Investigating the Drivers & Challenges of Implementing Immersive Sensory Technology within Construction Site Safety

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Abstract

The use of immersive sensory technology for safety management is generally shown positively in academic literature. Many researchers have demonstrated applications of this technology for improving safety training in a risk-free environment. Despite the reported benefits and a global pandemic forcing the digital agenda, the uptake of this technology for this purpose remains slow. This study aims to investigate current drivers and challenges of implementing this technology for safety from an industry-based perspective. To achieve this, qualitative data was collected through 4 online focus groups involving 21 industry professionals working within the field. The findings identified that even amongst these experts, the technology was rarely implemented on projects specifically for safety. Despite this lack of adoption, participants agreed that if implemented correctly this technology has the potential to enhance site safety processes such as inductions, tool box talks and general safety training. The commitment to safety and legislative requirements were identified as key drivers, whilst deep rooted challenges surrounding client demand, costs and leadership dominated the discussion. The onsite practicalities, personal comfort and lack of digital skills were also identified as concerns if this technology was to be adopted more mainstream in safety training. Further recommendations are made to develop understanding of these specific challenges, including investigating the industry need and availability of specific skills in immersive safety applications. In addition, it is recommended that further empirical evidence including the impact of this technology when implemented for safety on projects is provided in literature.

Keywords
construction, immersive technology, safety.

1 Introduction

The construction industry remains among one of the most dangerous of all sectors. This is due in part to its high-hazard nature (Li et al., 2018), its traditional reliance on temporary works, heavy site plant and manual tasks which can be difficult to predict (Getuli et al., 2019; Li et al., 2015). These complex and dynamic environments are susceptible to accidents that can result in life changing

injuries or fatalities (Le et al., 2014). According to the HSE (2021) 39 fatalities were reported in Great Britain in 2020 / 21, more than any other major industry. The moral and legal drivers should place safety as top priority (Hughes & Ferrett, 2016); supported by investment and ongoing development of innovative tools and techniques to reduce risks. Whilst much can be commended regarding the industries safety improvements in recent decades, there is still a desperate need to develop and further reduce accidents on site.

Despite the construction sectors strides in digital transformation, the often repeated criticisms related to deep-rooted issues including the need to modernise are still a concern (Farmer, 2021). Even with mandated processes, forward-thinking organisations and a global pandemic forcing the digital agenda, the industry is still falling behind. Fast-paced global technological developments have resulted in high specification immersive applications (such as virtual reality) being an available and affordable option for mainstream use. Within the construction sector the potential benefits of immersive sensory technology for safety purposes has been subjected to research for many years (Swallow & Zulu, 2020a). According to Smith (2020) the construction industry is at "*a tipping point*" regarding the adoption of immersive technology, stating "*now is the time to start paying attention*". The use of immersive technology has generally been presented in a positive ligh t within literature, identifying opportunities in safety training and planning with increased engagement (Sacks et al., 2013; Swallow & Zulu, 2020b). The ability to carry out activities such as scenario based training in a risk-free virtual environment has been researched by many (Olugboyega & Windapo, 2019). Despite the reported benefits, the use of immersive technology in the industry is not widely adopted (Ghobadi & Sepasgozar, 2020). Whilst research has begun to investigate the general challenges to its adoption (Delgado et al., 2020; Ghobadi & Sepasgozar, 2020) few have focused on the industries perspective for its specific integration in safety management.

Therefore, this study aims to take an industry-based view of the current drivers and challenges to identify recommendations for implementing this technology for safety purposes. In order to meet these aims, qualitative data was collected through a series of online focus groups. These groups were made up of industry experts within construction who had varied exposure to its use. Through thematic analysis, key themes were detected throughout the qualitative data sets. This study identified safety legislative requirements and remote working were assisting in the adoption of this technology. However, the low demand from clients and lack of leadership were seen as root causes for its limited use. The need for skills and investment along with on-site practicalities were identified as specific challenges for its wider adoption in the field of safety.

