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Virtual Reality with Virtual Humans simulation for an emergency training in a public sector

An extension of the specialization project

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To my family.

Abstract

In recent years, Virtual Reality have opened a novel approach for learning from where Emergency Management training is one of the largest focus areas. Several studies and empirical works have been used to explore the potential Virtual Reality could bring to users. With a combination of Virtual Humans, Virtual Reality has been applied to facilitate an artificial simulation between virtual training environments and users, from which could be evaluated in terms of training effectiveness.

This thesis is an extension from the specialization project "Area planning for government agencies in Virtual Reality", which primarily laid focus on a strategy of using office space efficiently in the public sector NAV (Oslo division).

Using the virtual office developed in the specialization project, this thesis has made improvements based on that project's evaluation. More important, it has built a virtual fire emergency situation to demonstrate how an evacuation could be conducted in a public sector. The thesis goal is to explore the potential that Virtual Reality with Virtual Humans bring for Emergency Management training.

The Virtual Humans part in this thesis has been inherited from the specialization project with an extension on behaviours for emergency circumstances. The evacuation process has been implemented based on various sources of research and theory in topics such as virtual humans, crowd simulation, psychological behaviours under pressure circumstances, emergency training. NAV security experts have also contributed significantly to the evacuation strategy applied in this thesis office layout.

The outcome of this thesis has been evaluated from three groups of users: Emergency Management students at the college in Molde (Høgskolen i Molde), civilians who have little or no experience in Emergency Management field and NAV officers in Oslo division. The diversity in groups created different perception and opinions towards emergency training. This has proved to be an advantage as the thesis has received fruitful diverse feedback for assessments and ideas for improvements, which achieved the evaluation goal for this empirical work.

Through evaluation results, Virtual Reality with Virtual Humans have shown that they have a potential for using in Emergency Management training. The virtual space and virtual humans play an important role in simulating participants to feel present and immerse during training process. Head-mounted displays have also proved to be an important tool for virtual training because they facilitated participants experience in virtual environments and by that affected their training effectiveness.

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Abbreviations

VR	=	Virtual Reality
VHs	=	Virtual Humans
VW	=	Virtual World
VWs	=	Virtual Worlds
EM	=	Emergency Management
ET	=	Emergency Training
VE	=	Virtual Evacuation
SL	=	Second Life
HMDs	=	Head-mounted Displays
NAV	=	Norwegian Labour and Welfare Service

Introduction

This chapter describes the motivation and main goals of the thesis, followed by research questions and methods. It then explains the project scope. Thesis outline is presented at the end.

1.1 Motivation

With a growing need for office space, Emergency Management training in building settings tends to gain more focus in the recent years.

Traditional Emergency Management training has been the popular learning approach so far that answers to this need. However, this training approach has many downsides such as low cost effectiveness, safety issues, big affect on personnel schedule and reproducible difficulty (Ribeiro et al., 2012). Another reason that hinders this training approach is that training scenarios cannot be extended dramatically as they should be in real life due to the harmfulness they may cause for participants health.

Virtual Reality has recently proved to be an alternative training approach that is able to solve the above downsides. Though the most applicable area still depends on academic studies and researches, Virtual Reality environments for Emergency Management training have shown a big potential when they are continually improving participants feeling of immersion and presence thanks to new technology supports (Ribeiro et al., 2012; Kobes et al., 2009).

This thesis, as an extension of the author's specialization project, attempts to create a virtual evacuation for fire emergency situation in the existing virtual office. Some suggestions for improvement from the specialization project have also been done in this thesis project. The main goal of this Proof-of-Concept is to evaluate the potential of using Virtual Reality with Virtual Humans simulation for Emergency Management training in a public sector. Most interesting, the project can be evaluated with different audience groups: observers and role players.

In order to judge the success of the project, the research question has been developed.

1.2 Research Questions

This thesis uses the existing virtual office and virtual humans from the specialization project (see Chapter 2). In other words, this thesis demonstrates daily working routines at the public sector NAV as an initial environment to highlight the surrounding changes and virtual humans behavioral changes when an emergency situation shows up.

The thesis goal is to explore the potential of using Virtual Reality and Virtual Humans for Emergency Management Training in a public sector. The thesis's research question is formed from this intention:

RQ. *How could Virtual Reality with Virtual Humans contribute to Emergency Management training in public sectors?*

Since the thesis attempts to utilize the simulation from virtual humans in presenting the fire emergency circumstance, a sub-question addressed virtual humans aspect can be identified:

RQ1. *How could Virtual Humans contribute to Emergency Management training?*

RQ1 explores the potential of using virtual humans to simulate emergency situations for training. In order to make training scenarios believable to participants, it is important to specify virtual humans appearance, their behaviours, their placements in office setting, their interaction with each other and human participants. In addition, the thesis wants to explore what advantage virtual Emergency Management training could have from allowing human participants to play roles.

Beside virtual humans aspect, the thesis also intends to find out the potential of using VR with Head-mounted display (HMDs) to enhance learning experience in Emergency Management training. Since the project allows role-playing model, participants can experience the fire situation and join the evacuation with other virtual humans in the office. Therefore, it is necessary for participants to feel immersive and present during training process. But how better could HMDs contribute to participants learning experience? This concern forms a new sub-question to the main RQ:

RQ2. *How could VR with HMDs support participants learning enhancement during the fire emergency training?*

This question will study the effect to which HMDs provide participants during this virtual training. It also measures the degree of potential to which participants think of using HMDs for their future virtual training plan.

1.3 Research Method

1.3.1 Literature

This thesis required research work on a wide range of topics including theory of emergency training, psychological reaction of humans under pressure circumstance, virtual space for emergency training, virtual humans behaviours and crowd simulation.

The fire emergency situation for this thesis's virtual office was designed with a guidance from various studies and empirical works in the emergency training field. Virtual Humans behaviours were also developed with a consideration on psychological impacts under pressure circumstances. A deep explanation of literature work can be found in Chapter 3 Theory.

In addition, NAV has provided a document of fire emergency instructions. This document helped to implement the virtual evacuation more similar to the original evacuation training they were familiar with at NAV.

1.3.2 Expert Consultancy

With a great assistance from NAV, the author was able to receive a consulting appointment with one of their security experts. The expert has given useful advice about how to design a fire emergency situation in this thesis's virtual office layout aligned with NAV's fire safety regulations, instructions and procedures. This has increased the authenticity of the virtual training. The collected information from this consulting hour will be explained in Appendix.

1.3.3 Quantitative and Qualitative Data

This thesis collected data from both quantitative and qualitative methods. Quantitative methods included questionnaires and qualitative methods included interviews and discussions.

The evaluation for this thesis was conducted in three rounds. At each round, there was a different group of audience with diverse perceptions about Emergency Management training. Evaluation content included a role-playing version (i.e. participants join the virtual emergency training actively with a role) and an observation version (i.e. participants observe the training by a demo or a video). HMDs were also available for volunteers. After attending the virtual emergency training, a questionnaire was distributed to collect participants feedback. All participants then attended an in-depth interview. Since audience groups were fairly small (5-10 persons), the interview was taken extra effort to stimulate discussions inside groups in order to gain valuable inputs. These inputs have yielded new insight and potential further directions for this thesis's research topic. This will be explained in details in chapter 5 and 6.

1.4 Project Scope

This thesis defines a scope in which to design and simulate a virtual fire emergency training in an office setting. Beside the existing virtual office and virtual humans from the specialization project, some new virtual humans were developed to make crowd effect and visualize the psychological impact under an emergency situation. There was also some work to create the fire with smoke effect in the office.

There could be some differences in perceiving a virtual emergency training between Emergency Management experts and civilians who have no or little experience in Emergency Management field. This thesis is served as a Proof-of-Concept to weigh the potential

of using such training approach to benefit Emergency Management training. Therefore, it will neither analyze the cause leading to different perceptions between these groups nor suggest how to solve that. Instead, it will provide valuable suggestions from both groups for improving the usage of virtual training approach in Emergency Management training.

1.5 Thesis Outline

Chapter 2, Project Background, describes shortly the specialization project from where this thesis reused virtual humans simulation in office settings. The motivation to extend the specialization project with a focus on emergency training from which this thesis's research context was identified is then explained. Some related projects in the same interest area are also mentioned.

Chapter 3, Theory and Related Work, covers all literature and theory used to develop this thesis. It also presents work that is relevant to this thesis.

Chapter 4, Implementation, explains an overview of implementation work of this thesis. This chapter will describe how the emergency situation was developed, the concepts behind its design and the purpose of choosing this design for research evaluation. The guideline used for virtual humans behaviours during evacuation process will also be presented.

Chapter 5, Evaluation, describes the evaluation sessions of this thesis conducted with three different groups; Emergency Management students, civilians and NAV personnel. This chapter will present the methods used to collect data from these sessions.

Chapter 6, Results, will present the outcomes from the evaluation sessions.

Chapter 7, Discussion, will discuss the results from chapter 6 as well as their implications.

Chapter 8, Conclusions and Future Work, summarizes and concludes the thesis work. Recommendation for future work is also included.

Project Background

This chapter presents the projects that build the foundation of this thesis; NAV's area-concept project (Eiendomsprosjektet), the Specialization project that built on the virtual office represented NAV's area-concept (Nguyen, 2014). Both of these projects affect how the work in this thesis will develop.

2.1 NAV's area-concept (Eiendomsprosjektet)

NAV pursued a building project to evaluate how the working space at their offices could be improved according to several factors such as Present (Til stede) Transparency (Tydelighet) - Solution oriented (Løsningsdyktig).

"The lay-out is required to fit different demands such as group work, confidential tasks, extra-focus required tasks as well as other individual work demands. In addition, the design followed universal standard whose focus lays on the mobile ability of workplaces; and effective space organization in the sense that it reduces noise affection by dividing space into zones such as entrance-zones, social-zones and working-zones." (Nguyen, 2014).

2.2 The Specialization Project - "Area Planning Project for a Public Sector"

NAV Oslo division considered to develop a 3D model in Second Life for visualizing the area-concept mentioned above. The goal was to build a virtual world as a Proof of Concept where contained a virtual office and virtual humans. That was the motivation of this project.

The research and methods presented in this project are built on the NAV area-concept project. In this project, a virtual office resembled the actual location in NAV Oslo division was created, and scenarios with VHs were developed for visualizing a regular working day at NAV.

Virtual humans were built in the virtual office to simulate working activities such as phone conversation, sitting in a meeting, passing through the entrance etc aligned with the space usage strategy that NAV aimed for. VHS were added also for a purpose of crowd simulation. NAV Oslo division considered to use this project outcome to propose the area-concept to other departments and divisions to help improve working quality and effectiveness in associated with a modern layout.

The evaluation with a group of NAV people in Oslo showed that the VHS were able to simulate working activities in office settings. There was confirmed that VHS simulation achieved a partial authenticity of NAV working context based on their appearances and behaviours. The combination of the virtual office and the VHS in this project proved that 3D simulation had potential for the participants' learning effect. The evaluation result suggested a list of future work including further development on the VH models, the improvement of VHS gestures to increase realism. New scenarios were also proposed including topics such as virtual meeting, virtual office tour and other virtual training.

2.3 Related Projects

Several projects focus on emergency training in virtual worlds in terms of evacuation in office settings. They propose various elements to implement a good simulation where VHS behaviours are a key for simulate training scenarios. Detailed descriptions of these projects can be found in Section 3.8.

Theory and Related Work

The goal of using virtual reality as a virtual environment for emergency training is for organizations to consider the potential of a new approach which contains more stimulation effects than in real life, more safety as well as saving time and budget. It is thus required that the virtual environment presents realistic compared with the original training location. The virtual humans together with their surrounding need to create a true image of where they represent. Beside providing correct information of emergency handling, virtual emergency training also integrates local rules of the original location into its virtual environment.

This chapter explains emergency training and how it could be implemented in virtual reality. A range of topics about evacuation in office settings, human behaviours in emergency situations, character development, virtual worlds, virtual humans, crowd simulation, HMDs, the potential of virtual emergency training and related work will be chronologically presented.

3.1 Evacuation in Office Settings

Nowadays, together with the growth of diverse departments within organizations, office settings become more complex. This leads to new regulations on how to use the space especially in case of fire. Two structural factors contribute to the effectiveness of evacuation are office layout and building evacuation models.

3.1.1 Office Layout

According to (Rassia and Siettos, 2010), office layout means *"the provisions of the office space and the density per person"*. Depending on how office space is organized, there will be different solutions for evacuation plans to ensure safety.

During evacuating in office settings, the risk ratio could be influenced among various factors such as distance to corridor, building material, visibility of exit signs, *"dimensions*

and location of stairs and windows” as well as “other indoor environmental design “obstacles”” (Rassia and Siettos, 2010).

This thesis used the virtual office represented a part of a typical NAV office. It presents an open-plan design with separate areas for different use. There are two exit paths leading to two opposite directions at the social area. Exit signs are shown visible at the eye sight. Since the virtual office is at a Proof of Concept level, the office design is relatively simple, distance to corridor is short and no obstacles on the evacuation paths. Thus, other simulation features needed to be defined and implemented in the virtual office in order to simulate an effective evacuation.



Figure 3.1: NAV virtual office in the virtual evacuation.

3.1.2 Building Evacuation Models

Many studies have shown that there were several evacuation models which impacted to certain building types. This thesis chose the review of Egress evacuation models in (Kuligowski et al., 2005) as a reference due to similar focus points on evacuation from buildings. In their review, a list of ten specialized features which presented evacuation simulation in building was mentioned as follows.

- Counterflow
- Manual exit block/obstacles
- Fire conditions affect behaviour
- Defining groups
- Disabilities/slow occupant groups
- Delays/pre-movement times
- Elevator use
- Toxicity of the occupants

- Impatience/drive variables
- Route choice of the occupants/occupant distribution

Each models is assigned one of the three types belonged to a modeling method category which (Kuligowski et al., 2005) indicates *"This category describes the method of modeling sophistication that each model uses to calculate evacuation times for buildings"*.

- Behavioral models: Occupants in these models perform actions in addition to movement to achieve a specified goal (exit)
- Movement models: Occupants in these models have movement which starts from one location in the building to another. These models are essential to indicate congestion areas, queuing, or bottlenecks within the building under simulation.
- Partial behavior models: Occupants in these models have primarily movement but possibly perform actions when the models begin to simulate their behaviors. Moreover, (Kuligowski et al., 2005) clarified *"Possible behaviours could be implicitly represented by pre-movement time distributions among the occupants, unique occupant characteristics, overtaking behavior, and the introduction of smoke or smoke effects to the occupant."*

When simulating an evacuation in office settings, it is important to understand how evacuating flows could be formed. This could be learned by observing occupants perspective towards the office. Refer to (Kuligowski et al., 2005), *"The occupant can view the building in either a global or individual way."* The *global* perspective of the occupants could be achieved when they automatically know their best way to evacuate and have an accurate view of the building/office in their memories. The *individual* perspective of the occupants is implied when they don't know the evacuation paths in the building/office well enough. In this case, the occupants will use the information from the floor, exit signs, personal experience or the information from the occupants around them to make up their minds on escape route. Especially, Hajibabai et al. confirmed from their research result that *"the better placement of the cues and optimum planning of the quality and quantity of the signage lead to shorter evacuation time from the building"* (Hajibabai et al., 2007).

In a virtual evacuation supporting role-players such as this thesis, the virtual humans in the virtual office present as occupants who have *global* perspective while role-players present as occupants who have *individual* perspective.

3.2 Human

3.2.1 Human Behaviors in Navigation

In order to simulate a virtual evacuation, it is critical to study about how humans behave in such situation. Several researches and studies have defined some important concepts that impact human behaviours to navigate in emergency situation.

Spatial Cognition

This concept has a focus on *"human perception, memory, reasoning and communication involving the spatio-temporal objects and events, both in the real world and in their digital representations"*(Hajibabai et al., 2007).

Human spatial cognition is a combination of the following features:

- Cognitive systems include *"sensing and perception, thinking, imagery, memory, learning, language, reasoning and problem solving"*(Hajibabai et al., 2007)
- Spatial properties include *"location, size, distance direction, separation and connection, shape, pattern and movement"*(Hajibabai et al., 2007)

It is observed that human spatial knowledge of places is gained by different elements:

- Landmark knowledge: structural details, unique features which identify a place
- Route knowledge: experience different routes connecting ordered sequences of landmarks
- Survey knowledge: familiarity and understanding of two-dimensional layouts including the simultaneous reciprocal relations of locations.

A good understanding of the location where evacuation takes place could facilitate human navigation with a little need of external help. Thus, it is important to have an accurate representation of the target location for training in order to support spatial knowledge of participants.

Way finding

Way finding, as its name yields a literal meaning, is a human activity involving making navigation decision with a purpose. It concerns about *"how people find their ways in the physical world, what they need to find it, how they communicate directional information and how people's verbal and visual abilities influence wayfinding"* (Hajibabai et al., 2007).

Spatial knowledge and various cognitive cues contribute to a successful way finding. The paper (Kobes et al., 2007) described four types of environmental variables that impacts way finding performance as follows.

- Visual access
- The degree of architectural differentiation
- The use of signs and room numbers to provide identification or directional information
- Plan configuration

3.2.2 Human Behaviors in Emergency Situation

Environmental Impacts

When an emergency situation emerges, the environmental setting will change which in turn can impact human behaviours. (Kobes et al., 2007) claimed that there were three basic activities that characterised the evacuation process such as

- Clue validation i.e. awareness of danger by external stimuli
- Decision making i.e. validating and responding to danger indicators
- Movement/refuge i.e. moving to a safe place

The environmental effects under emergency situation were proved to influence evacuees way finding performance. (Kobes et al., 2007) reported that many evacuees had to change their navigation or even withdraw training because of the sight reduction and breathing problem from smoke or fear.

Occupant's Habits in using the Space

Occupant's habits in using the space is an interesting factor when investigating how humans evaluate their navigation alternatives and make decisions for emergency escape.

Many studies have indicated that the familiarity of landmarks and the frequent travelings between specific locations by habits would influence people on their choice of navigation during evacuation. (Tan et al., 2014) suggested a list of factors based on previous studies and observations:

- In emergency situation, people seemed to select the nearest exit to evacuate
- When in panic state, people subconsciously select their most familiar exit to evacuate
- If the distance are similar, people prefer to select the path that is not crowded
- People won't change their route unless they see an alternative route which is less crowded or shorter

In the pressure of time, people tend to make decision based on what they have already experienced in order to reduce risk of failure. It was reported by (Kobes et al., 2007) that fire exits which were not regularly used would have a negative association. Mentioning their previous evacuation experiments, there was an assumption that fire exit would only be used if the door was open and additionally the distance to reach fire exit was half than that of the main entrance.

More on perspective of occupants, (Kobes et al., 2009) described the following findings:

- Occupants normally evacuate by selecting the routes they are familiar with. The direction to the main entrance of a building is considered the most.
- The route choice is decided by the perception of the length, not the actual length. For example, corridors with many bends and unfamiliar routes are perceived as being longer than straight and familiar routes.

3.3 Virtual Humans

3.3.1 Character Development

This thesis presents a virtual training with VHs simulation. Therefore, it is necessary to identify what VHs could perform in order to visualize human behaviours realistically under emergency situation.

Hayes-Roth, Maldonado, and Moraess Characteristic Qualities

The ten characteristic qualities by Hayes-Roth, Maldonado, and Moraes (Hayes-Roth et al., 2002) were used as a guideline in this thesis to develop characters more alive. Answering these questions would define how to implement a realistic character:

1. Identity

Who is the character?

2. Backstory

What shaped who the character is?

3. Appearance

How does the characters embodiment limit, expand, and communicate who he is?

4. Content of Speech

What does the character want to talk about, what does he avoid, and how does he say things?

5. Manner of Speaking

How does the character express himself verbally?

6. Manner of Gesturing

How does the character express himself non-verbally?

7. Emotional Dynamics

What angers or excites the character, how does he express it, and how long does this emotional charge last?

8. Social Interaction Patterns

How does the character address and react to those he interacts with? Does it change depending on gender, age, position, knowledge, or time he has known the interactor?

9. Role

What value does the character add [to the environment]? What is his job?

10. Role Dynamics

How does the character relate to human interactors in accordance with his role?

Proxemics

The theory about Character's personal space from Edward T. Hall (Hall et al., 1968) was considered to decide character behavior and their placements regarding to the suggested categories:

- The intimate distance, for touching or embracing
- The personal distance, for close friends and family members
- The social distance, for acquaintances
- The public distance

Cultural factors have been taken into account to determine these distances (Edward, 1966). In deed, the cultural traits had been integrated into the behavioral design of the characters so that they could look more persuasive to their surroundings.

3.3.2 Virtual Humans and Crowd Simulation

It is clear that VHS play a big role in simulating a virtual evacuation such as the one implemented in this thesis. In order to make VHS look realistic not only by their human-like appearance but also by their behaviours in different situations, this thesis used the work of Zerrin Kasap and Nadia Magnenat-Thalmann (Kasap and Magnenat-Thalmann, 2008) as a guideline. According to their paper, these following traits described an intelligent virtual character:

- Autonomous behaviour: This concept emphasizes the ability to make decisions by oneself depends on the circumstance (e.g. pre-defined rules) that one is in. There are three parts in a chronological order:
 - Perception: one perceives the surrounding environment and the specific situation that one is in
 - Decision-making and adaptation: according to the interpretation of the environment, one decides what to do with one's immediate situation in order to move to a better state. Adaption can be achieved "*through governing emotions to stressful conditions.*"
 - Action control: one could combine some actions together (e.g. running and holding something in hand) while one could not combine some other actions together (e.g. running and sitting)
- Interaction: interaction such as conversational abilities, facial expressions, hand-arm gestures, eye-gaze
 - Facial expression
 - Gestures

- Dialogue management: integration with emotional state, allowing interruption, repairing of dialog, feedback and turn-taking
- Personification: *"Social behavior of computer characters with emotion and personality increases the realism and quality of interaction such as in games, story-telling systems, interactive dramas, training systems and therapy systems."*
 - Personality: According to Five Factor Model or OCEAN model (McCrae and John, 1992) personality of a person can fall to five different traits: *"openness, conscientiousness, extroversion, agreeableness, neuroticism"*
 - Emotion: Ekman proposes six basic labels for emotions: *"fear, disgust, anger, sadness, surprise and joy"* (Ekman et al., 2013)

Crowd simulation is defined as a process of stimulating a big group of individuals with a set of behaviours identifying how the group will move, behave and act. Crowd simulation is an important element in emergency training. In order to present the realism of a virtual evacuation, it is necessary to define the factors contributing to the crowd simulation effect.

According to D.Thalmann and S.R.Musse (Raupp Musse and Thalmann, 2001), the following are relevant concepts for crowd simulation in virtual world.

- Entities of the simulation
 - Virtual human agent (agent): human-like avatar visualizes human appearance and behaviours
 - Group: group of agents
 - Crowd: a set of groups
- Intention
 - Beliefs: internal status of the entities (following tendency etc.)
 - Knowledge: information of the virtual environment where crowd simulation happens (for example: office layout etc.)
 - Events: incidents causing a specific reaction
 - Crowd structure: assembled of crowds, groups and agents
 - Crowd behaviour: a set of actions applied based on entities intention, beliefs, knowledge and perception

3.4 Virtual Reality and Virtual Worlds

Virtual Reality (VR) can be described as *"immersive multimedia or computer-simulated life, replicates an environment that simulates physical presence in places in the real world or imagined worlds. Virtual reality can recreate sensory experiences, which include virtual taste, sight, smell, sound, and touch"* (Wikipedia, 2015).

A virtual world (VW) can be described as an internet-based, simulated environment where users interact via motionable avatars, graphical images that represent people (Antonacci et al., 2008).

VW is potential for many industries including entertainment and education. Online games have had a long popular history with VW implementation, while serious games such as training exercises came in with less notice. However, many researches and studies have proved that VW has potential to be a new powerful medium for instruction. Many research topics have come along to find out a proper way to exploit this potential further into practices. The fact that VW implementation could compete well with traditional learning medium in terms of cost attracts more interest from people. Below are the areas involving the most use of VW in the recent years.

3.4.1 Entertainment

Online games are the most popular production of entertainment industry. Online games have brought a new way of interacting between humans. Nowadays, game players are used to be represented as characters in VW and interact with each other by these virtual forms. Some of most famous online games are listed as follows.

- World of Warcraft
- Minecraft
- Anarchy Online
- The Secret World

3.4.2 Education

In the recent years, many projects have been conducted to explore the potential that VWs could have for education industry. Projects such as virtual classroom, virtual training base or virtual information center have gained much interest and motivation. The results were positive as they promoted a new way to learn and train with more flexibility in terms of cost, location and time. Some of the main areas that VR/VWs could be applied for education are listed below:

- Learning Activities
- Serious Games for Training
- Collaborative Work

Since these areas are belonged to the interested research area of this thesis, several relevant projects will be mentioned in details at a later section in this chapter, which is section 3.8.1 Related work.

3.4.3 VR with components for immersion - HMDs

Immersion in VR

Hsu et al. (Hsu et al., 2013) stated in their paper *"VR-based systems encompass a wide array of technical capabilities ranging from personal computer-based software to fully*

immersive and high-fidelity platforms where participants don 3-D goggles in controlled environments.” VR with components are believed to increase immersion for users as their interaction with their VWs have more authentic feeling (Cummings et al., 2012). Cummings et al. indicated the features contributed to immersion in VR as follows:

- Tracking level: *”refers to the number and types of degrees of freedom with which user input is tracked by an immersive system”* (Cummings et al., 2012)
- Stereoscopic vision: *”refers to whether a given system provides the user with monoscopic or stereoscopic visuals”* (Cummings et al., 2012)
- Image quality: refers to *”a number of elements that influence the general quality, realism, and fidelity of visuals provided by an immersive system”* (Cummings et al., 2012)
- Field of view: *”refers to the relative field of the user’s view within which the environment’s visuals extend. This feature is commonly manipulated through blinders or the screen size of a head-mounted display (HMD)”* (Cummings et al., 2012)
- Sound quality
- Display type: *”refers to the form in which a virtual environment is displayed (HMD, projection, PC monitor, etc)”* (Cummings et al., 2012)
- Emotional content: *”refers to whether or not the immersive experience includes emotionally relevant content”* (Cummings et al., 2012)
- Update rate: refers to *”how the rate at which the virtual environment is rendered may influence user presence”* (Cummings et al., 2012)
- User perspective

This thesis will focus on the feature “Display type” such as HMD represented by Oculus Rift goggle.

HMDs

A head-mounted display is a supplement for users to achieve immersive feeling in virtual worlds. This is an equipment that can be worn on the head of the user. From the inside, it presents a display screen at a short distance to the user’s eyes so that the user could see an immersive picture of the virtual environment he is in. In the recent years, it has attracted a lot of attention thanks to its exclusive feature for enhancing immersion in virtual worlds. (Tasdemir, 2014) Gamers contribute to be the biggest portion of HMD consumers. In spite of that, HMD is believed to have potential to other virtual applications as well. It is hypothesized that the virtual emergency training would yield better learning effect if the participants used HMDs. In order to verify this hypothesis, Oculus Rift, a popular HMD product line, will be used in evaluation phase.

3.5 Related Work

3.5.1 Virtual Reality / Virtual Worlds for Learning

I. VR/VWs for Collaborative Work and Learning

As mentioned earlier, Virtual Worlds (VWs) have a great potential for learning. In Antonacci et al. paper (Antonacci et al., 2008), they described various learning activities in VWs and explained what and how this potential was put in use. They indicated that VWs could be a place for students to participate actively in learning experiences as well as exchanging ideas and having fun. In addition to that, they stated *"Educational games and simulations in virtual worlds engage students in higher-level cognitive thinking, such as interpreting, analyzing, discovering, evaluation, acting and problem solving. The ability to interact with one another simultaneously provides students the opportunity to learn concepts not easily learned from a textbook or lectures."*

It is worth noting that the 3D platform SL has attracted a lot of interest in terms of using VR for educational purposes. In the paper (Molka-Danielsen and Deutschmann, 2009), the authors discussed about the potential that SL offered to teaching and learning activities in VR by stating *"For learners and educators in Second Life (SL) the possibilities for learning are very numerous and exciting. Several courses offered in SL have prompted the potential student to imagine a learning environment where they can go anywhere and do anything while interacting and sharing experiences with others."*

The section below will present some suggestions on how VR/VWs can be used for collaborative work and learning (Antonacci et al., 2008) as well as provide accordingly some relevant projects developed in a variety of platforms.

Role-playing

Caruso et al. have indicated from their study findings that *"the interactive nature of Second Life fosters social interaction and collaboration among its participants by means of role-playing activities"* (Caruso et al., 2014).

Jarmon mentioned Ann Meyers Medical Center in SL as an example to support users to train emergency personnel and nurses by role-playing and improvisations (Jarmon, 2008).

Operating simulated equipment

OffshoreSims program, which is a simulation training solution by Kea Studios (Miri, Malaysia), offers off-shore learning experience from a virtual environment which *"enables trainees to learn safety procedures and then, apply their knowledge and skills learnt in the test scenarios effectively"* (PetroSims, 2015).

Genome Island in SL supports students to join in virtual experiences as well as generate data for analysis. Furthermore, the students can interact with Genetics experts for more knowledge (Macedo and Morgado, 2009).

In the paper (Fominykh et al., 2014), a series of prototypes using vAcademia (a desktop VR platform designed for collaborative learning) were presented with a goal of integrating immersive VR technologies into a VW.

- vAcademia-Kinect: supports users to control their 3D VW avatars with natural gestures. The motivation is to enable the teachers to lecture as usual while controlling their avatars with natural movements in VW at the same time (Fominykh et al., 2014)
- vAcademia-CAVE: uses a theoretical framework for learning "*threshold concepts*". This design aims to examine novel ways of learning that "*stimulate and enhance the potential of human creativity*" (Fominykh et al., 2014)
- vAcademia-Oculus Rift: shares the same motivation with vAcademia-CAVE. This prototype provides advanced visual experience to increase immersion and engagement in the virtual environment (Fominykh et al., 2014)

Designing and building purposes

ANGEL Learning Isle in SL: provides various possibilities for all educators to experiment using virtual collaboration technologies for online learning. Many interesting module works includes Virtual Classroom, Educators' Tool Gallery, SLED Sandbox (learn and practice SL building skills) and so on. (Antonacci et al., 2008)

Interacting with instructor-built or creating student-built simulations of physical or procedural processes

According to Antonacci et al. (Antonacci et al., 2008), VWs such as SL could be extremely useful for distance learning where the students gather to a common place to interact regardless of their physical locations.

