisfaction with how the course was taught." Wilkins "stressed the need for training to be subject sensitive for trainees, to be conducted by a trainer knowledgeable on the specific task or tasks relevant to the trainee, and to utilize tangible material that is comprehendible."

The dilemma of effective training becomes convoluted when the issue of human error is considered. "Human error has been considered as one determining factor in up to 80% of occupational accidents in the aviation, petrochemical, healthcare, construction, mining and nuclear power industries" (Garrett & Teizer, 2009). In 2005, Haslam, et al. (as cited in Zhao & Lucas, 2015), reported a significant percentage of construction incidents were attributed to worker unfamiliarity with hazardous situations. How do organizations provide safe and effective employee training on specific tasks or functions without directly subjecting employees to the associated hazards? The answer may come in the form of an emerging technology known as virtual reality (VR).

KEY TAKEAWAYS
- This article explains the concept of virtual reality.
- It describes the use of virtual reality and its impact on safety training.
- The authors discuss the advantages and disadvantages of virtual reality safety training, and explain the implications of this technology for OSH professionals.

What Is Virtual Reality?

According to Sacks, et al. (2013), "VR is a technology that uses computers, software and peripheral hardware to generate a simulated environment for its user." Mujber, Szecsi and Hashmi (2004) say that "VR falls into three main categories, namely, nonimmersive (desktop), semi-immersive and fully immersive systems." Nonimmersive VR closely resembles a traditional video game. Semi-immersive VR systems closely resemble the typical flight simulator in which users are placed in a chair or room and presented with screens or monitors relaying 3-D images. A semi-immersive VR setup may also utilize the application of the cave automatic virtual environment (CAVE). This includes the use of projectors to relay images on at least three of the walls in a room. The user is still aware of surroundings outside the virtual environment. Fully immersive VR is a computer-generated environment that gives a person a sense of being within an alternate environment by engaging multiple senses, which removes the perception or awareness of the real environment. A fully immersive VR system generally surrounds the wearer using a head-mounted display, reducing or removing signals from the physical environment and increasing the sense of presence within the VR environment. Via the heads-up display, a 3-D visual environment is relayed and the user's location and orientation within the virtual environment are tracked so that the virtual scene can be updated as the user moves through the virtual environment. Fully immersive VR also allows the user some ability to control objects within that virtual environment (Mujber, Szecsi & Hashmi, 2004).

All three variations of VR have appropriate times of use depending on the specific applications and needs of the user. Nonimmersive or desktop VR training systems are compatible with most laptops and still offer high levels of interaction. Desktop VR training is beneficial when training must be accessible by anyone in the organization from any location and when access to equipment required for higher-level VR systems is not readily available.

Semi-immersive VR is a useful tool for large groups. A semi-immersive system allows for the full immersion of one user while other users observe. The fully immersive VR system is extremely useful for singular interaction of highly detailed tasks or settings. The ideal scenario for users to receive the full benefits of VR would be to fully immerse a user group allowing all participants to interact with each other as well as objects within one virtual environment.