2 Literature Review

For safety purposes, immersive technology offers an interactive, virtual risk-free environment which can be the ideal solution for training and to communicate safety risks. According to the NBS (2020) in the 10th annual BIM report, 38% of those surveyed are currently using virtual / augmented reality technology (although this is not specific to safety purposes). For many years, the use and effectiveness of immersive technology for safety has been questioned in the construction sector. Whilst the RIBA (2020) recommended that such technologies should be taken seriously, these are yet to be commonplace on construction projects (Delgado et al., 2020).

The low uptake of technology in the construction industry has led to much debate and the specif ic factors have been investigated by many researchers. Specifically related to the adoption of AR and VR, Delgado et al. (2020) carried out research into the factors that limit and drive its adoption in the construction industry. Using a combination of industry focus groups and online questionnaires, the study reported that the technology enabled improvements in project delivery however is limited due

to unsuitability and high costs. A similar aim was set by Ghobadi & Sepasgozar (2020) who also investigated issues that have prevented the widespread adoption of immersive technology within the sector. In this study, interviews with academics found that high costs, software and hardware requirements in addition to low accessibility were key barriers. Despite the number of studies that have investigated drivers and challenges of this technology, there is limited research from an industry perspective or specifically to safety applications.

3 Research Methodology

This research aims to explore an industry-based perspective of the current drivers and challenges to the implementation of immersive sensory technology for safety purposes. To satisfy the research aim, online focus groups were conducted to collect qualitative data from active industry professionals. Individuals within the fields of digital management, contract management, safety, commercial and design, were asked to take part to ensure views from across the industry were included. The use of focus groups for qualitative research is a reliable and popular method in many fields (Guest et al., 2017) including construction disciplines and in safety research. Online focus groups are similar in most aspects to traditional face to face aside from the virtual nature of the interaction (Nyumba et al., 2018). The choice of an online environment as a platform for data collection was primarily due to government lockdown restrictions. However, the use of modern online virtual platforms assisted in both the accessibility for participants (who otherwise my not have been able to attend) and the ability to accurately capture the group discussions.

The number and size of the focus groups is important to consider, taking into account research practicality and saturation. Guest et al. (2017) carried out research into focus group sizes, suggesting that an average number of groups needed to identify 90% of themes was 4.3. In relation to the size of these groups, McQuarrie & Krueger (2015) suggested that the ideal size is between five and eight per group as larger groups would limit the individuals to share their thoughts and observations. In this study, the recruitment process used selective sampling to ensure participants who engaged with the study had a minimum of 5 years in the construction related sector and held management positions. As shown in table 1, a total of 21 participants contributed to the study and were allocated into groups, each group included a range of roles, ages and experiences in order for participants to exchange interdisciplinary views. The focus groups began by participants providing a brief overview of their role and exposure to immersive technology when used specifically for safety purposes. They were then asked a series of pre-determined questions (Hennink et al., 2019) to explore their views on drivers and challenges within the sector. This allowed for discussions to be open, yet provided the structure to maintain the groups focus on the topic. These focus groups were recorded via an online conferencing platform with verbal discussions transcribed for accurate accounts and analysed using NVIVO 12 software. Deductive thematic analysis techniques were subsequently used, synthesizing higher level codes and clusters of codes under focus themes (Romigh et al., 2017; Vasilevski & Birt, 2020; Vieira et al., 2014).

Table 1 Industry Participant Summary

	Participant	Role	Years in industry	Number of employees	Adopting Immersive tech for safety?
Focus group 1	FG1 Participant 1	Architect	31-40	1-20	never
	FG1 Participant 2	Project manager	5-10	21-50	rarely
	FG1 Participant 3	Client project manager	31-40	Over 1,000	never
	FG1 Participant 4	Civil engineer	21-30	Over 1,000	never
Focus group 2	FG2 Participant 1	4D modeller / consultant	21-30	1-20	rarely
	FG2 Participant 2	4D modeller	5-10	21-50	never

