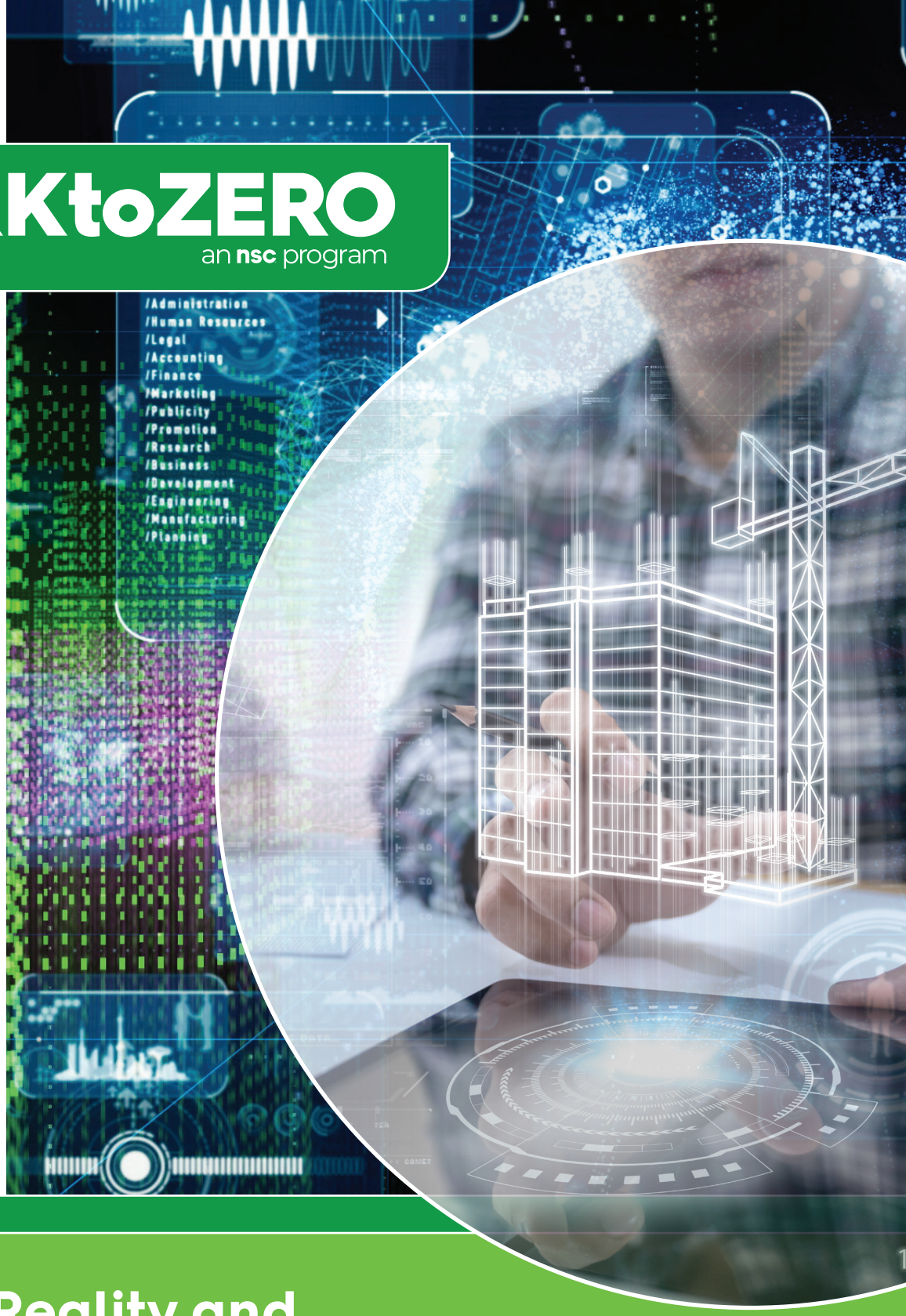
WORKtoZERO
an nsc program



Virtual Reality and Augmented Reality For Hazardous Work Training

National Safety Council

Executive Summary

Every year, lives are lost due to incidents that could have been prevented with proper training and awareness of workplace hazards (Zhao & Lucas, 2015). Between 2003 and 2011, construction workers accounted for 47.8% of all U.S. electrical fatalities, and over half of the relevant fatal or non-fatal incidents were ascribed to human errors (Zhao & Lucas, 2015). The objective of the Work to Zero initiative at NSC is to eliminate workplace fatalities through the use of technology. Out of the 18 top hazardous situations identified in the Work to Zero Safety Technology 2020 white paper, lack of training was earmarked as a systemic risk in every scenario (NSC, 2020). Effective training programs are believed to be the most direct way to mitigate human errors, and firms are increasingly leveraging Virtual Reality (VR) or Augmented Reality (AR) training to reduce these situational risks (Zhao & Lucas, 2015; NSC, 2020).