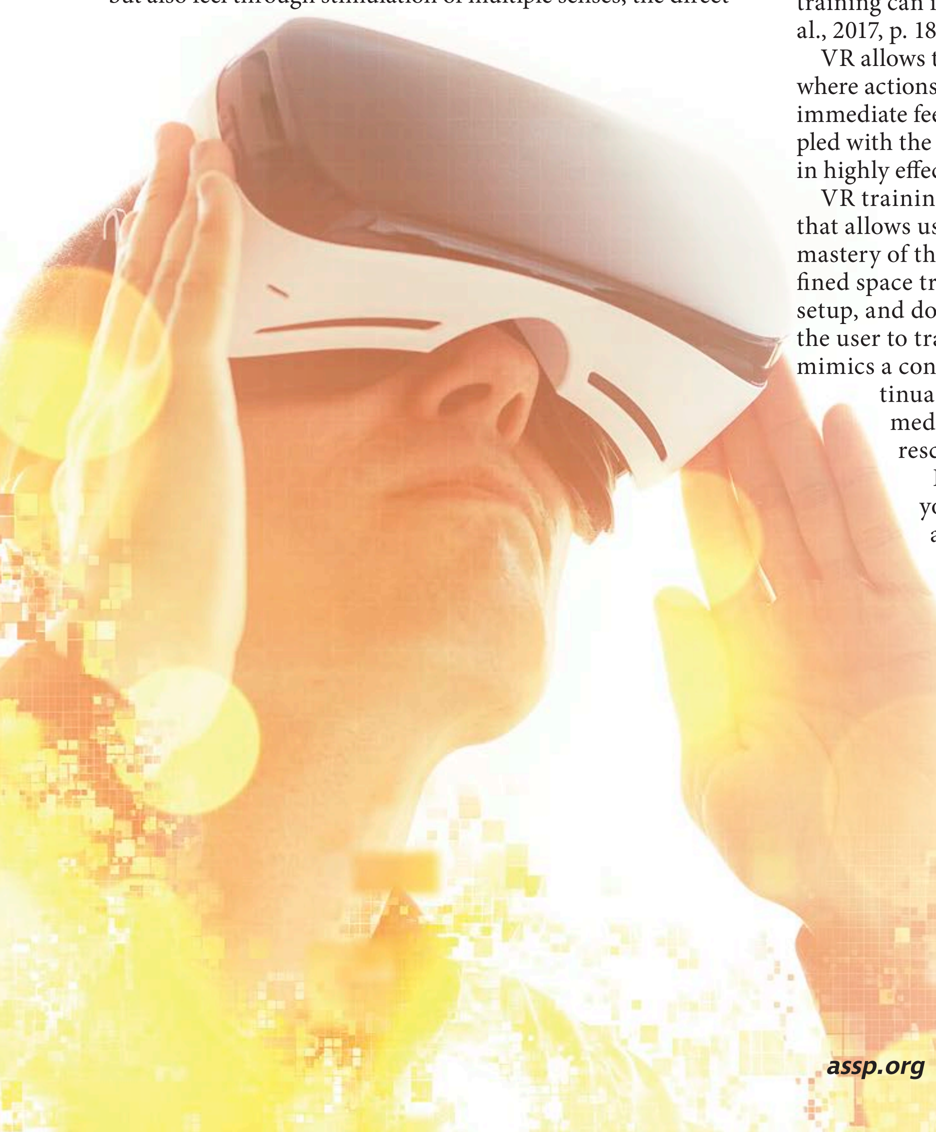
VR Safety Training

The purpose of a VR-based safety training program is to offer a safe working environment where employees can effectively rehearse tasks and ultimately to promote their abilities for hazard recognition and intervention (Zhao & Lucas, 2015). It allows training through the experience of failure without suffering possibly life-changing consequences.

Safety failures (e.g., injuries, fatalities, near-hit incidents) have served as what-not-to-do examples and have been used to improve safety programs in most industries. VR scenarios wherein employees can experience failure without real-time penalties or costs can be one of the most valuable training tools as it provides firsthand knowledge of circumstances that cannot easily be replicated in a classroom setting. From failure, employees not only gain a better understanding of job tasks and the associated risks, but also often place an even higher value on safety procedures and have greater retention of training objectives.

VR scenarios provide employees an opportunity to gain firsthand on-the-job experience. VR affords trainees an opportunity to practice identifying and assessing hazards and risks in specific tasks and scenarios that closely mimic the real-world scenario or task, thereby bridging the gap between classroom-conducted safety training and real-world, on-the-job hazards.

The ability to identify risk is something workers hone through years of work experience. VR offers an opportunity to expedite that process and allows an organization to cultivate a workforce whose experience in hazardous situations is both robust and varied. VR also offers the potential for workers to not only see but also feel through stimulation of multiple senses, the direct consequences of hazardous actions. These low-probability, highly hazardous virtual scenarios allow users to develop a default appropriate response in a completely safe environment, a default response that would not be possible to teach safely without this technology. VR allows this scenario to become reality through the repetition of hazardous situations without the undesired outcome of risking workers' safety and health.



Advantages of VR

As noted, the advantage of VR training over conventional methods of training is that it affords the user the ability to experience hazardous situations while never compromising his/her safety and health. Beyond this, there are many other clear advantages to VR training, especially when compared to conventional methods of safety training. Chao, Wu, Yau, et al. (2017), cite a number of researchers whose investigations have shown the many and varied advantages of VR training.

> Lin, Ye, Duffy and Su (2002) listed high interaction, less restrictive space, repeatability, flexibility and low cost to be among the advantages of the VR training method. Osbery (1995) and Bhagat, Liou and Chang (2016) proved that VR could increase the motivation of users and cause them to focus more on learning.

Following the 2010 research of Duarte, Rebelo and Wogalter, "Cates, Lonn and Gallher (2016) showed that using VR in training can improve performance by 17% to 49%" (Chao, et al., 2017, p. 187).