	FG2 Participant 3	Innovation manager	5-10	Over 2,000	rarely
	FG2 Participant 4	BIM manager	5-10	Over 4,000	often
	FG2 Participant 5	Director project planner	11-20	1-20	rarely
	FG2 Participant 6	Planning / data consultant	5-10	21-50	rarely
Focus group 3	FG3 Participant 1	Contract's manager	31-40	51-100	never
	FG3 Participant 2	Commercial manager	11-20	51-100	never
	FG3 Participant 3	Contract's manager	21-30	21-50	never
	FG3 Participant 4	Quantity surveyor	11-20	51-100	never
	FG3 Participant 5	Company director	11-20	1-20	never
Focus group 4	FG4 Participant 1	Digital manager	11-20	Over 7,000	rarely
	FG4 Participant 2	Structural engineer	5-10	100-500	never
	FG4 Participant 3	Visualisation specialist	5-10	Over 2,000	rarely
	FG4 Participant 4	Head of digital	21-30	Over 40,000	rarely
	FG4 Participant 5	4D planning manager	5-10	Over 5,000	rarely
	FG4 Participant 6	Digital engineer	11-20	100-500	rarely

4 Findings and Discussion

As part of the focus group discussion, participants were asked to introduce themselves with a brief background of their role, size of organisation and whether they used immersive technology specifically for safety purposes. These initial questions identified that out of the 21 participants, only one had often used it, 10 indicated that it was rare and 10 had never used this technology specifically for safety. Subsequent questions and discussions focused on the drivers and challenges to the adoption of immersive technology for safety purposes. On analysing the transcripts two main themes were identified as drivers, and within challenges there were five themes. Organisational and industry were key across both, with challenges also including individual, technological and project based themes. Figure 1 illustrates these themes and their relationships to the transcripts, each of the five themes are presented in further detail with discussions taken from the focus groups.

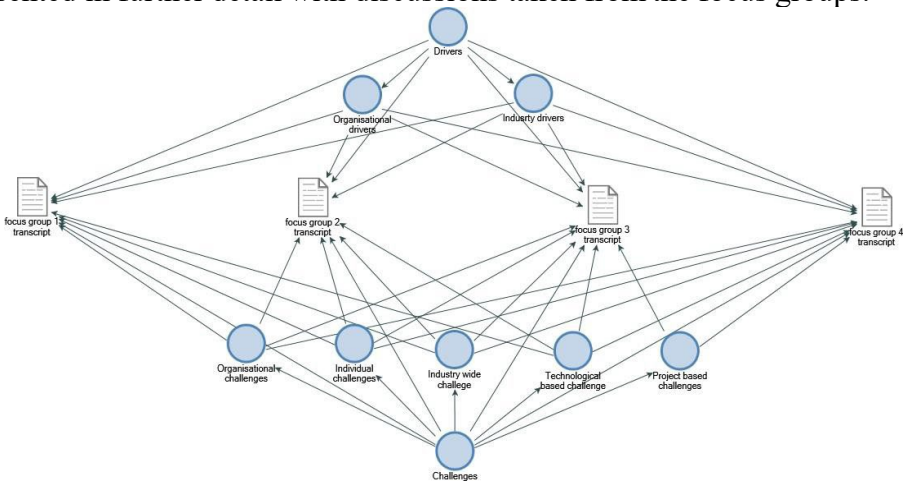

Figure 1 Drivers and Challenges focus themes

4.1 Organisational

This theme linked to drivers and challenges mainly surrounding organisational adoption. It was clear from the focus groups that immersive technology has much to offer in terms of integration within organisational safety management systems, such as "*you can use it for identification, and you can*

use it through management" (FG2 Participant 1). This said, many in the groups stated that the technology was not used for practical safety applications. For example, FG2 Participant 2 suggested "*…it was a bit of a gimmick to engage with the client, it was more of a sales pitch than actually a tool that was used for anything practical*" and FG4 participant 2 stated *"I have only worked for companies who buy a headset and have a desktop computer to run it but it was more of a gimmick and did not find a useful way of using it".* From these discussions in various groups it was clear that many companies have invested in the equipment however have not used this practically for onsite safety purposes, more as marketing tools. The benefits of immersive technology for safety was explored within the focus groups, for example FG1 Participant 4 stated:

