Human factors in emergency management

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SUMMARY

Good emergency management is essential when human beings face natural disasters. However, there are many human factors challenges in this area, in particular teamwork amongst those involved with the response efforts, but also communication, navigation, and workload. This article presents the findings from nine interviews with emergency management practitioners based in China, with an emphasis on the potential use of Virtual- and Augmented-Reality to address the aforementioned human factors issues.

KEYWORDS

Emergency management, Virtual Reality, Augmented Reality.

Introduction

Natural and artificial disasters such as earthquakes, floods, and workplace incidents are all crises that humankind must deal with. Take, for example, flood: according to UK government figures, almost 5 million people in England and Wales live in flood-prone locations. However, 25% of flooding occurs outside areas formally designated as being flood-prone. Annual flood damage costs are £1.1 billion across England (EFRA, 2021; GOV.UK, 2022). Emergency management plays a critical role in reducing the impact and loss of life and economy in these disasters (Wilson & Oyola-Yemaiel, 2001). Emergency management can include disaster prevention, emergency preparation (training and safety planning), emergency response (evacuation and rescue), and disaster recovery (recovery of basic services such as hospitals and other life rescue services) (Murphy, 2007). Researchers and professionals will get a better understanding of the most appropriate response strategies necessary for diverse catastrophes via emergency management research, therefore enhancing emergency management measures and creating a safer environment for the public.

Emergency management teams face numerous human factors challenges, for example, emergency management is highly dependent on teamwork (Hayes, 2017).. When responding to an emergency, emergency management teams are often faced with issues such as task allocation, team decision-making, team communication, team leadership and trust between team members (Frye & Wearing, 2016; Johnson, 2017; McLennan et al., 2017; Owen, 2017). In natural disasters, emergency management teams are often confronted with complex environments that are unpredictable and accompanied by a variety of unexpected factors, such as sudden secondary disasters or communication instability (Frye & Wearing, 2016). This usually has the effect of overloading the cognitive capacity of emergency responders. The cooperation of team members will determine whether the team is able to respond to the complex disaster environment successfully (Hayes, 2017), which is why good teamwork is so essential in emergency management.

Communication is an issue that most teams face, but this can be even more significant for emergency management teams (Hayes, 2017). Emergency management teams often work in a variety of disaster scenarios and are exposed to complex disaster environments that greatly affect team communication. Especially in the rescue of large natural disasters such as earthquakes and floods, the interruption of power and the damage of communication facilities have greatly affected the communication ability of rescue teams. (Fischer III, 1996). Good team communication and management will greatly enhance the effectiveness of emergency management teams. Natural disasters can present a particularly large challenge to communication, as they often require a coordinated response from several teams. Cooperation between different teams relies on communication ability of the team leader. (Kapucu & Hu, 2016). Furthermore, in an emergency management network, communication between government agencies and public and private organisations can also have a significant impact on the response (Kapucu & Garayev, 2011). The emergency rescue team should also have efficient methods of communication within team members. (Owen, 2017). How to improve the effectiveness of communication in emergency management networks is, therefore, an issue that requires more research and input.

In emergency situations, stress is an important factor in emergency decision-making. A study by McLennan et al. (2017) shows that in wildfire rescue, firefighter stress often leads to difficulties in decision-making and rescue operations. Stress can have a large impact on memory, decision making, attention, and perceptual-motor skills. This is why training before an emergency and reviewing after an emergency are so important. These actions will help emergency teams reduce the impact of stress during emergencies, especially in training for worst case scenarios (Johnson, 2017). Considering emergency training, worst-case scenario simulations are the most frequently used training method (Johnson, 2017). By simulating the worst-case scenarios, emergency response teams are able to improve their effectiveness and teamwork in real-life disaster situations. In future research, how to conduct simulation training through VR and AR devices will be an important research direction. These studies will help the emergency rescue team to alleviate stress and other human factors problems they face in the rescue, to help them better complete the decision-making in the rescue work.

A severe natural disaster is a very complex environment that involves many people and circumstances, such as the emergency management team, the residents of the affected area, the businesses in the affected area, etc. Frye (2017)'s research on forest fires shows that fire commanders often use metacognitive skills (cognitive models based on previous disaster response experience) to help them think under complex cognitive loads. Metacognitive helps commanders to make better decisions and thus reduce the damage caused by fires. Thus improving the cognitive abilities of emergency response teams can help them to better cope with emergencies during disasters.

