connec2 FROM THE VIRTUAL DUTCH MEN

MULTI-USER TRAINING SIMULATION IN VIRTUAL REALITY

GRADUATION THESIS

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Abstract

Connec2 is a device-agnostic multi-user virtual reality platform which is developed by The Virtual Dutch Men (TVDM) Their platform is a communication platform that helps illuminate physical limitations companies deal with and currently functions as a design review, online meeting, 3D workflow, and remote expert tool. VR Brandveiligheid is a training simulation platform which has been created by TVDM as well. TVDM wanted to know if and how a training simulation like VR Brandveiligheid could be added to the functionally Connec2 has.

To be able to find the actual question of the client, the first step taken was to conduct a theoretical analysis. The Connec2 platform as well as currently used emergency training methods were analyzed. This research showed that most used emergency training methods teach trainees certain procedures in case of emergency and are used to create and test emergency plans. Virtual Reality Based Training can solve these limitations but often lack the multi-user functionality. Analyzing the Connec2 platform gave an overview the question of the client is what most important elements for the design of an Emergency Training Simulation for a Multi-User Virtual Reality Platform are. These elements include the training of emergency protocols and the creation, adjusting and testing ability of emergency plans.

To be able to answer this question, a preliminary experiment had been developed and tested. This experiment resulted in a list of the design requirements of the product and its technical boundaries and limitations. Additional research about user experience in VR had been conducted as well as research about skill transfer in VR to be able to answer the formulated question. The product concept explains how a combination of a functional exercise, tabletop exercise and full-scale exercise need to be designed to create the desired training simulation. In this section, the current functionality in Connec2 and the additional functionality which need to be developed to be able to create a product out of the concept are considered.

For TVDM to create an additional training simulation to their platform Connec2, important elements need to be taken into consideration to teach trainees emergency protocols. These include the assurance of skill transfer and proper user experience in VR. Additionally, adding observational learning elements, high cognitive fidelity, and tracking the trainee's performance increases training time and ensures skill transfer. Good usability of the simulations is a must considering it decreasing the technological barrier which is a weakness in most Virtual Reality Bases Training. It is recommended for the future approach of the development to enable users of the platform to create their own exercises for their training purposes.

Keywords: device-agnostic, multi-user, virtual reality platform, design review, online meeting tool, remote expert tool, emergency training methods, tabletop exercise, physical exercise, full-scale exercise, emergency plans

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Introduction

When emergencies occur in any kind of workspace, the personnel need to be adequately trained to respond correctly to the ongoing situation. Most industrialized countries have mandates concerning these emergency exercises (McEntire and Myers, 2004). According to Daniel E. Della-Giustina (2009), methods used to prepare staff for these situations like drills, decrease the identification time of specific cases and cuts down the decision-making time of actions taken.

Abdulmohsen H. Al-Elq (2010) states that the main problem with every type of training simulation is the amount of money that needs to be spent on simulating the real potential emergency. Specific locations cannot be used and recreating such settings, and potential emergency scenarios result in high expenses. These expenses cause a low frequency of training sessions, which results in the emergency exercises to come in short of their pivotal role in the preparedness process (McEntire and Myers, 2004). Therefore, different approaches to secure the emergency preparedness of personnel should be investigated.

TVDM are the developers of the Virtual Reality platforms VR Brandveiligheid and Connec2. VR Brandveiligheid focuses on teaching the user how to recognize and use specific props like fire extinguishers in emergencies and has been designed to be used by one user at the time. Connec2, on the other hand, is a multi-user Virtual Reality communication platform which enables distance collaboration. This platform is currently used for – among other things – meetings, design reviewing and remote expertise but has not been used for emergency training, as of yet.

TVDM wants to know if a training simulator like VR Brandveiligheid can be added as an extension to the service Connec2 provides. Companies that focus on the creation and use of real-life training simulations can use this extension to enhance the effectiveness of the methods they currently use. This research will focus on the possible functionalities the multi-user Virtual Reality platform will need, to enhance the limitations appearing with real-life training simulations. This functionality will be based on the limitations that exist in real-life training simulations. The main objective of this report is about what the overall design and functionality of this extension should be so that it can function as a successful addition to real-life training simulations.