The intrinsic properties of VR offer an almost real-world experience in a harmless environment, allowing workers to train on potentially hazardous situations while remaining in the comfort and safety of a non-hazardous location. AR offers the ability to overlay correct procedures and real-time instructions onto hazardous tasks which can reduce risk and improve efficiency. Unlike VR, the AR interface does not interfere with the wearer's perception of the working environment, making it particularly well-suited for on-the-job and real-time training.

VR and AR technology has the greatest application potential for firms that rely heavily on comprehensive health and safety training. These firms sit in industries that primarily fall under OSHA's general industry classification, work heavily with highly hazardous materials, use vehicles for goods transportation and services, or operate and work with heavy machinery and equipment (Verdantix, 2019).

VR and AR training are found to be more effective than traditional classroom training programs and help improve knowledge recall and retention (Zhao & Lucas, 2015). Despite these benefits, demand for VR or AR for safety training is stymied by the high costs of the technology, cheaper market alternatives and ergonomics challenges from the Head Mounted Displays (HMD). The hardware and software for VR and AR for training are still in the launch phase of technological maturity. While they are not yet widespread workplace technologies, VR and AR for training represent promising business value and show strong potential to improve the effectiveness of training for hazardous work.

Introduction and Background

Work to Zero

Despite concerted efforts to reduce serious injuries and fatalities (SIF), workplace fatalities have not seen a drastic reduction in the U.S. Between 1992 and 2017, the OSHA (Occupational Safety and Health Administration) recordable injury rate dropped from 8.9 injuries per 100 workers to 2.8 injuries per 100 workers, a 67% decrease (National Safety Council, 2018). In the same time span, the workplace fatality rate (preventable fatalities) only dropped 26%, with 4,414 preventable workplace fatalities in 2017 (Bureau of Labor Statistics, 2018). Additionally, 5,250 total fatal work injuries were recorded in the U.S. in 2018, a 2% increase from the 5,147 in 2017, according to the U.S. Bureau of Labor Statistics. Between 2017 and 2018, the fatal work injury rate remained unchanged at 3.5 per 100,000 full-time equivalent workers. The expansive efforts by companies to reduce workplace injuries do not seem to translate into impactful reductions in workplace fatalities.

Recognizing this trend, the National Safety Council (NSC) kicked off its Work to Zero Initiative in 2019 – supported by a grant from the McElhattan Foundation – to focus on combatting the lagging decline in workplace fatalities and serious injury events. The end goal of the Work to Zero initiative is to eliminate workplace fatalities through the use of technology. Using decades of insight and data, and leveraging expertise of NSC members and networks, Work to Zero will identify promising technology innovations geared toward eliminating workplace fatalities within our lifetime.

Digital Technology as an Approach to Reducing Workplace SIF Events

In 2020, the Work to Zero initiative released its first white paper detailing the top 18 hazardous workplace situations (e.g. work at height, machinery operation, confined space entry) and associated situational risks (e.g. falls, struck-by, hazardous gas exposure). The report further identified the systemic contributing factors (e.g. lack of training, fatigue, work design) that can exacerbate risk within these hazardous situations. Next, NSC worked with Verdantix researchers to identify and map over 100 relevant EHS technologies that could help mitigate both situational and systemic risks. These risks were also mapped in ways that surveyed EHS professionals perceived to be most effective.

The initial Work to Zero report identified several key technologies that garnered the most interest and value among the surveyed professionals. In addition, safety leaders within the Campbell Institute at NSC have demonstrated interest in assessing and evaluating certain technologies, such as virtual reality, wearables, sensors and unmanned aerial vehicles (drones). This report is one in a series of reports taking a more focused look at specific hazardous risks and associated promising technologies.

Specifically, this report will look at the use of virtual reality (VR) and augmented reality (AR) for hazardous work training. It will explore the various use cases associated with VR/AR in the commercial, industrial and civil government sectors. Additionally, it will investigate the identified and proposed benefits of these technologies, as well as limitations and risks associated with adoption. Finally, this report will shine some light into the vendor landscape associated with VR/AR to educate readers on the market and offerings. In the context of training for hazardous work, VR use cases are better defined and thus VR forms the primary focus of this report, with supplementary information on AR also included.