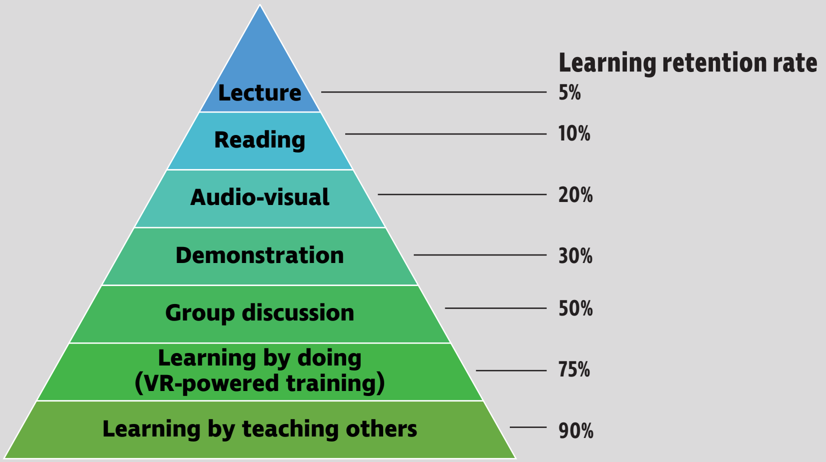
VR allows the user to interact in a virtual environment where actions have programmed consequences resulting in immediate feedback to the user. This immediate feedback, coupled with the ability to affect the virtual environment, results in highly effective training.

VR training systems use programmed gaming technology that allows users to repeat training sessions until they achieve mastery of the task or materials. For example, hands-on confined space training can require tremendous preparation and setup, and does not allow for efficient repetition. VR allows the user to train in a virtual environment that effectively mimics a confined space scenario and could allow for continual air monitoring training for confined space immediately followed by an emergency confined space rescue scenario.

Placing workers in a virtual "it can happen to you" scenario allows trainees to experience hazardous situations in real time, making training more meaningful (Zhao & Lucas, 2015). With the flexibility offered by VR, safety-training programs can be tailored to meet the safety training needs of almost any industry and simulate innumerable environments and scenarios. The possibilities are only limited by imagination.

VR also boasts the ability to accurately simulate less visible or tangible hazards such as radiation, electricity and gasses (Nedel, de Souza, Menin, et al., 2016). This ability is key because of how difficult it can be to properly train workers on these less visible hazards. VR provides users an environment in which they can develop their skills to recognize and respond to situations in which less visible hazards may be present.

FIGURE 1
LEARNING RETENTION RATES



Note. Adapted from Learning Pyramid, Alexandria, VA: NTL Institute for Applied Behavioral Science.

Disadvantages of VR Training

While many advantages of VR training exist, there are drawbacks for trainers and trainees. Users of some VR training systems have reported side effects similar to motion sickness, known as "cyber-sickness." Cyber-sickness can occur when there is conflict between the vestibular system and visual perception mechanisms of the body. Other side effects of VR can include vertigo, ataxia, disorientation, headache, eyestrain and nausea (LaViola, 2000).

A less documented yet potentially realistic disadvantage of VR training are the challenges associated with an aging workforce. In a recent study, researchers acknowledged the average age of trainee subjects (almost all in their early 20s) might have resulted in an undesired correlation to positive VR results as people in this age group are familiar with computerized learning and, therefore, are better at utilizing computerized training methods (Sacks, et al., 2013). Older trainees unaccustomed to computerized learning systems could struggle with VR safety training, resulting in poor training outcomes.

VR scenarios are only as useful as the programming that created them. This programming may lack flexibility, particularly for off-the-shelf VR training modules. It can be expensive to develop company-specific or site-specific VR training programs. The benefit of exposing workers to virtual hazardous scenarios for training purposes is only a benefit if the knowledge of the hazards of a situation is effectively developed into a virtual scenario.

Finally, as with any computer-based training, technical issues including software functionality can always present unwanted challenges. A learning curve exists for trainers using VR technology, not only with learning the software and developing the skills to use it for training purposes, but also with troubleshooting potential hardware and software issues as they arise. While these potential disadvantages have been noted, they are not likely significant enough to warrant avoiding the use of VR technology for safety training.

VR Compared to Conventional Training Methods

Limited research has been conducted comparing the benefits of VR safety training to that of conventional methods. However, recent findings have shown the benefits of VR safety training often outweigh those of conventional training methods.

Guo, Li, Chan, et al. (2012), investigated the possible contribution of the VR platform when used for safety training in a construction environment. Comparisons were made between conventional training methods to those that utilized the VR platform via interview and questionnaire surveys. The survey results show clear advantages of the VR platform over traditional safety training. Guo and colleagues cite the main benefit of the VR platform as its ability to simulate the true environment of the worker.

Sacks, Perlman and Barak (2013) conducted a study testing the hypotheses that "safety training in a VR construction site would be feasible and more effective, in terms of worker's learning and recall in identifying and assessing construction safety risks, than would equivalent training using conventional methods." Study results indicated VR training to be more beneficial than conventional training methods in various areas. Researchers noted higher levels of engagement along with opportunities for direct, yet safe, exposure to hazardous environments allow for real-time interaction and feedback that ultimately reinforce trainee learning.