Practical Analysis

Company Outline

TVDM started initially as ArchiVision. ArchiVision was founded in 1995 and mainly focused on creating 3D visualizations of real estate. Throughout the years, this industry has changed due to the development of new technology. The same founder of ArchiVision founded "The Virtual Dutch Men" in 2014 to focus on this new technology, Virtual Reality and Augmented Reality. In 2017, these companies merged and continued as The Virtual Dutch Men and were since then located in Almelo, the Netherlands.

The VR and AR team develops Virtual Reality solutions for hospitals, fire departments, and construction companies. They create specific products based on what the client exactly wants. The products are for recreational purposes or more serious purposes like specific training applications in Virtual Reality.

> *"Passion, flexibility, extensive testing, and the application of new techniques will serve as our guiding principles in the future. We want to enhance our impact on clients and help them get demonstrably further in their challenges and projects."* ***(TVDM, 2020)***

TVDM has created two functional Virtual Reality platforms called VR Brandveiligheid and Connec2. These platforms are both designed to be expanded with extra functionality to cover the needs of potential users and so create a broader user base. VR Brandveiligheid is a platform that consists of several modules that test and evaluate the knowledge of the user about the prevention of specific emergency hazards. The other platform, Connec2, is a multi-user Virtual Reality platform. This platform is developed to decrease the limitations that physical distance creates.

Objectives of the Client

TVDM is currently extending the Connec2 platform with extra functionality. One of the functionalities includes a multi-user training simulation extension. The question of the client for this graduation assignment is how a platform like VR Brandveiligheid can be added to Connec2 and if it would be a positive addition to Connec2. TVDM wants to know if this extension can function as a possible enhancing method to increase the effectiveness of currently used emergency training methods.

A product that contains functionality to surpass the researched limitations in currently used training methods, will be the product of this graduation. The product result will function as a recommendation for the development of the training simulation for connec2. The client's question can be answered with a product that has been designed and tested based on properly conducted research. TVDM will be able to decide if this simulation is a positive addition to Connec2 and can be used to reduce the time spent on the development of the extension by already having eliminated potential, but not practical solutions.

The ideal approach to present the product would be by developing it in Unity3D due to the Connec2 platform being fully developed within this game engine. Parts of the functionality of the product will have to be translated from currently used training methods to the virtual reality platform, while other functionality might already be developed within Connec2. Developing this product in the Unity3D engine comes with technical boundaries and challenges due to me having only basic knowledge of programming, at the start of this internship. The skillset needed to create the desired product required me to improve my programming skills.

The ideal Virtual Reality device to use for testing the module would have been the Oculus Quest. The device is standalone, which makes it easy to transport and set up. The Oculus Quest is a device that can run without the use of a high-end computer, which results in performance limitations. For the product to properly run on an Oculus Quest, the product needs to be fully optimized. After having discussed this possible limitation with the client, the decision has been made to test the product with a different but not standalone VR device. Due to Connec2 being a device-agnostic platform, multiple types of VR devices can be used.

Problem Analysis

TVDM is extending Connec2 with extra functionality because of its broad use case. The platform is built around the idea of giving the user as many possibilities to create their personally preferred workflow and so be able to work productively without having to deal with physical limitations. TVDM their goal is to create as much functionality within the platform so companies from all kinds of industries can make use of it. The already developed and implemented 3D model importer for Connec2 has increased the interest of the client to develop an additional training simulation for this platform. This 3D model importer gives the user the ability to import their models into the platform and make specific models interactive. The client sees this functionality as a possibility for users to create a training simulation with their models, whether this being an assembly/ maintenance procedure or it being an emergency training exercise. TVDM requested the product to contain an interactive tabletop exercise. While keeping this request in mind, the design of this functionality in the extension should still ensure that it answers the client’s question.

Preliminary Problem

Based on the outcome of the problem analysis, the approach towards the theoretical analysis has been formed. The focus of the theoretical analysis revolves around the following questions:

1. VR Brandveiligheid is also a training simulation, why does VR Brandveiligheid not simply get added to Connec2?

The functionality and use case of both Connec2 and VR Brandveiligheid had to be analyzed to create a better idea of what TVDM want to achieve with this requested training simulator.

2. What is a tabletop emergency exercise, and how can it be designed to answer the client’s question?

By researching the currently used training methods for emergency response, which includes the mentioned tabletop exercise, and analyzing the advantages and disadvantages will help determine what functionality the training simulation extension needs. By researching how these training sessions are set up and what the training limitations are, the problem definition can be defined better.