Importance of Training for Hazardous Work

Health and safety training provides needed education and knowledge for job tasks, workplace hazards and personal safety in order to protect workers and firms. Such training is an essential tool across all industries and geographies, and a key regulatory compliance criterion. While many incidents can occur due to unsafe working conditions, the importance of identifying inadequate or non-existent training is often overlooked.

Out of the 18 top hazardous situations identified in the Work to Zero Safety Technology 2020 white paper, lack of training was earmarked as a systemic risk in every scenario (NSC, 2020). Furthermore, an NSC survey of 100 EHS professionals found that lack of training or supervision was one of the top three most relevant systemic risks for 10 of these situations (workplace violence, repair and maintenance, construction and installation, electrical work, emergency response, process safety operations, confined space entry, inspections, heavy equipment operation, excavation, hot work) (NSC, 2020).

Technological innovation has driven the emergence of Industry 4.0, which represents the overall transformation of industries into a digitized and technology-driven environment. VR and AR training are among a slew of new technologies helping to enhance worker health and safety.

Research Approach

The methodology of this paper consists of two actions:

1) Identification of case studies, clinical trials, and use cases for virtual reality and augmented reality for hazardous work training.

2) Development of a market landscape shortlist of relevant vendors associated with these technologies

Data for this paper came from literature reviews of several academic and industrial journals related to these technologies. Additionally, Verdantix researchers used case studies and interview data from previously published reports and interviews. The vendor shortlist was compiled through a search of Verdantix market databases and external research. Vendors were selected based on the size and maturity of the firm, relevance to risk area, demonstrable use cases and applicability to the U.S. market.

Overview of the VR/AR Training Market

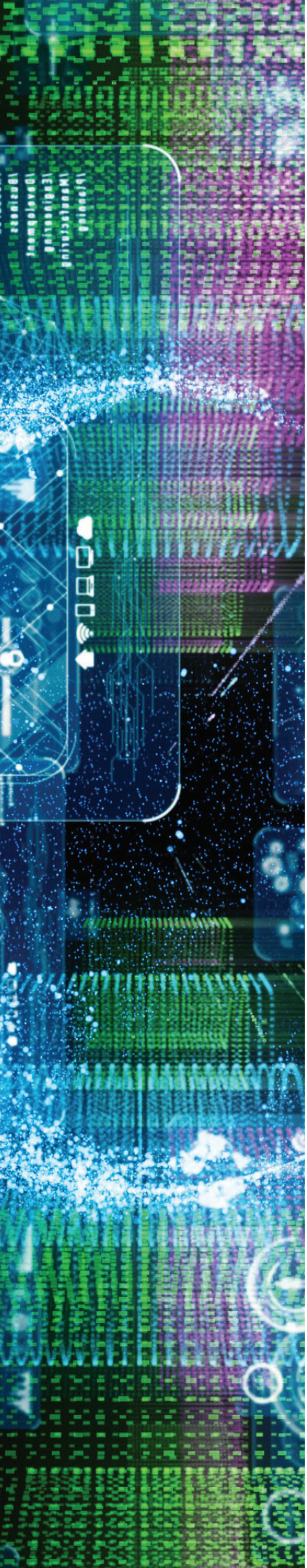
Technology Introduction

A virtual reality (VR) device immerses the user in an entirely computer-generated environment, but allows the individual to navigate the environment as if he or she were physically there (Verdantix, 2019). VR and related technologies can be categorized into five major groups based on the different use of visualization media and display platforms (Wang, et al., 2018):

- Desk-based VR uses a simple computer monitor as the platform and displays a 3D virtual world on a desktop screen without any tracking equipment to support
- Immersive VR relies on special hardware to withdraw users from the physical world and provides an immersive environment
- 3D game-based VR refers to computer-based, game-like training scenes through the integration of visual, interactive, network and multi-user operating technologies
- Building Information Modelling (BIM)-enabled VR relies on the model so users can access BIM data to simulate construction, processes and operations in an immersive, more detailed way

In comparison, augmented reality (AR), also known as mixed reality, is an interactive experience of a real-world environment into which sensory information (sound, video and graphics) are overlaid or augmented (Wang, et al., 2018). AR can enhance natural environments using a range of technologies including headsets, mobile devices, camera displays and video feeds (Verdantix, 2019). Compared to a VR environment, AR enables users to interact with objects — including modifying properties such as scale and position — that fit perfectly into the real-world environment (Wang, et al., 2018). Following the development of BIM, AR is now commonly adopted to support interactive visualization (Wang, et al., 2018).