Fominykh's article (Fominykh, 2012) discussed about the potential of 3D collaborative virtual environments for educational purposes. The author brought in some of the main approaches including virtual campuses and virtual cities.

- Virtual campus: is defined as "*a 3D collaborative virtual environment that uses the university metaphor and provides users with a range of tools for educational activities.*" Virtual campus model enables educational simulations, encourages collaborative learning and helps develop learning communities (Fominykh, 2012)
- Virtual city: is defined as "*an environment representing a real or fictional city and supporting a range of different activities for the purposes of education, cultural development, entertainment, and socializing for local communities and virtual tourists.*" Virtual city model provides the information about the city as well as the local educational locations to potential tourists and visitors (Fominykh, 2012)

In the paper of Chen et al. (Chen et al., 2008), On-Line Interactive Virtual Environment (OLIVE) is introduced as a software platform that "*allows customers, partners, and developers to create persistent virtual worlds where users can collaborate over networks to communicate, train, rehearse, analyse, experiment, socialise, and entertain*". An application using the OLIVE platform was mentioned in the paper; Stanford Medical School project. This platform was used to "*support training sessions of medical staff using a replica of the Stanford emergency driveway, entrance, waiting area, acute five-bed suite,*

treatment area, hospital beds and equipment". This training proved to increase trainees' confidence as well as team work skills (Chen et al., 2008).

II. Serious Games and Simulation in VWs

According to Ribeiro et al., *"Serious Games refer to video games whose application is focused on supporting activities such as education, training, health, advertising, or social change"*.(Ribeiro et al., 2012) In the same paper, they proposed an approach which using serious game to train evacuation behaviour. Their approach included a model created using Blender resembled accurately the actual location and a single simulation scenario using Unity3D game engine. The simulation aims to *"recreate the experience of the user being physically there and exploring their surroundings"*.

As mentioned above, SL seems to be a popular platform in terms of supporting for academic learning and training purposes. Angelina Macedo and Lina Morgado stated in their paper (Macedo and Morgado, 2009) that *"This virtual world has the potential to develop a simulation of 'real life' skills and competencies or to create new worlds rather than 'academic life', that is, it can enhance an experiential learning through activities such as simulations and role-plays."* They mentioned some virtual training applications as examples as follows:

- Thomson Netg Training: this center develops professional training in ICTs, management, sales and customer support. It supplies on-demand training and synchronous classes using audio, video and podcasts for teaching materials (Macedo and Morgado, 2009)
- Heart Murmur Sim: this place is for cardiac training where the participants can visit virtual patients, listen to their cardiac rhythms and make a diagnosis (Macedo and Morgado, 2009)
- National Oceanographic and Atmospheric Administration: this place created the visualization in real time of some weather phenomena such as tsunami or the melting glaciers effects on the ocean level (Macedo and Morgado, 2009)

Their paper also suggested a good way on how SL and VWs in general could be used optimally for educational purpose as *"Students and tutors can meet in-world, share information and resources (audio and video files, for instance), discuss projects, make presentations, and do group projects. They can also interact with other educational institutions and develop international projects"* (Macedo and Morgado, 2009).

It is obvious that serious games, using VWs for education, training and so on, have become an interesting research topic in the recent years. While these VR applications have potential, they also contain challenges. Hsu et al. mentioned about potential shortcomings including the lack of experience on VR applications could result as *"a barrier to adopt such technology"*. They thus suggested to provide preliminary training for users so that users could effectively use new systems (Hsu et al., 2013). Another challenge coming from the nature of digital games was indicated by De Freitas as *"There has been a dominant perception of gaming as a leisure pursuit with no pedagogic value"* (De Freitas, 2006). She also pointed out a potential problem due to different definitions of immersive

learning as *"Differing definitions of immersive learning abound and create problems when discussing the subject of educational or serious games. There is a need for educational games to appropriate their own terminologies (as different from those used in leisure gaming contexts), although this may create greater confusion when researchers and games developers attempt to work together"* (De Freitas, 2006).

Several points from these papers are relevant and used as guideline to define requirements as well as to design questionnaires and interviews for this thesis evaluation.

3.5.2 Virtual Agents / Virtual Humans for Emergency Training

A virtual evacuation would yield learning effect only when it could illustrate a realistic image of virtual humans behaviours during the emergency situation (Ribeiro et al., 2012; Kobes et al., 2009). Several researches and studies have worked on defining how to achieve this with current technologies. Observing real human behaviours in various pressure circumstances and applying the latest technologies to build virtual agents imitated the finding on real human behaviours have been so far one of the main research directions. Tan et al. proposed an evacuation model which contained agents *"capable to make decisions regarding escape route choice and move along the route while interacting with the surrounding people"* Tan et al. (2014). The virtual indoor space was a grid graph-based representation that enclosed the movement probability extracted from GIS base route analysis.

They designed virtual agent behaviours based on the observations from real humans. These observations were interpreted as a guideline to build realistic virtual agents, as they described *"On the one hand, people move to the next goal along the shortest path given time pressure. On the other hand, people try to keep a distance from others and obstructions when moving on. Besides, people tend to keep its previous moving direction because of inertia force."* The psychic stress in pressure situation which could affect humans perception of distance was well aware. Thus, they set a threshold for agents' awareness of the shortest path associating with some specific rules. Their research result showed that virtual agents didn't move accurately along the shortest path during evacuation due to interactions with the surrounding agents. This could be observed clearly in the corridor area where the crowd density was high.

Pelechano Gomez et al. research (Pelechano Gómez et al., 2007) has taken one step forward in the way that it explored the complex psychological and sociological impacts of evacuation behavior which the previous paper (Tan et al., 2014) lacked. In this paper, it was mentioned that *"When simulating human behaviour, it is essential to model the psychological factors that affect their decisions."* Carrying out a observation work on human behaviours during emergent situation, Pelechano Gomez et al. achieved a qualitative finding including human behaviours when being simulated panic during evacuation:

- Individuals may not be aware of the building's internal connected routes. Thus, they may skip some suitable paths for evacuation
- Increasing stress level could affect the full functioning of one's sense, which leads to reduce awareness, especially the ability to orient oneself quickly in rooms and surrounding areas

- People who have not been properly trained are likely to feel stressed and might find themselves incapable of making the right decision due to time pressure
- People in panic tend to get disoriented
- People in panic may also change their role from leader to follower

They offered a model which they could *"specify different personality types by assigning different roles to the agents in the simulation (i.e. trained personnel, leaders and followers), so that each individual will exhibit its own behavior."* All agents could communicate with each other to share information about the evacuation paths and obstacles found within the building while they explored the surrounding environment. Moreover, it was possible to *"specify the percentage of agents in the crowd that will exhibit impatience behaviour, panic or panic propagation, tendency to fall, pushing predisposition, and weaker or stronger avoidance behaviour."*

This model after simulation provided many interesting findings such as:

- Pushing allows to simulate panic and panic propagation: *"This proves to be very useful when simulating panic individuals or just people trying to get through the crowd faster"*
- Navigation with learning and simulation of disorientation under panic: *"An agent under panic, will try to figure out the way to exit a building when the known path appears to be blocked, but its ability to remember the different features can be altered by the effect of stress. Therefore the search for the exit will be more chaotic, with the possibility of walking over and over to parts of the environment that have previously been explored"*
- Different types of queuing behaviour leading to more realistic types of bottlenecks: queuing types would be varied between a panic and a non-panic situations. This model allowed to specify the type of queuing behaviour, therefore it simulated more accurately people behaviour in a non-panic situation.
- Falling people becoming new obstacles: *"When an individual falls due to the strong pushing from the crowd, the other individuals will walk around to avoid it until the individual would eventually stand up and continue walking. When the crowd is very dense, some individuals may not be able to walk around and so could also fall down"*

Several interesting points from these works, especially how to create realistic panicked virtual humans for simulation, gave a lot of insights and were taken into account for the implementation of the panicked virtual human in this thesis. The idea on crowd simulation was also applied to a certain degree in the virtual evacuation.

A paper by Buono et al. presented a simulation model for a virtual fire situation in office setting in SL(Buono et al., 2008), which used both human participants and virtual humans. The virtual office was an accurate representation of a real life location furnished with sufficient indoor emergency information in terms of exit signs, flashing signals of

anti-fire danger, reflective materials. Human participants were role-players who got assigned with different tasks such as representing a wheelchair person to simulate discomfort and eventual movement inconveniences, a person who was responsible for assisting disabled people in case of fire, a extinguisher operator who attempted to stop the fire with extinguisher, a panicked person to simulate unexpected reaction emerged by the danger situation (e.g. ask for help, obstruct others to evacuate). Virtual humans in this model represented as coordinators to lead the progress of the evacuation simulation including start and end action of simulated blaze as well as providing instructions to human participants before and during the fire situation. In this model they used simulation cues such as:

- Fire with spreading effect
- Smoke with spreading effect
- Red light effect that lights walls and objects. This is meant to guide the avatars' behaviour during the simulation
- Doors that close automatically in case of fire
- Wheelchair person
- Extinguisher operator
- Panicked person

The result after testing this simulation model confirmed a few points as follows:

- The human participants could get familiar with the environment interactive features easily although they weren't familiar with new technologies beforehand. This is a meaningful fact to contribute to the potential that VR and VHs could have for emergency training (Buono et al., 2008)
- In half of the cases, the panicked human was successful to hinder the evacuation in the way that he/she managed to get other human participants to help him/her, which in turn postponed their own escape. In another half of the cases, he/she remained inside an office room or hid somewhere, which in turn couldn't influence anyone in the evacuation. This finding could be explained by the lack of a personal bond attachment (i.e. participants didn't know each other beforehand) which led to that they didn't bother to search for others under emergency situation. There would be more noticeable if the panicked person had shouted out for help or a sound of the blocked door where he/she remained inside (Buono et al., 2008)
- Emergency signals and their position played an important role during the evacuation simulation as they helped those human participants who weren't familiar with the floor layout to find the way out (Buono et al., 2008)

This model contained a number of good points to which the thesis work referred. In fact, the combination of human participants (role-players) and VHs to enrich the virtual evacuation from this model has been applied to the thesis's idea of implementation. The simulation cues such as fire, smoke, wheelchair person and panicked person have also been introduced in this thesis with a purpose to increase simulation for human participants.

Implementation

The goal of this project is to implement a virtual emergency training in an office setting by using VHS and environmental effects to simulate the evacuation in case of fire. Thus, VHS implementation is one of the major tasks in this project. In order to create VHS with realistic behaviours in emergency scenarios, it is crucial to observe and study these relevant behaviours from real life humans. Virtual space used for this project needs to be modified so that it can be used for a fire emergency case. Literature from chapter 3 as well as the result from the Specialization project are used as a guideline in designing a list of requirements for this project.

In the first section of this chapter, a brief description of the emergency training will be introduced so that readers have an idea about what needs to be implemented. After that, requirements for VHS will be explained followed by requirements for Virtual Space (The office). The requirements created from the result of Specialization project and NAV feedback from that project evaluation will be added appropriately in either VHS or Virtual Space requirements. Theories from (Kuligowski et al., 2005; Hajibabai et al., 2007; Kobes et al., 2007; Ribeiro et al., 2012; Tan et al., 2014; Pelechano Gómez et al., 2007; Kasap and Magnenat-Thalmann, 2008; Buono et al., 2008) will be mentioned suitably to reason the corresponding requirements. Other theories in chapter 3 have been taken into account with awareness of relevant advantages and challenges. In the second section of this chapter, the implementation of these requirements will be presented.

A full list of the requirements with the reasons from where they arrive can be found in Appendix.

4.1 Requirements Design

4.1.1 Virtual Emergency Training

The training starts with a regular working day in the virtual office. VHS aka co-workers perform various daily routines including meeting, answering phone call, typing, gathering in a social area. There is a kitchen with an oven, a fridge and a coffee machine in the

social area. All of a sudden fire starts showing at the oven area, which in turn activates the fire alarm. Smoke starts spreading to surrounding area. All co-workers move to evacuate towards exit doors. There is a wheelchair co-worker who has trouble to evacuate due to movement inconvenience. There is a panicked co-worker who loses her sense of direction so that she keeps randomly running around. Her unpredicted behaviours hinder other co-workers to evacuate if they meet her on their way out. The training will be ended when all co-workers have evacuated to a specific meeting place outside the office. The only co-worker who remains in the office is the panicked one. The illustration for this scenario can be seen in figure 4.1, 4.2 and 4.3. This training supports role-playing mode. Every human



Figure 4.1: The virtual office with the co-workers in normal conditions.



Figure 4.2: The virtual office with the co-workers in a fire situation.

participant will be assigned to a role which defines a special task he/she will carry out during the training. The tasks will be among to help the wheelchair co-worker to evacuate, to trigger fire at the oven area and to join the evacuation with the co-workers.



Figure 4.3: The training ends when co-workers evacuate out of the virtual office except the panicked one.

4.1.2 Virtual Humans

VHs implementation is an essential task in this project. In order to look and behave realistically in different situations e.g. normal conditions and emergency situation in an office setting, the co-workers were required to follow an office culture in terms of clothing, behaviours and interactions. This set of project requirements defines the co-workers key characteristics and behaviors.

In normal conditions

As inherited from the Specialization project, this project continues to use Hayes-Roth, Maldonado, and Moraes 10 character qualities and Hall's proxemics theory, discussed in Chapter 3, to decide requirements for appropriate behavior and appearance as well as how and where they should be placed in the office.

(*) sp: Requirements derived from the result of the Specialization project and NAV feedback from that project evaluation.

Req	Description
CE_N_1	Co-workers appearance should look realistic
CE_N_2	Co-workers behaviours should look realistic
CE_N_3	Co-workers should behave appropriately in an office context
CE_N_4	Co-workers should dress appropriately in an office context
CE_N_5	Co-workers should elucidate gender roles in the office
CE_N_6	Co-workers should display office interaction pattern
CE_N_7	Co-workers should give an understanding of working routines in a public sector
CE_N_8	Co-workers should have varied appearance (sp.)

Table 4.1: Co-workers effects in normal conditions (CE_N)

In order to create a believable image of the co-workers, the requirements CE_N_1, CE_N_2, CE_N_5, CE_N_8 need to be fulfilled. Beside concentrating to create realistic appearances and behaviours for these co-workers, it is equally important to ensure their looks and behaviours make sense in an office context, which in turn present a working day

in a public sector Therefore, the requirements CE_N_3, CE_N_4, CE_N_6, CE_N_7 are defined to achieve this effect.

Req	Description
CP_N_1	Co-workers have a social distance to each other when walking opposite
CP_N_2	Co-workers have a social distance when following each other
CP_N_3	Co-workers have a social distance to each other when standing and talking

Table 4.2: Co-workers placements in normal conditions (CP_N)

These requirements are derived from Proxemics theory by Edward T. Hall which defines distances between humans based on their relationships. This theory needs to be applied so that the co-workers placements look realistic.

In emergency situation

When an emergency situation arises such as fire, humans tend to react in the way that they perceive and validate the signs of danger, then they make decisions to escape the fire situation with lowest physical harm. This reaction is called *"fire response performance"*. (Kobes et al., 2007) According to Kobes et al., fire response performance is influenced by the behaviour of nearby people, the building layout and the fire effect. Moreover, they state *"Aspects like clue validation and way finding performance during evacuation are found to have important effect on the probability of survival in case of fire."* Hajibabai et al. also mentioned about this activity as *"Way finding is a complex human activity involving moving along while evaluating alternatives and making decisions."*

The requirements for VHs in emergency situation will be derived from way finding concept and three basic activities characterising an evacuation process which are proposed by Kobes et al. (Kobes et al., 2007), namely:

- Awareness of danger by external stimuli (clue validation)
- Validation of and response to danger indicators (decision making)
- Movement to /refuge in a safe place (movement / refuge)

In Tan et al. article (Tan et al., 2014) and Pelechano et al. article (Pelechano Gómez et al., 2007), their agent-based behaviour models have similar features to the three basic activities from Kobes et al. This is to say, their models define that each virtual agent has two levels of behaviour that we refer to high level (decision-making, planning, familiarity, crowd, navigation) and low level (movement, social force, inertia, locomotion).

The needed requirements will also take into account tendencies that a panicked human could follow during evacuation from (Tan et al., 2014; Pelechano Gómez et al., 2007), crowd behaviours from (Ribeiro et al., 2012; Kobes et al., 2007) and the simulation for discomfort from a wheelchair human from (Buono et al., 2008). In addition to that, concepts such as *"Autonomous behaviour"* and *"Interaction"* from Kasap et al. paper (Kasap and Magnenat-Thalmann, 2008) are aware when designing these requirements.

These requirements will be used to evaluate whether or not the design of co-workers appearances and behaviors could convey information about an evacuation in a public sector.

(*) sp: Requirements derived from the result of the Specialization project and NAV feedback from that project evaluation.

Req	Description
CE_E_1	Co-workers should move out of their current places when the fire alarm goes off
CE_E_2	A co-worker should notify the relevant fire department when evacuating
CE_E_3	Co-workers should evacuate towards exit entrances
CE_E_4	Co-workers should choose nearest exit
CE_E_5	Co-workers should evacuate in groups (group behaviour)
CE_E_6	In case of potential collision with others, co-workers should avoid by adjusting their positions or replanning their evacuation routes
CE_E_7	Crowd density should be high in the corridor area
CE_E_8	Co-workers should reach a meeting place situated outside the office after evacuation
CE_E_9	All co-workers except the panicked co-worker should evacuate successfully
CE_E_10	The panicked co-worker should randomly move from one place to another with chaotic patterns
CE_E_11	The panicked co-worker should hinder other co-workers to evacuate when she encounters them on her way
CE_E_12	The wheelchair person should be assisted
CE_E_13	The wheelchair person should simulate discomfort and movement inconvenience
CE_E_14	There should be a natural placement of co-workers when changing from normal conditions to evacuation situation
CE_E_15	Co-workers should give an understanding of evacuating process in a public sector
CE_E_16	Co-workers behaviours should look realistic when an emergency situation occurs.

Table 4.3: Co-workers effects in evacuation situation (CE_E)

4.1.3 Visual Space

Virtual space is an essential factor to simulate an evacuation. This means that it should contain various simulation cues to trigger an emergency situation and interact with VHS as well as role-players. One activity that involves humans during evacuation is way finding. According to Hajibabai et al. (Hajibabai et al., 2007) and Kobes et al. (Kobes et al., 2007), there are four types of environmental variables that impact way finding performance within built environments: *visual access, architectural differentiation, signs and*

room numbers to provide identification or directional information, plan configuration.” In the thesis project, these environmental variables will be reflected by exit signs with arrow (on the walls) for exit directions, exit signs at exit entrances, corridors. They also mention that the fire and smoke effect influence the occupants way finding abilities to a great extent. Thus, fire and smoke are important simulation cues for this project evacuation. In the same paper, Hajibabai et al. present a finding that *”The better placement of the cues and optimum planning of the quality and quantity of the signage lead to shorter evacuation time from the building.”* This is an evidence to indicate that sufficient information to instruct evacuation will ease the evacuation process. The needed requirements will take into account the sign placements. (see Table 4.4 and 4.5) Last but not least, according to NAV security expert, meeting places are an important element in emergency training which indicates where the occupants should gather after evacuation. This designs a new requirement in table 4.4.

(*) sp: Requirements derived from the result of the Specialization project and NAV feedback from that project evaluation.

Req	Description
ES_N_1	The office should have sufficient information and equipment in case of fire
ES_N_2	The office should have exit signs indicating exit directions
ES_N_3	The office should have exit signs situated visible at eye sight level
ES_N_4	The office should have meeting places situated outside the virtual office
ES_N_5	The walls in the office should not be able to walk through (sp.)
ES_N_6	The corridors in the office should be scaled to be broader (sp.)
ES_N_7	The office should have some sitting places (sp.)

Table 4.4: Environmental simulations in normal conditions (ES_N)

It is worth noting that the requirements ES_N_1, ES_N_2, ES_N_3, ES_N_4 take into account the collected information from the consulting hour with NAV security expert regarding fire emergency response.

Req	Description
ES_E_1	The fire should look realistic
ES_E_2	The smoke should look realistic
ES_E_3	The smoke should emerge as soon as the fire starts
ES_E_4	The fire alarm should be activated as soon as the fire starts
ES_E_5	The smoke should spread to surrounding areas in the office
ES_E_6	The smoke should hinder occupants navigation because of sight reduction
ES_E_7	The combination of fire, smoke and fire alarm should contribute to the evacuation simulation

Table 4.5: Environmental simulations in emergency situation (ES_E)

4.2 Project Implementation Overview

This thesis project contains improvements derived from NAV's suggestions for the Specialization project evaluation. That is to say, CE_N_8 "Co-workers should have varied appearance (sp.)"; ES_N_4 "The walls in the office should not be able to walk through (sp.)"; ES_N_5 "The corridors in the office should be scaled to be broader (sp.)"; ES_N_6 "The office should have some sitting places (sp.)"

Below is a summary of the implementation in the sense that it explains about what have been reused from the Specialization project and what have been newly implemented for this virtual emergency training. At the same time, the list of needed requirements (see Appendix) used to guide this implementation will be checked whether they are implemented by the implementation work. After that, the actual work of newly implemented features will be described.

4.2.1 Implementation of Virtual Humans

Inherited features from the Specialization project

- The existed working scenarios with animated co-workers. Results from the Specialization project have shown that using these scenarios could give an understanding about working routines in a public sector. See details in (Nguyen, 2014)
- The scripts that animated gestures such as walking, talking on the phone, talking face-to-face, asking for a discussion
- The UV textures which were used in designing co-workers appearances

This thesis uses the animation technique called "frame swapping" and 3D software Blender to create animated VHs. This technique has been also used in the Specialization

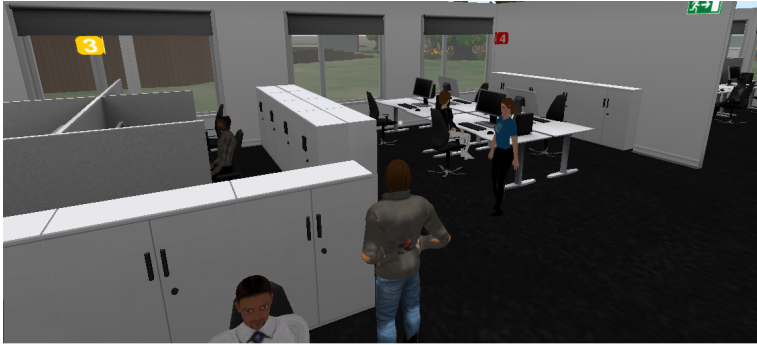


Figure 4.4: Regular activities in the virtual office.

project. The concept is that every frame presents the model in a specific moment. A series of these frames associated with a time line will produce an animation of that model. That is to say, in a fraction of time, one frame will be shown; the next fraction of time, next frame in the series will be shown. The quicker the frames get swapped, the more natural the model's movement looks.

Since this thesis inherits the existing working scenarios with VHS from the Specialization project, most of the requirements in tables "*Co-workers effects in normal conditions*", "*Co-workers placements in normal conditions*", "*Co-workers models requirements*" and "*General office requirements*" are derived from the requirement list of that Specialization project, (see Appendix). The requirements which are for improvement or new implementation will be discussed in the next section - "*New features*"

New features

In table "*General office requirements*", there is a requirement *GO_1 The office contains equal or greater than 8 co-workers*. 8 co-workers were the number of VHS used to visualize the office regular activities (working scenarios) in the Specialization project. Therefore, this thesis needs have at least 8 co-workers in order to keep all the working scenarios from the Specialization project. Actually in the implementation, this thesis extends this number of VHS to increase performance of crowd simulation during the evacuation.

The Specialization project only had two 3D models of VHS which were one male model and one female model. In order to implement the working scenarios, these two models were reused in all scenarios which in turn decreased the realism of the virtual environment. This led to a requirement to make more diversity regarding 3D models. In this thesis, there are 12 models implemented for the evacuation. Hence, the requirement *CE_N_8* is implemented.

The walking script and sitting script of the models have also been modified to demonstrate the evacuating behaviour. In fact, the scripts have added a new part to handle the behaviour of the VHS when the fire starts and fire alarm goes off. There is another added part of script to handle the reset method which is supposed to bring all VHS back to their assembled positions. The final version of walking script and sitting script aim to fulfill the requirements *CE_E_1*, *CE_E_2*, *CE_E_3*, *CE_E_4*, *CE_E_5*, *CE_E_8*,

CE_E_9, CE_E_14, CE_E_15. Below is the pseudo code of the modified scripts:

```
while in move state do
  navigate to chosen destination;
  set timer event;
  while timer do
    show walking animation;
  end
  if destination has been reached then
    go to pause state;
  end
  if receive fire message then
    go to escape state;
  end
end

while in pause state do
  say pause;
  show pause frame;
  choose next destination;
  set timer event;
  while timer do
    go to move state;
  end
end

while in escape state do
  navigate to nearest exit path;
  set timer event;
  while timer do
    show walking animation;
  end
  if exit has been reached then
    go to waiting for reset state;
  end
end

while in waiting for reset state do
  if receive reset message then
    reset script;
  end
end
```

Figure 4.5: Pseudo code of the walking script

```
while in sit state do
  set timer event;
  while timer do
    show sitting animation;
  end
  if receive fire message then
    go to escape state;
  end
end

while in escape state do
  navigate to nearest exit path;
  set timer event;
  while timer do
    show walking animation;
  end
  if exit has been reached then
    go to waiting for reset state;
  end
end

while in waiting for reset state do
  if receive reset message then
    reset script;
  end
end
```

Figure 4.6: Pseudo code of the sitting script

The requirements CE_E_6, CE_E_7 which about collision avoidance and crowd density can only be tested when the evacuation happens. Figure 4.7 shows that these requirements are implemented.

There is a specific script written to handle the complicated behaviour of the panicked co-worker. This script is supposed to satisfy the requirements CE_E_10, CE_E_11.

The wheelchair co-worker does not have script to handle behaviour when the fire emerges. Instead, she has a script to simulate her wheelchair movement when someone wants to assist her out of the office. This script is to allow moving the wheelchair with her on it on a certain discomfort level. The requirements which this script means to answer are CE_E_12, CE_E_13.

4.2.2 Implementation of Virtual Space

Inherited features from the Specialization project

- The existed virtual office



Figure 4.7: Crowd simulation and collision avoidance in the evacuation.

- The existed exit paths

This project has got a permission from NAV about continuing to use their virtual office built from the Specialization project. Thus, NAV suggestions for improvement to this virtual space are considered for implementation. As a result, these suggestions shape the needed requirements ES_N_5, ES_N_6, ES_N_7. The next section *New features* will discuss all requirements which are for improvement or new implementation regarding the virtual space in this project.

New features

In order to simulate a fire situation in an office setting, there is required to implement fire, smoke and fire alarm in the current virtual space of the project.

The oven in the social area is chosen for this implementation. The idea is when someone touches the oven, he/she will activate fire. A script implementing that idea is made and hid in the oven object. In association with the fire, the smoke as well as the fire alarm will be triggered. These effects are put into the same script file of the oven object. Section 4.4 will explain in details about the script and how it aims to fulfill the requirements ES_E_1, ES_E_2, ES_E_3, ES_E_4, ES_E_5 which in turn attempts to meet the requirements ES_E_6, ES_E_7.

The corridor area in the virtual office needs to be scaled to be broader to a certain degree. This will facilitate the VHS when evacuating in the way that it is possible more than one VH move towards the exit doors at the same time and pace. The requirement ES_N_6 is used for this implementation. The walls in the virtual office need to be no longer walked through to fulfill the requirement ES_E_5.

Two sitting places are implemented on the sofa opposite to the oven area, which attempt to meet the requirement ES_N_7, see Figure 4.8.

The requirements ES_N_1, ES_N_2, ES_N_3, ES_N_4 are implemented as emergency signs are placed on the walls and above the exit doors. Two meeting places outside of the virtual office are also built. Figure 4.9 shows one of these two meeting places. Section 4.4 will cover more details on emergency signs implementation.

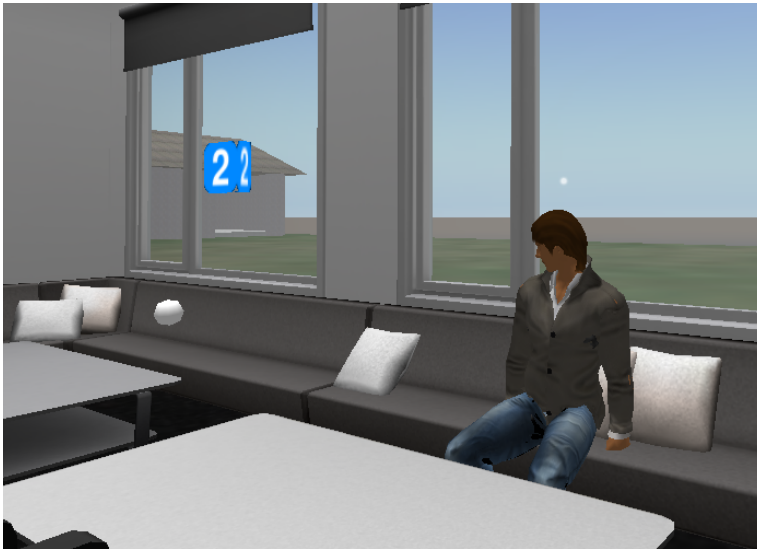


Figure 4.8: Sitting places in the social area.



Figure 4.9: Meeting place outside of the virtual office.

4.3 Implementation of Agent-based Simulation

4.3.1 Wheelchair co-worker

This is an important factor in evacuation simulation. The wheelchair co-worker aims to create discomfort and eventually movement inconvenience to a degree. More than that, this character reflects the realistic working environment at NAV, which supports disabled people to have active careers.

The wheelchair co-worker is implemented by using a 3D model of a wheelchair scaled to fit a 3D model of a female VH, see Figure 4.10.

There is a script to control the movement of the wheelchair when a helper moves it. The script is activated when the helper selects "Move", see Figure 4.11. The script uses a vehicle motor standard script from SL to manoeuvre the wheelchair co-worker in corresponding with the direction that her helper navigates to. There is an adjustment



Figure 4.10: Wheelchair co-worker in the virtual office.

modified to the manoeuvre ability to make the movement somewhat inconvenient as it is expected to be so in real life. Figure 4.11 also illustrates that the helper hands are positioned on the wheelchair handles when moving the wheelchair co-worker. A .bhv file (avatar animation file) is made and uploaded to SL for this helper gesture.



Figure 4.11: An illustration about how a helper can assist the wheelchair co-worker.