Theoretical Analysis

VR Brandveiligheid

VR Brandveiligheid is a single user training platform in Virtual Reality which trains and tests the user specific skills for fire-related emergencies. The training includes – among other things – how to correctly open a door in case of a fire emergency, how to properly use fire extinguishers, recognize specific emergency icons and how to use an automated external defibrillator (AED). These modules are developed for employees in the healthcare industry who do not get officially trained for these emergencies. The platform makes the user more aware of the needed actions taken to prevent emergency scenarios. A Virtual Reality device and the VR Brandveiligheid application is needed to make use of this platform. The application is free to download from the VR Brandveiligheid website and currently contains three out of the four developed modules.

Door procedure – A door procedure is done when a fire is suspected in the room behind the designated door. This module tests if all six steps are taken correctly by the user. The module does not explain these steps during playtime. The module does inform the user if the steps are taken once the user has completed the module. The module is set up in a 3D environment.

Figure 1 VR Brandveiligheid (2020) Training recognizing fire hazards. Retrieved from: https://www.youtube.com/watch?v=ege9xwIxQ0Y

Hazard awareness – The user will see a room filled with fire hazards. In this module, the user needs to recognize fire hazards and remove these. When the user has completed the module, the module will inform the user how many hazards the user has found. This module is done with 360-degree photos.

Extinguishing fire - This module lets the user extinguish a fire without any explanation. When the module is completed, the user will get notified about their performance by visualizing whether the user took the right decision. This module is set up in a 3D environment.

Use of AED - This module is still under development and has not been added yet to the platform. (VR Brandveiligheid, 2020).

The platform does not guide or explain to the user what steps need to be taken during playtime. The platform does track the progress made by the users and presents these at the end of the module. The user can so see how well they did, and if needed, they can replay the specific module to improve their previous results.

Connec2

Connec2 is a device-agnostic multi-user Virtual Reality platform which helps eliminate physical distance and other limitations from the real world. This platform enables users to collaborate in a virtual space from anywhere in the world. This communication platform creates a lifelike social experience due to the support of high-quality voice, precise movements and low latency communication. The base of the platform has been developed, and future extensions are now being researched. The platform can be currently used as an online meeting, design reviewing and remote expertise tool. Users will have to invest in a Virtual Reality device and subscribe to this service by paying a monthly fee to be able to use it. TVDM can customize the platform to fit the needs of their clients and or the company will be able to make

Figure 2 Connec2 (2020): Connec2 makes design reviewing of 3D models easier. Retrieved from: https://connec2.nl/

use of the Software Development Kits (SDK) which will be developed further down the road (Connec2, 2020). By creating a SWOT overview of Connec2 the strengths, weaknesses, opportunities and threats of the platform are collected (table 1).

Strengths	Weaknesses
- Multi-user - Device agnostic - Self-deployable - 3D Importer - Limitation of physical boundaries - Long development cycle	- Lack of facial expression - Technology barrier - Long development cycle
Opportunities	**Threats**
- Custom features - Increase physical fidelity - Data recording	- High maintenance - Lack of specialization

Table 1 – Overview of SWOT findings Connec2

Emergency Management Training Methods

Walter G. Green (2000) states that most used methods for training emergency management are; mock casualty exercise, discussion-based exercises like board game simulation, TableTop drills, paper drills and individual self-directed learning. According to McEntire & Myers (2004) these most used methods can be divided into the following three categories (p. 148);

Tabletop exercises (TTX):

These exercises are shaped like a brainstorming session or group discussion and are often performed in a meeting room like spaces (McEntire & Myers, 2004, p 148). With TTX, the emergencies will be visualized on a table by only using a blueprint of the designated department of a building or location. Small props like Playmobil or Lego are often used to function as pawns. The emergency organization and firefighters, police or ambulance personnel can be assigned to these pawns. Equipment that objects wheelchairs, beds, tables are also often indicated with small props like Legos. The emergency exits, fire extinguishers, first- aid kits and other equipment are indicated with specific pictograms. These pictograms are the same as the pictograms used in buildings to indicate the location of this equipment (Actiz, 2015).