Immersive VR and AR both use headsets, also known as head-mounted displays (HMD), to deliver their content. HMD are devices worn on the head or as part of a helmet, and have a small display optic in front of one, or both, eyes. There are many kinds of HMD in the market; the most common include unibody devices (such as the Oculus Rift and HTC Vive) or separated devices made up of a VR headset and smartphone (Zhang, 2017). For augmented reality, the devices typically are optical head-mounted displays (OHMD), which are transparent goggles or glasses that allow augmented content and digital information to be superimposed on the display. While augmented reality HMD devices have received heavy investment over the past three years, AR is at the beginning of its commercialization phase for the industrial safety environment. The launch of portable headsets has decreased the computing requirements of this technology, which has made VR/AR training more accessible (Verdantix, 2019).



Use Cases for VR and AR Training

While training is essential across all industries, VR and AR technology has the greatest application potential for firms that rely heavily on comprehensive health and safety training. These firms sit in industries that primarily fall under OSHA's general industry classification, work heavily with highly hazardous materials, use vehicles for goods transportation and services, or operate and work with heavy machinery and equipment (Verdantix, 2019).

VR's current market penetration is in the video game and entertainment industries, however VR training is also used to a certain extent by the military, medical and transport industries (Verdantix, 2019). While VR is not yet a widespread workplace technology, it is increasingly being employed as a tool to deliver safety training and entrench a consistent safety culture within the workforce as part of the broader EHS landscape (Verdantix, 2019). The intrinsic properties of VR offer an almost real-world experience in a harmless environment, allowing workers to train on potentially hazardous situations while remaining in the comfort and safety of a non-hazardous location.

AR has gained popularity over the last few years in mobile games such as Pokémon GO, but it can also serve as a useful tool for firms' risk management strategies. The ability to overlay correct procedures and real-time instructions onto hazardous tasks can reduce risk and improve efficiency. Unlike VR, the AR interface does not interfere with the wearer's perception of the working environment, making it particularly well-suited for on-the-job and real-time training.

Vendor Landscape

VR and AR for safety training sits within the broader market of digital safety training and can be segmented into hardware vendors and content providers, respectively. While VR and AR hardware is still nascent, there is growing competition among major brands such as Google, Oculus and HTC.

Many content providers develop training materials for both VR and AR deployment, although specialists are also active in the market. Vendors such as Atheer and Upskill have created AR enterprise platforms to manage, create and deploy AR applications to give customers a highly configurable experience. Other firms, such as STRIVR, have developed VR platforms allowing customers to develop bespoke training content to meet specific needs (Verdantix, 2019).

As this technology has provided demonstrable value for safety training over the past few years, many large eLearning firms, such as Vector Solutions and Convergence Training, have started to develop and offer VR and AR training software as part of their total training packages as they seek to capture additional market share (Verdantix, 2019).

Example Vendors

Vendor
Google
Microsoft
PTC
Trimble
Oculus VR
Valve
Vector Solutions
HTC Vive
EON Reality
STRIVR
Realwear
VectorForm
Vuzix
Ubimax
Librestream
Upskill
Atheer
Ethosh
Immersive Factory
Convergence Training

Color Code
AR Content
VR Content
AR and VR Content
AR Hardware Devices
VR Hardware Devices

Benefits of Leveraging VR or AR for Hazardous Training

Firms are using VR engagements to increase their health and safety compliance. For example, DHL requires all warehouse employees to complete an occupational health and safety training program. With a goal of reducing the risk of workplace injury, DHL deployed a VR tool that uses live-action animation to simplify complex tasks. The tool is easy to understand in any language and at any level. The results showed a 100% reduction in lost time due to injury, a 32% reduction in reported near misses and higher incident reporting rates, illustrating employees better understood how to report EHS incidents (Tag, 2020).

Though the technology is nascent and long-term studies are still required to validate initial findings, many existing studies have found that virtual reality training, on average, is more effective than conventional teaching methods such as visual aids and classroom training (Karakhan & Alsaffar, 2019). A VR training pilot by Walmart and STRIVR found that employees using VR reported 30% higher employee satisfaction, scored higher on tests 70% of the time and logged a 10% – 15% higher rate of knowledge retention than before VR training (Strivr Labs, 2020). Due to the success of the pilot, the retail giant has since rolled out VR training to the company's nearly 4,700 stores across the U.S.