4.3.2 Panicked co-worker

From the literature used for this thesis, it is clear that a panicked agent is an essential element to an evacuation simulation. It is not only because that being panicked is one of possible human behaviours during emergency situations, it is also that panicked humans could propagate panic to others during evacuation.

The panicked co-worker is implemented by using a 3D model of a female VH. The script used for this co-worker is a modified version of the walking script which makes her navigate to random locations inside the virtual office except making a way out.

4.4 Implementation of Environmental Simulation

4.4.1 Office Layout

The virtual NAV office layout follows the principles demonstrated in Figure 4.12. This means that space is divided to satisfy different usage purposes with an attention to reduce noise in concentrating areas such as working areas.

According to the virtual office layout, there are two exit paths leading from the working area. One exit path aims to the right side of the social area while the other one aims to the left side, see Figure 4.13.

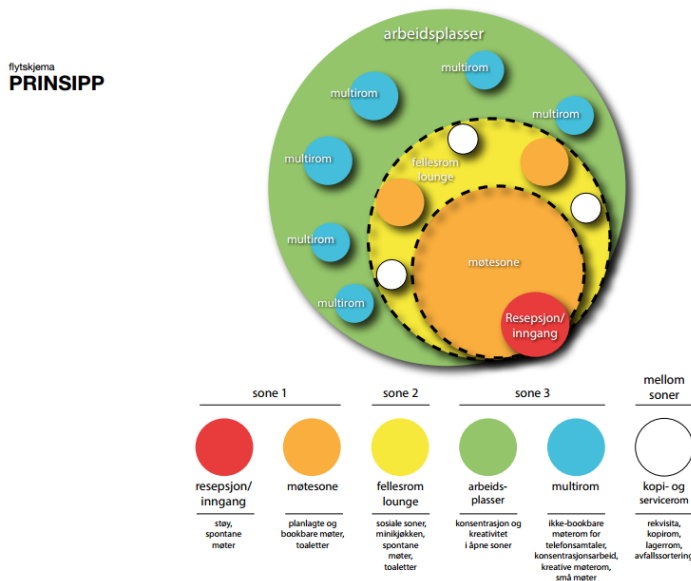


Figure 4.12: NAV Office principles.

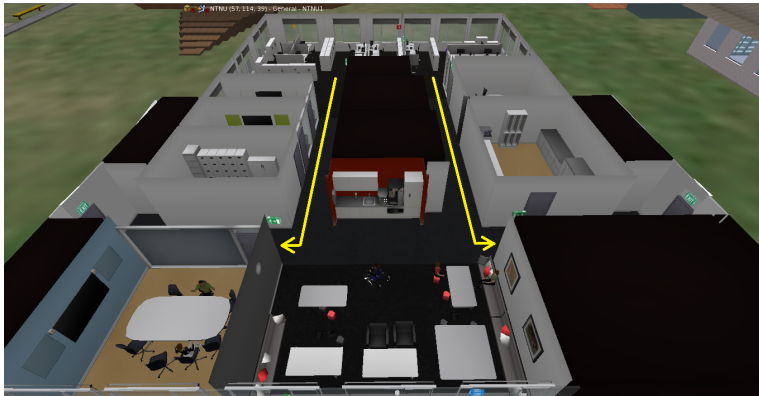


Figure 4.13: The virtual office with highlighted exit paths.

4.4.2 Emergency Signs

In order to meet the requirements ES_N_1 , ES_N_2 , ES_N_3 , exit signs with arrow to indicate exit directions are placed on the walls. Moreover, there are exit signs above the exit doors. Figure 4.14 shows these information. Emergency information, fire blanket and alarm button are also placed on a side wall in kitchen area in the same way as they are placed in the real NAV location, see figure 4.15.



Figure 4.14: The virtual office with available exit signs.

4.4.3 Fire - Smoke - Alarm

As mentioned above, fire is supposed to appear at the oven area. When someone touches the oven, fire will start, which in turn trigger smoke and fire alarm. Figure 4.16 and 4.17 show how to activate fire and how fire and smoke effect look like in the virtual office. The pseudo code for the script of handling fire, smoke and alarm will be introduced in Figure 4.18.



Figure 4.15: Emergency information, fire blanket and alarm button in the real location and in the virtual office.



Figure 4.16: Fire will be activated when the oven is touched.



Figure 4.17: Fire with smoke emerge after the oven is touched.

```
while in default state do  
  if the oven is touched then  
    if the fire state is off then  
      update fire state is on;  
      go to fire state;  
    else  
      update file state is off;  
      go to reset state;  
    end  
  end  
end  
  
while in fire state do  
  send fire message to co-workers;  
  show fire animation;  
  play alarm loop sound;  
  show smoke animation;  
end  
  
while in reset state do  
  send reset message to co-workers;  
  stop fire animation;  
  stop alarm loop sound;  
  stop smoke animation;  
end
```

Figure 4.18: Pseudo code of the fire-smoke-alarm script

Chapter 5

Evaluation

This thesis has been evaluated in three sessions. The first session is evaluated in a group of Emergency Management students at the college in Molde (Høgskolen i Molde - HiMo). The second target group for evaluation is civilians from NTNU campus and other locations. This civilian group has little or no experience in Emergency Management field. The final session is conducted with a group of NAV personnel in a video call at NTNU campus.

The purpose behind this multi-session evaluation is to verify whether virtual training approach could have potential for Emergency Management training both for trainer side (Emergency Management students) and for learner side (civilians). This thesis also aimed to get feedback of the virtual fire emergency training from NAV personnel who were familiar with the virtual office layout. If results show that the trainers could use this virtual training approach for their work and the learners could extract essential emergency information during the virtual training, this thesis work could be extended to suit more varied training purposes. In the evaluation with NAV personnel, if the feedback is good and the virtual training is helpful for their training purpose, this thesis work could be adopted and possibly extended to suit their future training plan.

The evaluation with Emergency Management students consisted of a demo to show the fire emergency training on a big screen, a self-trying session in SL with and without Oculus Rift, a questionnaire and an interview.

The civilian evaluation consisted of a demo to show the fire emergency training, a role-playing session, a questionnaire and an interview. The role-playing session was filmed in SL and edited to be a good training video. This would be used as an important documentation for last evaluation with NAV.

The reason this thesis provided a video to NAV is that in their feedback from the specialization project, they have suggested that a video clip could be a suitable approach for them to train in virtual environments. The evaluation with NAV consisted of a video observation, a self-trying session in SL and an interview.

5.1 Emergency Management Students

This was the first evaluation session. The fire emergency training in SL had been completed with a light smoke version in the fire scene. A questionnaire and an interview were designated. A computer lab in HiMo was arranged with SL installation and SL accounts for the participants to try a small role-playing session. There were also some people in SL ready to help film the role-playing and take screenshots of the virtual training.

Participants

The participants (10 members) were students from Emergency Management Training major at HiMo. They all have active career in operation staffs from a vast range of industries such as medical, fire department, police, petroleum (on-shore), maintenance department, logistic. Their expertise in Emergency Management Training both from study and work made them highly suitable to evaluate the virtual fire emergency training.

Procedure

The evaluation started right after they finished their lecture time. Firstly, the fire emergency training was shown on the big screen with explanation so that they all could get the idea about what to evaluate. They attended an introduction tour where they were showed around in the virtual office. They saw different areas and observed regular office activities carried by the virtual humans. They saw the social area connected to a kitchen place with coffee machine, an oven and a fridge. There were two virtual humans sitting at one corner, a virtual human in wheelchair stayed nearby. In a meeting room, there were two virtual humans visualizing a discussion. Going further into the working area, there was an open space with workspace such as desks, chairs, computers, cabinets. There were some virtual humans demonstrating a short conversation over their workspace. Other virtual humans were working quietly. There was a virtual human went to another virtual human, she talked something and shortly after that they both went to a separate room for discussion. Another virtual human received a phone call and she left her workspace to go to a nearby room to talk. After exploring this space, the tour took the participants back to the social area.

Suddenly they noticed the fire started at the oven area, the alarm went off, the smoke emerged and the virtual humans nearby moved from their seats to evacuate. The participants could observe the exit routes that all virtual humans used during their evacuation process. The virtual human in wheelchair was assisted to move out of the danger area. The participants also noticed a virtual human in panic who lost her sense of direction and kept running around randomly. The training ended when everyone reached the meeting place outside the office, except the panicked virtual human. It should be mentioned that there was no sound to illustrate the fire alarm during the fire emergency situation because it was some technical problem with the cable which connected the author's laptop to the big screen.

During the demo, all participants have expressed a positive attitude to the project idea. They also showed a curiosity towards this training approach. However, when they were offered to do a small role-playing session, most of them were hesitated. The problem was that they had little to no experience with navigation in Virtual Reality so they didn't think they could do their roles well in this virtual training. This resulted a a lesson learnt about having role-playing session in this thesis evaluation. The role-playing part is a good



Figure 5.1: Regular office activities in the virtual office.

opportunity only if participants have some experience with virtual worlds and know how to navigate around without making a big effort. Therefore, the best preparation is to make sure there are a few participants in the group who are familiar with Second Life/virtual worlds navigation.

Since the role-playing session was cancelled, the people who were ready to help in SL could not perform their promised tasks. This yielded another lesson learnt about the special condition of the trial and the participants in it. This trial was for volunteers in a situation that they didn't get any chance to try out SL before hand. Moreover, the trial started after their late class (at 16.00) so there was a difficulty to plan accurately what



Figure 5.2: Training ends with everyone evacuating out of the virtual office, except the panicked one.

would need to be done during the time they remained in the classroom. Because of that, it was also difficult to cooperate remotely with helpers in SL for filming or taking screenshot because it's unable to control the actual situation might happen in the trial.

Although the participants didn't join the role-playing session, they were encouraged to try to navigate around the virtual office and interact with the virtual humans individually. Some of them volunteered to do that. However, they didn't want to try to move the virtual human in wheelchair due to lack of navigation convenience. This is understandable as most of them were new to navigate in a 3D world. Nevertheless, six participants have volunteered to try out the Oculus Rift when navigating in the virtual office. Indeed, they were excited to try Oculus Rift and enjoyed the experience with it despite of their not-yet comfortable with VR navigation.

When they finished their exploring tour, a questionnaire time was arranged. This questionnaire with responses can be found in Appendix.

After that, the group gathered for an interview. They were asked a set of questions including the general realism of the training, the virtual humans appearance and behaviors, their ability to extract the information during training process and their opinions on the potential of this training approach. A few discussions were brought in between questions. A focus was laid on finding out how much they weighed the potential of using Virtual



Figure 5.3: Participants turned head to look around in the virtual office.

Reality with Virtual Humans for their work in Emergency Management Training.

5.2 Civilian Participants

The fire emergency training had been added a few more details to support role-playing session. Five locations for role-playing were marked with number from 1 to 5 inside the virtual office. Each location provided a different observation spot for the participant and by that, his/her role would be integrated with activities that happened nearby.

A heavy smoke version was newly implemented in the fire scene. This aimed to obstruct participants' pathfinding ability during the evacuation process.

Participants

The participants consisted of some students and citizens living in Norway and Vietnam. Except one participant who had EM background, the rest had little or no experience in the EM field. Since the role-playing session demanded the participants to gather in SL at the same time, the evaluation was arranged in two rounds. On the evaluation day, the first round happened in the afternoon at NTNU campus with 4 participants and the second round happened in the evening in SL with 3 participants. Each round observed a combination of introduction and training similar to the one provided to Emergency Management students. In addition to that, they were explained about their roles and where they would assemble in the virtual office. After that, there were a few "drill" attempts before the participants were comfortable to play roles together.

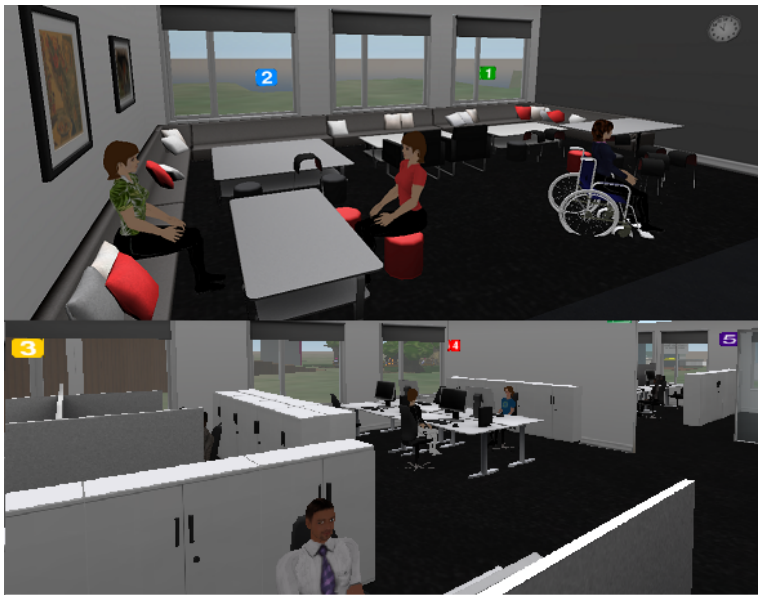


Figure 5.4: Locations for role-players to assemble in the virtual office.

Procedure

The role-playing session started with the participants logging in SL and assembling at their assigned locations. Then role-player number 2 would trigger fire by "touching" the oven in kitchen area. When fire appeared, smoke also emerged heavily and spread over the office. At the same time, fire alarm went off and virtual humans started to evacuate.

Role-player number 3, 4, 5 would join the evacuation with their nearby virtual humans. This meant that they would follow these virtual humans to exit routes. Role-player number 1 on the way to evacuate would help move the virtual human in her wheelchair.

The role-playing session concluded when all virtual humans and role-players reached meeting places outside the office, except the panicked virtual human

Since the heavy smoke version made it difficult to film the evacuation due to lack of visibility of virtual human escape traits, a decision was made to divide the film in two parts, the heavy smoke version and the light smoke version. The first part filmed the evacuation with heavy smoke as before. The second part filmed the evacuation with a modification of smoke which produced a thinner and smaller scale of smoke. After completing the role-playing session, the participants were provided a questionnaire and invited to an interview. Those participants in the second round answered questionnaire and interview online. This questionnaire with responses can be found in Appendix.

5.3 Interview with NAV

The heavy smoke version from the civilian evaluation was commented as too obstructive for the participants to find their ways during evacuation, especially at the first try. The



Figure 5.5: Views from location number 2 and 4 in the virtual office.



Figure 5.6: Three participants gathered in the social area before the role-playing session.

participants with little experience in virtual reality navigation suffered the most difficulty. In contrary, the light smoke version from the EM students evaluation created little obstructive effect to the participants, which was reported as not very realistic. In order to conquer this problem, a modification to smoke level had been implemented. As a result, the smoke became thick enough to hinder the participants to evacuate but not totally block their sight.



Figure 5.7: Virtual humans started to evacuate when fire emerged in the virtual office.



Figure 5.8: Role-player number 1 assisted the virtual human in wheelchair to move out of the danger area.



Figure 5.9: Role-players and the virtual humans have evacuated out of the virtual office.

A good training video had been produced from the raw videos filmed during the role-playing session in previous evaluation. A list of questions for interview was also prepared.



Figure 5.10: Panicked virtual human kept running randomly inside the virtual office.

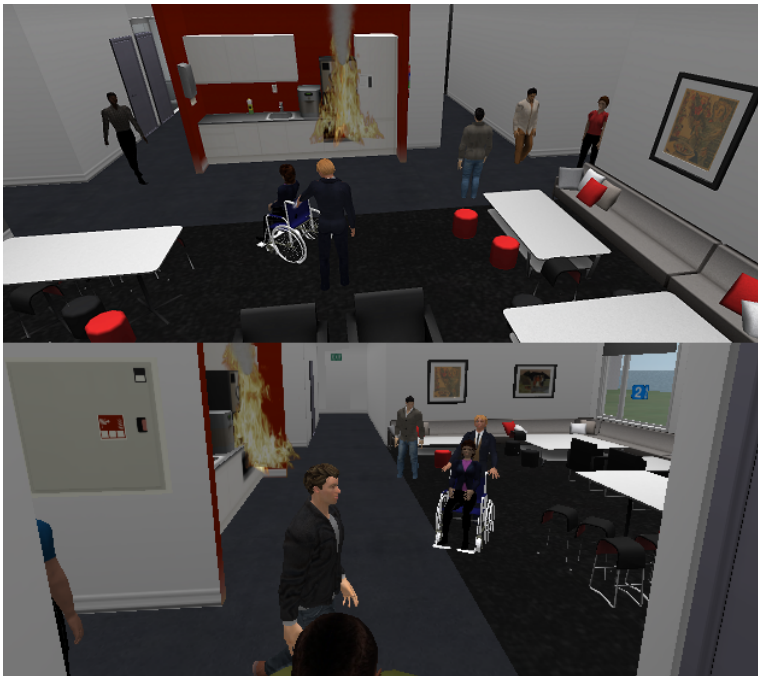


Figure 5.11: Virtual evacuation in the light smoke version.

Participants

The participants (2 members) were NAV officers who experienced with the office layout used in SL. Actually, the virtual office was designed based on their real location.

Procedure

The evaluation took place in a conference room at NTNU campus. The screen was shared and the participants could be observed via a webcam. The session started with a brief presentation in SL to highlight some key findings that the thesis had achieved from previous evaluations. This would help NAV to have a broader insight about the potential of this training approach, which could encourage them more to consider this approach for their training plan.

After the presentation, the video session was performed. The video was made of chronological events happened to form a good sense of an emergency situation in office setting. It also combined sound effect and text explanation to ease the comprehension of the participants during observation process.

One participant logged in SL after the video session to experience the virtual training in a live way. He was able to trigger the fire, simulated by the smoke and the alarm sound, helped the virtual human in wheelchair and evacuated with other virtual humans. Since the virtual training could be reset by "touch" the oven again, the participant could repeat the evacuation many times to have full experience with this training approach.

An interview was conducted afterwards to find out the degree of potential for using VR with VHS in Emergency Management training according to their newly experience with the video and self-trying session. The interview questions and corresponding answers can be found in Appendix.

Chapter 6

Results

This chapter starts with an overview of the results from the specialization project "Area Planning Project for a Public Sector" in terms of VHS and virtual space. This means to explain the foundation from which this thesis has been extended. After that, the results from the three evaluations of this project including Emergency Management student evaluation, the civilians evaluation and NAV personnel evaluation will be presented and discussed chronologically.

6.1 A Review of Results from the Specialization Project

The participants were co-workers from NAV Oslo division. In the evaluation, they reported that there was a connection of realism between the virtual office and their office in reality. 3D simulation was also fun to join according to their feedback. However, some of them got problem with navigating around in a 3D world due to lack of game-playing experience. The navigation difficulty made them busy to focus solely on fixing their navigation instead of concentrating on main information conveyed by the virtual space with virtual humans. They also got confused with navigation as the walls in the office could be walked-through. They suggested the simulation could be recorded as a film with an active avatar navigating smoothly in the virtual office.

The participants commented that VHS looked realistic in terms of their appearances and their placements in the office. However, there were only two 3D models implemented for this project so the office looked unrealistic when replicated these two models to fill up the space. Furthermore, the VHS needed to have various gestures as well as more natural movements when they walked.

The data collected from quantitative data tool (questionnaire) and qualitative data tool (interviews, discussions) proved that there was a potential to use virtual reality with virtual humans for training at NAV. This thesis aims to realize that finding with further empirical work which results are as follows.

6.2 Results from the Emergency Management Students Evaluation

There were 10 participants from Emergency Management major doing the first evaluation. The questionnaire focused on the immersion of the virtual training, the realism of the virtual space as well as the appearance and behaviours of the virtual humans. Moreover, the questionnaire and interview also aim to find out whether the participants could extract sufficient information from the virtual training; and the potential using virtual reality with virtual humans for Emergency Management training. Since the participants didn't attend role-playing session, the prepared questions for this topic yielded small relevant result.

Participants Background

The participants (4 females, 6 males) have high competence in Emergency Management field. However, 9 out of 10 have answered "Very little" when being asked about their experience with navigation in VR/virtual worlds (see Figure 6.1). This made them greatly suitable for the evaluation of this thesis since their answers would be based on their expertise in Emergency Management Training without bias toward virtual reality potential.

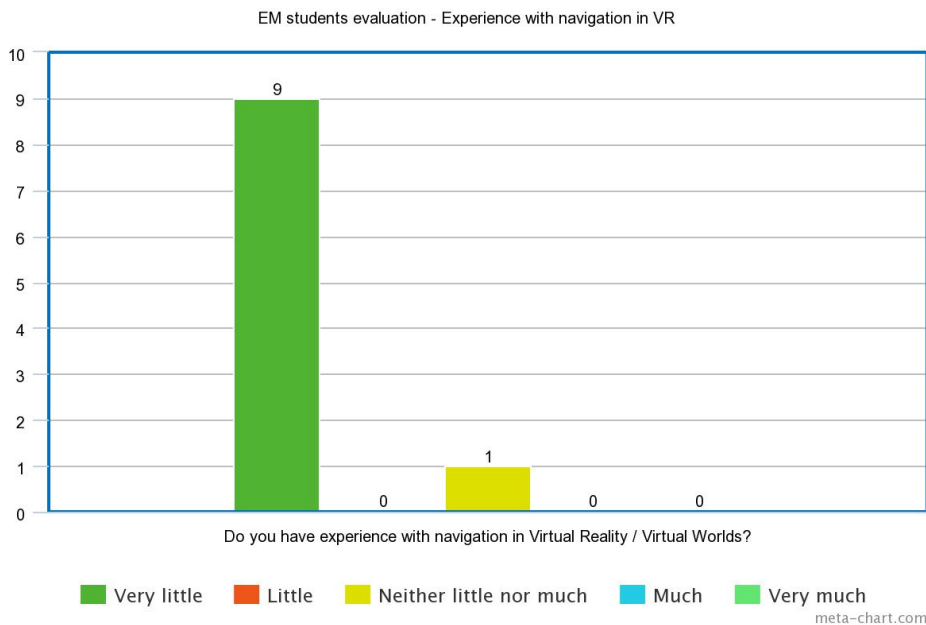


Figure 6.1: Emergency Management students evaluation - Experience in VR / virtual worlds.

When they were asked about what activities they have participated in VR / virtual worlds, 4 of them said they have tried "Online games", 2 others answered "Virtual education courses" who happened to mention the corresponding virtual worlds they experienced was "Second Life". One participant who answered "Online games" had also written "Other" and "Don't know, it was a long time ago" when being asked about what virtual

worlds/environments he had experience with. One participant indicated that he participated in "Virtual trainings" and he had experience in "World of Warcraft" while 3 others left blank answers for both questions about what activities they have participated in VR/virtual worlds and what virtual worlds/environments correspondent to their activities. The details could be seen in Figure 6.2.

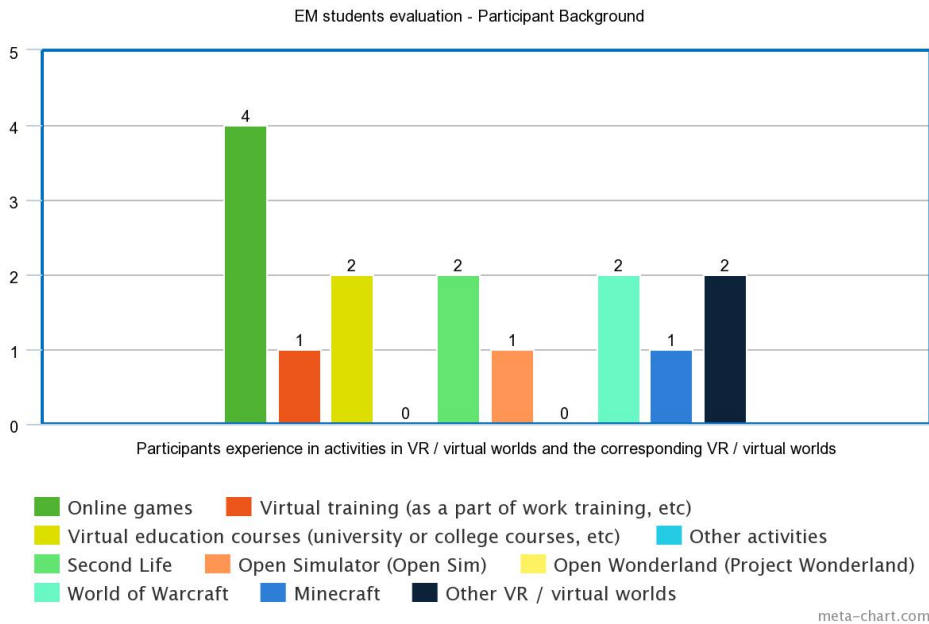


Figure 6.2: Emergency Management students evaluation - Participants Background.

Virtual Evacuation (VE) in Second Life

On the questions related to the VE in general, see Figure 6.3, fifty percent gave neutral answers (Neither little or much) while twenty percent said they felt much engaged in the VE when they followed other VHs to evacuate. Eighty percent were neutral or agreed very much that the simulation contributed to give them a better understanding of an evacuation process in public sectors while the remaining twenty percent agreed very little. Seventy percent gave neutral answers for the question about extracting information from the VHs appearance, behaviours and movement during the regular working process in the office while twenty percent meant that they extracted much information and ten percent meant the opposite. Seventy percent were neutral about the amount of information they could extract from the VHs appearance, behaviours and movement in evacuation procedure while ten percent meant that they extracted much information and the remaining twenty percent meant the opposite. This should be mentioned that the questionnaire was distributed for the participants right after the demo on the big screen. Therefore, many new findings had not yet emerged at that time. The interviews after the self-trying session with Oculus Rift yielded much more interesting and completed result for this evaluation.

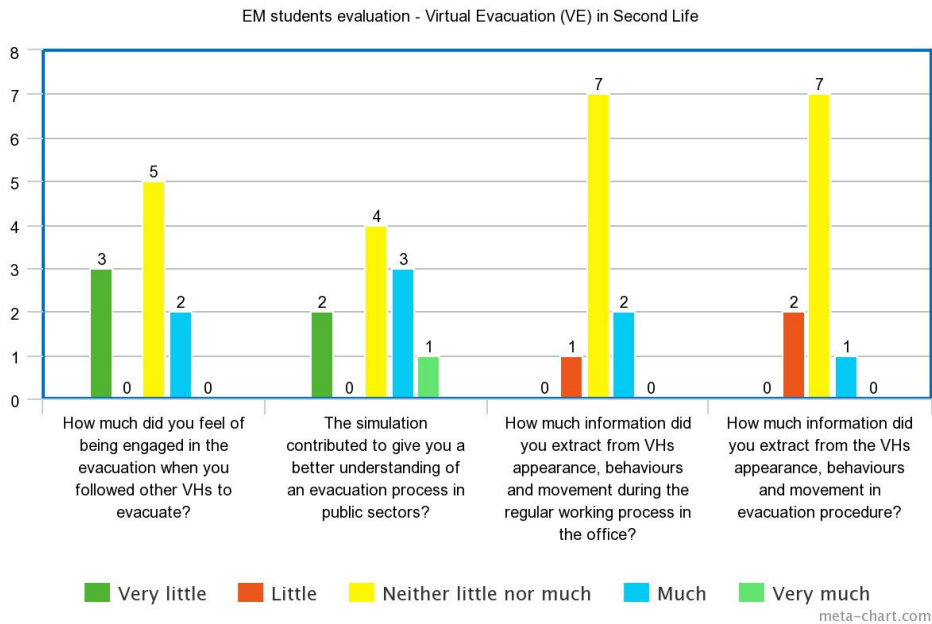


Figure 6.3: Emergency Management students evaluation - Virtual Evacuation in Second Life.

Figure 6.4 contains questions about measuring the extent of various impacts which this specific virtual evacuation could have for the participants during the training process. Eighty percent were neutral or agreed that the VE looked realistic while twenty percent agreed to a slight extent. Ninety percent of the participants were neutral or thought this training was fun and motivating to a great extent. Only ten percent thought the opposite. Seventy percent of the participants gave neutral answers when being asked about the simulation of VHS contributed to their understanding of the evacuation procedure while twenty percent thought the simulation contributed to a certain extent, the remaining of the participants (10 percent) thought the simulation contributed to a slight extent. When asked if they felt immersed with the virtual evacuation process, sixty percent of the participants were neutral, and twenty percent stated they felt immersed to a certain extent while the remaining twenty percent felt slightly or little immersed with the virtual evacuation process. Regarding the question about consideration of using similar simulations in the participants education, 60 percent were neutral or agreed while 40 percent chose answers such as "Slight extent" or "Little extent".

Figure 6.5 evaluates the impact of various simulation cues to the participants diagnosis of the emergency situation. Emergency escape signs contributed the most impact (70 percent) according to the participants responses. Active participation and office layout shared the equal impact of 50 percent. Effects such as smoke and fire contributed 30 percent while other simulation cues such as sound, VHS behaviours and positions yielded minor contribution to the participants diagnosis.

Figure 6.6 reveals the participants reactions during the virtual evacuation. Feeling

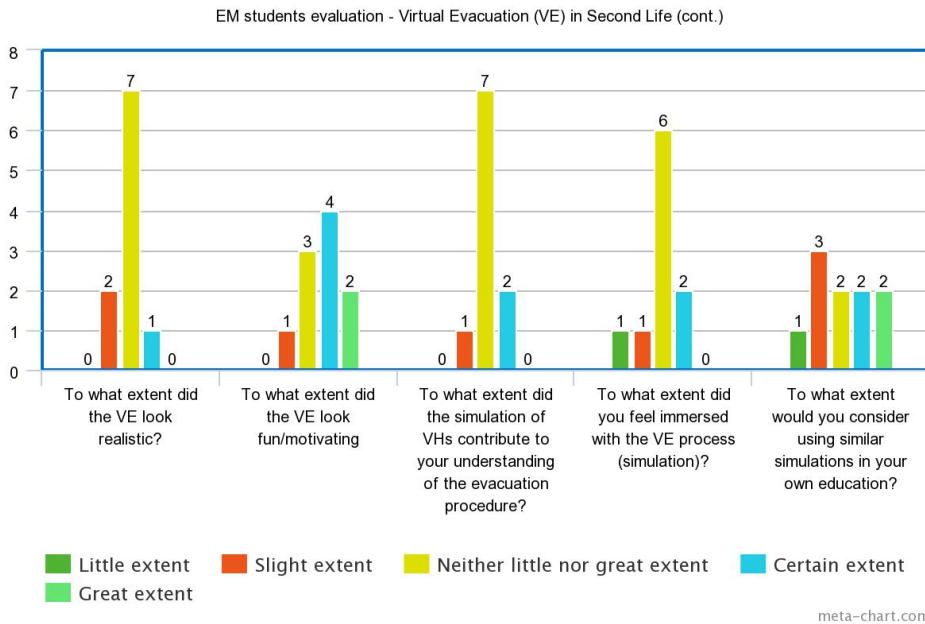


Figure 6.4: Emergency Management students evaluation - Virtual Evacuation in Second Life. (cont)

calm was the dominant reaction. Curiosity and a feeling of not involving were also highly resulted among the participants. It was interesting to find out that there were some participants reacted to the virtual evacuation in a combination of calm-curious, calm-not involved or calm-control feeling.