Figure 3 Tabletop Exersice (2020). Retrieved from: https://www.zve-veiligheid.nl/bhv-basisopleiding-ploegleider

TTX is used to evaluate the preparedness program and so identify certain deficiencies. With TTX, recently changed procedures can be tested and validated with other participants. By obtaining participant feedback and recommendations, the program can be improved. By clarifying roles and training these roles, the coordination within the internal team can be improved as well as the coordination with external teams. This method also increases the awareness and identification of potential hazards. By using the pictograms which are used to indicate specific equipment in the real building, the identification and awareness of existing resources are increased as well.

Trnka, J., & Jenvald, J. (2006) states multiple advantages of board game simulations and TTX. The first advantage is the evaluation that provides opportunities to test both the effectiveness of emergency plans and the abilities of personnel to execute them. The second advantage is that these exercises are useful for introducing and testing new emergency programs as well as for pinpointing formerly uncontrollable emergencies. TTX's are cost-effective due to its low preparation expenses and deployment (Perry, R.W, 2004, p67).

To the contrary, Trnka, J., & Jenvald, J. (2006) also states that TTX and board game simulation exercises are informal types of emergency exercise. This due to the trained emergency assessments often being generic and that the user does not experience the realism of the execution of these emergency assessments. Another similar study refers to the actions taken in TTX exercises to 'action intentions' and not operational executions, stating that Tabletop exercises do not achieve realism (Perry, R.W, 2004).

Functional Exercises (FE):

The main goal of a FE is to test and evaluate the skills of the trainee related to emergency events. A FE focusses on exercises emergency procedures, emergency plans, and policies. FE are exercises that are used to test and improve the participant's skill set as well as to test emergency protocols more in-depth. This is done by dividing the emergency into several functions that can be trained. Functional exercises are similarly shaped to TTX's. Other than TTX, which are often performed on location, these exercises are conducted in realistic environments and are often setup at Emergency Operation Centers or other at similar locations. The main difference with FE and TTX is the lower number of participants and limited guidance from an instructor.

Full-Scale Exercise (FSE):

FE's simulate emergencies as realistic as possible, these exercises are drills where the environment trained in is as realistic as possible and the crisis trained is unknown for the trainees (Borodzicz and van Harperen, 2002). An FSE is a combination of all the elements trained during a FE. Although with an FSE most equipment and personnel that would be involved in case of a real emergency are deployed at the same time.

According to Ready, 2016, the advantages of full-scale exercises are that they are a combination of drills and tabletop/functional exercises. These exercises create real-time interaction which help increase decision-making time of trainees (Daniel E. Della-Giustina, 2009). The other positive side of FSE's are the utilization of rarely trained or used resources. The disadvantages of FSE's are the high expenses as well as the extensive time commitment. The other disadvantage is also the high safety risk, due to this exercise replicating real emergencies as close as possible.

Virtual Reality-based Training (VRBT)

With the use of Virtual Realty, interactive and immersive training methods have been developed in a virtual environment. These training methods are called Virtual Reality-based training (VRBT) and are deployed in industries including health care, education, the military and law enforcement (Rouse, M, 2017).According to Gao, Gonzalez, & Yiu, (2017) and Lovreglio, Gonzalez, Amor, Spearpoint, Thomas & Trotter (2017) immersive VRBT provides the trainee more engagement and perception compared to instruction videos and text-based instructions.

In Figure 4, the SWOT findings of a VRBT for firefighters have been collected (Engelbrecht, Lindeman &Hoermann, 2019, p 10 - 11). Advantage of VR for training is mainly it being safe to use, cost-effective, and provides the ability to prepare trainees with a large variety of high fidelity training environments. The lack in specialization of the applications for the fire-service sector and issues with technology acceptance and limitations need to be addressed. Looking to current research, there are promising findings that might be directly transferable, creating affective, and multi-sensory experiences for more effective mental and physical training of firefighters in the future.

TABLE 1 | Overview of SWOT findings.

Strengths	Weaknesses
- Cost effectiveness - Complex and varied training scenarios - High ecological validity - Increased safety for high risk training - Trainee engagement - Data recording	- Lack of specialization and testing of systems - Immaturity of technology - Technology barrier - Lack of multi-user fidelity
Opportunities	**Threats**
- System engineering progress - Transfer of findings from other domains - Increase in physical fidelity - Increase resilience against adverse effects	- Uncertain skill transfer - Worsening of overall net-effects of training - Adverse effects of habituation - Adverse effects of engagement stimulation

FIGURE 4 OVERVIEW OF SWOT FINDINGS - VR FOR FIREFIGHTER TRAINING (ENGELBRECHT, H., LINDEMAN, R.W. AND HOERMANN, S., 2019, P 10 - 11).