> "*it will definitely have a role for safety - it is inevitable. For tool box talks this could support the verbal discussions, this illustrating it and them putting on the headset walking about in the digital world and spotting the potential hazards"*

The potential advantages of risk-free training was agreed by several participants, stating that organisations needed to be forward thinking in regards to their safety practices. Although participants unanimously agreed on practical uses of this technology for safety management, when it came to implementation the challenges for organisations dominated the discussion, with one participant suggesting "*It all comes down to cost, it's the cost time and resources*". In addition to costs, a lack of organisational leadership, investment and awareness were common themes stated by many, including:

> "*The people who pay for things in our industry don't really know what they are buying in innovation – they just see it as tech… it needs leadership. It needs someone to say "this is not a gimmick, we are actually going to plan our projects using these tools"* (FG2 Participant 1)

The financial implications associated with purchasing such equipment was directly referenced in every focus group. Participants also discussed this in relation to the size of the organisations, suggesting challenges are from both limited funds and due to a lack of skills in smaller companies. On this topic, FG1 Participant 4 stated "*they might not see it as necessary because of the costs associated. The smaller builder is concerned with making money on the project and see this as unnecessary work and costs*". Concerns around organisational resources and project costs were also highlighted, specifically discussing the use of immersive technology in common safety activities such as site inductions: "*it's the people to be able to manage it, to develop it, monitor it, to amend it. All of these people… who pays for them*?...*it would cost a fortune*" (FG3 Participant 3). Although, FG2 Participant 5 questioned the term 'cost' leading to a discussion regarding organisational commitment and investment to new ways of working, stating "*defining the purpose of it and seeing it as an investment rather than a cost. I mean how much do construction companies put into research and development? Nothing really*".

4.2 Individual

During the online focus groups many challenges emerged that often stemmed from an individual hesitancy to use the technology. FG4 Participant 6 noted "*There is still a reluctance to use it… and I can see as to why - that is as people are not comfortable going into that environment*". Links to personal comfort were discussed in focus group 4, mainly surrounding symptoms of motion sickness and vertigo whilst using VR. Reflecting on this, FG4 Participant 2 shared their experience "*Yeah vertigo, I remember I was put into a tower crane and it feels really high! It's scary! You know its fake but you don't want to edge too far forward*". Although many have recommended that these technologies be incorporated (RIBA, 2020) this study has found that some doubtful perceptions of this technology remain in the industry, for example FG3 Participant 2 suggested "*I think the big*

challenge in the uptake is changing that perception. Clearly this does have practical benefits, it is getting beyond that scepticism and selling it to people to show them what they can get out of it". The importance of individual perceptions was expressed by many, one participant furthered this by sharing their experience of purposeful implementation and the importance to maintain engagement, stating

> "*It depends on how it is implemented, because if it's a VR headset sat in a corner and you expect people to go and use it to check something – probably not. But if you are doing an induction or having a workshop or working through what your method of work is going to be and you are facilitating that, either taking people through an individual VR scenario or in a group where they don't necessarily have to do the driving then I think you would get more people engaging than leaving it in the corner as a novelty*" (FG2 Participant 6).

A resistance to change traditional safety processes (particularly in relation to site safety inductions) was further explored in all focus groups, from a site perspective several agreed that the common attitude is: "*we have always done it this way… we don't need the gizmos*" (FG2 Participant 6). Some also linked this to previous poor experiences using VR. For example, FG4 Participant 3 stated

> "*Its past bad experience isn't it. We are human and we always remember the bad stuff. I have had clients say to me that they hate VR 'I had a bad experience and felt really sick' but if you say that this one wont they often say 'oh yes it will I have made my mind up'*".