Virtual Reality (VR) and Virtual Humans (VHs) potentials in general

When asked if the participants thought VR with VHs would be suitable for EM training in public sectors, see Figure 6.7, the majority of them, 70 percent, agreed while 30 percent were neutral. Forty percent agreed to a certain or great extent that VR with VHs can contribute to EM training for general public locations such as school building, supermarket, hospitals etc...the remaining sixty percent gave neutral answers on that. Ninety percent were neutral or agreed that VHs can represent human characteristic in virtual EM training. Only 10 percent said to a slight extent. All participants were neutral or agreed to suggest virtual EM training for their future customers in the industry, especially thirty percent meant that to great extent.

Figure 6.8 presents questions about representation of the real location and role-playing in virtual EM training. Seventy percent of the participants indicated that it was highly important to have an accurate representation of the real location in virtual EM training while thirty percent were neutral about that. There were fifty percent agreed that role-playing provided a better learning effect in virtual EM training, the other fifty percent gave neutral answers.

Regarding the question about which fields they thought virtual EM training could have

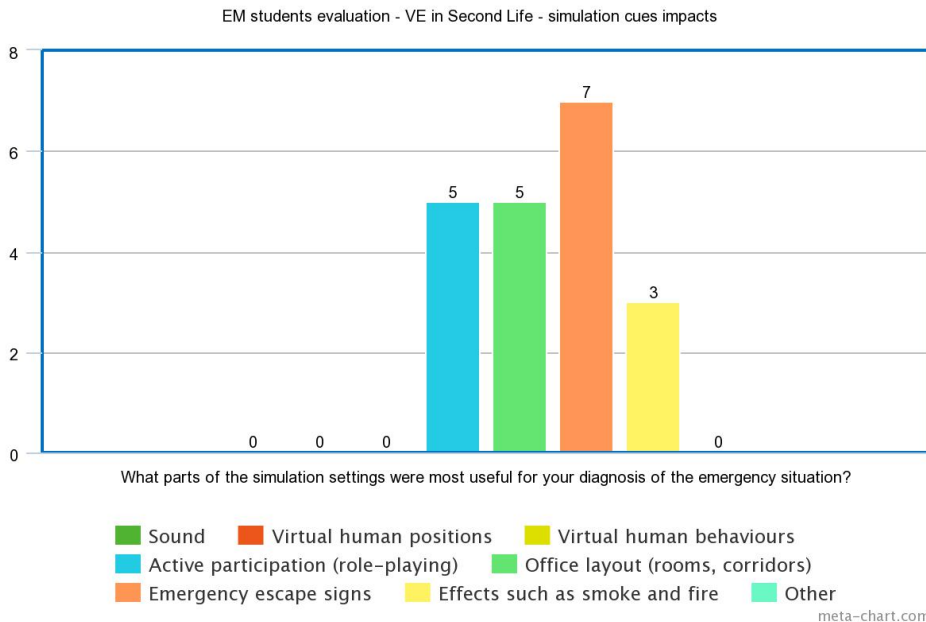


Figure 6.5: Emergency Management students evaluation - Virtual Evacuation in Second Life - Simulation cues impacts.

most potential (Figure 6.9), seven participants chose "Oil and gas" and "Firefighter". Five participants chose "Medical". One participant chose "Oil and gas" and "Other" where he stated "*Industrial Plants*".

Improvements for the virtual evacuation

When asked about suggestions for improving the VE, many participants chosen "Improve fire scene to be more realistic (broader scale of fire and smoke .etc) Creating crowd sound and ability to communicate between participants and VHs were also highly suggested. VHs improvements were mentioned. One participant contributed his own suggestions via "Other" option, stated "*Damage to virtual humans, due to incident or during evacuation. Also, lighting issues (missing lights or pitch dark)*" Details of this question are presented in Figure 6.10

Second Life with Oculus Rift

The first question regarding this part asked if the participants had previous experience with Oculus Rift. The answer was that none of the participants had tried Oculus Rift before this evaluation. Six out of ten participants had tried Oculus Rift after this thesis's demo. The following questionnaire results were provided from these six participants.

Figure 6.11 shows that 83.3 percent of the participants thought Oculus Rift improved the experience of immersion and presence in the virtual evacuation, while 16.7 percent

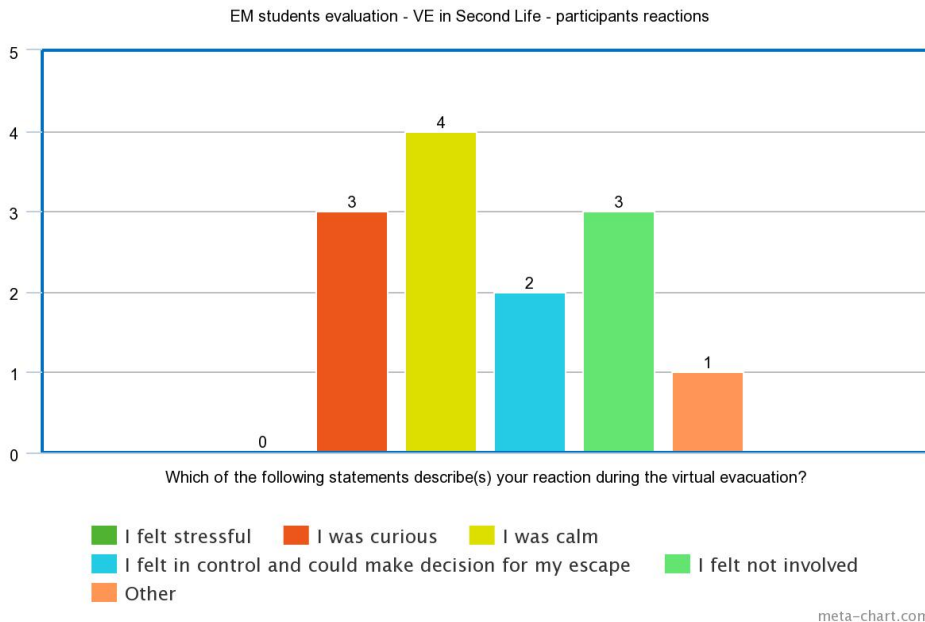


Figure 6.6: Emergency Management students evaluation - Virtual Evacuation in Second Life - Participants reactions.

were neutral. When asked if they thought using Oculus Rift for virtual EM training provided a better learning effect, fifty percent agreed to certain extent and other fifty percent agreed to great extent.

Figure 6.12 indicates that 83.3 percent of the participants agreed that Virtual Reality such as Oculus Rift and Augmented reality such as Google glass would have much to very much potential for EM training. Only 16.7 percent were neutral about that.

Questions for Role players

Since the role-playing was not conducted by the participants, the questions had somewhat biased answers due to limited role-playing access and different observing focus. There were six out of ten participants who gave answers. These were the participants who joined the self-trying session and tried Oculus Rift in SL.

Figure 6.13 indicates that 83 percent were neutral or agreed that the wheelchair human contributed to the evacuation simulation, while 17 percent meant that to little extent. When asked if they felt the panicked human contributed to the evacuation simulation, 67 percent were neutral or agreed while the remaining 33 percent meant that to little extent.

As illustrated in Figure 6.14, two participants felt of being engaged in the scenario when they moved the wheelchair human while two other participants felt neutral and 2

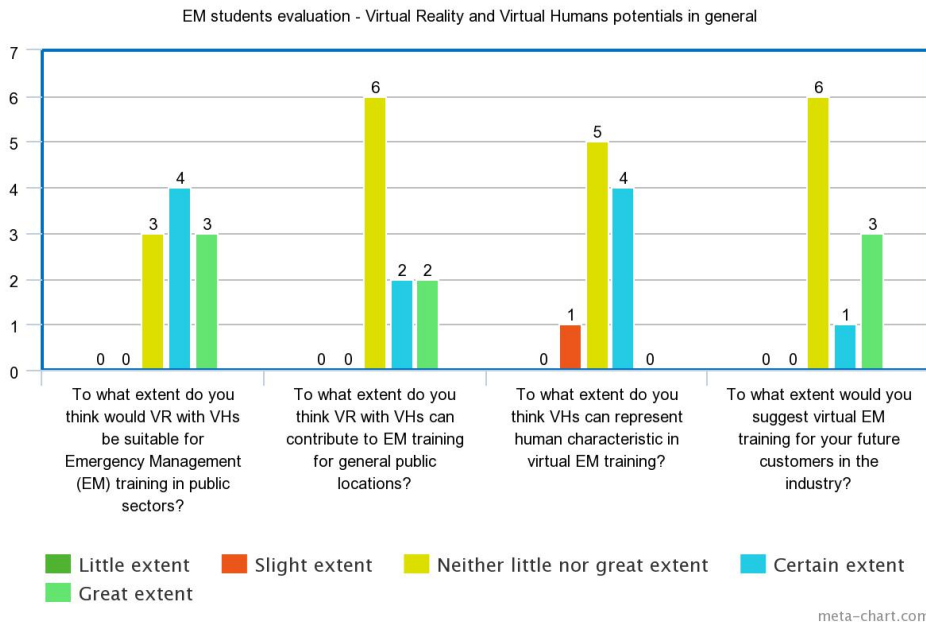


Figure 6.7: Emergency Management students evaluation - Virtual Reality and Virtual Humans potentials in general.

last ones felt very little engaged. This could be natural since the ones who moved the wheelchair human would feel more engaged in the scenario than the ones who just observed that. The second question yielded somewhat same pattern of answers. Fifty percent were neutral or agreed that they felt of being engaged in the scenario when they triggered the fire, while other fifty percent meant that to little extent. As mentioned in the beginning of this part, the lack of role-playing access and different observing focus could lead to biased answers. Biased answers in the questionnaire will be discussed more in Limitations section in chapter 7.

Observations

The participants were observed during the demo on the big screen and when they joined self-trying session with Oculus Rift. In general, the participants were both curious and excited to the demo. They held a positive attitude to this technology approach throughout the trial. Taking into consideration that they remained in the classroom at late hours for this evaluation, it was very encouraging. After the demo, they were very cooperative in the questionnaire phase and gave insightful comments on what could be improved in the virtual evacuation.

When being offered to try the Oculus Rift in SL, many participants seemed to be very positive, they volunteered and waited in turns for trying this equipment. When one tried on the Oculus Rift, he/she would soon comment on how they felt when seeing 3D images

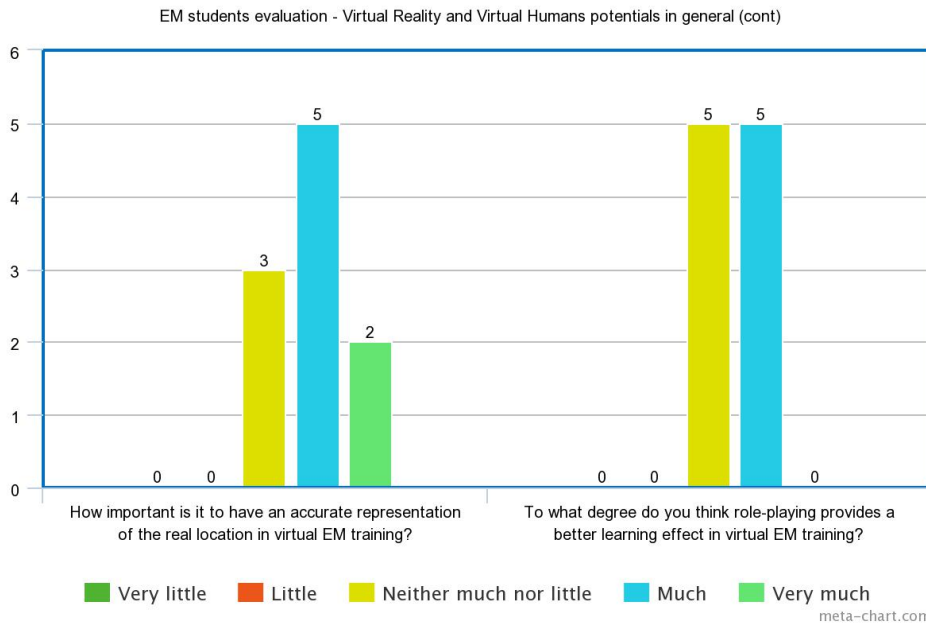


Figure 6.8: Emergency Management students evaluation - Virtual Reality and Virtual Humans potentials in general. (cont)

in Oculus. They had a tendency to turn head around to see the surroundings in 3D; many participants also looked down to see their 3D version of "feet". After a while, the Oculus Rift equipment seemed to work in a malfunctioned manner. The last participant who tried it reported that he observed there was something wrong with the navigation in Oculus, i.e. when his avatar walked in SL, he observed the side-walked effect on his avatar; another thing was that when hitting the up-arrow key on keyboard, it made his avatar walk backward while hitting the down-arrow key on keyboard made his avatar walk forward. The equipment seemed not get back to proper function after a few restarts both of the Oculus Rift itself and the laptop. Therefore, we stopped evaluating with Oculus Rift from that moment. A lesson learnt could be bringing more than one Oculus Rift or using a newer version of Oculus Rift for better stability to prevent technical problems might showed up during the evaluation.

Interview

The participants joined a short interview after they finished answering the questionnaire.

Question 1: Do you think this virtual emergency training is fun or motivating?

All participants agreed that it was fun to see how a virtual emergency training carried out. To many of them, this was the first time seeing a virtual evacuation in a public sector which made the experience more interesting.

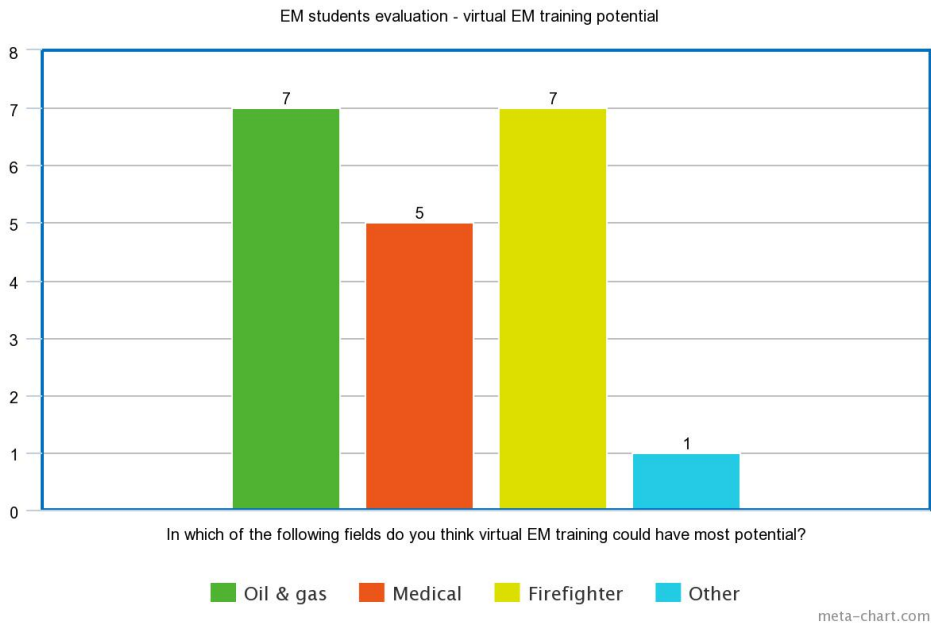


Figure 6.9: Emergency Management students evaluation - virtual EM training potential

Question 2: Which simulation cues urged you to evacuate?

Six participants (60 percent) said that the simulation cue most obvious urged them to evacuate was that the virtual humans moved out of their place. Three participants (30 percent) meant that the fire and smoke also made them diagnosis about an emergency situation. One participant commented *"It would have been better if we could hear the fire alarm. I understand that this was implemented in the virtual evacuation but we have some technical problem with the cable. I am sure when the sound works, it will be a dominant simulation cue in emergency situations."*

Question 3: Is it easy to extract the information of on-going situation from these simulation cues?

All participants agreed that it was easy to extract the information of on-going situation from these simulation cues. Four participants meant that the on-going situation in this virtual training scenario was simple, everything just happened smoothly without unexpected problems. Therefore, the information could be extracted without disruption. However, they suggested the virtual emergency should contain more incidents to make the virtual more realistic.

Question 4: Does the presence of VHs lead to increased realism in this emergency training?

In general, all participants agreed about that. One participant said *"Absolutely. The virtual humans resemble the people working in an office. Their appearance and their be-*

6.2 Results from the Emergency Management Students Evaluation

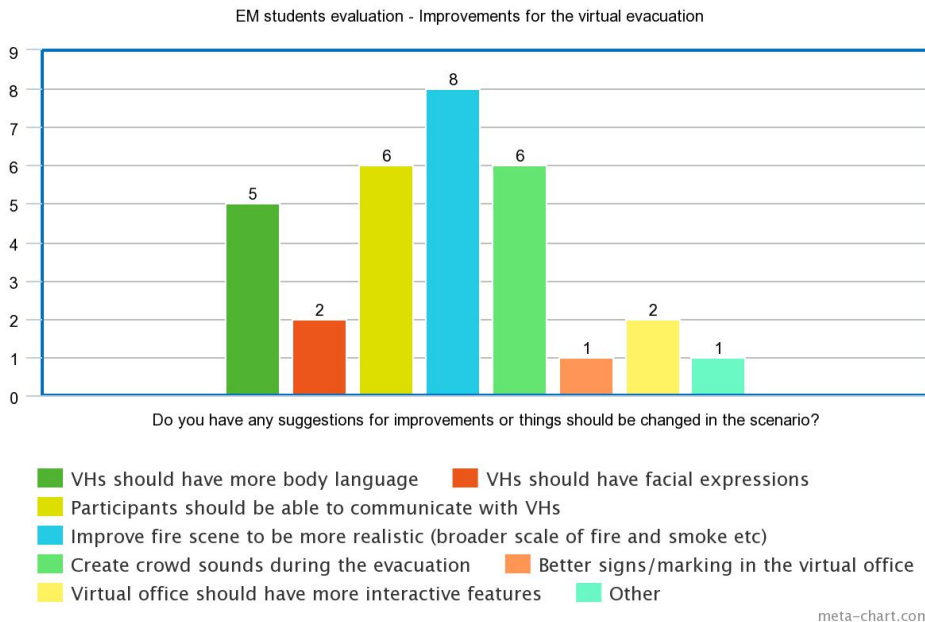


Figure 6.10: Emergency Management students evaluation - Improvements for the virtual evacuation

haviours could help us relate to the reality. Without them would make the virtual training more difficult to be realistic ” However, they said that the VHS should be improved in terms of movement, body gesture and more interactive features. Two participants commented that all VHS walked at the same tempo both before and in the emergency situation. This should be adjusted to visualize the different influences of situations.

Question 5: In the evacuation process, did the VHS react realistically?

Six participants said that the VHS react realistically to a certain extent. This meant that they saw the VHS moved to evacuate when the fire and smoke emerged. Nevertheless, they judged the realistic movement from these VHS. One participant said *”They should have moved in different tempo. Probably someone may fall on the floor which change the evacuating direction.”* This is an useful comment for improving the evacuating pattern in the emergency situation.

Question 6: How much potential do you think VHS would have for emergency training?

All participants believed that, together with new technology, VHS would contribute very much for emergency training purpose. One participant stated *”We need VHS in training scenarios. Emergency situations usually lead to crowds so VHS will be useful to demonstrate the emergency process.”*

Question 7: Can you suggest how to improve this virtual training?

This question gained a lot of valuable suggestions and ideas for improving the virtual

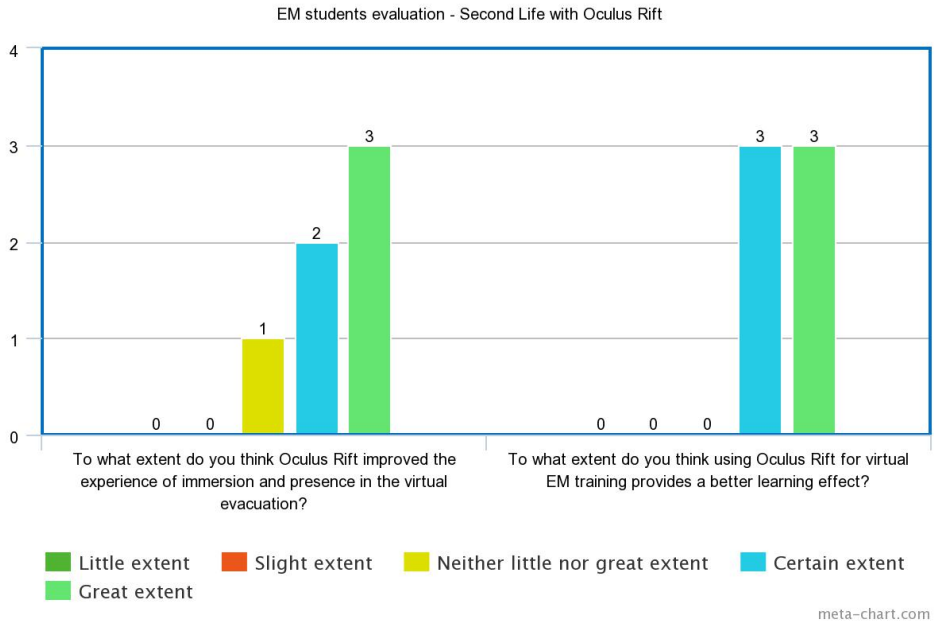


Figure 6.11: Emergency Management students evaluation - Second Life with Oculus Rift.

training. One participant said that the VHs should look more realistic in terms of facial expressions and body gestures. Three other participants suggested to make better smoke effect by spreading the smoke more to surrounding areas inside the office. One participant gave a lot of useful ideas for better simulation such as:

- The office got power cut and becomes dark or partially dark due to some light bulbs go off
- Some VHs are falling on the ground during evacuation, which in turn obstruct others (the same purpose as the wheelchair person and panicked person)
- VHs get hurt by falling will be carried out by either other VHs or active players.
- Fire detectors on the ceiling go off and shower the floor which in turn make it slippery and dangerous for the evacuation.
- A chair falls off on the floor after being hit by someone in the evacuation.
- The noise from the evacuation crowd such as yelling/panicked noise, running foot-step noise.
- Other obstructive objects on the floor to hinder people to evacuate smoothly.
- Sometimes people need to climb to get out of the fire area so there should be stairs or ladder for simulating the climbing part.

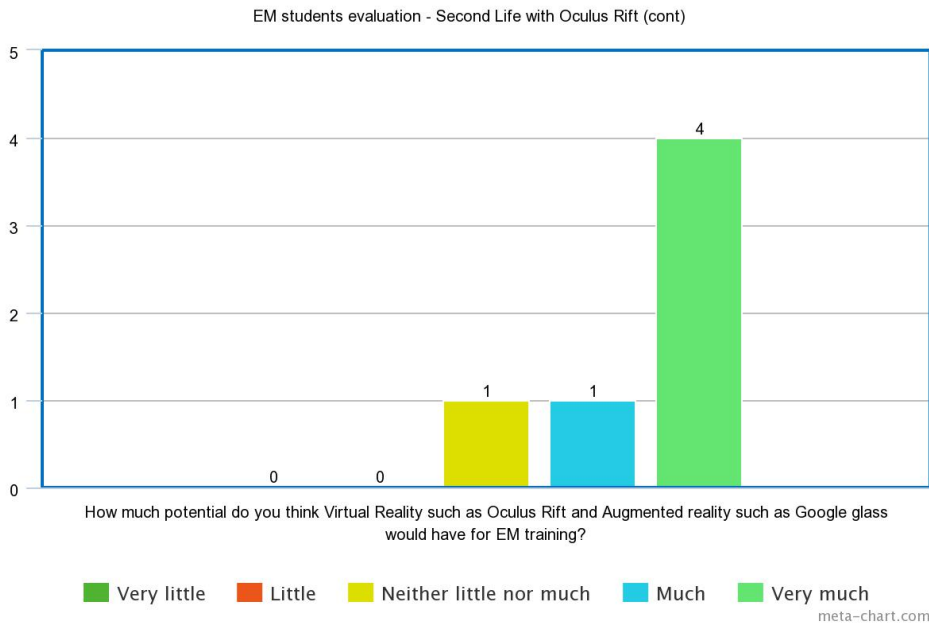


Figure 6.12: Emergency Management students evaluation - Second Life with Oculus Rift. (cont)

Question 8: Would you be interested to train evacuation or similar in virtual environments / virtual reality?

The participants meant that they would like to attend more training in virtual reality. They also said VR and VHS seemed to be suitable for Emergency Management training in public sector. They hoped to see more implementations on this new approach.

Question 9: Do you think VR with VHS could be considered broadly for EM training in the future?

One participant stated "As I said, it seemed that VR with VHS have potential and suitable for EM training so there is a big chance this new approach would be considered and put more in use in the future." Other participants indicated that virtual training had big potential because it was cheaper and safer than traditional one. A traditional emergency training could get people hurt by accidents, spend a lot of money on materials to set up the training environment, stop operation of a department in order to attend training sessions while a virtual emergency training could set up environment with little material and possible to carry out new training session sooner, for example in a week time.

Question 10: Which alternative public location could we apply virtual emergency training for?

One participant commented that virtual emergency training could be applied to big

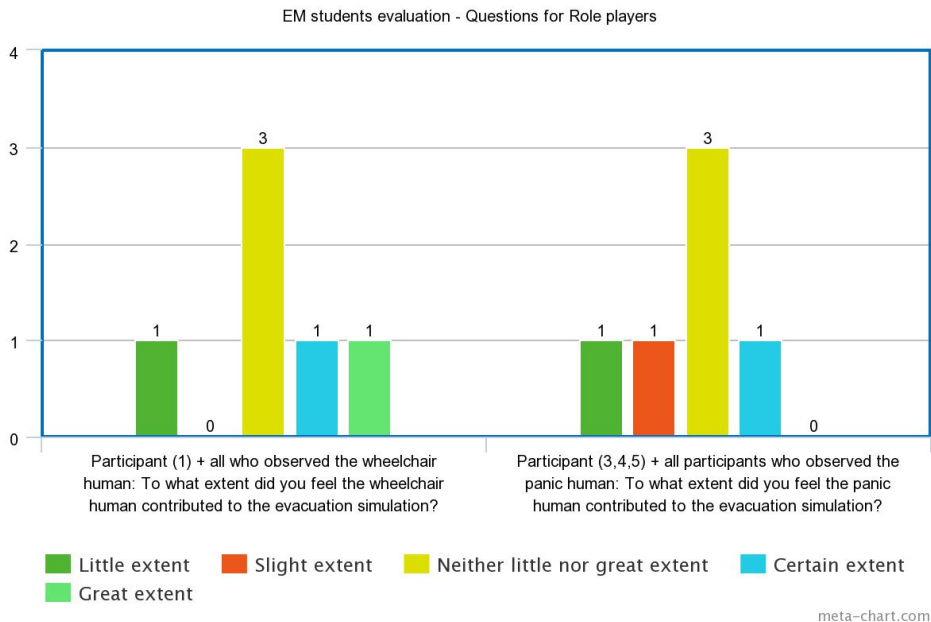


Figure 6.13: Emergency Management students evaluation - Questions for Role players.

event locations such as stadium or conference hall. Another participant added that it could also be applied in oil and gas sector, school building or supermarket. On participant said *"As I see this kind of training has high flexibility in designing emergency scenarios, it could be applied in many public locations and should be encouraged to do so."*

Question 11: How much potential do you think VR such as Oculus Rift and Augmented Reality such as Google glass would have for EM training?

All participants who had tried the Oculus Rift during the self-trying session agreed to a great extent that these equipments would facilitate the participants experience very much in virtual training. One participant reflected *"When I put on the Oculus Rift, I could see the virtual humans much more in details. This contributed a lot to feel immersive and "be-there" in the virtual environment."* Another participant added *"It is cool to see around the virtual space by turning your head. That makes me feel it so real."* However, they mentioned that the way Oculus Rift offering for navigation in virtual space needed to be improved. They said that it was difficult to have the glasses on and at the same time keep the fingers on the four arrow keys to navigate around. The participants suggested that there should be a more natural way to navigate when having the glasses on, for example, joystick or glove with sensors. They also believed that new technology on 3D implementation would help increase user experience in virtual training in the future.

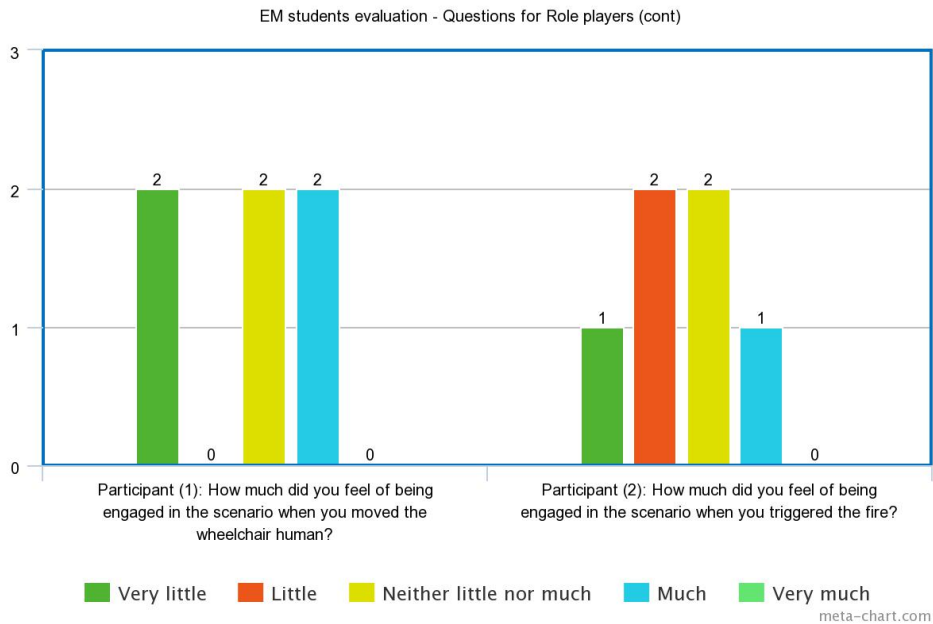


Figure 6.14: Emergency Management students evaluation - Questions for Role players. (cont)

6.3 Results from the Civilian Participants Evaluation

There were 7 participants in total. The first session contained 4 participants. The second session contained 3 participants. The questionnaire for this evaluation was modified to be more general topic of emergency training for civilians. It laid focus on finding out the potential of this training approach according to civilians perspective. Moreover, it was expected that the participants would give more relevant answers regarding role-playing questions. The questionnaire results for both sessions will be collected and presented in same illustrations. After that, the interviews will be presented side by side so that it is easy to compare the evaluations from both groups.