In summary, in addition to teamwork challenges, emergency team members are often faced with a number of human factors challenges which may be experienced individually, even if working in a team, such as stress, workload, cognitive, decision making, and excessive demands on working memory (Owen, 2014) These human factors problems also have a significant impact on the cooperation and efficiency of emergency management teams (McLennan et al., 2017). How to address these issues is, therefore, a key consideration for researchers.

Methodology

I designed a semi-structured interview to confirm that the human factors issues reported above in the academic literature are those encountered by front-line emergency rescue workers in real-world rescue scenarios, and to explore in greater depth the nature of these issues from the perspective of these rescue workers. Ten emergency management practitioners from Sichuan, China, were interviewed, including firefighters, emergency management personnel, members of civilian rescue teams, and others. The sample size was restricted to ten participants as this is a specialist population, who need government approval to participate, so the overall population is not large nor easily accessible. One participant withdrew from the interview thus the analysis is based on the interview data of nine participants. The interview was approved by University of Nottingham's Faculty of Engineering Ethics Review Committee.

The first set of questions in the interview focused on learning about the participants' work backgrounds in order to obtain an in-depth understanding of their experience. We discussed their work over the last few years to decades, with a focus on emergency rescue work. The second set of questions in the interview focused on the human factors areas identified in the previous literature (Table 1). The goal was to determine whether the problems identified in these documents exist in first-line rescue work, as well as to establish the perspectives of front-line rescue teams on these issues. These issues are primarily associated with teamwork, communication, workload, navigation, and work stress.

HF issues	Questions
Teamwork	What is your current teamwork model? What do you think is the biggest problem in the existing team cooperation? What works well?
Communication	What is your communication mode in the current team cooperation? How do you complete the communication between the rear support team and front-line staff at the emergency front? Where are you during this process? Are there any problems/issues with the current communication mode? What works well?
Workload	Do you experience a large amount of complex information? Does this impact your workload in anyway? Please tell me about this.
Navigation	Have you ever experienced any problems with navigation during disaster areas? How do you navigate? What tools do you use to help you navigate? Do they pose any issues? What works well?
Stress	Do you experience any stress at work? If so, please explain how this manifests. How do you cope with any stress?

Table 1: Interview questions about human factors challenges identified from previous literature.

During my doctoral research, I intend to use Virtual Reality (VR) and Augmented Reality (AR) technology to assist rescue teams in resolving their human factor issues. As a result, I included the third set of questions in this interview (Table 2) to explore the perspectives and recommendations of front-line emergency staff regarding the use of VR and AR in emergency rescue. I showed participants current applications of VR and AR technologies in the field of emergency management prior to this group of questions. These applications included, for example, VR technology being used for fire safety training. I also showed Head Up Display (HUD) technology, which similar to AR technology, has been widely used in special forces. This technology can improve communication efficiency among special forces members and can help members obtain mission information faster (Goldiez et al., 2007). Furthermore, if AR technology is used in emergency rescue teams, such as post-disaster search, rescue and survey, it can theoretically improve the efficiency of communication and task execution (Park et al., 2018). The interviewees were asked about their attitudes towards applying AR and VR technologies in emergency management.

Serial	Questions
1	What is your attitude towards using VR and AR technology in emergency management? Could you explain why you have such an attitude?
2	Through our introduction and your understanding of VR and AR. Do you think this technology could help you in your work? Please explain your answer.
3	Do you have any suggestions for using similar technologies in emergency management?

Table 2: Questions to understand interviewees' views on the application of new technologies.

After the interview, I transcribed the interview recording, transcribed it into text and translated it into English. Then I used NVivo to code the topic of the interview and conduct qualitative analysis.

Results

Experience

All nine participants have rich experience in emergency rescue. Among the nine participants, one from the civilian rescue team had the least amount of emergency rescue work. His main line of work is as a lawyer, but in his spare time he participates in emergency rescue training and follows the rescue team to assist in disaster relief. One of the participants who worked the longest was a former fire commander with over 30 years of experience in the fire department.. He also assisted in the rescue of many large-scale natural disasters during his career.