A study by Zhao and Lucas (2015) illustrates the gap between current training program results and industry expectation on safety. The offered solution to narrow the gap "demonstrates the development and utilization of a training program that is based on VR simulation" (Zhao & Lucas, 2015). The study focuses on the aspects of human error, postulating that VR can be used to reduce the opportunities for error. The results of this study suggest that VR simulation for training and testing has the potential to reduce injuries and fatalities.

Chao, et al. (2017), set out to "investigate the effects of VR training and traditional training methods (technical manuals and multimedia films), on training performance and mental workload." Subjects for this investigation were university students ranging in age from 19 to 27 years old. Researchers found VR training to result in lower levels of mental workload when compared to traditional training methods. The researchers suggest the resulting lower mental workload can be attributed to the ability of the VR training system to present abstract ideas in a more concrete manner. Allowing for better interaction between trainees and training material. Again, this shows that high-engagement training involved in VR results in a workforce that is better prepared to face the real hazards and risks associated with job functions.

Lastly, Tyson Foods, front-runners in the food processing industry, recognized the need to better prepare its workforce to meet the stringent safety requirements necessary for the safe use of equipment and food handling. After exploring several training avenues, the company set out to reduce injuries within the workforce by 15% through the use of VR training. The company began working with STRIVR, an immersive learning and training VR provider, and in 2017 "experienced more than a 20% reduction in injuries and illnesses compared to the year prior" (O'Donnell, 2018). Further, 89% of Tyson's workforce reported a higher level of preparedness and readiness for work after participating in the VR training (O'Donnell, 2018).

In each of the studies noted, researchers found that VR safety training was more effective than conventional training methods (Figure 1). VR training offers higher engagement training, better learning experience, higher retention of material and better training of complex tasks. This is made possible because of the virtual training environment's ability to introduce hazards and risks in a way that closely portrays the real on-site environment without compromising the safety and health of trainees.

Feasibility

In the early stages of VR development, it was extremely costly and required immense time and effort to create usable scenarios for training. With today's gaming technologies and software support systems, the cost and developmental timelines have decreased significantly no matter the level of immersion. The cost of equipment varies from $2,000 to $3,000, depending on the desired immersive VR setup. Other costs can be incurred if the user desires a CAVE setup, in which projectors and screens are needed.

The hidden costs of VR safety training may lie in the software design processes of the virtual environment. Not every organization has the time or resources to design or code software for the virtual environment. The best option may be to contract with a company that specializes in this field and is able to create scenarios tailored to the specific organization or tasks within the organization. However, the use of gaming engines is streamlining this process making it more efficient. While creating the software for the virtual environment may be seen as an obstacle for smaller organizations, the technology is growing rapidly, so further accessibility to that technology may surface, similar to the increase seen in accessibility to other equipment necessary for VR training. Furthermore, off-the-shelf training software and VR applications are growing in availability; ASSP currently has a VR fall protection training app available for purchase for only $500 (ASSP, 2018), and more of these packaged products are becoming available.

Implications for the Safety Professional

Many VR training systems have been developed to train machine operators or provide training on specific operating tasks. There are seemingly no bounds to the implementation possibilities of VR training. It can be used to train workers on hazards associated with confined spaces or simulate the lockout/tagout process of a highly complex system involving multiple energy isolation points without placing the worker in an unsafe environment.

VR can be used to help managers or engineers better understand how safety is incorporated in certain processes. VR can allow safety professionals to simulate the consequences of actions in real time, which could lead to better overall employee work performance throughout the organization. VR can be the training tool that drives employee engagement and fosters a more positive safety culture. VR allows the safety professional to better illustrate why certain standards, regulations and best practices are in place. Through the use of VR, the safety professional can create a workforce that is highly experienced in recognizing hazards and assessing risk that may not otherwise have field or on-site experience.

VR safety training could serve as a vital function in the academic setting as well. A long-held notion has existed that learned curriculum in academia falls short of real-world experience. VR could offer safety sciences students an opportunity to refine assessment and decision-making skills in hazardous situations without real-world consequences, connecting academic theory and real-world practice better than ever before.

Conclusion

There is an opportunity for VR to enrich training programs in almost all industries. Enhanced safety training will only result in an improved workforce that has the ability to quickly and efficiently recognize hazards and assess risks. The gap between training and real-world scenario can now be bridged in a timely, cost-efficient and safe manner. This technology could ultimately save lives and all organizations should be looking at ways to implement it. **PSJ**

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