Participants Background

There were totally seven participants (1 female, 6 males) for this evaluation. Five of them are NTNU students, one participant is vietnamese citizen and one participant is norwegian citizen. The first question in this part asked if the participants had experience with navigation in Virtual Reality / virtual worlds. Four out of seven participants answered with option "Very much" while one participant answered "Very little" and one participant answered "Little" (see Figure 6.15) This result gave a high expectation that the participants would perform well in role-playing session and thereby give relevant answers on the corresponding questions.

Figure 6.16 presents various activities in VR / virtual worlds and the corresponding VR / virtual worlds in which the participants had experience. In particular, one partici-

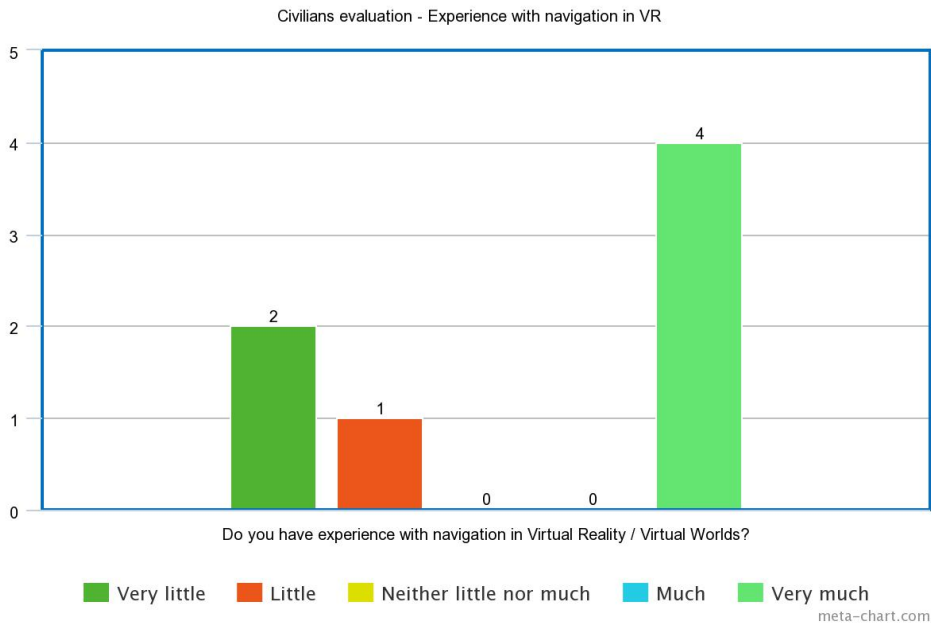


Figure 6.15: Civilians evaluation - Experience in VR / virtual worlds.

part seemed to have very much experience about gaming including "World of Warcraft", "Minecraft" and "Other" where he wrote "Anarchy Online, Age of Conan, The Secret World" In general, most participants had sufficient to high level of gaming skill, this could result some bias in their answers about the realistic of the virtual world and virtual humans in SL.

Figure 6.17 indicates that 57 percent of the participants had participated in emergency trainings in general while 43 percent of them had not. When they were asked if they had participated in a training for fire emergency in an office/building, 57 percent said "Yes" and the remaining 43 percent said "No". The participants who said "Yes" to the first question said "Yes" to the second question, the same went for the participants who said "No".

Virtual Evacuation (VE) in Second Life

The questions in this part focused on the experience which the participants got from their observing part and role-playing part during the virtual evacuation. The results in Figure 6.18 show that 86 percent of the participants were neutral or being engaged when they joined the evacuation with other VHS, only 14 percent (one participant) felt little engaged in this case. Comparing with 30 percent (three participants) felt little engaged from the evaluation with Emergency Management (EM) students, this new result is much more positive. The reason could be that in Civilians evaluation, the participants played together in the virtual evacuation, they also had to manage to escape by themselves when the fire emerged. Therefore, they felt more engaged to the situation. Moreover, the heavy smoke had been made in this evaluation and its effect probably contributed to make the scene

6.3 Results from the Civilian Participants Evaluation

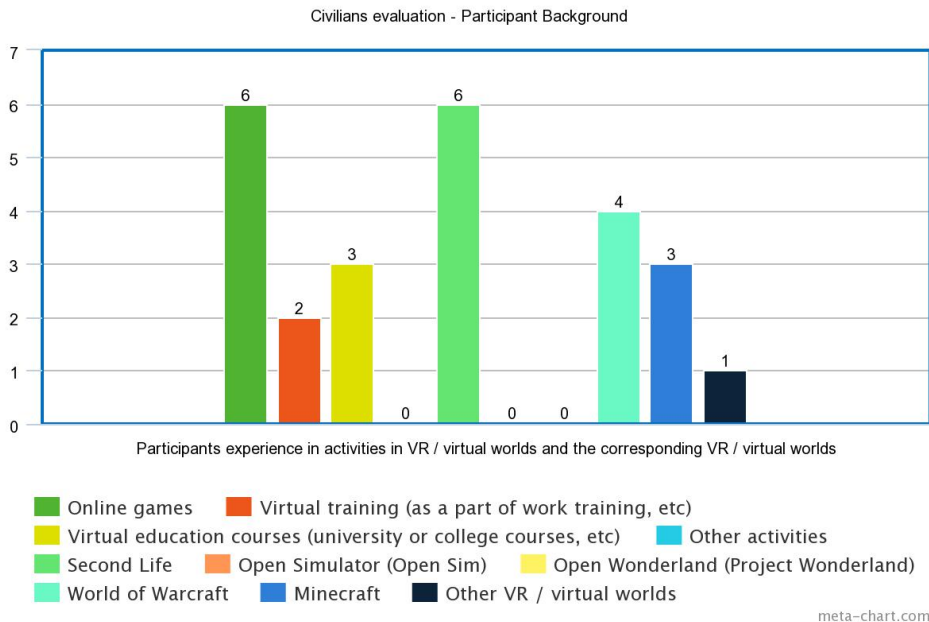


Figure 6.16: Civilians evaluation - Participants Background.

more realistic, as one participant had commented *"When the smoke started, I felt scared because it blocked my way out so much."*

There were 57 percent agreed that the simulation contributed much to give them a better understanding of an evacuation process in public sectors, while the remaining 43 percent were neutral. This is much more positive to compare to the results from EM students evaluation which recorded 40 percent agreed in this case, 40 percent were neutral and 20 percent said to very little degree. When asked about how much information the participants extracted from VHs appearance, behaviours and movement during the regular working process in the office, 57 percent were neutral or agreed that they extracted much information in this case, while 43 percent said to little degree. This showed less positive result than the one in EM students evaluation (90 percent neutral/agreed to much degree; 10 percent agreed to little degree) It should be mentioned that most of the participants in Civilians evaluation had experience with online games. That could lead to a more demanding expectation for how SL should look and feel comparing with other games they have played. Some participants gave comments such as *"The virtual humans are so calm"* or *"They have so rigid movements"*. However, it seemed the participants could extract much more information from the VHs appearance, behaviours and movement in evacuation procedure.

The result had shown that 4 participants (57 percent) could extract much information, 2 participants (29 percent) were neutral in this case and only 1 participant (14 percent) agreed to little degree. This result is very positive to compare to the results from EM students evaluation, see Table 6.1.

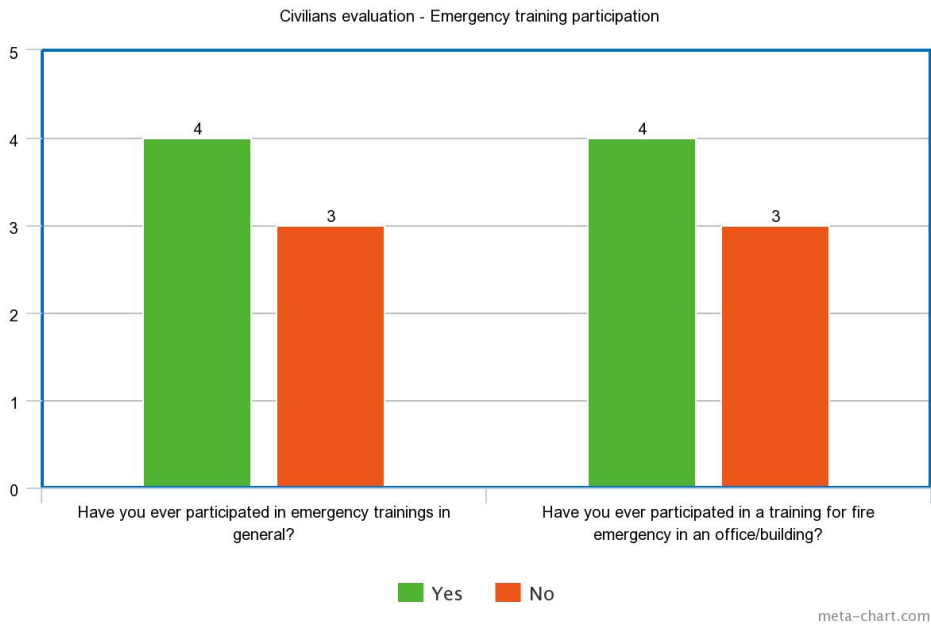


Figure 6.17: Civilians evaluation - Emergency Training Participation.

	EM students evaluation	Civilians evaluation
Little	20 percent	14 percent
Neutral	70 percent	29 percent
Much	10 percent	57 percent

Table 6.1: "How much information did you extract from the VHs appearance, behaviours and movement in evacuation procedure?"

Figure 6.19 presents that 57 percent of the participants were neutral when being asked if the VE looked realistic while 43 percent agreed that the VE looked realistic to a certain extent. No participants reported to a lesser extent than these. This result is very good to compare with the result from the same question in EM students evaluation which yielded 70 percent of neutral answers, only 10 percent chose "Certain extent" answers and the remaining 20 percent chose "Slight extent". Other questions regarding the level of feeling immersed and understanding of the participants from the VE simulation also got very promising feedback. Table 6.2 and 6.3 shows a comparison between EM students evaluation result and Civilians evaluation result.

Despite these positive results, when being asked if the VE looked fun/motivating, the result yielded somewhat less positive than the one of EM student evaluation (see Figure 6.19 and a comparison in Table 6.4) There were many reasons to that. Some participants had commented that they compared the quality of virtual reality in SL with other games

6.3 Results from the Civilian Participants Evaluation

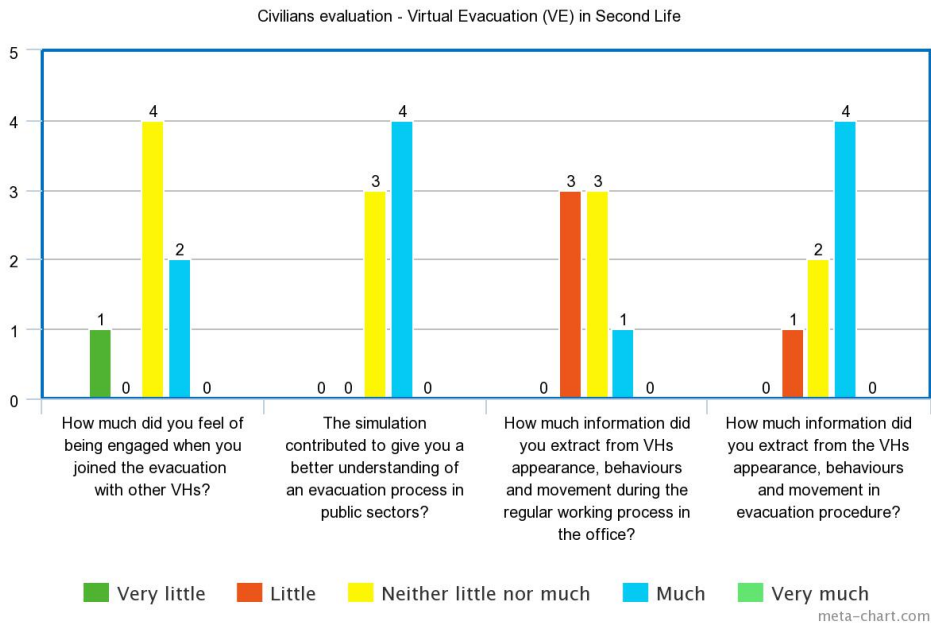


Figure 6.18: Civilians evaluation - Virtual Evacuation (VE) in Second Life.

	EM students evaluation	Civilians evaluation
Slight extent	10 percent	14 percent
Neutral	70 percent	43 percent
Certain extent	20 percent	43 percent

Table 6.2: "To what extent did the simulation of VHs contribute to your understanding of the evacuation procedure?"

	EM students evaluation	Civilians evaluation
Little extent	10 percent	0 percent
Slight extent	10 percent	0 percent
Neutral	60 percent	57 percent
Certain extent	20 percent	43 percent

Table 6.3: "To what extent did you feel immersed with the VE process (simulation)?"

they had experienced and soon they found significant limitations of this technology which they meant "hindered the training to be smooth and interactive". Another participant commented "the VE training is so simple, the exit doors are just nearby the fire scene so that the evacuation path happens to be so short. You reach the way out in just a few steps." Another participant said "Since you know what will happen next in your role-

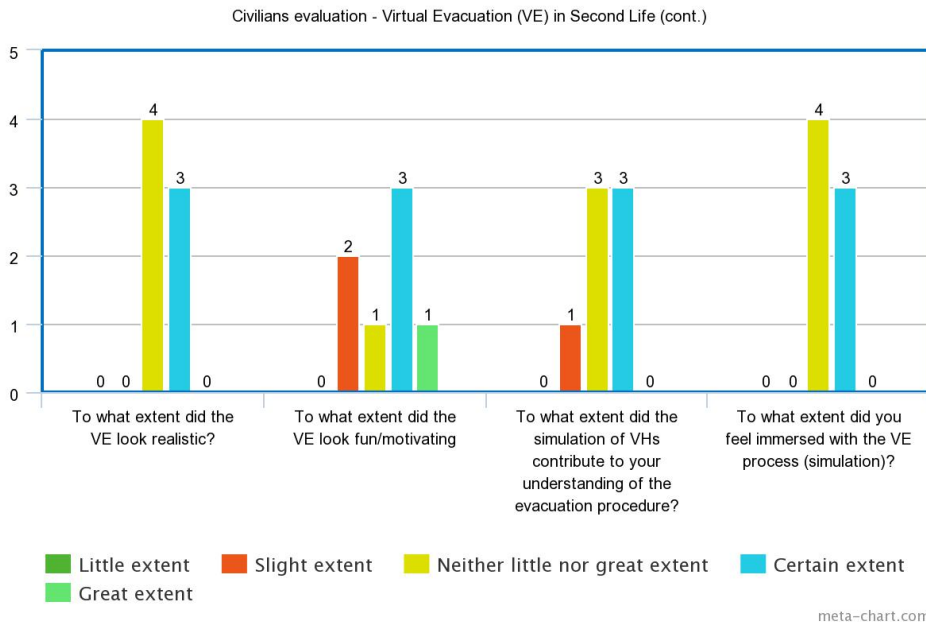


Figure 6.19: Civilians evaluation - Virtual Evacuation (VE) in Second Life. (cont)

playing session so it ruins the surprise. The first try gave the most fun experience, the heavy smoke did a good job and surprised me, though.” It should be mentioned that many of the participants have technical background in IT. This could make their expectation in this VE training higher than EM students, therefore led to higher demand when evaluating it. However, this is not totally a bad result. In fact, it was interesting to know one of the two participants who graded "Slight extent" to this question was the same one who described his reaction during the VE training as "stressful". He explained that the thick smoke blocked his way out leading to that feeling of stress. This could indicate that stress did affect on how this participant perceived the VE training.

	EM students evaluation	Civilians evaluation
Slight extent	10 percent	29 percent
Neutral	30 percent	14 percent
Certain extent	40 percent	43 percent
Great extent	20 percent	14 percent

Table 6.4: "To what extent did the VE look fun/motivating?"

When discussed about the impact of various simulation cues to the participants diagnosis of the emergency situation (Figure 6.20), it showed that "Effects such as smoke and fire" gained most simulation impact (100 percent), "Sound" was the second simulation cue that impacted the participants (86 percent). This makes the huge difference from the result

collected when asked the same question to EM students (0 percent). Obviously, the sound problem at EM students evaluation hindered a fair judgement for this simulation effect. Many participants revealed that fire alarm sound was the most useful simulation cue for their diagnosis of the emergency situation. The other factors such as "Active participation (role-playing)" and "Office layout (rooms, corridors) scored lower (29 percent) than "Virtual humans behaviours" (43 percent), which was opposite than the result from EM students evaluation. The details would be analyzed and discussed more in chapter 7.

Figure 6.21 reports how the participants reacted during the virtual evacuation. One participant selected "I felt stressful" while others reported with a combination of curious-control reaction or calm-control reaction. Especially there was one participant had a combination of curious-calm-control reaction. None of the participants mentioned that they felt not involved during the virtual evacuation, which is very good to compare to 3 participants selecting "I felt not involved" in EM students evaluation. This is considered as an advantage of using role-playing in virtual training to increase participants engagement.

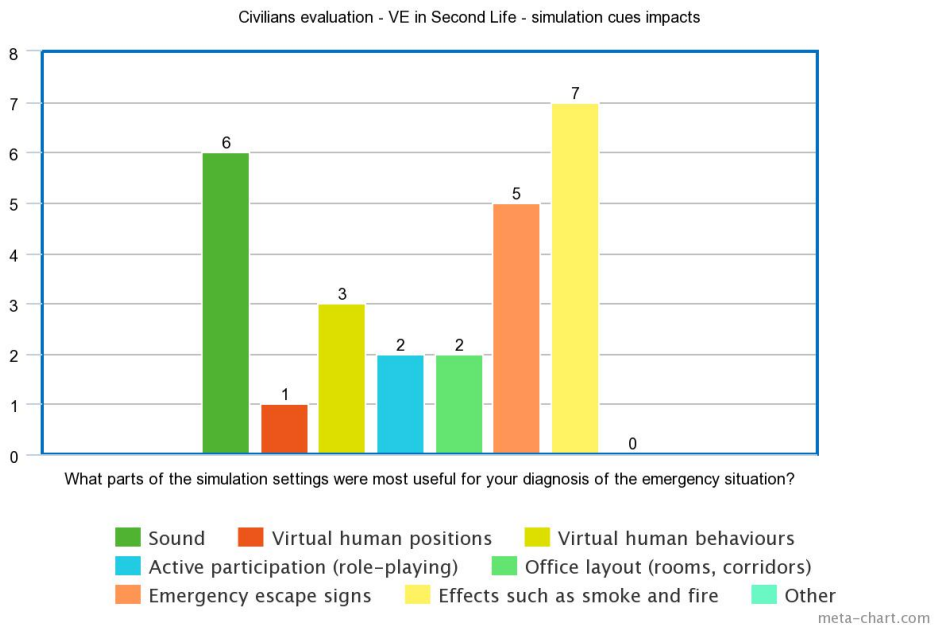


Figure 6.20: Civilians evaluation - Virtual Evacuation in Second Life - Simulation cues impacts

Virtual Evacuation (VE) in Second Life

In Figure 6.22, it indicates that 86 percent of the participants agreed that VR with VHs would be suitable for emergency training in public sectors to a certain or great extent while only 14 percent (one participant) were neutral about that. In the EM students evaluation, the same question was asked and the result was less positive than that of the Civilians evaluation. Regarding the second question in the same figure, there were 86 percent meant that VR with VHs could facilitate their learning in emergency training to a certain or great

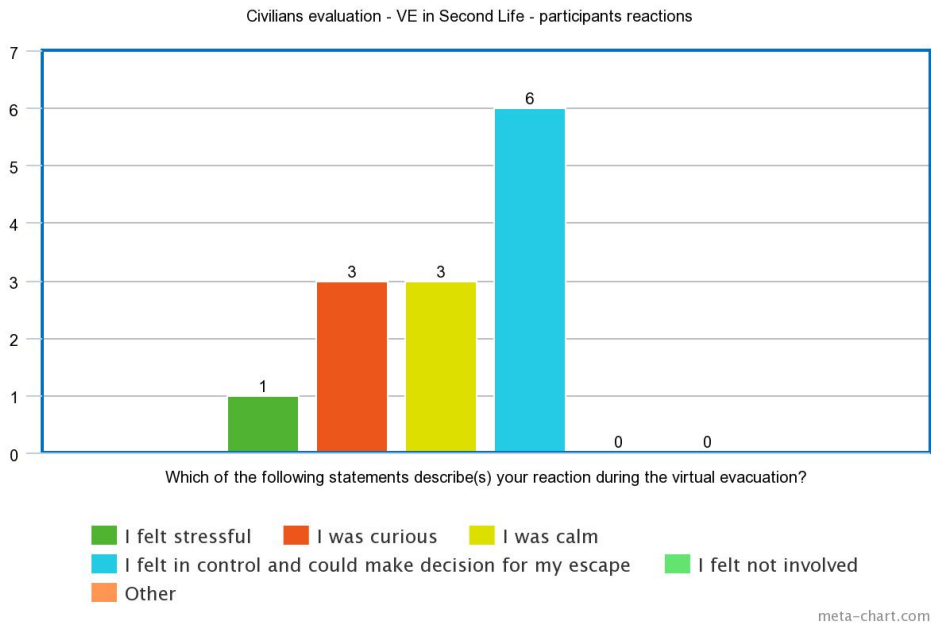


Figure 6.21: Civilians evaluation - Virtual Evacuation in Second Life - Participants reactions

extent.

On the question about the role of the virtual space and layout of virtual office in this emergency training (Figure 6.23), 43 percent agreed this role was important at a high degree while another 43 percent were neutral about that and 14 percent agreed to a little degree. When asked them if it was important to have an accurate representation of the real location in virtual emergency training generally, the responses from the civilians group showed a noticeable difference when comparing with the result from the EM students. (see Table 6.5) It seems that the rating on the important level of having such representation of the civilian group was lower than that of the EM students.

	EM students evaluation	Civilians evaluation
Little	0 percent	14 percent
Neutral	30 percent	43 percent
Much	50 percent	29 percent
Very much	20 percent	14 percent

Table 6.5: "How important is it to have an accurate representation of the real location in virtual emergency training generally?"

In the questionnaire for civilians, there is an interesting question asking their opinion about the importance of virtual space compared to VHS in emergency training. Their answers are presented below:

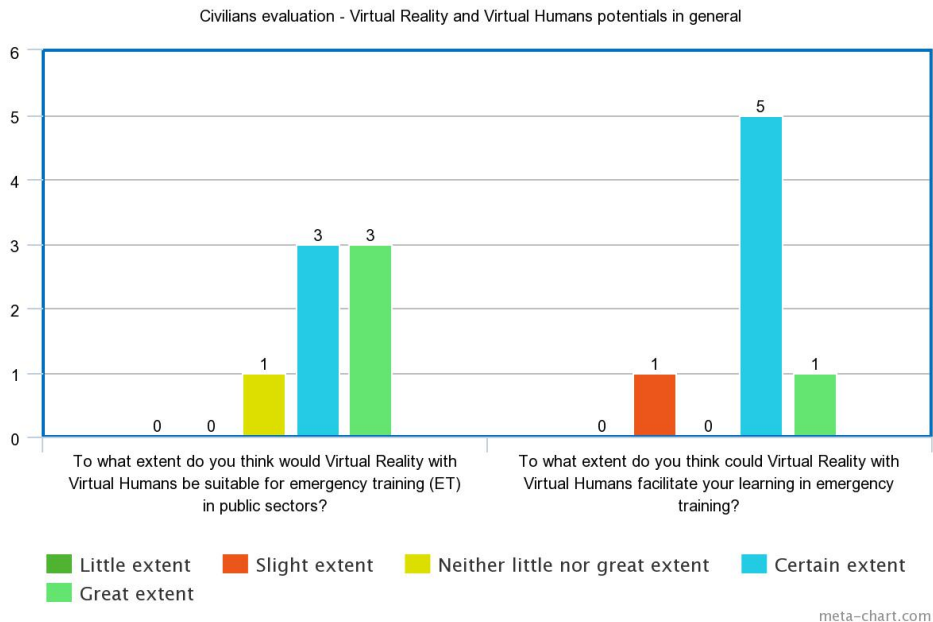


Figure 6.22: Civilians evaluation - Virtual Reality and Virtual Humans potentials in general

"Fairly important."

"Important in ET in general."

"They're both important to create as realistic as possible scenario, which in turn creates involvement for the participants."

"It was more important to understand where to escape, rather than waiting for the virtual humans to show the path."

"Both are equally important. Virtual space gives you immersive feeling so the more realistic, the better. Virtual humans also need to present in different forms to make the overall simulation more realistic."

"In this ET, my impression is that virtual space is important for the feeling of reality. Virtual humans can be improved to support this space and scenarios."

Improvements for the virtual evacuation

Figure 6.24 illustrates what could be improved rated by the participants. Before this evaluation, the fire scene had been improved with the heavy smoke version. This new effect gained much positive feedback from the participants and it therefore yielded a low rate for being chosen for improvement according to the responses. Only two civilians chose "Improve the fire scene to be more realistic (broader scale of fire and smoke etc)" while eight EM students had chosen this suggestion before. This evaluation managed to ask an EM student (who joined the previous evaluation) for feedback about the new smoke version; and the comment was *"The smoke effect is much better now."* For the civilians, it was more important to "Create crowd sound during the evacuation". All participants chosen

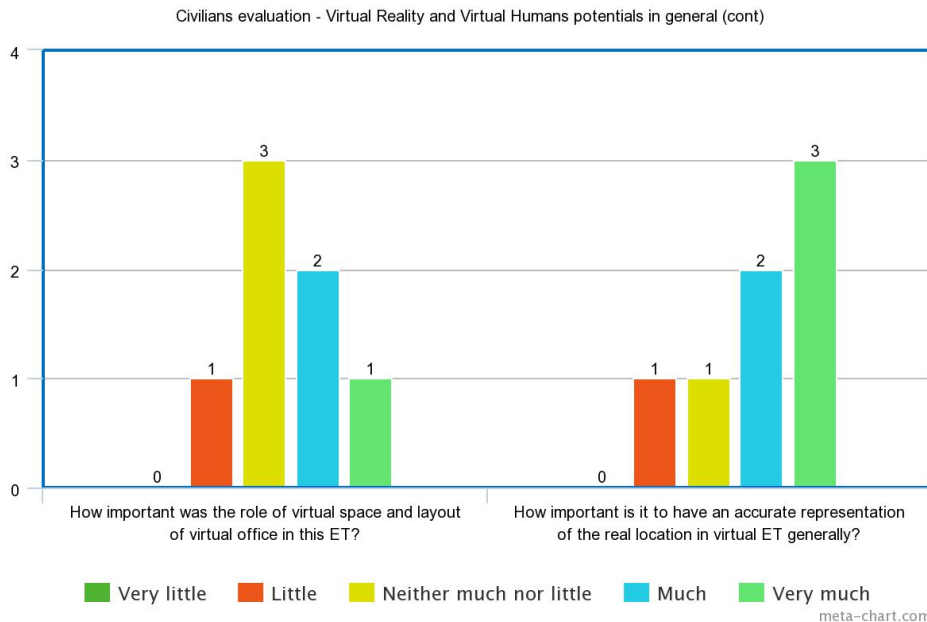


Figure 6.23: Civilians evaluation - Virtual Reality and Virtual Humans potentials in general (cont)

this suggestion, while 6 out of 10 EM students had chosen this before. Obviously, this suggestion should be prioritized for next improvement. The suggestion "Participants should be able to communicate with VHs" was chosen by 4 civilians and 6 EM students, which was considered as a high rated suggestion. It seems that the civilians group suggested improvements for both virtual humans and virtual space equally while the EM students focused more on virtual humans improvements. "Partial power cut situation" is a new option for the suggestions. This option was suggested by one of the EM students in the previous evaluation. From the responses, it is clear that this option is potential for improving the VE simulation. The participants who chose "Other" also commented "*More virtual humans, to highlight the problem with getting people out without panic.*" and "*After the fire emerged, virtual humans should be panicked or move more quickly.*"

Second Life with Oculus Rift

Oculus Rift (OR) wasn't available for trying in this evaluation due to the limitation of distributed locations. However, some participants had experience with OR from before so they could still answer the survey questions regarding this device. It is difficult to either analyze this result or compare it with the one from the EM students evaluation. The reason was that the number of participants who answered these questions regarding OR varied from question to question, see Figure 6.25 and 6.26. There was a case that four participants answered the first two questions while only two of them answered the last question. Remote questionnaire exposes a risk that the participants could choose which questions to answer without being asked for a completed set of answers. This problem

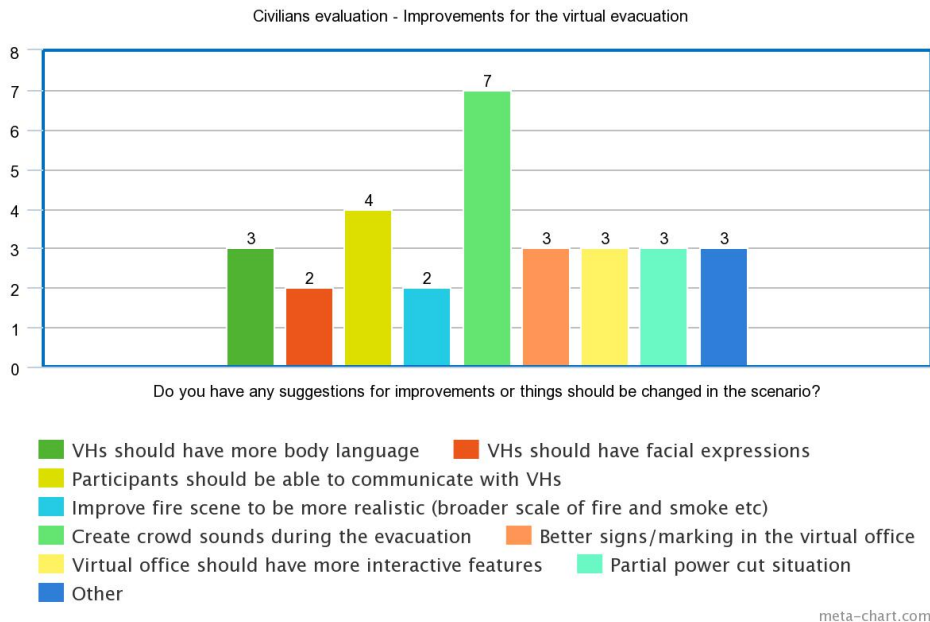


Figure 6.24: Civilians evaluation - Improvements for the virtual evacuation

will be discussed more in Limitations in chapter 7.