Teamwork

Participants reported that in previous emergency situations, teamwork was the most important factor influencing the success of the rescue. Participant 2 is a firefighter and has led teams in earthquake rescue many times, most notably during the Wenchuan earthquake in 2008. Through close collaboration, he and his team completed many rescue tasks. The Chinese fire brigade was a paramilitary organisation at the time. Therefore, they placed a high value on teamwork training during their daily training process. As a result, Participant 2 reported having a strong team understanding of each task. However, Participant 2 also discussed the challenges of teamwork in large-scale disasters. For example, due to the smoke and fire, it can be difficult for them to confirm the position of their teammates during the search and rescue operations of a large fire incident (overlapping with Communication and Navigation issues). Simultaneously, due to noise interference on the scene, it is sometimes impossible to receive assistance requests from teammates from their walkie-talkies in a timely manner (also Communication). Participant 4 works for a public welfare rescue organisation. He has also assisted in flood rescue numerous times. In terms of teamwork, he claims that because they are from non-governmental public welfare rescue organisations, their training is often not as extensive as that of professional rescue teams. Participant 4 reported that many rescue operations have poor teamwork due to team members' lack of awareness of disaster relief operations or the urgency of the task. During my interviews, all nine participants mentioned similar issues to those raised by Participant 4. The degree of difficulty encountered in Teams differs due to the distinction between professional and ordinary training.

Communication

All nine participants reported that communication is a major challenge for emergency response teams. Despite the fact that relevant technologies and equipment are constantly being updated and iterated, communication difficulties were reported as frequently encountered in real disaster environments. Participant 1 has worked in safety supervision and has assisted in the rescue of many safety production accidents. He stated that communication is often the most difficult issue for rescue teams in coal mine accidents, as due to the obstruction of underground rocks, wireless communication equipment is difficult to use. This creates a significant communication barrier, reducing rescue efficiency significantly. Participant 2 has worked in firefighting for over 30 years. He has witnessed the development of the entire communication equipment of China's emergency rescue team, from the first radio station to today's satellite communication. He stated that with technological advancements, new communication equipment has provided them with better solutions. However, in disaster relief operations, response teams continue to face various communication devices frequently necessitates diverting their own attention to ensure contact with team members and other teams. Participant 6 reported that in the rescue of high-rise building fires, communicating with teammates and confirming the position of teammates was a more difficult thing.

Workload

Emergency rescue entails a heavy workload, and this is frequently a major issue that plagues firstline rescue workers. They are confronted with the load rescue environment and noise pollution. At the same time, they must ensure the safety of the rescued personnel while also protecting themselves and their teammates. Also, the cognitive workload is also a problem for rescue participants. Especially in the rescue of fire and building ruins, the cognitive workload has increased significantly. In a complex disaster environment, the complex site conditions will increase the cognitive load of rescue workers. Participant 8 has a long history of firefighting experience. He believes that firefighters face a massive workload when it comes to fire rescue. Firefighters must wear heavy fireproof clothing while searching for trapped people through the fire and smoke. Participant 8 also mentioned in the interview that as a professional firefighter, he should not only pay attention to the trapped people, but also pay attention to the development of the fire and the destruction of buildings. This is a huge challenge for firefighters' cognitive workload. When discussing the workload in earthquake relief, the second participant stated that the terrain often changes dramatically in large earthquakes. These changes require them to use more energy, as well as using a variety of equipment to locate trapped people in buildings that could collapse at any time. These duties significantly increase their workload. At the same time, many participants reported that in the large-scale disaster scene, such as earthquake rescue, because of the damage of the earthquake to the landform, the rescue personnel not only need to complete the rescue of the trapped, but also need to identify the risk through careful observation of the scene. This has also greatly increased their cognitive workload.

Navigation

Navigation is a significant human factors issue in emergency rescue. From various perspectives, all nine participants described the difficulties they had encountered while navigating. Participants 1, 5, and 8 are all emergency management personnel from China, and have all assisted in the rescue of numerous production safety accidents. These navigation issues were most acutely experienced in chemical plant accident rescues and mine navigation in coal mine safety accidents. Due to the presence of various pipelines and equipment in the factory, rescue workers face complex search routes. Due to the complexity of underground tunnels and route changes caused by various collapses, mine rescue workers frequently face difficult navigation routes. Participants 2 and 8 have previously helped with earthquake relief. They stated that due to the topographic changes caused by the earthquake, it was difficult for them to locate their true location on the map. The navigation problem in fire rescue was mentioned by five participants from the fire department. They believed that the fire and smoke had hampered their navigation.