Problem Definition

The problem definition can be formulated based on the outcome of the practical analysis and theoretical research. By having researched VR Brandveiligheid and Connec2, it got clear that the design of VR Brandveiligheid does not match the design of Connec2. The reason for this being the difference in use case. The design of VR Brandveiligheid is that it is single user based and the goal of the modules are to create awareness for untrained employees for possible emergency hazards. The platform tracks the progress of the user and every module can be replayed with the same exact gameplay. This while Connec2 is multi-user based and has a broader user case. The base of this platform is the communication element. Therefore, the design of the training simulation for Connec2, should not be based on the design of VR Brandveiligheid.

The theoretical analyses gave an overview of the strengths of Connec2 as well as the limitations occurring with currently used emergency training simulations. The main limitations include the lack of physical testing of emergency plans and personnel, due to cost and time inducing reasons. Testing the emergency plan is often solved with performing a TTX with the people. The limitation for this method is mainly the lack of immersion. While Virtual Reality Simulations have helped solve these specific limitations, the multi-user and system testing functionality still often lack. Therefore, the 3D model importer, multi-user functionality and device agnostic compatibility which Connec2 has, should be used wisely to design its Virtual Reality Training Simulation.

For Connec2 to overcome limitations occurring with currently used training simulations, Connec2 must provide opportunities to evaluate the design of emergency plans. This evaluation should include functionality to test the effectiveness of the emergency plan as well as the ability of the personnel to execute it. Connec2 should also ensure skill transfer, engagement and performance of the trainee.

Main Question

Based on the problem definition, the following main question has been formed:

> *"What are important elements for the design of an Emergency Training Simulation for a Multi-User Virtual Reality Platform to teach trainees emergency protocols and create, adjust and test emergency plans?"*

Sub questions

To be able to answer the main question, the following sub questions have been formulated:

1. How can the training simulation provide opportunities to create and adjust emergency plans?

2. How should the training simulation be designed to decrease the technical barrier and so increase the usability?

3. How should the exercises be designed to communicate specified learning elements to the trainees and ensure this skill transfer?

Approach/Method

The Communication and Multimedia Design methods (2015), have been used to be able to find the fitting approach of this research. To define the product design and so answer the sub-questions, the first step taken was to create a preliminary experiment. This experiment was done to create a better idea of what the client expected from this graduation product and contains the basic functionality of a tabletop exercise. A testing session, which has been done with the client, resulted in a list of technical boundaries/challenges and design requirements of the product. The outcome of this experiment also clarified what additional desk and literature research had to be done to be able to answer the sub-questions. The theoretical analysis focused on the methods used for emergency management training, which always includes multiple participants. To be able to answer how specific learning goals can be transferred to trainees, the additionally conducted desk research focused on skill transfer of individual trainees in virtual Reality. The additional literature research focused on the user experience in VR.

The results of the preliminary experiment and the additional desk and literature research resulted in dividing the product design into three categories. The design requirements and technical challenges of each category get defined and described how these should be approached. The result of the product concept helped to determine which testing methods suited the product of each category most.

A. Preliminary Experiment - Tabletop

The first step taken towards the final solution was to create a prototype to help define the requirements for the design of the product. This prototype also helped to get familiar with the assets needed for the final prototype. These assets are developed by TVDM in Unity3D and include the Virtual Reality character rig which is used for Connec2. The outcome of the testing session with the client helped to define the more precise requirements of the Multi-user Virtual Reality Training Simulation and my ability to develop the needed functionality.

By creating a simple 3D tabletop model which was placed in the middle of the 3D space, the first version of the visual design of the Virtual Reality tabletop exercise was made. The functionality within this prototype included the interaction with objects and teleportation of the user in VR. Within this experiment, the task for the user was to place the presented 3D models on the designated 2D icons in the 3D tabletop. By having the user interact with objects by pointing at these and dragging these into the designated area, the task could be completed. The user was also forced to use the teleportation mechanic in need to finish the given task.