Questions for Role players

The questionnaire designed some specific questions for role-players while other questions could be answered by all participants. Therefore, the number of participants who answered this section varied from question to question. There is a huge difference between responses from civilians group and EM students group. It is clear that practical role-playing in the virtual evacuation yielded better influence to the training simulation.

In order to remind about the role players and their corresponding tasks, a short summary is created as follows: (see Figure 5.4 for role-players' locations in the virtual office)

- Player 1: Assemble at the location marked [1]. Player 1's observation spot is facing the kitchen in the social area. When the fire starts, player 1 helps evacuate the wheelchair co-worker.
- Player 2: Assemble at the location marked [2]. Player 2's observation spot is facing the kitchen in the social area. Player 2 starts the fire and join the evacuation with VHs.
- Player 3, 4, 5: Assemble at the location marked [3], [4], [5]. The observation spots of these players are facing the working area. When the fire alarms goes off, these players follow other VHs to evacuate.

From Figure 6.27, four out of six civilians agreed that they felt the wheelchair human

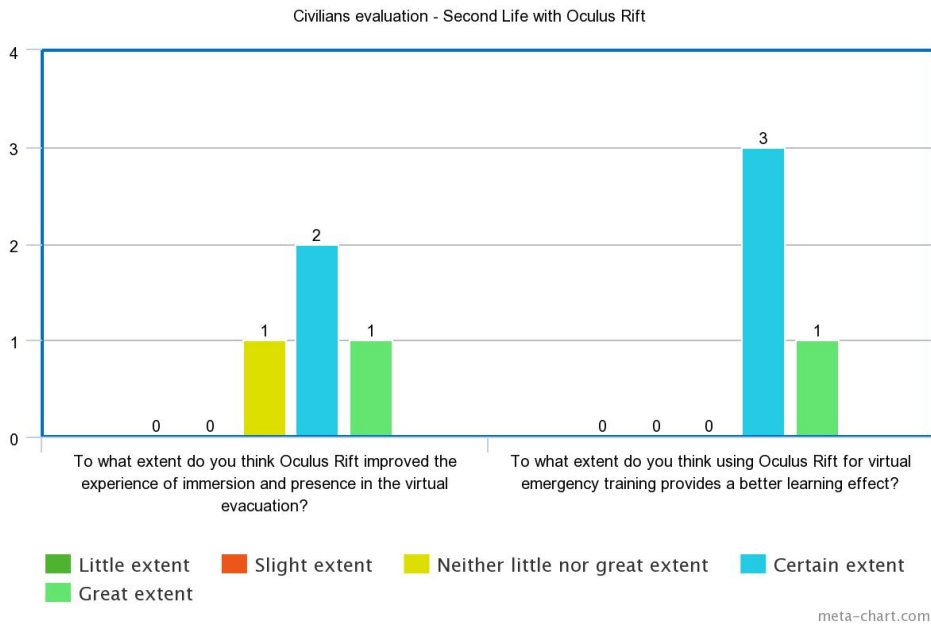


Figure 6.25: Civilians evaluation - Second Life with Oculus Rift.

contributed to the evacuation simulation to a certain extent, while only one EM student agreed the same. Three out of four civilians answered that they felt the panicked human contributed to the evacuation simulation, while only one EM student agreed the same. Although this comparison is inadequate due to biased responses from EM students regarding Role-playing, it still indicates an important role of role-playing in virtual training generally. When asked the participants playing Role 1 about the degree they felt of being engaged in the scenario when they moved the wheelchair human, 1 rated to a little degree, 1 was neutral, 3 meant that they felt much or very much engaged. The participant who rated to a little degree also commented that *"The wheelchair woman didn't look particularly worried."* Overall, this is a positive result, see Figure 6.28. Three out of four participants who played Role 2 reported that they felt of being engaged highly in the scenario when they triggered the fire while the last participant felt little engaged. Four out of seven participants highly agreed that role-playing provided a better learning effect than non role-playing in virtual emergency training while the remaining three participants were neutral about that.

Observations

There was a limitation of observation during the evaluation. The first session with civilians in NTNU campus (and one abroad) was observed partially but the second session with gathering in SL made it impossible to witness the participants reaction in real. Therefore, the chat comments during the evaluation were paid much attention.

The first group sat in distributed places in order to prevent sound echo in SL from various computers at the same time. It was observed that some of the participants needed

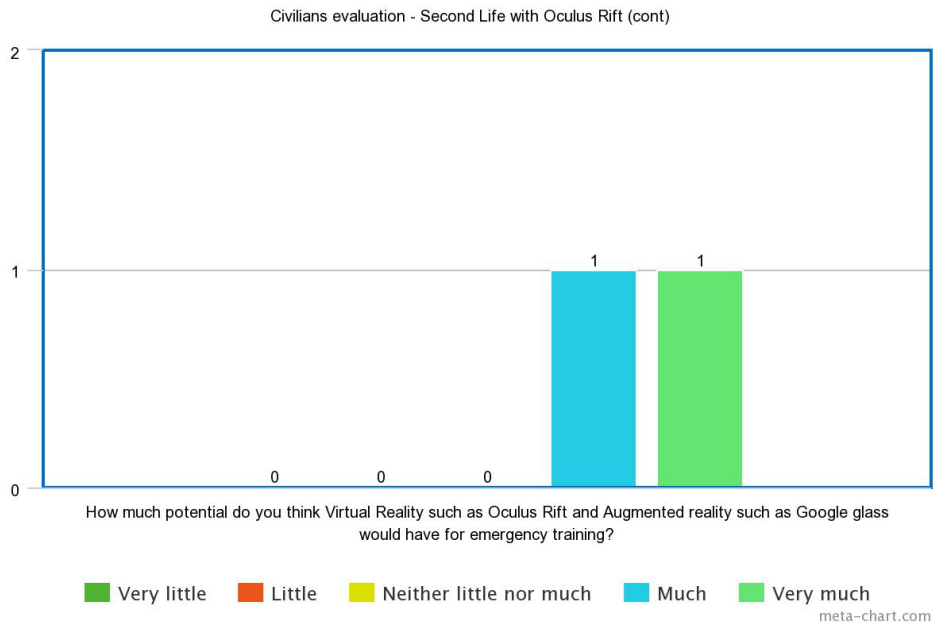


Figure 6.26: Civilians evaluation - Second Life with Oculus Rift.(cont)

more time to get familiar with the SL navigation than others. Because of that, there were a few "drills" where all participants could practice their navigation skills before they set in the real play. There were times that some participants accidentally triggered the fire and the smoke spread widely right after that hindering them to navigate around. The comments were among "Wow, I didn't mean to trigger the fire. I actually planned to hover the oven only..." and "The smoke is so heavy. I cannot see a way out...". This is a positive thing because the role-playing seemed to be fun and all participants could get involved even in the "drills". As mentioned above, there was a participant felt stressful in the evacuation. It was observed that this person had a navigation problem in SL due to his slow computer. Another thing observed was that he had never been to this virtual area (include the office and surroundings resembled NTNU campus) so he felt lost sometimes with directions. At one time, he flew his avatar to see the office from above and got stuck in a building nearby when he landed. Anyway, all participants appeared to be quite effective in cooperating with others during the role-playing. This resulted that there were many useful play scenes recorded for making a good video of virtual training.

The second group could only be observed by the comments in chat box. However, one of them had already visited the virtual office the night prior evaluation day to get familiar with the office layout and the virtual humans simulation. In his exploring tour, he also accidentally triggered the fire, which in turn created a lot of smoke and he didn't know how to stop it. The thesis's author was notified for help in SL. Nevertheless, it was highly appreciated for such effort to prepare for the evaluation. His preparation also made him more competent in the role-playing. Two other participants had their technical back-

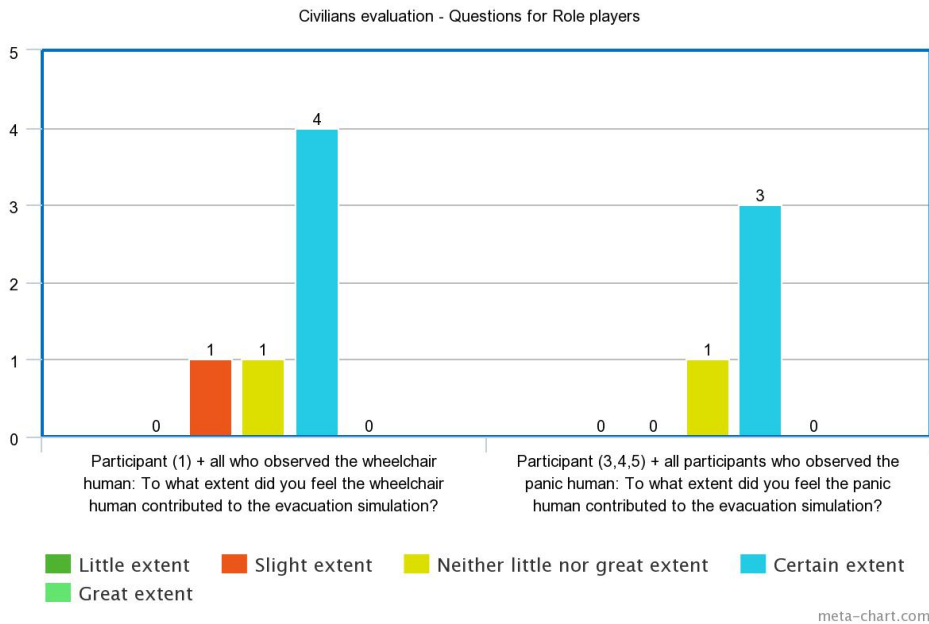


Figure 6.27: Civilians evaluation - Questions for Role players.

grounds and good navigation skills in virtual worlds. Together, three of them cooperated smoothly which made the role-playing session successfully.

Interview

(*) In second session, participant 1 is an Emergency Management student from the college in Molde. This participant also attended the first evaluation.

The virtual evacuation in Second Life

Question 1: Which simulation cues urged you to evacuate?"

1st session: All participants agreed that sound and smoke were the dominant cues to urge them to evacuate.

2nd session: Participants responses were among the fire, smoke and fire alarm.

Question 2: Is it easy to extract the information of on-going situation from these simulation cues?

1st session: All participants responded that sound and smoke could make sense to extract cues from the on-going situation.

2nd session: All participants agreed.

Question 3: How immersive did you experience in the virtual emergency training (ET)? And which features had the most contribution for that?

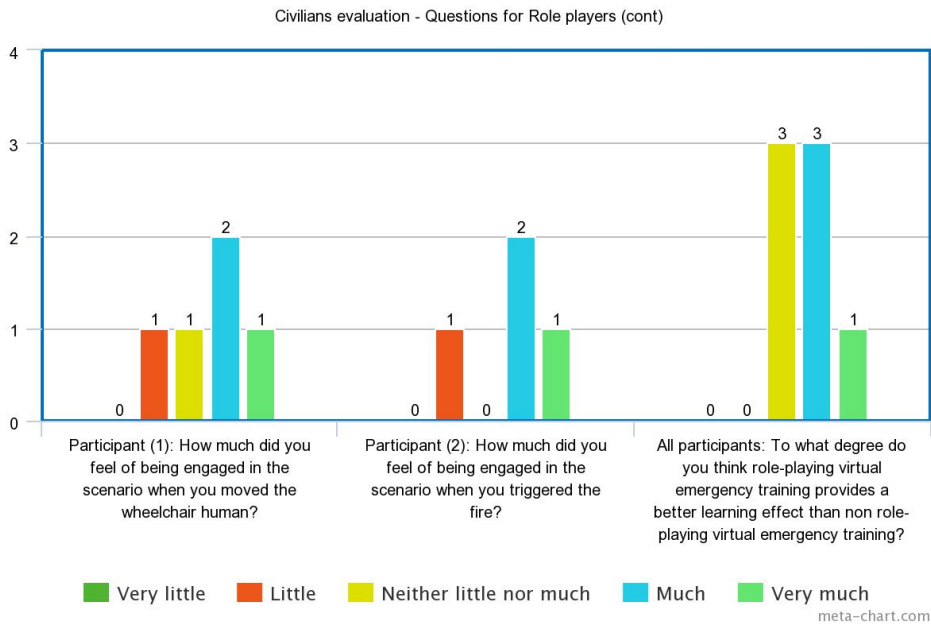


Figure 6.28: Civilians evaluation - Questions for Role players. (cont)

1st session: A member mentioned that the layout gave him immersive feeling. He also commented that the fire looked real and the sound was real to him which contributed to his experience in the virtual emergency training. Two other participants stated that the training was lack of stimuli for instinct except the first time when the smoke emerged really thick that hindered their sight and urged them to escape. The last one suggested to use background sound for immersive improvement.

2nd session: Participant 1 and 2 agreed that it was highly immersive experience. One of them stated *"It was quite immersive and I think it's due to the cues mentioned above as well as the layout of the office and the emergency signs."* However, participant 3 pointed out that *"The major drawback for me was that I knew what was coming. Even if I controlled a character, it felt more like being a part of a movie."*

Question 4: Would you be interested to train evacuation/similar in virtual environments/virtual reality?

1st session: They were positive to train evacuation or similar in virtual environments or virtual reality. They emphasized that this approach had potential, but it would need a lot of improvements including more interaction with participants. They recommended to use Oculus for a better training experience.

2nd session: Participant 1 and 2 said yes with a comment as *"really interested, cool and fun."* while participant 3 meant that this approach needed to be improved in the sense that *"More interactive environment, where my actions matter. Make a mistake then someone dies, for example. With newer technology, I think it has potential."*

Question 5: Which kind of training do you like to attend in virtual reality? (e.g. collaborative or single player training, with only virtual humans (VHs) or with only human participants or both) Why?

1st session: Some participants chose collaborative option with voice support in SL. Others chose both collaborative and single player trainings because *"it is close to real situation"*

2nd session: Participant 1 wanted to attend virtual training with only human participants while two others considered both options for this approach. Their comments are listed as follows:

- *"I like collaborative training with only human participants. It is fun with somebody who is real, not a virtual human."*
- *"A combination of virtual humans following procedures strictly and a collaboration of human participants make it possible to test several scenarios."*
- *"Both, because virtual humans can show how to (not) behave as instructors. Humans introduce human errors, which is good for training."*

Virtual humans (VHs) in Second Life

Question 6: Does the presence of VHs lead to increased realism in this virtual ET?

1st session: One participant agreed. He indicated *"VHs presence is good when it created crowd effect in evacuation."* However, three other participants commented that the VHs didn't look so realistic due to lack of movement. Some of them stated *"not much realistic, most of them didn't move their body, for example when in meeting, they just do simple movement with arms."* or *"People sitting in front of the PCs look very steady. If only they did something more then that would be"* or *"They need to show more body language. For example, the wheelchair woman, she looked very calm, there was no panic, she was just sitting there. If I didn't know I needed to move her, then she would just sit there. Everyone will leave her there. People look very calm, not panicked"*

2nd session: All participants agreed highly about that.

Question 7: How realistic is the distribution of VHs in the specific office setting?

1st session: All participants said the distribution of VHs naturally occupied the specific office setting. One participant mentioned *"VHs distribution are not far from real life. There are some people occupying working area."*

2nd session: Participant 1 and 2 agreed that it is enough realistic distribution of VHs in the specific office setting while the last one reported that he didn't really notice about that. Participant 1 commented *"It is like people sitting in a real office."* Participant 2 suggested *"Maybe you could consider to unbalance the amount of people evacuating on each side of the building. An improvement could be a big meeting with more people in the large meeting room, they would then have to evacuate the meeting room first."*

Question 8: In the evacuation process, did the VHs react realistically? (except the wheelchair person, she is placed for role-playing interaction)

1st session: All participants agreed to a certain degree. One participant mentioned positively *"I think they are controlled by human participants, otherwise they are so real."* However, three other participants with a long experience in video games and virtual reality, they pointed out what they considered not so realistic about VHs reaction:

- *"I didn't see many persons in a panic. In reality, this situation of fire and smoke could cause more panic."*
- *"Maybe the people far from the fire area can act calm, but people close to fire area should look more panicked"*
- *"They move at the same tempo, some people should run in varied tempo, someone could fall..."*
- *"Someone should show that they want to stop that fire by getting an extinguisher"*

2nd session: Participant 1 agreed. Participant 3 mentioned that he was focused on controlling his character in the evacuation, therefore he didn't pay much attention to the VHs. Participant 2 stated that *"Well, if I was exposed to that amount of smoke, I would try to find another way out, or at least crawl along the floor. Both escape routes were covered with smoke."* This statement could be assumed that this participant didn't think the VHs reacted very realistically.

Question 9: Did you extract information from VHs behaviours during this ET? How much did this information contribute to your understanding of evacuation process in a public sector?

1st session: All participants agreed. One participant commented *"I think what helped me to understand the evacuation process were the fire alarm and the environment of that moment."* Other participant gave their points of view such as *"For me it's easy to understand what they are doing by seeing their placement and behaviours."* and *"It made sense that people would move out when the fire emerged. Even though I know what they will do but looking at them doing that, it's a natural occurrence."*

2nd session: Participant 3 meant that since he didn't really notice the VHs so he couldn't comment more about information extraction process. Participant 2 reported that she could understand the evacuation route. Participant 1 meant that the evacuation yielded no special information than visualizing how the fire might be emerged and where the people could get out of the office.

Question 10: How much potential do you think VHs would have for emergency training? Why?

1st session: All participants agreed that VHs would have potential for emergency training to a certain degree. One participant shared his impression *"If I was the only person in a training like this, I would surely feel panicked and might fail the training as well."* Other participants suggested that VHs could gain more potential by being used for crowd simulation. Addition to that, VHs could be used as guiders in virtual trainings who could give hints or set up actions for participants. The participants pointed out that VHs would help very much in virtual trainings where the group of participants was small. There was also a suggestion to the evaluated virtual evacuation which is *"VHs should start the fire, the*

participants should not know when the fire starts.”

2nd session: Overall, all participants agreed VHs would have potential to a certain degree for emergency training. Participant 1 stated *”It would be good if it showed a real scenario with screaming sounds. The office should look like in a real building with roof so that there wouldn’t be an urge to fly. There should be direction how to go to the exit door since it is difficult to find out the exit immediately when the smoke is everywhere.”* Participant 2 commented *”I think it has great potential. You can test the evacuation capability and capacity while planning the optimized use of space.”* Participant 3 also indicated *”The potential is great, but I suspect a greater degree of gamification is needed along with better technology.”*

Role playing

Question 11: Do you think it’s fun/motivating to be a part in this emergency training (ET)? Which part did you enjoy the most?

1st session: All participants agreed about that. One participant stated *”It was fun. I did enjoy with the role triggering fire.”* Another participant who happened to trigger the fire accidentally added *”I didn’t expect to trigger the fire but it happened. When the smoke came out at the first time, I was a little bit panicked. Thus, I think that’s helpful and motivating. However, when I played in this training several times, I didn’t feel so fun anymore because I’ve already known what to do.”* One participant indicated that he had to wait for the VHs to pass before he could go to exit door due to the downside of VHs in small area in SL. This reduced the fun part for him.

2nd session: Two out of three participants agreed that it was fun to be a part of this emergency training. Participant 1 stated *”It was fun. I liked to trigger fire.”* Participant 2 said *”For me, it’s new and I was curious. I liked playing different roles in the evacuation.”* Participant 3 felt this ET kind of static to compare with the online games he used to play.

Question 12: Did you feel connected with other virtual humans in this ET? How?

1st session: Three out of four participants meant that they felt distant from other virtual humans in this ET. One participant gave his reason as *”I felt distant from them. I had to wait for them to pass before i could go. They ignored me, the wheelchair woman couldn’t interact with me.”* Another participant mentioned that *”When I tried to get out, I blocked some of the VHs at one corner closed to exit door, which then made them stuck there. The technical problems of VHs have led to their unusual behavior in this case.”* One participant suggested that the VHs should wait for the wheelchair person to go first.

2nd session: All participants meant it was little connected feeling with other VHs in this ET. Participant 1 stated *”It is like somebody triggered a fire and I am trying to escape.”* Participant 2 had a similar statement. Participant 3 simply reported as *”No”*.

”Question 13: Did you feel connected with other participants in this ET? How?”

1st session: The participants reported that they didn’t feel connected with other participants in this ET. One reason was that *”You play a role and you just focus on your role alone. If you have some group tasks, you will feel more connected with others.”*

2nd session: The answers for this question were similar to those in the previous question.

Question 14: Did you feel a need to communicate with other participants when the evacuation started? If yes, did you attempt to communicate with them? In which way?

1st session: All participants emphasized that they didn't feel a need to communicate with other participants during evacuation process. The reasons were among "Because of the manuscript. We just know what to do as individual role-players." and "There were enough exit signs for evacuating path so I had no need to communicate with others." and "The office is small and simple. Finding a way out was not challenging."

2nd session: All participants said "No" and explained that they already knew what to do in the evacuation.

Question 15: Did the panicked virtual human hinder you from evacuating? What was your reaction to this problem?

1st session: It was surprising to find out none of the participants had encountered the panicked VH on the way out. The reasons were listed as follows.

- "I did not see that person. She/he should have shouted to attract attention."
- "I couldn't see her on the way. It's better to relocate her to a more visible place."
- "I didn't see anybody remaining in the office. It's a disadvantage of small office because you walk out so fast before she could appear in your sight."

These reasons would be useful to improve the effect of this panicked VH in further work.

2nd session: None of the participants have seen her.

Question 16: Can you suggest how to make the role playing part more interesting for this ET?

1st session: Here is the list of suggestions from the participants regarding this question:

- Improve VHs to have more gestures, more interaction with participants in terms of communication and unexpected behaviours
- Organize group tasks with unexpected simulations to encourage more cooperation, less manuscript
- Extend the virtual office with new challenges in terms of obstacles and complex layout so that it takes longer time to evacuate

2nd session: Participant 1 stated "Screaming sounds. Roof. Direction show how to go to exit door." Participant 2 indicated "Assign different tasks." Participant 3 suggested "Give the players tasks to carry out, and let the fire come more as a surprise."

Question 17: Can you suggest new features which can generally enhance the collaboration between participants and VHs in ET?

1st session: The participants gave their responses as follows.

- More group tasks

- Unexpected behavior/reaction from VHs (for example: VHs ask participants for help, the wheelchair VH refuses to be moved etc.)
- More dynamic fire in the sense that it spreads to unexpected directions which in turn blocks your way and you need to change your direction to evacuate

2nd session: Participant 1 said *"Need an option to talk or ask for help."* Participant 2 agreed about that and added *"More VHs need help to evacuate, perhaps because of being injured."* Participant 3 gave an example for new feature like *"The woman in wheelchair should call out for assistance, as it looked like she could have handled herself just fine."*

Virtual reality (VR)

Question 18: Do you think VR with VHs could be considered broadly for emergency training in the future thanks to its flexible approach?

1st session: There were different opinions answering this question. One participant stated *"This could be considered as frequent training in a month time but we also need real training in case of evacuation."* Another participant said *"Yes. In case of new employees, virtual training seems to be a better choice than real training because it avoids to use entire office just to train the new comers."* One thing was noted is that all participants agreed that an accurate representation of the real training location is a must. An explanation was that *"If someone works in a building in China that doesn't have the same office layout as the virtual one we have here, it won't matter for him to do this training."*

2nd session: All participants were very positive in the responses. Participant 1 mentioned *"It is good and can be used for training. It will help us to understand about the situation and how immense and dangerous it could be."* Participant 2 thought there was possible to scale this evacuation for different emergency cases. Participant 3 indicated that VR with VHs had great potential not only for emergency training but also for education in general.

Question 19: To what extent do you think VR with VHs can enrich ET scenarios in general?

1st session: All participants agreed to a great extent. They meant that doing this kind of training was a plus to them because they could learn something from virtual training scenarios. In the future, they believed that VR with VHs could make more complicated ET scenarios thanks to new technologies.

2nd session: Participant 1 thought it could be used for training to students, firefighters or office employees, or used for awareness purpose to children. Participant 2 stated *"It gives you the possibility to create scenarios that you would do in traditional training."* while participant 3 meant that VR gave us a possibility to create more dramatic scenarios for ET than we could do in the real life.

Question 20: Which challenges do you think you may encounter when doing ET in VR?

1st session: The participants reported a challenge they encountered when doing ET in VR which was *"In physical training, your action is associated with stimulating of your body and brain. In virtual training, only your brain got stimulated not your body because you train with a screen."* They all agreed that using Oculus would help to remove challenges

thanks to a more immersive feeling. One participant mentioned that he saw the fact "little sense of danger" as a challenge in doing ET in VR. He explained that *"I don't have the sense of real danger when training in virtual reality. Everyone knows that the danger approaches you in virtual reality won't hurt you in real. I think if virtual training has some kind of incentive to encourage participants to avoid getting hurt during emergency situation, that would make the training more interesting. Besides, adding more danger to virtual emergency training would be helpful."*

2nd session: Participant 1 reported that there was no challenge except it was difficult to find out the exit door. Participant 2 gave in her opinion *"Some people will consider ET in VR as a game, then they will judge its realism. Because of that, they may not involve themselves as much as they should."* Participant 3 indicated that the biggest challenge was creating realism in this approach.

Question 21: The habit of being familiar with traditional emergency training might hinder people from trying virtual emergency training. How can we overcome this problem?

1st session: All participants recommended to create interesting training scenarios and fulfill all above suggestions for improvements.

2nd session: Participant 1 stated *"It's good for being used at schools and colleges to students who don't get any training in traditional emergency training."* Participant 2 said *"This training could be a supplement to traditional training, something that can be used to test different scenarios in a convenient way without involving many real people."* Participant 3 indicated *"Gamify it. Make it fun and interesting to take part."*

Question 22: Which alternative public location could we apply virtual emergency training for?

1st session: A list of alternative public locations was given to answer this question.

- Department store
- Parking area
- Public entertainment location such as cinema, stadium
- Library
- Canteen (this place has a potential of catching fire from cooking)

2nd session: Here is a list of suggestions:

- Cinema or shopping center. Big crowds create challenges
- Private and public sectors and schools
- Passenger boat, ferry
- Sports stadium
- Night club
- Subway station

Question 23: Which alternative emergency training could optimize the potential of virtual reality?

1st session: All participants stated that there would be no limit about this. Virtual emergency training could be implemented for other types such as terrorist attack, tsunami, earthquakes etc...The technology will decide how realistic and dramatic the training scenarios could achieve.

2nd session: Here is a list of suggestions:

- Training to escape from a vehicle in accident
- Training how to give emergency first aids
- Big event planning, moving large crowds from an emergency situation
- Training at public transportation (train, subway) in case of fire
- Disasters
- Terrorist attacks

Question 24: How much potential do you think VR such as Oculus and Augmented Reality such as Google glass would have for emergency training'?

1st session: All participants agreed that these equipments were very much potential for virtual emergency training.

2nd session: Participant 1 and 2 have tried Oculus before so they thought this equipment had a certain potential. Participant 3 hadn't tried Oculus so no comment.

Other suggestions

Question 25: Which scenarios would be relevant to use for emergency training in office setting?

1st session: The responses to this question are among "Earthquakes in office setting for example in Japan, Nepal; Terrorist attack at work; People suddenly collapse at work

2nd session: Here is a list of suggestions:

- First aids
- Different locations for the start of the fire. Fire blocks escape routes.
- Lighting is out, only exit lighting remains on.

Question 26: What features do VHS need to possess for simulation improvement?

1st session:

- VHS crash with others and fall down during evacuation
- VHS stay at information desk to give instructions, guidelines

2nd session: Here is a list of suggestions:

- Conversations (asking for help)

- Reacting to human participants
- Sounds (shouting, screaming, footsteps, doors slamming, coughing etc.)
- Crawling (if a lot of smoke)
- Pointing directions, waving arms

Question 27: What features should virtual space possess in general for emergency training?

1st session: A participant indicated that *"There should be chairs or sofa where the participants can sit down. We currently cannot sit anywhere except on the floor."* Other participants also suggested to make bigger corridors for crowd simulation and place more boxes, obstacles on the floor.

2nd session: Here is a list of suggestions:

- Emergency signs
- Locked doors
- Movable chairs and tables
- Extinguisher
- Toilet (maybe someone's there when the alarm goes off)
- Stairs

6.4 Results from NAV

Video session

A video recording a virtual fire emergency training with role players (from last evaluation) was presented to NAV participants. This video started with visualizing a regular office day in a public sector where the VHs in different placements performed working routines. Then, a role player triggered the fire which in turn created a lot of smoke spreading around. The VHs started to move out of the danger area. Some of them were walking out from the working area, some of them were walking from the social area where the fire located. Other role players evacuated with these VHs. One role player helped move the wheelchair VH to evacuate. There was a panicked VH walking randomly in the virtual office as she lost her sense of direction. The video ended when everyone had reached the meeting places outside the virtual office, except the panicked VH.

During the video was playing, the participants seemed to extract the information very well. When the fire emerged, they expressed such as *"Ah! This is interesting!"* or *"This is nice!"* which proved that the on-going event attracted their attention in a positive way. The evacuation of the VHs also yielded good reactions from them.

After the video finished, a participant commented *"I suggest more movements before the alarm went off. There should have some more diverse movements. Anyway, the concept is interesting, it shows what is possible."* They seemed to be very positive about the video

content. However, they pointed out some problems with it. For example, they thought the corridors of the virtual office were too narrow than that of the real location in terms of spatial scale. Another problem is that the current virtual training showed a lack of realistic crowd simulation. This is because VHS have a "bouncing" layer to prevent collision which hinders them to be placed too close to each other. This limitation will be discussed more in Limitations of chapter 7.

Interview

After a short self-trying session, the participants were invited to an interview. This interview aimed to find out if this fire emergency training could be relevant for NAV training program and if virtual emergency training had potential for future trainings at NAV. The participants' answers are categorized into several topics used during the interview.