This reluctance was also specifically linked to the age of individuals. Comments included: "*you are going to get negativity, often from the older generation. They are just not going to buy into technology"* (FG3 Participant 3) and "*If we were to try and inject immersive technology into site safety processes, we will always get that backlash from site teams 'this is how we have always done it'*" (FG4 Participant 3). Increased technology usage following the government lockdowns was highlighted in many groups, FG1 Participant 1 argued that age is not a factor, stating "*necessity is the mother of invention, since I have been working from home, I have had to embrace technology. I think it's more the need rather than the age of people*". Considering the approach of mandating such technology on projects, FG2 Participant 6 suggested

> "*The operatives will probably interact with whatever environment they come into, so it needs to be those people to say - 'so this is how we manage health and safety here, we are going to walk you through this, we are going to expect you to do these things' then those who come onto that site have no choice but to engage with it*".

Although individual benefits were acknowledged, an interesting discussion emerged linking to long term behavioural effects of using this technology for safety training. FG1 Participant 4 stated "*relying on the technology could lead to complacency…youngsters are in danger of relying too much on the technology, without practical experience may leave themselves open to some of the risks that may exist*". Several participants agreed with this, highlighting the importance of experience and the need for practical based training in addition to virtual ones.

4.3 Industry-Wide

Industry wide codes captured a range of drivers including legislation and mandated processes as well as deep rooted challenges linked to culture, a lack of client demand and concerns around digital skills. The current use of technology within safety management was questioned with many participants referring to the industry as still in need of modernisation. To assist with skills, the need to draw in younger generations who have grown up with technology was highlighted. Many participants believed that outdated site processes may discourage some from wanting to start a career

in the industry: "*They will probably think they have stepped back in time to the 80 s, a bit of a time warp really. I think a lot of areas of the industry are behind compared to most industries nowadays"* (FG3 Participant 2). This slow adoption of new technologies within construction has often been linked to cultural issues and a resistance to change (Henderson & Ruikar, 2010). The wider concerns around the need to upskill the current workforce as well as the need to recruit new staf f was clear from participants responses: "*Not enough skills*" (FG2 Participant 5) and "*EVERY expertise its struggling with*" (FG4 Participant 1). The question of who should be skilled in this technology was also raised: "*on site you would want your health and safety teams to be the ones that are upskilled because they are ones delivering inductions etc, they're the ones who are driving health and safety* " (FG2 Participant 6). Due to a reported lack of skills within the industry, participants choosing to use immersive technology on projects had to outsource expertise causing higher level management to question these additional resources: "*we had to hire outside of construction, we had to hire a games designer…they would be saying "why do we need game designers? We are a construction company who pour concrete*" (FG2 Participant 1).

A lack of demand was highlighted as a core challenge by many participants who voiced concerns around the client paying for such technologies. For example, FG3 Participant 2 stated:

> "*a big part is the culture of the industry which is very much delivering projects. Clients are cost driven, if you have clients wanting the job done the cheapest way possible, they will not want to be paying a premium for technology which they see as non-essential*"

This said, the need for clients to take an active role in their duties under CDM 2015 were reinforced with comments such as: "*the Clients have responsibility for health and safety…its probably a reason for having immersive technology – it can prove that you have done way above and beyond what you can do to ensure safety*" (FG4 Participant 3). Participants also discussed that many contractors are now taking the lead in health and safety innovation without the demand from clients. FG3 Participant 1 suggested: "*Its new technology and they would lead on it more than the client or any mandatory requirement - because contractors want to reduce accidents*".

4.4 Technological

This theme focused on the readiness and use of the technology for safety purposes. Participants discussed the technologies used in their organisations, focusing on the applications and challenges. The use of virtual reality headsets was commonly identified as a tool used in training and logistics planning. Practicality challenges of this technology were discussed among the groups, with FG4 Participant 1 highlighting:

> "*The next challenge is doing this on mass, if you wanted to induct 30 workers … are you going to have 30 headsets? Would you have enough space to put everyone in a CAVE? Particularly with COVID. So don't get me wrong I think it's really good but it's the practicalities around it*".