VR safety training can allow workers to identify hazards and take necessary actions in a realistic and immersive simulated environment. VR provides a completely participatory and repeatable experience without the safety risks, which assists in improving retention and recall (Zhao & Lucas, 2015). Trainees can rehearse high-risk tasks, access all related hazards and experience possible consequences in real life, which promotes their abilities for hazard cognition and intervention in the field (Zhao & Lucas, 2015).

The benefits of AR wearables for training are their ability to be on-demand, hands-free and directly in the wearer's field of view. As a result, a worker can immediately retrieve a specific microlearning module exactly when required for the task at hand, or review equipment instructions and user manuals as needed (Verdantix, 2020).

Using VR and AR as the vehicle for safety training offers a range of benefits. This technology can suit a number of different learning styles while also offering efficiencies in training delivery (NAEM, 2019). Furthermore, in contrast to static applications, VR and AR content is dynamic by nature, and can be quickly adapted and consistently self-developed to better meet training requirements (Zhao & Lucas, 2015).

Risk and Considerations in Using VR or AR for Hazardous Work Training

Barriers to Adoption

A 2019 survey of 102 EHS professionals found that wearables for remote content delivery or mentoring are too expensive (28%), insufficient (27%) or simply unavailable (28%) (Verdantix, 2019). The biggest barriers to the adoption of VR or AR for safety training are the high costs and cheaper alternatives available in the market. VR and AR are two components within an expansive digital learning environment. Firms' investment plans are still focused on more traditional methods of safety training, such as eLearning and blended learning (a combination of in-person and online training), that can be more cost-effective and are widely available (Verdantix, 2019).

From a hardware perspective, AR faces a range of ergonomics constraints (Re, et al., 2016). The use of head-mounted displays can cause problems such as discomfort and poor depth perception (Rowen, et al., 2019). Furthermore, long-time use of HMD can also lead to fatigue and motion sickness (Zhang, 2019).

AR for on-the-job training runs the risk of distracting or overloading the operator with information during safety-critical tasks (Rowen, et al., 2019). Firms should work with their AR providers to ensure the right information is presented at the right time to the right person to mitigate this risk.

Limitations of the Technology

Although technological and design enhancements in the consumer AR HMD market have increasingly spread into industrial devices, the technology can still be bulky and unsuitable for use over long periods of time (Re, et al., 2016). Furthermore, current AR HMD show a narrow field of view that barely covers the operator's active view and fails to show the whole natural field of view (Re, et al., 2016).

Innovation in VR and AR software is closely tied to the maturity of the HMD market. As the display technology market grows, the requirements for VR and AR software will grow as well. Low adoption rates for AR and VR compatible technologies will hinder the growth of the associated software (Verdantix, 2019). Vendors are focusing on developing the ability for VR and AR software and applications to be used in any technology that has a camera and video display, which will permit more flexibility in using this software (Verdantix, 2019).

Conclusion and Future Direction

The goal of the Work to Zero initiative at NSC is to eliminate workplace fatalities through the use of technology. Initial research for Work to Zero undertaken by NSC shed light into the situational and systemic risks that play pivotal factors in workplace SIF events. Using expert interviews, NSC identified promising technologies to combat these high-risk activities. Of these technologies, VR and AR were of interest among survey respondents and NSC members.

Every year, lives are lost due to incidents that could have been prevented with proper training and awareness of workplace hazards (Zhao & Lucas, 2015). Between 2003 and 2011, construction workers accounted for 47.8% of all U.S. electrical fatalities, and over half of the relevant fatal or non-fatal incidents were ascribed to human errors (Zhao & Lucas, 2015). Effective training programs are believed to be the most direct way to mitigate human errors, and firms are increasingly leveraging VR or AR training to reduce these situational risks (Zhao & Lucas, 2015; NSC, 2020).

VR and AR for safety training have traditionally found their footholds in the airspace, military, transport and medical fields, but are increasingly being piloted and rolled out in a host of industrial settings. VR and AR training are particularly applicable to firms in industries that primarily fall under OSHA's general industry classification, work heavily with highly hazardous materials, use vehicles for goods transportation and services, or operate and work with heavy machinery and equipment (Verdantix, 2019).

VR has demonstrated value for safety training, as this technology enables workers to train on potentially hazardous situations while remaining in the comfort and safety of a non-hazardous location. Furthermore, AR provides the ability to overlay correct procedures and real-time instructions onto hazardous tasks, which can reduce risk and improve efficiency (Verdantix, 2020).

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The hardware and software for VR and AR for training are still in the launch phase of technological maturity. While they are not yet widespread workplace technologies, VR and AR for training represent promising business value and show strong potential to improve the effectiveness of training for hazardous work.

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