The virtual evacuation in Second Life

When asked if it was easy to extract the information of on-going situation from the simulation cues such as fire, smoke, alarm, people escape..., the participants agreed. They meant that the virtual training was able to visualize the emergency situation and how it should be handled. To their opinion, it was understandable about what was happening during the evacuation. They believed virtual training had potential because it could implement the effects such as fire, smoke, people screaming or shouting, collapsed walls, which were very difficult to do in real life.

They responded positively when being asked if they would be interested to train evacuation or similar in virtual environments or virtual reality.

Regarding the question about the kind of virtual training would be suitable for NAV personnel, the participants suggested that role-playing and live training in SL could be used for certain people who are responsible in case of fire. The rest of people could use videos for training.

Virtual Humans (VHS) in Second Life

In general, the distribution of VHS in the virtual office was reported that it looked similar to how it was in the reality. They suggested to have more virtual humans to fill up space inside the virtual office. They thought VHS would certainly have potential to resemble the office settings for emergency training.

Virtual Reality (VR)

The participants emphasized that VR with VHS could enrich emergency training scenarios in general to a great extent. VR with VHS had the possibility to create features that hard to do in real life, for which they believed that there were a lot more VR with VHS could implement emergency training.

They were pleased to see the virtual emergency training contained a wheelchair person and indicated this was a good point. They mentioned that there could be other relevant tasks that certain personnel who were responsible for assisting wheelchair persons needed to be trained. These could be integrated in new training scenarios in SL.

Concerning the question about considering to use this video and this virtual office as training material for NAV training plan, they were very positive. They stressed that

this virtual office was very good for this training concept. They thought the video was absolutely useful. They really liked the idea of using videos for training as they indicated that *"the audience wouldn't need to have experience in VR to attend the training"*. In their point of view, a good video could show the training idea easily so that the audience could understand it.

When asked if they thought VR such as Oculus and Augmented Reality such as Google glass would have potential for emergency training, they said this was not necessary to their training basis due to the computer settings they use at work. They said it could be potential for certain personnel to train directly in SL with Oculus. However, the video approach would be the best for bigger audience.

Other suggestions

The participants had many suggestions towards the question about other relevant scenarios could be used for emergency training at NAV. They proposed interactive video solution which provided participants with questions and various options so that participants could experience different outcomes based on which decision participants make. The training flow could be different scenarios built up based on the next move participants choose. This would give the virtual training approach more flexible and helpful for them.

They saw a potential to combine VR videos with reality videos to take advantage of illustrating the physical details, for example when operating an extinguisher to stop fire.

They came up with new scenarios such as:

- Fire emerges near exit door
- Exit door is unexpectedly locked
- People need to break a window to escape
- People crawl on the floor to evacuate
- The lighting goes off and thick smoke hinders the sight (in this case exit signs and/or reflective stripes will be highlighted to instruct evacuation)
- People use extinguisher or a blanket to stop fire

They also stated that *"Training can include rules that we have at local office. For example, if the door of a print room is heated, there could be a fire inside. Therefore, don't open it."*

When asked about other concerns that NAV preoccupied with regarding virtual emergency training, they indicated the problem *"Attack training or a fire emergency training where the scenarios combine NAV employees and customers. This is what impossible for us to do training in real life"*. They also concerned about the situation of explosion by gas or water leakage in areas where electronic and electrical devices located.

Discussion

This chapter starts with a restatement of the research question and its sub-questions before it shows a general discussion of the results mentioned in the Results chapter, exploring which causes may have affected them. The discussion is organized into categories for clarity.

The research question and its sub-questions will then be revisited and answered to determine the success of this project.

This chapter will also discuss whether or not the requirements regarding the emergency training aspects have been met, before go to the final conclusions.

7.1 Retrospective on the Research Questions

As mentioned earlier, this thesis goal is to examine the possibility of using Virtual Reality with Virtual Humans for Emergency Management Training in a public sector. The research question and its sub-questions come from this intention:

RQ. *How could Virtual Reality with Virtual Humans contribute to Emergency Management training in public sectors?*

RQ1. *How could Virtual Humans contribute to Emergency Management training?*

RQ2. *How could VR with HMDs support participants learning enhancement during the fire emergency training?*

RQ1 and RQ2 concentrate in the following elements:

- The potential of using virtual humans to simulate emergency situations for training
- The degree to which the virtual humans could convey an evacuation in a public sector
- The degree to which the virtual humans could interact with human participants (both active and passive participants)

- The degree to which VR with HMDs contribute to participants' feeling of immersion and presence
- The impacts VR with HMDs have on participants' perception of the virtual space, virtual humans and their learning effect from the emergency training.

The full explanations of the research question and its sub-questions can be found in section 1.2.

The rest of this chapter will focus on discussing the results from Emergency Management students evaluation and the Civilian evaluation and NAV evaluation in the way that these results will be compared and evaluated in order to respond to the research question and its sub-questions.

7.2 Discussing the Results from the Evaluations

There were three evaluations in this thesis. The only difference between them regarding the virtual emergency training is the smoke effect. In the first evaluation, the smoke effect was made in the shape of chimney smoke. In the second evaluation, the smoke effect was made more heavily and in a larger scale. The last evaluation, the smoke effect was adjusted once more to hinder the participants sight during evacuation but prevent the time lag problem for heavy object loading in SL. Because of this problem, there can be some difference in the participants' impression about the realism of the emergency situation.

In the following sub-sections, the answers from questionnaires and interviews as well as observations from these evaluations will be discussed and compared.

7.2.1 Emergency Management Background

Except the first evaluation with Emergency Management students, the rest of participants in both Civilian evaluation and NAV evaluation don't have Emergency Management background. This gives the thesis evaluations more diverse judgements which in turn yields more valuable findings.

7.2.2 General Experience in the Virtual Emergency Training

Based on the responses from the questionnaires presented in chapter 6, when being asked about whether the virtual emergency looked fun / motivating, 10 percent of EM students disagreed about that while 29 percent of civilians gave the same response.

This can be explained that the EM students evaluation was carried out as a demo where the participants joined passively in the virtual training. They attended the virtual training by observing the scenario on a big screen, like watching a film. During the demo, they followed a sequence of events happened chronologically and smoothly. Thus, the experience about the virtual training could describe as fun or motivating.

On contrary, the civilian evaluation required an active participation. The participants needed to play a role in the virtual training. On the one hand, this created an impact of engagement for the participants. From interviews result, it showed that participants joined the evacuation with other VHs felt more engaged in a role-player position. On the

other hand, the participants could experience all the technical downsides where they could compare with other better visualization games. In addition, the virtual training became less fun because of predictable events when keep playing repeatedly in the scenario. These are regards as limitations of platform and evaluation, which will be explained more in section 7.3 However, there is an interesting finding where one participant reported that he felt stressful during role-playing session because the heavy smoke blocked his way out too much, which in turn made him lose the fun of the training. An assumption is that the degree of immersion and presence he experienced had influenced his sense during the virtual training.

In the interview with NAV after their seeing the training video, they agreed that the training was interesting and motivating. In their opinions, the video could convey the purpose of this emergency training, they therefore understood it and enjoyed watching it. While this is considered to fulfill the requirement CE_E.15, it could at the same time raise an argument about whether a high engagement in a virtual training could reduce the fun or motivating on it.

According to Tasdemir (Tasdemir, 2014), one of her findings also stated that *"Data from the NTNU participants also show that the NTNU participants enjoyed the simulation on a higher degree than the CAMO participants, where 84 percent found the experience enjoyable. As mentioned, the NTNU participants, like the Oslo participants, were mostly passive in the village."* Although Tasdemir came up with a different explanation about her finding, the characteristic of her finding seemed to be similar with that of this thesis finding.

7.2.3 The Virtual Space and VHs Realism

Data from the questionnaires and interviews have shown that EM students had more positive answers than that of the civilians when being asked about the realism of the virtual space and VHs in the training.

One reason for this could be that EM students joined the training by observing the demo while civilians participated more actively in the training. The active participation could lead to that civilians had more interaction with the virtual space and VHs, which in turn have a possibility to judge the realism more in details.

Another reason for this could be that EM students looked at the virtual space and VHs from training perspective, focusing on how these elements convey the emergency information to audience, while the civilian group with relevant game background had seen these elements as more of a game, judging the realism of this elements with their experience or expectation of how virtual space and virtual humans look.

It is worth noting that under observation, participants who had relevant game background focused more on the graphic side of the virtual training which might prevent them to judge the training in a whole context. Other participants who didn't get bothering too much about the graphic side of this training agreed that the virtual office and virtual humans look realistic and they could understand the scenario simulated by these elements. Since the final result on the realism of the virtual space and VHs collected by all participants is above average indicator (i.e. neutral), the requirement CE_N.1, CE_N.2 are considered as fulfilled. However, if this virtual space and VHs are to be used for further

emergency trainings, it's important to extend the office to be bigger, having more complicated exit routes as well as obstacles and improving VHS appearances and gestures. From the evaluations, it is obvious that graphical quality of the virtual emergency training was paid much attention and an improvement on that could make virtual reality and VHS have more potential for EM training.

It is good to mention that HMDs provided a better experience with virtual reality under training. The details will be discussed more in sub-section "HMDs".

7.2.4 Virtual Humans Behaviours

When being asked the extent where VHS can represent human characteristic in virtual EM training, a half number of participants selected a neutral answer, while another 40 percent gave high scores in their responses. In contrast, when being asked a similar question, 86 percent of civilians gave high scores in their answers while 14 percent rated a low score. This could be explained with an assumption that role-playing increased the interactions between participants and VHS which in turns influenced the participants to perceive VHS as individuals with unique characteristics, which again made the participants avoid judging and comparing VHS behaviours with their own behaviours.

Nevertheless, both the EM students and the civilian group confirmed that VHS were lack of gestures and expressions which made the participants see the VHS as unusual calm "humans". While the EM students didn't give detailed comments, the civilians who had a chance to interact more with VHS throughout the role-playing session came with a lot of detailed comments about the VHS behaviours (see chapter 6 - subsection Interview) Quite many civilians in the group said that the VHS looked so calm under fire situation. They expected that the VHS would look panicked or at least some of them. Especially, the wheelchair co-worker has drawn a lot of attention. The participants were surprised about her calmness, they meant that in such event which demands fast movement to evacuate, she should have been more worried to be perceived as naturally reacted.

There was a surprise when almost all participants in the civilian group reported that they didn't see the panicked co-worker on the way to evacuate. The panicked co-worker was primarily implemented in order to simulate with other VHS and human participants. From the interview data, there were some reasons leading to that. Firstly, the virtual office was small and exit paths were relatively very short. Therefore, the human participants reached exit doors before having a chance to see or interact with the panicked co-worker. Secondly, the panicked co-worker didn't create a special signal to notify others about her existence. Some of the participants in the civilian group suggested "*She/he should have shouted to attract attention.*" The last reason was that she was placed in a place that obstructed observation from others. One participant commented "*I couldn't see her on the way. It's better to relocate her to a more visible place.*" Because of the above comments, the requirements CE_E_10, CE_E_11 are just partially met.

The tempo when the VHS evacuate was also not realistic very much according to both the EM students and the civilian group. They suggested that some people could run fast, some people could be pushed and fall. It is clear that the VHS need to improve in terms of gesture and expressions in order to offer more interaction with human participants. The requirement CE_E_16 therefore is partially achieved.

Other requirements include CE_E_1, CE_E_2, CE_E_3, CE_E_4, CE_E_5, CE_E_8, CE_E_14 are considered to be fulfilled as the VHs were able to visualize all these requirements during the evacuation.

7.2.5 Virtual Office Presentation

The virtual office is an important factor in this virtual training as it integrates emergency information such as exit signs, emergency contacts, corridor design. Many civilians mentioned that they had to look for exit signs and the office layout in order to plan their evacuation. The EM students emphasized that the virtual office could play a significant role in simulating different scenarios in emergency training. According to them, the virtual office for fire emergency training would not only contain all important emergency information but also simulate different scenarios such as chairs fall, walls collapse, slippery floor or other kinds of damage which are possible for such event in real life. NAV also agreed that there should be able to create more emergency scenarios with the current virtual office for training.

The current office has solved the problem with walk-through walls so the requirement ES_N_4 is achieved. Anyway, other objects in the office such as table, desk, chair, sofa still remain the walk-through problem. The reason is that the office is small while there are many objects (furniture) in it which reduce the space capacity if not allowing walk-through option. Small space capacity could lead to a huge problem for VHs when they navigate their exit paths. Therefore, this problem still continues to exist.

Regarding emergency information visibility as well as the realism of the fire-smoke-alarm effect in the virtual office, all participants agreed that they looked acceptable for simulating the fire emergency training. This fulfilled the requirements ES_N_1, ES_N_2, ES_N_3 and the requirements in the table ES_E.

7.2.6 Information Extraction

According to the questionnaires, there is a big difference in answering about the level of extracting information during the training between the EM students and the civilian group. In the questionnaire of the EM students, while 20 percent reported that they extracted much information from the VHs during the working process, only 10 percent reported that they extracted much information from the VHs in evacuation procedure. On the contrary, 14 percent of the civilians said they extracted much information from the VHs during the working process while 57 percent confirmed that they extracted much information from the VHs in evacuation procedure. A reason for this could be that the civilian group joined the role-playing session which received more information from interacting with the VHs than the EM students regarded as passive participants. However, the fact that the EM students gave higher score for the information extraction during working process while the civilians gave lower score on that could be explained by observing the participants reaction during the training. It's worth to note that many EM students weren't familiar with 3D technology, especially in a training context. Thus, they tend to judge the virtual training based on some basic standards of office settings. In contrast, several members in the civilian group were students and showed a high competence in playing 3D games/online games. Hence, they could judge the virtual training based on more complex demands such as graphical

quality, the natural reactions of VHS, VHS facial expressions. They might see that the VHS exposed themselves unnaturally in terms of lacking gestures, expressions and adaptations. That would be noticed easily when the context remains static such as a presentation of a normal working day.

This finding could be used for explaining the different perceptions about simulation cues impacts from both groups. The questionnaire result from the civilian group has shown that simulation cues such as "Active participation (role-playing)" and "Office lay-out (rooms, corridors) scored lower (29 percent) than "Virtual humans behaviours" (43 percent) when being considered as useful for the participants diagnosis of the emergency situation, which was opposite to the result from EM students evaluation. It is possible that the participants who play a role would feel more interactive with VHS therefore they think "Virtual humans behaviours" make a certain impact to their diagnosis of the emergency situation.

However, in the interview with NAV, they reported that the training video gave them a good understanding of the training purpose. This meant that the information extraction was considered successful. In summary, the information extraction yielded better result for who played a role in the virtual training or observed the training video (which followed a manuscript to perform the training purpose) than who observed the live demo with more unexpected incidents. Because of the above finding, the requirement CE.E.15 can be classified as partially fulfilled.

7.2.7 Interactions

VHS with VHS

From the questionnaires and interviews data, all participants emphasized that there was a lack of interaction between VHS. As mentioned above in the subsection *Virtual Humans Behaviours*, the lack of gestures and expressions from VHS when they presented next to each other made the participants feel strange.

VHS with role-players

The civilian group reported that they didn't have much interaction with the VHS when the evacuation started. One participant stated that "*They ignored me, the wheelchair woman didn't interact with me.*" This kind of feeling led to that the role-players stayed disconnected from the VHS which then formed a low connection between the role-players and the simulating crowd. It is clear that an improvement on VHS behaviours will be needed if this virtual training wants to gain better training effect. Another reason contributed to this low interaction issue was the limitation of technology. One role-player commented that he needed to wait for the VHS to evacuate first before he could run out. That made him feel distant with the VHS.

Nevertheless, the research data have shown that role-playing contributed to a better engagement between the participants and the virtual environment. The proof could be taken from the answers about participants reactions during the virtual evacuation. While 30 percent of EM students reported that they felt not involved in the evacuation, none of the participants from the civilian group reported so. Actually it was interesting to know one civilian felt stressful during this training. This could mean that this specific participant got high engagement as a role-player during the evacuation.

7.2.8 HMDs

Some of the EM students had tried Oculus Rift in the evaluation and they gave very positive feedback on the experience they had when seeing the training through the Oculus Rift lense. One participant stated thFrom the questionnaire, they also graded highly the effect that Oculus Rift provided them in terms of immersion and presence. Indeed, 83 percent thought Oculus Rift improved the experience of immersion and presence in the virtual evacuation and 100 percent agreed that Oculus Rift could provide better learning effect for virtual EM training. The result from the civilians questionnaire was also very positive. In the interviews from both EM students and civilians, it also showed that the participants believed HMDs would solve the challenges of VR including graphical issues and immersion creation.

However there is one downside of using the Oculus Rift for VR navigation. That is the problem with not seeing the keyboard because of the VR glasses. Many participants commented that it was burdensome when they hit the wrong key while navigating around which in turn made them take off the VR glasses to locate their fingers again at correct position on the keyboard before continuing to walk in SL.

According to the interview data with NAV, Oculus Rift was regarded as a minor choice for the big audience. This is because of the navigation difficulty in associated with this VR glasses. It is no doubt that navigation is an important factor for virtual training, especially under time constraint such as emergency training. Unfortunately, navigation in SL is still far from mature when being compared with online games. Both 2D (screen-based solution) and 3D (HMD solution) navigation still need a lot of improvements in order to ease user exploration in SL.

Overall, the participants expressed that they saw the potential of using Oculus Rift for virtual emergency training, and they would definitely like to see Oculus Rift develop further in the future.

7.3 Limitations

7.3.1 Platform Limitations

As mentioned throughout this chapter, limitations in SL hindered partially the motivation and joy of participating the virtual emergency training. This problem presented clearer in associated with role-playing session. One role-player commented about his frustration during the evacuation *"I had to stand there look around the corner to wait for them to pass before I can go."* This is a technical problem in SL which defined that each avatar would have a personal distance to prevent collision. However, such personal distance caused trouble to crowd simulation when that happened in a small office with narrow corridors like the one used in this thesis. The trouble was that if human participants came so close to them then they would interfere the VHs path-finding pattern, which in turn led to that the VHs couldn't continue walking to their target locations, they instead would walk in circles as to prevent to collide to the human participants.

Another limitation was about the smoke effect. As explained earlier, the smoke effect in this emergency training has been modified in totally 3 times. The problem was that the more natural the smoke looks, the heavier graphic the computer needs to deal

with in SL. The heavy smoke effect used a script which set many particles per second to shape a flow-like look for natural movement purpose. However, in a role-playing session, one participant complained *"I was annoyed that my frames in rendering the heavy smoke dropped so I couldn't do anything due to this graphic issue."* Indeed, his avatar was somewhat unresponsive at that moment causing a new role-playing round. This triggered a few adjustments to the number of the particles in order to solve the graphical problem at the same time maintain the flow-like look for the smoke.

The sophisticated side of VHs behaviours and their appearance are also limited to a degree in SL which leads to that the participants who have experiences with online games could have negative perception of the graphical performance during the virtual evacuation.

7.3.2 Limitations of Research Methods

The thesis uses questionnaire as quantitative data tool and interview as qualitative data tool. Since there is a challenge in designing questions in the way that the participants can prevent misunderstanding or prevent to use bias tendency in their answers. The questions starting with *"Do you think..."* seem to lead the participants to focus their answers on a subjective perspective instead of staying neutral.

It is worth noting that there was a risk of missing collected data by using online questionnaire solution. This case happened in the second session of the civilian evaluation. Due to the limitation of physical location for gathering, the group met online in SL, participated the role-playing session and then filled out the online questionnaire and the online interview form. When collecting the data from this session, there was a case that some answers left blank by the participants. Remotely answering the questionnaire contains a risk of missing data because it is impossible to check for a completed set of answers before they submit the answer sheet.

Another limitation should be mentioned is that the questionnaire used for each group has been tailored to adapt to their backgrounds. This means that if a participant belonged to a civilian group, he/she would not receive questions which required a Emergency Management perspective. However, there were also some common questions that both groups shared. The results, in brief, were used as indicators to explain the differences between these groups with an awareness of not being directly compared on statistical level.

Since the number of participants in each group was rather small, there was a big effort investing in the interviews with adjusted questions based on the backgrounds of participant groups. The goal of using this qualitative data tool is to get the project evaluated with multidimensional perspectives as well as exploring the potential of further implementation based on the participants' constructive feedback.

7.3.3 Limitations of Evaluations

One of the main challenges encountered during evaluations was that many participants had experiences in popular online games such as World of Warcraft, The Sims...etc brought their expectation of high graphical demand to the virtual training in SL, which could influence their reaction to examine the virtual training in a neutral way. This could increase a bias tendency in their answers for the questionnaire as well as the interview. One participant also stated that *"Some people will consider ET in VR as a game, then they will judge*

its realism. Because of that, they may not involve themselves as much as they should.” De Freitas has a comprehensive description about this challenge in one of her papers as *”The representation of the virtual world itself therefore can have a negative impact upon learning, not least because of the level of expectation on the part of the learner. There is evidence that regular gamers find the graphics of virtual worlds too low level, and can experience negative transfer as a result”* (De Freitas et al., 2010). In the other side, the EM students and NAV people who participated in the evaluation had little experience with navigation and VR technology. This could lead to a bias tendency from their responses when determining the potential VR with VHs could have for EM training. This is a foreseen risk which may affect the evaluation outcome.

In the first evaluation, EM students refused to participate in the role-playing session as planned, which removed the role-playing topic out of the evaluation agenda. This reaction could be explained by the fact that they had little confidence in navigating in VR due to a lack of game experience. According to Hsu et al. (Hsu et al., 2013), the lack of acquaintance with VR applications could be a significant challenge to participants.

The virtual office used in this thesis work is a Proof of Concept so it remains many limitations in terms of diverse spatial areas, complex exit paths, staircase, elevators, lighting solution and a roof. In the role-playing session, these limitations made the evacuation plan too simple and easy according to the role-players.

”Little sense of danger” could be mentioned as another challenge this project encountered. According to one participant, training in virtual reality doesn’t hurt the participant physically, which reduces the motivation during the training session. He suggested that *”I think if virtual training has some kind of incentive to encourage participants to avoid getting hurt during emergency situation, that would make the training more interesting.”* This suggestion belongs to De Freitas’s one of the key factors that influence the players’ motivation: *”player sense of challenge”* (De Freitas, 2006)

The lack of various emergency scenarios in this project is another limitation. This limitation could lead to that the participants only examine the current implemented scenario (i.e. fire emergency case) to draw a conclusion on the potential VR and VHs could have for EM training. The evaluation result could hence contains some one-directional inputs.

Due to the limitations of platform, the current virtual training showed a lack of realistic crowd simulation, which could hinder the participants to see the potential of using VR with VHs for EM training.

7.4 The Fulfillment of the Research Questions

7.4.1 VR for Emergency Training

Many researches and studies have shown that VR with VHs simulation had a potential for emergency training. Although VR technology still needs a lot of improvements, it is a promising approach as one article on Techradar stated *”But VR technology has evolved dramatically in recent years and the industry is now heating up and heading towards a virtual arms race.”* (Ripton and Prasuehsut, 2015)

In order to use this project for presenting virtual training approach, the character development and human behaviours need to be studied. The literature from 10 characteristic

qualities by Hayes-Roth, Maldonado and Moraes as well as research papers from Margrethe Kobes et al. have been used as a guideline to implement this project. Crowd simulation concepts and Proxemics theory from Edward Hall have been used to design requirements for evacuation implementation. In addition, articles from Tan et al., Buono et al., Hajibabai et al., Pelechano et al. as well as Magnenat-Thalmann et al. have contributed to decide the direction of VHs behaviour implementation. The virtual space also held a great focus when designing requirements because it's important that the virtual space could provide environmental impacts to occupants in emergency situations. Furthermore, a careful consideration on how to design this project for an effective training purpose was conducted using the Four Dimensional Framework by De Freitas (De Freitas and Oliver, 2005) with an awareness of pros and cons of VR-based training implementation from Hsu et al. (Hsu et al., 2013). Chapter 3 presented a decent amount of relevant literature for this interest.

7.4.2 Research Questions Evaluation

From the collected data in chapter 6, it is clear that the participants could extract information about the evacuation in a public sector by the help of VHs simulation and the virtual environment / virtual space.

The following section will summarize how the evaluation result answers to the research question and its sub-questions. It will start with the sub-questions and then finalize an answer to the main question.

RQ1. *How could Virtual Humans contribute to Emergency Management training?*

The results have shown that there's a potential using virtual humans to simulate emergency situations for training. The fulfillment of CE.E.15-*Co-workers should give an understanding of evacuating process in a public sector* and partial achievement of CE.E.16-*Co-workers behaviours should look realistic when an emergency situation occurs* confirmed positively that the VHs could convey an evacuation in a public sector to a certain degree; and with the development of VR technology it is promising for the quality of VHs simulation in emergency training.

NAV showed very positive reaction with the training video. They thought the VHs simulation was fun and motivating in the training. NAV pointed out in the training video that it could be better by having more VHs to fill up the space areas in the virtual office.

Overall, the result data contributed to a positive answer to the sub-question **RQ1**.

RQ2. *How could VR with HMDs support participants learning enhancement during the fire emergency training?*

From both quantitative data and qualitative data, it is affirmed that VR with HMDs contributed to participants' feeling of immersion and presence to a great extent. Feedbacks from the EM students have shown that VR with HMDs have a positive impact on participants' perception of the virtual space, virtual humans and their learning effect from the emergency training. In addition to that, the civilian group gave high score answers to VR with HMDs question section. Although NAV didn't consider VR with HMDs as a major option, they agreed that VR with HMDs could facilitate the information extraction which then could improve the participants' understanding of the scenarios they trained with. To summarize, VR with HMDs would have a great potential for participants learning enhancement during the fire emergency training, which answered to the second sub-question **RQ2**.

RQ. *How could Virtual Reality with Virtual Humans contribute to Emergency Management training in public sectors?*

The evaluation outcome has shown positive answers to the sub-questions **RQ1** and **RQ2**. This meant that a potential found in using VR with VHS for EM training in a public sector which confirmed that this is a direction worth to pursue further in the future. From the findings in this thesis, it is noted that:

- it's necessary to do a decent research on literature about human behaviours in emergency training as well as how VHS can be implemented to achieve the realism purpose, and crowd simulation concepts
- to utilize the contribution of VR with VHS to EM training, beside actively updating about new VR technology, it's important to involve more people from EM profession to gain insightful inputs in designing virtual emergency scenarios
- it's critical to evaluate virtual emergency training with civilians who have little or no EM knowledge to examine how VR with VHS could facilitate their information extraction

Overall, the research question **RQ** has found an acceptable and useful answer from the evaluation data and the fulfillment of this project requirements. This answer could be a foundation to extend the research direction of the thesis as well as inspire to start exploring other aspects of the potential VR with VHS contribute to EM training.

7.5 Suggestions for Improvements

In order to make this project more useful, improvements in VHS and virtual space for this training needed to be made. Throughout this chapter, many improvements have been mentioned including direct suggestions from the participants and a lesson learnt drawn from the study of the evaluation outcome.

Below is a summary of the needed improvements for this project:

- The panicked co-worker behaviour: Currently this co-worker is hardly seen by the participants when the evacuation starts
- The wheelchair co-worker behaviour: The wheelchair co-worker behaviour needs to be improved in the sense that she should express some reaction when fire emerges
- More interactions between co-workers
- Dynamic fire and smoke
- Crowd sounds
- New emergency scenarios to simulate in case of fire
- Extend the office layout to be more complex
- More group tasks for role-players

7.5.1 Office Layout Recommendations

According to the collected data from consulting hour with NAV security expert and the literature research, it's critical to design the office space so that all emergency information becomes visible to the occupants in case of fire. The corridor areas should be wide and clear so that they could solve the bottle-neck problem when the crowd evacuate at exit entrances. It's important to make sure the office has an illuminating solution for indicating evacuation routes in case lighting is gone.

It is good to mention that the habits of organizing furniture and working materials of the occupants could impact the evacuation effect. Literally, piling up boxes, cases or alike, especially along the passages could obstruct the evacuation routes.

Last but not least, the office should be equipped with fire rescue tools such as extinguishers, fire blankets, water hoses and fire sprinklers.

7.5.2 Possible Situations for a Virtual Emergency Training

There are many interesting suggestions in chapter 6 for possible situations regarding virtual emergency training. Below is a summary of these situations suggested from the EM students, the civilian group, NAV as well as the literature research:

- Lighting is gone or partially gone which hinder the occupants view
- Fire sprinklers are activated and make the floor slippery. Some co-workers may fall when passing this area
- Some co-workers are impatient and push others in order to evacuate faster. Because of that, some co-workers could fall by being pushed, some other co-workers could get panicked and propagandize this negative reaction
- The exit doors are unexpectedly locked, the crowd must change evacuation plan
- The fire spreads to the exit entrance or obstructs the evacuation routes. Co-workers probably need to climb on the floor or break a window to escape

Besides, there are other suggestions to make scenarios for disaster emergency training, first aids emergency training, terrorist defense training. In addition, many participants also suggested to implement fire emergency training in other public locations such as train/subway stations, school canteen, school library, supermarket.

In order to achieve an effective training goal, it is important to keep in mind that "*Develop realistic scenarios to allow transfer of learning from rehearsal to real life contexts*" (De Freitas, 2006).

7.5.3 Collaborative Development

As mentioned in chapter 6, role-playing has proved to increase engagement among participants. It is necessary to improve the role-playing experience by adding more group tasks to simulate communication and interaction among role-players during training.

Some participants suggested to involve VHS in the roles such as guiders or messengers to support the collaboration when role-players do their group tasks. By having VHS played in such roles, the interaction between role-players and VHS also promise to increase.

There should be opportunities for reflection upon training via dialogue and discussion. (De Freitas, 2006) De Freitas explains the importance of reflection and learning from role-playing support "*Design role plays to allow students to empathise and reflect upon situations from real life, this will support learner motivation and allow learners to transfer learning from a learning context to a real life context more readily*" (De Freitas, 2006).

Conclusions and Future Work

This chapter presents the overall conclusions from the project as well as the contributions of this thesis to the research area. After that, some recommendations will be given for future work.

8.1 Conclusions

This thesis examined the potential of using VR with VHs simulation in EM training. Moreover, it explored the potential that HMDs could bring for the participants' information extraction under training.

The fulfillment of the project requirements which guided by the literature in chapter 3, the consulting hour with NAV security expert, answers to the research question and its sub-questions.

Using HMDs in the virtual emergency training got positive feedback from the participants. Oculus Rift, a popular HMD device has been confirmed to facilitate immersion and the participants sense of presence, which in turn helped benefit the participants' learning effect.