Limitations around isolating individuals in headsets were also discussed in many of the focus groups, with the benefits of alternative forms of immersive technology identified: "*I think BIM CAVEs are more effective for training people to bring them into one space rather than isolating someone with a headset on*" (FG4 Participant 4). The cost of these technologies was also identified as a challenge in addition to the accessibility, particularly if used for site safety training. Further ways to integrate immersive technology onto site were shared and compared to other methods such as mobile phone apps. Many were also concerned of the investment into fast-moving technology, for example FG4

Participant 6 stated "*We are not ignoring virtual reality, but we are not sure how long that will last in our business for – it might be there currently but maybe not in a year or two years' time*".

4.5 Project-Based

These codes formed a theme focused on project-based challenges, specifically in reference to the practicalities of using immersive technology for safety inductions and project-based training. In the discussions cost was again highlighted as a key challenge. This referred mainly to smaller projects, with concerns raised around the financial investment and budgets. For example, one participant stated "*I don't know if small scale projects would have the capacity or funding to do it in the first place*" (FG4 Participant 3). Participants spoke of the need for value from investment, for example FG3 Participant 1 suggested "*on smaller sites this type of investment would be huge, and I guess it would on a big site too but the rewards on a bigger site could be better as well*". Concerns over project resources, time and expertise to implement this for safety was widely debated in focus group 4. FG4 Participant 1 stated:

> "*You need a 3D model, you need a decent computer, you need the immersive environment, you need expertise and if they all exist on your project then it does not matter if its small or not, this does not exist on most of the big projects let alone the smaller ones*".

Several participants within this focus group agreed that the lack of these key components would result in this technology not becoming commonplace for safety, or any other purpose.

5 Conclusions and Further Research

The aim of this study was to investigate industry-based perspectives of the current drivers and challenges of implementing immersive sensory technology for the purposes of safety management. The study used focus groups involving industry practitioners who were invited to discuss their views and experiences. Generally, the use of this technology was welcomed as a means to improve safety, however it was found that it was rarely implemented on projects and even rarer specifically for safety. Practitioners acknowledged a drive for this technology and discussed various benefits of it becoming more widely used in safety applications. This mainly focused on providing tools to assist the project team in identifying potential hazards and communicating these effectively. The use of this technology during safety workshops and site inductions was shown to add value to existing methods as well as its use in hazard recognition training. However, there was a mixed view of the practicality and accessibility of VR, concerns regarding personal comfort and its acceptance from the site teams perspective. There was also a concern that using virtual training platforms as a substitute for real-life experiences could lead to complacency, particularly with inexperienced practitioners.

The need for effective leadership, investment and resources to successfully adopt immersive sensory technology within organisations was a common theme. Whilst the participants did explore the challenges of implementation when specifically used for safety purposes, the wider industry issues preventing its more general adoption dominated the discussions. It was apparent that an absence of client demand, the associated costs and lack of specialist digital skills within the industry to produce and manage these immersive environments are root causes. This appeared even more evident in smaller organisations, although it was argued that smaller projects could have the freedom to try new processes if they had the time, expertise and tools. Even with the recent government lockdowns brought about by the COVID pandemic accelerating digital capabilities within the industry, the sustainable adoption of this technology must be driven by clients and organisational management. Without a demand from clients to force the agenda, construction companies are left to choose to adopt this technology. Although many suggested that it's the contractors driving safety innovations,

the issues surrounding time, cost and skills would be a challenge only overcome by company investment and upskilling / outsourcing expertise. Whilst the industry is still committed to safety, the matter of cost appears to remain top priority which requires a deeper cultural change. The adoption of technology with the potential to improve safety comes at a cost and is still feared by many, this also linking to a reluctance to change traditional safety processes. Considering the challenges identified in this paper, it is suggested that further research into the digital skills required to implement such technology for safety management on site is investigated. It is also recommended that further research into the practical application of immersive sensory technology on projects specifically for safety be carried out. Documenting further empirical evidence of its application and its impact on project safety outcomes can assist organisations and clients alike to make informed decisions as to its implementation.

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