Stress

Stress is another major human factor that afflicts emergency staff. High-intensity work in disaster relief has put rescue workers under a lot of strain (related to *Workload*). At the same time, participants reported on their stress levels following the disaster. This is because in disaster rescue, sometimes they will face the situation that not all survivors can be rescued, and the response teams have to make a difficult choice about who to rescue. This not only causes them to face great pressure during the process of disaster relief, but also after the rescue action, they sometimes fall into self-blame. This has also affected their mental recovery after the disaster.

VR and AR application

Following the explanation and presentation of VR and AR applications, each participant was enthusiastic about the use of these technologies in emergency rescue. However, Participant 2 mentioned that the heat from a fire would damage the VR/AR helmet or glasses if used during firefighting. He also brought up concerns about the battery life; rescuers are frequently faced with long-term continuous work in real-world scenarios, and he questioned whether VR/AR equipment could support long-term work. A communication issue with VR/AR equipment was raised by participant number four. The communication infrastructure is frequently severely damaged in natural disasters such as earthquakes and floods. His concern was how to use the equipment under such communication conditions. Participant 6 inquired about 3D vertigo. He mentioned that he had used VR devices before, but they made him dizzy, and was concerned about this if the technology was adopted in emergency response efforts. However, he was very interested in the technologies and hoped to learn more about the use of VR and AR in emergency management. Participant 1 reported being impressed by a VR training facility for earthquake escape in a civic disaster reduction education centre. He believes that if such equipment can be used in rescue work to solve problems such as teamwork, navigation, communication, and so on, it will be a huge step forward in the rescue mode.

Findings

The results showed that good teamwork is the most important factor influencing the success of emergency rescue missions. However, communication, navigation, and workload are also important factors in team cooperation. These factors interact with one another, resulting in an emergency rescue that is inherently complex. Interviewees explained that this is partly due to the unpredictable nature of disasters: emergency managements team composition and activities are not consistent across all events. Thus, cooperation and communication across teams are essential factors determining the efficiency and success rate of rescue activity as the teams respond to each individual event.

Interviewees reported that VR and AR has the potential to alleviate some of the human factors challenges in emergency rescue and team cooperation by supporting visualisation of data from existing technologies (e.g. sensors and scanners). Simultaneously, the integration of VR and AR-based technologies with communication, navigation, and various other rescue equipment may help the emergency team improve its work efficiency.

Discussion and Conclusion

This paper reports on in-depth conversation with interviewees about the human factors in emergency rescue that I discovered. This confirmed that teamwork, communication, navigation, and workload issues discovered in the literature are, in fact, the main issues confronting the emergency rescue team.

This paper presents a more detailed depiction of the human factors concerns that are associated with emergency management. When dealing with a wide variety of crises, emergency managers face a number of challenges related to human factors. Working together effectively is one of the most difficult human factors challenges that emergency management teams must overcome. Communication, workload, stress levels, and perceptions are all examples of human factors that play a role in determining the efficiency with which emergency management teams collaborate. This is because of the specific nature of emergencies; teamwork in the context of emergency management teams entails more than just cooperation between the individuals that make up the team. As a result of the complexity of emergency situations, it is necessary for emergency management teams from various localities, regions, and even countries to collaborate with one another. Cooperation between different emergency management teams is therefore another significant challenge that they face.

Emergency management teams can combine virtual environments with real-world disaster scenes using augmented reality technology. This will help frontline emergency responders reduce the amount of work they have to do while also improving the communication and collaboration within their teams. The virtual reality technology can bring a more realistic representation of the disaster scene to the command centre. It is anticipated that emergency team commanders will be better able to direct their teams and make decisions if virtual reality technology is utilised at the scene of a real disaster. When the benefits of augmented and virtual reality are combined, emergency management teams will have access to a new method of operation that will assist them in better coping with the human factors that are involved in responding to emergency situations. However, human factors are an essential foundation to any technological development work in this area.

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