The fact that the research question and its sub-questions formulated in this thesis have been answered affirmed that there is a potential using VR with VHs simulation for EM training; and the proposed implementation in the project reflected effectively the contribution of VR with VHs simulation in the sense that the participants confirmed their information extraction from VHs, which helped them understand the evacuation process in a public sector.

Furthermore, there was an evidence proving that role-playing could increase the engagement of the participants during training. It is suggested to have more group tasks to utilize the collaborative work as well as increase the motivation in this kind of training. Ribeiro et al. and Kobes et al. papers have shown some significant research about this collaborative work in the form of serious games for training. (Ribeiro et al., 2012; Kobes et al., 2009)

The simulation can go further than demonstrating fire emergency training. It can be extended to other emergency training areas such as disaster training, terrorist defense training or medical emergency training.

The same requirements framework for VHs simulation can be used with modification to fit other training settings.

This project got evaluated with small groups of participants. It is suggested to be tested with bigger groups, especially in role-playing mode, to further confirm some of the discovered facts presented in this thesis.

8.2 Contributions

- Proposed a method for designing VHs simulation in a fire emergency training in an office setting
- Developed a requirements framework for VHs that will be used for demonstrating regular working activities in normal conditions as well as evacuation process in emergency situations
- Designed 3D co-workers to follow an office working context
- Proposed a solution for positioning the emergency information in the virtual office
- Designed 3D fire-smoke effect as well as fire alarm sound effect
- Confirmed that HMDs can facilitate the participants' experience in virtual training

Due to limitations of the platform SL as well as the nature of small virtual space such as the project's virtual office, the crowd simulation couldn't achieve the effect as planned. However, the evacuation process has fulfilled all three basic activities guided by Kobes et al. (Kobes et al., 2009).

The VHs in the project could performed spatial cognition and wayfinding features referred to the paper of Hajibabai et al. to some degree (Hajibabai et al., 2007).

Compared with Pelechano et al. work (Pelechano Gómez et al., 2007), this project made a better effort to create an immersive evacuation scenario by using VR with VHs in a 3D platform (SL), while their work used a 2D simulation platform. This thesis project provided a realistic virtual space with fire/smoke effect and VHs to simulate an evacuation while Pelechano et al. project used primitive objects as occupants with a training base formed by walls, pillars, exits and passages. However, their work built on a more complex framework in terms of agent's behaviors in emergency case, which this thesis could refer for improvement of VHs' behaviours in the future.

Buono et al. work (Buono et al., 2008) inspired this project to a certain degree as their work shared the focus on evacuation simulation because of fire in an office setting. It's difficult to compare their project with this project due to the different numbers of people engaged in these projects. While there are similar features that both projects achieved such as the simulation of the panicked person, the wheelchair person, fire and smoke, the thesis project will need to consider to implement an information center as the *evacuation expert cabin* in Buono et al. project. This is supposed to be where the VHs get involved for collaboration during training.

8.3 Future Works

8.3.1 Extension of the current project

Below is a list of items that can be improved or added to the virtual emergency training.

- Further evaluations with larger groups, with EM students, civilians (little or no EM experience), other public sectors' personnel, and with and without HMDs
- Develop new scenarios for emergency training (detailed in chapter 6 and 7)
- Create group tasks to support collaborative work in role-playing mode
- Improve the virtual office:
 - Add a roof to the office so that it looks more like authentic
 - Extend the layout to contain more spatial areas, staircases, elevators
 - Increase the complexity of the layout
 - Increase the complexity of the exit routes
 - Exit doors can simulate open and close behaviour
 - Lighting system can simulate on and off behaviour
 - Implement an illuminating solution in the office for exit indication in case out of light
 - Improve fire and smoke effect to be able to spread gradually and change direction of flame unexpectedly based on the materials the fire passes on its way
- Improve the VHS behaviour:
 - Add more gestures and facial expressions to demonstrate the mental impact from pressure situations
 - Add more gestures and facial expressions when VHS visualize interaction with others
 - Reposition the panicked person to a place easy for observation
 - The panicked person should have more expression to attract others' attention, for example she can shout out for help, come to someone to ask for help, wear clothes that could be stand out from the crowd and in the smoke condition
 - The wheelchair person should have more expression such as feeling worried, asking for help
 - Implement wheelchair carrying behaviour
 - Improve the crowd simulation to visualize the bottleneck problem at corridors
 - Add crowd sound when they evacuate such as shouting, crying, yelling
 - Implement pushing and falling simulation
 - Implement climbing behaviour

- Add more VHS to fill out the office space
- Implement VHS as guiders to provide information and give hints during training
- Implement communication support for VHS to human participants

8.3.2 Future of VR with VHS for Emergency Training

It is clear from the thesis evaluations that VR with VHS have potential for emergency training. Based on the experience from implementing this project as well as the information collected from research work, there are some factors recommended to consider carefully in order to implement an effective virtual emergency training.

Immersion Quality

Users generally keep a high expectation for immersion in virtual training. In particular, users who are familiar with games will compare the graphic quality in terms of realism, natural movements and smooth operation between a virtual training and their experienced games (De Freitas, 2006). This challenges not only the skill of people who develop the training program but also the capability of VR technologies. There is always a trade-off between operation cost and immersion quality to which a VR system could reach (Hsu et al., 2013).

Training Content

It is critical to mention that the virtual training scenarios need to be relevant to what is supposed to be trained in real life (De Freitas, 2006). It is necessary to consult with security experts in the emergency management field in which the training content aims to develop. The consulting hour with NAV security expert has proved to be very useful for the early stage of designing this project.

In addition, it is recommended to take into account the Four Dimensional Framework in order to develop training content effectively (De Freitas and Oliver, 2005).

Training Execution

The foremost goal of a virtual training is that it could convey the training information to participants. A challenge in introducing a virtual training to the audience is that there are people will not accept to try it, especially at the first time. This thesis also encountered that challenge when the EM students refused to join the role-playing session in the first evaluation. De Freitas described a similar challenge from her finding *"Learning can be undertaken in quite different settings and with different groups, some learners may welcome learning through games, but others may prefer other modes. Offer a choice to learners who find learning in game-based contexts problematic"* (De Freitas, 2006). Therefore, it is important to find a solution when this challenge shows up. NAV personnel had a good suggestion which proved to work; that is making a training video with a clear instruction to guide the training process. This training video solution will work best for:

- participants who have little or no experience with VR applications
- big audience such as department meetings or conferences

Reflection opportunities are encouraged during and after a virtual training via dialogue and discussion in order to increase the collaborative learning effect (De Freitas, 2006).

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Appendices

C Requirements

(*) Sp: Requirements derived from the result of the Specialization project and NAV feedback from that project evaluation.

(**) Exp: Requirements derived from the collected information in the consulting hour with NAV security expert.

Req	Description	Derived from
CE_N_1	Co-workers appearance should look realistic	(Hayes-Roth et al., 2002)
CE_N_2	Co-workers behaviours should look realistic	(Hayes-Roth et al., 2002)
CE_N_3	Co-workers should behave appropriately in an office context	(Hayes-Roth et al., 2002)
CE_N_4	Co-workers should dress appropriately in an office context	(Hayes-Roth et al., 2002)
CE_N_5	Co-workers should elucidate gender roles in the office	(Hayes-Roth et al., 2002)
CE_N_6	Co-workers should display office interaction pattern	(Hayes-Roth et al., 2002)
CE_N_7	Co-workers should give an understanding of working routines in a public sector	(Hayes-Roth et al., 2002)
CE_N_8	Co-workers should have varied appearance	Sp

Table H.1: Co-workers effects in normal conditions (CE_N)

Req	Description	Derived from
CP_N_1	Co-workers have a social distance to each other when walking opposite	(Hall et al., 1968) (Edward, 1966)
CP_N_2	Co-workers have a social distance when following each other	(Hall et al., 1968) (Edward, 1966)
CP_N_3	Co-workers have a social distance to each other when standing and talking	(Hall et al., 1968) (Edward, 1966)

Table H.2: Co-workers placements in normal conditions (CP_N)

Req	Description	Derived from
CE_E_1	Co-workers should move out of their current places when the fire alarm goes off	(Tan et al., 2014) (Pelechano Gómez et al., 2007) Exp
CE_E_2	A co-worker should notify the relevant fire department when evacuating	(Tan et al., 2014) (Pelechano Gómez et al., 2007) Exp
CE_E_3	Co-workers should evacuate towards exit entrances	(Tan et al., 2014) (Pelechano Gómez et al., 2007)
CE_E_4	Co-workers should choose nearest exit	(Tan et al., 2014) (Pelechano Gómez et al., 2007)
CE_E_5	Co-workers should evacuate in groups (group behaviour)	(Tan et al., 2014) (Pelechano Gómez et al., 2007)
CE_E_6	In case of potential collision with others, co-workers should avoid by adjusting their positions or replanning their evacuation routes	(Ribeiro et al., 2012) (Kobes et al., 2007)
CE_E_7	Crowd density should be high in the corridor area	(Ribeiro et al., 2012) (Kobes et al., 2007)
CE_E_8	Co-workers should reach a meeting place situated outside the office after evacuation	(Ribeiro et al., 2012) (Kobes et al., 2007) (Buono et al., 2008) Exp
CE_E_9	All co-workers except the panicked co-worker should evacuate successfully	(Tan et al., 2014)
CE_E_10	The panicked co-worker should randomly move from one place to another with chaotic patterns	(Tan et al., 2014) (Buono et al., 2008)
CE_E_11	The panicked co-worker should hinder other co-workers to evacuate when she encounters them on her way	(Tan et al., 2014) (Buono et al., 2008)
CE_E_12	The wheelchair person should be assisted	(Buono et al., 2008)
CE_E_13	The wheelchair person should simulate discomfort and movement inconvenience	(Buono et al., 2008)
CE_E_14	There should be a natural placement of co-workers when changing from normal conditions to evacuation situation	
CE_E_15	Co-workers should give an understanding of evacuating process in a public sector	
CE_E_16	Co-workers behaviours should look realistic when an emergency situation occurs	

Table H.3: Co-workers effects in evacuation situation (CE_E)

Req	Description	Derived from
CM_1	Co-workers must display animations (manner of gesturing)	(Hayes-Roth et al., 2002)
CM_2	Female co-workers should have a sitting model	(Hayes-Roth et al., 2002)
CM_3	Female co-workers should have a walking model	(Hayes-Roth et al., 2002)
CM_4	Female co-workers should have a talking on phone model	(Hayes-Roth et al., 2002)
CM_5	Female co-workers should have a talking model	(Hayes-Roth et al., 2002)
CM_6	Male co-workers should have a sitting model	(Hayes-Roth et al., 2002)
CM_7	Male co-workers should have a walking model	(Hayes-Roth et al., 2002)
CM_8	Male co-workers should have a talking model	(Hayes-Roth et al., 2002)

Table H.4: Co-workers models requirements (CM)

Req	Description	Derived from
GO_1	The office contains equal or greater than 8 co-workers	To reuse the working scenarios from Specialization project
GO_2	The office must contain male and females co-worker	-see above-
GO_3	Male co-workers should wear long pants, a (t)shirt and shoes	-see above-
GO_4	Female co-workers should wear long pants, a (t)shirt and shoes	-see above-

Table H.5: General office requirements (GO)

Req	Description	Derived from
ES_N_1	The office should have sufficient information and equipment in case of fire	(Hajibabai et al., 2007) (Kobes et al., 2007) Exp
ES_N_2	The office should have exit signs indicating exit directions	(Hajibabai et al., 2007) (Kobes et al., 2007) Exp
ES_N_3	The office should have exit signs situated visible at eye sight level	(Hajibabai et al., 2007) (Kobes et al., 2007) Exp
ES_N_4	The office should have meeting places situated outside the virtual office	(Hajibabai et al., 2007) (Kobes et al., 2007) Exp
ES_N_5	The walls in the office should not be able to walk through	Sp
ES_N_6	The corridors in the office should be scaled to be broader	Sp
ES_N_7	The office should have some sitting places	Sp

Table H.6: Environmental simulations in normal conditions (ES_N)

Req	Description	Derived from
ES_E_1	The fire should look realistic	(Hajibabai et al., 2007) (Buono et al., 2008)
ES_E_2	The smoke should look realistic	(Hajibabai et al., 2007) (Buono et al., 2008)
ES_E_3	The smoke should emerge as soon as the fire starts	(Buono et al., 2008)
ES_E_4	The fire alarm should be activated as soon as the fire starts	Exp
ES_E_5	The smoke should spread to surrounding areas in the office	(Hajibabai et al., 2007) (Buono et al., 2008)
ES_E_6	The smoke should hinder occupants navigation because of sight reduction	(Hajibabai et al., 2007) (Buono et al., 2008)
ES_E_7	The combination of fire, smoke and fire alarm should contribute to the evacuation simulation	(Hajibabai et al., 2007) (Buono et al., 2008)

Table H.7: Environmental simulations in emergency situation (ES_E)

D Expert consultancy - 20 March 2015

The collected information will be presented into separate topics for clarity.

Emergency training procedure

NAV schedules a fire evacuation aka a drill once a year to train people what to do in a fire or other emergency cases.

NAV regulations in case of fire

The most important thing to do in emergency situations is to *get out* of the office. However, in order to cooperate in case of fire, there are three things that need to be done chronologically as soon as possible:

1. Trigger alarm
2. Call fire department for help
3. Get out

In the kitchen, alarm system is built in so that if it is on fire, the alarm will go off automatically.

There are different ways to stop the fire depends on each fire case. For example, extinguishers or fire hoses can be used to stop oven fire, while fire sprinklers can be used to stop electrical fire.

Special handling for wheelchair people

There are teams to assist wheelchair people in case of fire at NAV. These teams usually locate at the same floor as the wheelchair people. They are normal co-workers beside having the special tasks with the wheelchair people.

When an emergency situation occurs, a team of 6-8 persons will help get the wheelchair person to evacuate. The number of helpers is based on the size of the wheelchair person and the disability of him/her. There is no fixed rule on how to evacuate the wheelchair person. This means that he/she could be carried out to either main entrance or exit door depends on how big and how handicapped the wheelchair person is.

Situation with panicked people

Panicked people barely trouble the evacuation because the exit direction will be piled up very soon when people start to escape, the panicked people therefore can't run around too much. Additionally, nearby co-workers will help the panicked people to escape.

In case the panicked people get blacked out and fall unconsciously, this is considered as a problem for the evacuation. However, such case is very rare.

E Questionnaire for EM students - 23 April 2015

YOUR PROFILE

1. You are

Male	6
Female	4

2. Do you have experience with navigation in Virtual Reality/Virtual Worlds?

Very little	Little	Neither little nor much	Much	Very much
9		1		

3. In what activities have you participated in Virtual Reality/Virtual worlds?

Online games	4
Virtual training (As part of work training, etc)	1
Virtual education courses (university or college courses, etc)	2
Other (please specify)	

4. What virtual worlds/environments do you have experience with?

Second Life	2
Open Simulator (Open Sim)	1
Open Wonderland (Project Wonderland)	
World of Warcraft)	2
Minecraft	1
Other (please specify)	2

-Don't know, it was a long time ago

-The Secret World

VIRTUAL EVACUATION IN SECOND LIFE

5. To what extent did the virtual evacuation look realistic?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	2	7	1	

6. To what extent did the virtual evacuation look fun/motivating?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	1	3	4	2

7. How much information did you extract from virtual humans appearance, behaviours and movement during the regular working process in the office?

Very little	Little	Neither little nor much	Much	Very much
	1	7	2	

8. How much information did you extract from virtual humans appearance, behaviours and movement in evacuation procedure?

Very little	Little	Neither little nor much	Much	Very much
	2	7	1	

9. To what extent did the simulation of virtual humans contribute to your understanding of the evacuation procedure?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	1	7	2	

10. What parts of the simulation settings were most useful for your diagnosis of the emergency situation?

Sound	
Virtual human positions	
Virtual human behaviours	
Active participation (role-playing)	5
Office layout (rooms, corridors)	5
Emergency escape signs	7
Effects such as smoke and fire	3
Other (please specify)	

11. Which of the following statements describe(s) your reaction during the virtual evacuation?

I felt stressful	
I was curious	3
I was calm	4
I felt in control and could make decision for my escape	2
I felt not involved	3
Other (please specify)	1

- I felt interesting.

12. How much did you feel of being engaged in the evacuation when you followed other virtual humans to evacuate?

Very little	Little	Neither little nor much	Much	Very much
2		6	2	

13. To what extent did you feel immersed with the virtual evacuation process (simulation)?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
1	1	6	2	

14. The simulation contributed to give you a better understanding of an evacuation process in public sectors?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1		5	3	1

15. To what extent would you consider using similar simulations in your own education?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
1	3	2	2	2

VIRTUAL REALITY AND VIRTUAL HUMANS POTENTIALS IN GENERAL

16. To what extent do you think would Virtual Reality with Virtual Humans be suitable for Emergency Management (EM) training in public sectors?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		3	4	3

17. To what extent do you think Virtual Reality with Virtual Humans can contribute to EM training for general public locations?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		6	2	2

18. To what extent do you think Virtual Humans can represent human characteristic in virtual EM training?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	1	5	4	

19. How important is it to have an accurate representation of the real location in virtual EM training?

Very little	Little	Neither little nor much	Much	Very much
		3	5	2

20. To what degree do you think role-playing provides a better learning effect in virtual EM training?

Very little	Little	Neither little nor much	Much	Very much
		5	5	

21. To what extent would you suggest virtual EM training for your future customers in the industry?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		6	1	3

22. In which of the following fields do you think virtual EM training could have most potential?

Oil and gas	7
Medical	5
Firefighter	7
Other (please specify)	1

- *Industrial plants.*

IMPROVEMENTS FOR THE VIRTUAL EVACUATION

23. Do you have any suggestions for improvements or things should be changed in the scenario?

Virtual humans should have more body language	5
Virtual humans should have facial expressions	2
Participants should be able to communicate with virtual humans	6
Improve fire scene to be more realistic (broader scale of fire and smoke etc)	8
Create crowd sounds during the evacuation	6
Better signs/markings in the virtual office	1
Virtual office should have more interactive features	2
Other (please specify)	1

- *Damage to virtual humans, due to incident or during evacuation. Also, lighting issues (missing lights or pitch dark)*

SECOND LIFE WITH OCULUS RIFT

24. Have you used Oculus Rift before the demo?

Yes	
No	10

25. To what extent do you think Oculus Rift improved the experience of immersion and presence in the virtual evacuation?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		3	2	3

26. To what extent do you think using Oculus Rift for virtual EM training provides a better learning effect?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		2	3	3

27. How much potential do you think Virtual Reality such as Oculus Rift and Augmented reality such as Google glasses would have for EM training?

Very little	Little	Neither little nor much	Much	Very much
		2	2	4

QUESTIONS FOR ROLE PLAYERS

28. Participant (1) + all who observed the wheelchair human: To what extent did you feel the wheelchair human contributed to the evacuation simulation?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
1		3	1	1

29. Participant (1): How much did you feel of being engaged in the scenario when you moved the wheelchair human?

Very little	Little	Neither little nor much	Much	Very much
2		2	2	

30. Participant (2): How much did you feel of being engaged in the scenario when you triggered the fire?

Very little	Little	Neither little nor much	Much	Very much
1	2	2	1	

31. Participant (3,4,5) + all participants who observed the panicked human: To what extent did you feel the panicked human contributed to the evacuation simulation?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
1	1	3	1	

F Questionnaire for Civilians - 07 May 2015

YOUR PROFILE

1. You are

Male	6
Female	1

2. Do you have experience with navigation in Virtual Reality/Virtual Worlds?

Very little	Little	Neither little nor much	Much	Very much
2	1			4

3. In what activities have you participated in Virtual Reality/Virtual worlds?

Online games	6
Virtual training (As a part of work training, etc)	2
Virtual education courses (university or college courses, etc)	3
Other (please specify)	

4. What virtual worlds/environments do you have experience with?

Second Life	6
Open Simulator (Open Sim)	
Open Wonderland (Project Wonderland)	
World of Warcraft	4
Minecraft	3
Other (please specify)	1

5. Have you ever participated in emergency trainings in general?

Yes	4
No	3

6. Have you ever participated in a training for fire emergency in an office/building setting?

Yes	4
No	3

VIRTUAL EVACUATION IN SECOND LIFE

7. To what extent did the virtual evacuation look realistic?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		4	3	

8. To what extent did the virtual evacuation look fun/motivating?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	2	1	3	1

9. How much information did you extract from virtual humans appearance, behaviours and movement during the regular working process in the office?

Very little	Little	Neither little nor much	Much	Very much
	3	3	1	

10. How much information did you extract from virtual humans appearance, behaviours and movement in evacuation procedure?

Very little	Little	Neither little nor much	Much	Very much
	1	2	4	

11. To what extent did the simulation of virtual humans contribute to your understanding of the evacuation procedure?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	1	3	3	

12. What parts of the simulation settings were most useful for your diagnosis of the emergency situation?

Sound	6
Virtual human positions	1
Virtual human behaviours	3
Active participation (role-playing)	2
Office layout (rooms, corridors)	2
Emergency escape signs	5
Effects such as smoke and fire	7
Other (please specify)	

13. Which of the following statements describe(s) your reaction during the virtual evacuation?

I felt stressful	1
I was curious	3
I was calm	3
I felt in control and could make decision for my escape	6
I felt not involved	
Other (please specify)	

14. How much did you feel of being engaged when you joined the evacuation with other virtual humans?

Very little	Little	Neither little nor much	Much	Very much
1		4	2	

15. To what extent did you feel immersed with the virtual evacuation process (simulation)?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		4	3	

16. The simulation contributed to give you a better understanding of an evacuation process in public sectors?

Strongly disagree	Disagree	Neutral	Agree	Strongly agree
		3	4	

VIRTUAL REALITY AND VIRTUAL HUMANS POTENTIALS IN GENERAL

17. To what extent do you think would Virtual Reality with Virtual Humans be suitable for emergency training (ET) in public sectors?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		1	3	3

18. To what extent do you think could Virtual Reality with Virtual Humans facilitate your learning in emergency training?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	1		5	1

19. How important was the role of virtual space and layout of virtual office in this ET?

Very little	Little	Neither little nor much	Much	Very much
	1	3	2	1

20. How important was virtual space compared to Virtual Humans in ET?

- Both are equally important. Virtual space gives you immersive feeling so the more realistic, the better. Virtual humans also need to be presented in different forms to make the overall simulation more realistic.

- It was more important to understand where to evacuate, rather than waiting for the virtual humans.

- In this ET, my impression is that virtual space is important for the feeling of reality. Virtual humans can be improved to support this space and scenarios.

- Fairly important.

- ET in general.

- They're both important to create as realistic as possible scenario, which in turn creates involvement for the participants.

21. How important is it to have an accurate representation of the real location in virtual ET generally?

Very little	Little	Neither little nor much	Much	Very much
	1	1	2	3

IMPROVEMENTS FOR THE VIRTUAL EVACUATION

22. Do you have any suggestions for improvements or things should be changed in the scenario?

Virtual humans should have more body language	3
Virtual humans should have facial expressions	2
Participants should be able to communicate with virtual humans	4
Improve fire scene to be more realistic (broader scale of fire and smoke etc)	2
Create crowd sounds during the evacuation	7
Better signs/markings in the virtual office	3
Virtual office should have more interactive features	3
Partial power cut situation	3
Other (please specify)	3

- After the fire, virtual humans should be panicked or move more quickly
- More people and uneven distribution of the evacuees through the two doors.
- More virtual humans, to highlight the problem with getting people out without panic.

SECOND LIFE WITH OCULUS RIFT

23. To what extent do you think Oculus Rift improved the experience of immersion and presence in the virtual reality?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		1	2	1

24. To what extent do you think using Oculus Rift for virtual emergency training provides a better learning effect?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
			3	1

25. How much potential do you think Virtual Reality such as Oculus Rift and Augmented reality such as Google glasses would have for emergency training?

Very little	Little	Neither little nor much	Much	Very much
			1	1

QUESTIONS FOR ROLE PLAYERS

26. All participants: To what degree do you think role-playing in virtual emergency training provides a better learning effect than non role-playing in virtual emergency training?

Very little	Little	Neither little nor much	Much	Very much
		3	3	1

27. Participant (1) + all who observed the wheelchair human: To what extent did you feel the wheelchair human contributed to the evacuation simulation?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
	1	1	4	

28. Participant (1): How much did you feel of being engaged in the scenario when you moved the wheelchair human?

Very little	Little	Neither little nor much	Much	Very much
	1	1	2	1

29. Participant (2): How much did you feel of being engaged in the scenario when you triggered the fire?

Very little	Little	Neither little nor much	Much	Very much
	1		2	1

30. Participant (3,4,5) + all participants who observed the panicked human: To what extent did you feel the panicked human contributed to the evacuation simulation?

Little extent	Slight extent	Neither little nor great extent	Certain extent	Great extent
		1	3	

G Interview with NAV - 19 May 2015

The names of the participants have been changed.

The virtual evacuation in Second Life

Q1. Is it easy to extract the info of on-going situation from the simulation cues such as fire, smoke, alarm, people escape...?”

Jon: Yes, it is easy. The concept is able to visualize the meaning, make it understandable so I think it is good enough for training purpose. Its interesting concept in the way that it could simulate people sound, panic, the crowd, fire and smoke which are very difficult to do in the real life. Thats a good thing!

Tony: Yes.

Q2. Would you be interested to train evacuation or similar in virtual environments/virtual reality?

Jon: Sure, its interesting approach.

Tony: I agree with him.

Q3. Which kind of virtual training do you think would be suitable for NAV personnel?

Jon: I think the potential here is to train for different solutions if things go wrong. The simulations such as one fire starts another fire, wall break down, stairs are closed or similar things could be difficult to do in the real life. This approach can be used to train people who have certain responsibility in case of fire, like people who have special tasks such as helping wheelchair persons. Its potential to train them in different scenarios, so that when they meet the things for which they have been trained in real, they can reflect the training scenarios to do their task better. Its good to have a movie with different scenarios so that the participants can discuss solutions on these scenarios. This kind of film will be interesting for all audience.

Tony: Role-playing and live training in SL could be used for certain people who are responsible in case of fire. The rest of people could use videos for training.

Q4. Could NAV use this video and this virtual office as training material for your training plan?

Jon: Yes. I think its relevant for office meetings about fire emergency training. We can for example show videos and then discuss how we should behave in the emergency situations in these videos.

Tony: Yes, the virtual office is very good for this training concept. Especially the video. It doesnt require the audience to have experience in VR or competence of navigating around in virtual reality. It could show the training idea easily and the audience can understand it.

Virtual humans (VHs) in Second Life

Q5. Does the distribution of VHs in the virtual office similar to how it looks in the reality?

Jon: Yes, and it would have been better if the VHs had more movement before the alarm went off.

Tony: The virtual office should have more virtual humans to fill up more space.

Virtual reality (VR)

Q6. To what extent do you think VR with VHs can enrich emergency training scenarios in general?

Jon: A great extent. As I mentioned, VR with VHs could make many features that it's difficult to do in the real life. Thus, there are a lot more that VR and VHs could implement for emergency training. For example, various scenarios in the situation of fire.

Q7. About the wheelchair assistance in training is there any other relevant tasks could be used for training?

Jon: Its very good that you have the wheelchair person in the fire emergency training. There could be other relevant tasks that certain people who are responsible for assisting wheelchair persons need to be trained. These tasks could be integrated in new training scenarios in SL. That would also make virtual training more useful to us.

Q8. How much potential do you think VR such as Oculus and Augmented Reality such as Google glass would have for emergency training?

Jon: Its not necessary to our training basis. As you see, we have this kind of laptop at work which needs complicated configuration to access to HDMI so we couldnt take the advantage of using Oculus and alike for virtual training. Maybe, certain people who are in charge of the business here (i.e. leadership) could use it in live training in SL but with the bigger audience, the video approach is the best.

Other suggestions

Q9. Which scenarios would be relevant to use for emergency training at NAV?

Jon: There are many scenarios that could be used for emergency training here. In general, we can have interactive videos which provide participants with questions and various options so that participants experience different outcomes based on which decision partic-

ipants make. For example, if there is a fire, then participants can choose among options like find an exit, use tool to stop fire etc. If they choose find an exit then a new video will show how to find an exit in case of fire, if they choose use tool to stop fire then a new video will show how to use extinguisher or blanket to stop fire.

Tony: Yes, I agree. In addition, videos about how to use/operate tool to cease fire could be best filmed in reality instead of being made from virtual humans and objects. The reason is that there needs more details to illustrate how to use tool, I think virtual humans couldn't handle these details with their gestures.

Jon: There is a potential to combine virtual reality videos with reality videos. Its important that virtual training make use of interactive questions. For example, what should we do when fire is close to exit door? or How to get out when the usual exit is locked/unable to open? In this situation, participants can experience the outcomes based on their decision making. Different scenarios could be built up based on the next-move participants choose. This will give the virtual training approach more flexible and helpful for us.

Tony: There are also some cases where participants must crawl in order to get out of the room, or use a chair to break the window for escape It's also possible to have scenarios where the lights go off and thick smoke hinder the sight, that would require the participants to follow the exit signs and/or reflective stripes on the floor to find a way out. Another possible scenario is where virtual humans fall on the floor and obstruct others to evacuate.

Jon: Training also can include rules that we have at local office. For example, if the door of a print room is warm, there could be fire inside. Therefore, dont open it. Although our regulations in the case of fire is just get out but it should be able to have emergency training categorized as cases we can handle by ourselves and cases we should get out and let professional firefighters do their work. Thus, we could have different scenarios associated with these types.

Q10. What are other concerns that NAV preoccupies with regarding virtual emergency training?

Jon: Self-defensed training under attack or a fire emergency training where the scenarios combine NAV employees and customers. This kind of training is currently impossible for us to do in real life. For example, a fire case at NAV where there were 20 customers using NAV services at that moment, then its interesting to know how we should evacuate.

Tony: It should be possible to make emergency training for the cases such as explosion by gas or sprinkle water/water leakage in areas where electrical and electronic devices locate.

Other comments

"I think that the corridors are too narrow in this virtual office. The corridor area in reality is actually bigger in relation to the office space... So this is a question about realistic scale in this virtual office."

"If we integrate noise or lights which can change where people have to evacuate, we could see different solutions or workarounds for exit paths."

"Best use of virtual training to NAV is Video - Discussion - Reflection"

"Common training routines can use common training videos which are sharable among offices. Other routines affecting local offices would be best implemented in the specific virtual office of the original location. Each NAV office has different layout/details so it is important to have their accurate virtual office of the original offices."

"With the big audience, we could train by using the videos and reflection sessions to learn training knowledge."