FIGURE 5 – PRELIMINARY TABLETOP EXPERIMENT: OVERVIEW

To be able to limit the technology barrier, which a part of the target group often deals with, the ease of use of the navigation and interactivity within the product needs to be assured. The interaction with objects was done by pointing at the interactive objects from any distance. This choice was made to limit the frequency of the user having to teleport within the scene and so increase the ease of use.

The outcome of testing this prototype with TVDM resulted in more clarity about the ease of use and the visual design. The testers experienced difficulties with the placement of the 3D models on the 2D icons. The main difficulty the testers experienced was the distance between the grabbed object and the controller. This meant that the design choice of the interaction mechanic had to be revised. Another alternative would have been to grab the interactive objects by colliding the controller with the interactive object. This does results in the user having to be located verily close to the interactive object, which increases the frequency of having to teleport in the scene. For the next tabletop version, ease of use of interaction and scaling down the size of the 3D tabletop had to be tested to see if it decreases the frequency of the user having to teleport within the scene. For the visual design, the product should give the user a clear overview of steps that need to be taken. The product should also be a realistic visual representation of the real-life exercises, including the visual style and correct scaling of 3D objects. Screenshots and more detailed feedback collected from the testing session of this prototype can be found in **Appendix A:** ***"Prototype 1 – Assuring TVDM their objectives and getting familiar with the TVDM assets"*** in the Appendices.

B. Desk Research – Skill Transfer with Virtual Reality

To be able to translate real-life functional emergency exercises to a virtual reality exercise, the specific type of skill and its skill transfer had to be researched. Gavish, Gutierrez, Webel, Rodriguez & Tecchia (2011) state that the primary skill involved in this type of exercise is called a procedural skill. Mastering procedural skills mean that the user knows what actions need to be taken at what exact moment. The user also knows what appropriate method needs to be used (p.1).

Gavish, Gutierrez, Webel, Rodriguez & Tecchia (2011) have created several guidelines to formulate the primary design requirements for the development of VR and AR training platforms. These guidelines are based around the tutoring of procedural skills (p. 2-4). The guidelines are summarised in five sections and formulated below;

1. Observational learning- Gavish, Gutierrez, Webel, Rodriguez & Tecchia (2011) showed that using preliminary observational learning can increase training time. Their study showed that, by starting the training with a demonstration, the basic knowledge already gets transferred. This strategy provides only visual information and is being used at the start of the training. After this section, the trainee can start with the interactive training exercise (p.2).

2. Cognitive fidelity - To be able to enhance the transfer of these skills, the need for excellent cognitive fidelity is high. High cognitive fidelity means that the trainee's intended input is adequately translated to the device used.

3. Physical fidelity - is the extent to which the conditions of the training program, such as equipment, tasks and surroundings, mirror those in the performance situation (Werner & DeSimone, 2012). A study was conducted to compare real-world training and two alternative virtual trainers, one emphasizing the physical fidelity and the other the cognitive fidelity of the task. Hence combining physical fidelity and cognitive training methods enhances procedural skills acquisition.

4. Guidance aids - By receiving guidance aids, the trainee will know how a task needs to be executed. These guidance aids can, however, decrease the performance of the trainee due to the lack of trial and error (Gavish, Gutierrez, Webel, Rodriguez & Tecchia (2011). This study suggests only to provide these guidance aids on request of the trainee (p.3).

5. Enriched information about the task – By dividing the task into smaller sub-tasks, the chance of the trainee developing an accurate mental model of the whole task increases.

C. Literature Research - User Experience in Virtual Reality

Because real-life training exercises need to be translated to a multi-user virtual reality platform, the user experience will need to be examined. According to Jason Jerald (2016), the interaction in either the real or virtual world starts with human perception. To steer this human perception into the wanted direction, the input is needed through the human senses. These human senses include sight, hearing, touch, proprioception (sense of the location of body parts), balance and physical motion, smell and taste and multimodal.

The Virtual Reality devices used for this platform are either an Oculus Rift or an Oculus Quest which both exists out of a Head Mount Display and two hand controllers. This means there are fewer ways for the user to have input in Virtual Reality compared to real-life input. To be able to trigger these human senses in Virtual Reality, the modalities will need to be replaced.

Finding the right replacement methods to stimulate these human senses is not only essential to create the wanted human perception. Jason Jerald (2016) states that motion sickness in Virtual Reality can mostly also be prevented by correctly stimulating these human senses. Especially the vestibular-visual conflict, which means that the users see something but does not feel it inner ear, causes this motion sickness. According to Jason Jerald (2016), the human senses can be triggered in Virtual Reality by the correct use of highlights, vibrations and audio.

D. Product approach

As shown in figure 6**,** the development of the product has been divided into three categories. The first one being the tabletop category, here the user can create and adjust the emergency plan. The second category is the physical exercise category, this category focuses on teaching the trainee specific learning goals. The final category is the full-scale exercise, this exercise can be used to test the effectiveness of the emergency plan as well as the ability of the trainees to execute this plan. Dividing the product categories is done to help create a clear overview of design requirements as well as for deciding on the best fitting testing approach for each category. With these results, the sub-question can be answered more specifically.

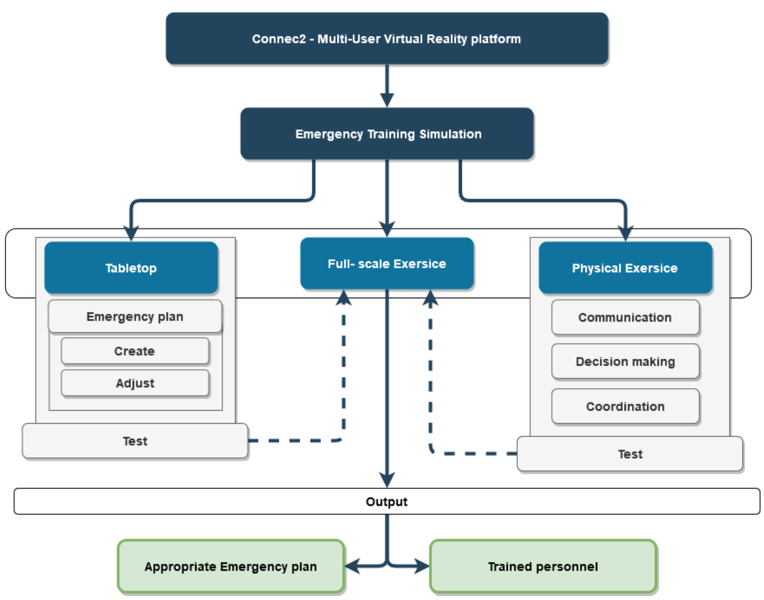


FIGURE 6 – DIVIDING PRODUCT CATEGORIES

Scope

The main goal of the requested product by TVDM is to enhance the researched limitations with training simulations with their multi-user platform. The functionality in Connec2 has been designed around a broad use case. This results in the training simulation extension to be extra hard to design due to the potential target audience being from different types of industries coming with different needs. The design of this product will be based on the general required training elements which are stated by the laws of emergency training in workspaces in the Netherlands **(Appendix E - "Emergency Training in The Netherlands")**. Basing the design on these laws will help to approach a broad target audience which is still within the scope of this graduation project.

To be able to create a testable product, an emergency program had to be setup. By following the training setup schematic Wilson's (2000) created, which can be found in **Appendix C – "Training Setup"** in the appendices, the functionality needed for the base of the emergency program has been established. The focus of the emergency program this system has been built on is fire safety.

Due to the limiting time of this project, the focus will be put on the following functionality of the product mainly.

In the Tabletop category the user will need to be able to:

- Create an emergency plan
- Adjust an emergency plan
- Set-up an emergency case to test the emergency plan
- Receive emergency plan testing results (from full-scale exercise)

In the Full-scale Exercise Category, the functionality will contain:

- A Fire-related emergency
- Individual progress tracking

Product Concept

The product concept covers how the tabletop, functional and full-scale exercises can be designed fitting the use case and general design of the Connec2 platform. The design of the concept integrates the theory gathered from the theoretical knowledge section as well as the theory gathered in the method/approach section.

Tabletop

To be able to translate a real-life tabletop exercise to virtual Reality, tabletop exercises had to be researched more in-depth. This desk research can be found in Appendix D – ***"Tabletop exercise in-depth"*** in the appendices. By going through every step of a tabletop exercise and analyzing the needed materials and functionality, the design concept of the virtual reality tabletop has been covered.

Communication - Tabletop exercises can be described as brainstorming sessions held to evaluate emergency plans. The multi-user functionality in Connec2 provides the communication which is needed for the brainstorming element in the tabletop exercise in Virtual Reality. Real-life tabletop exercises provide the opportunity to gather participant feedback and further recommendations to improve the emergency plan. For the participants to do the same in the virtual reality version of the tabletop, the smartboard functionality in Connec2 can be used.

Setup - The user can import a 3D model of the designated building for which an emergency plan needs to be created or adjusted. This can be done by using the 3D model importer Connec2 already has.

Adjust and Test Emergency Plan - To be able to add and adjust the emergency elements to the emergency plan, the user will first need to be able to select items from a library and adjust these when they are placed on the tabletop board. For the user to test the emergency plan in the full-scale exercise, the user will also need to be able to create and adjust an emergency case in the tabletop using the same functionality. Multiple interaction iterations need to be tested to find out how this interaction should be designed.

Visual Design - By testing the preliminary prototype with the client, the client stated that the tabletop should stay as close to the visual style of real-life tabletop exercises. This, to keep the overview as clear as possible but also due to the trainee needing to recognize the icons representing specific emergency elements. The outcome of the preliminary prototype also resulted in the importance of the 3D tabletop being the right scale. The right scaling can be decided on by simply testing different scaling sizes with users.

Figure 7 - Left indicates the emergency elements with the corresponding icons, right indicates the emergency elements with 3D models.

Output - The user will need to be able to save the created emergency plan and, if tested, the corresponding results of the execution of the emergency plan.

Functional Exercise

A functional exercise should be included in Connec2 for Connec2 to function as a full training simulation. A functional exercise focuses on teaching trainees specific individual procedures. This concept focuses on how TVDM can provide the user of Connec2 the ability to create their own exercise to trains individual users. This because TVDM wants to provide their users as many tools as needed for the user to create their own workflow within the platform.

TVDM have previously created a virtual reality platform with training exercise modules called VR Brandveiligheid for individual trainees. However, the theoretical analysis showed that VR Brandveiligheid mainly tests the performance of the trainee and not does not focus on the teaching element specifically.

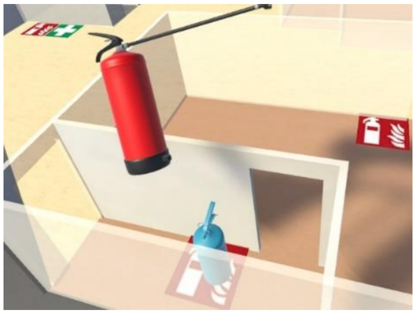


FIGURE 8 – ENABLING COGNITIVE FIDELITY

Procedures need to be executed by following a step-by-step exercise. To allow the user to create a step-by-step exercise, the 3D model importer can be used in Connec2. Increasing the training time and efficiency can be done by designing this type of exercise around the guidelines stated in the design theory section in this research. The guidelines stated that the use of observational learning prior to the execution of the training simulation increases the training time drastically. Observational learning in Connec2 can be done with the use of 360 videos. Connec2 already has functionality to import and watch 360 videos with the use of interactive spheres. The way the 360 interactive spheres are designed does not force the trainee to watch the video and the trainee can pause the 360 video at any time. The trainee can view the 360 video by placing the interactive sphere over their head in virtual reality. Putting the interactive sphere down allows the trainee to exit the 360 video and results in the 360 video to be paused. By allowing the creator of the training to import 360 content of the procedure they want, allows the creator to import their own instructional videos corresponding with the desired exercise. High cognitive fidelity, which has been stated by the guidelines to have a positive effect on training efficiency, can also be applied rather easily. By displaying a copy of the currently being manipulated object in the correct position or state, cognitive training can be used to guide the trainee, as shown in Figure 8. The tracking of the trainees performance can be done similarly to how this is done in VR Brandveiligheid. This means that the information will be displayed when the exercise has been finished which allows further analyzation.

Full- scale Exercise

The final category is the full-scale exercise. This exercise can be used to test effectiveness of the emergency plan. The exercise can also function as a tool to test the ability of the personnel to execute this plan according to their role.

Setup – When the user is importing their 3D model with the 3D model importer at the start of the tabletop functionality, the user can specify which 3D objects need to be interactive, and the user should be able to set the navigation surface. Setting the navigation surface is needed for the user to teleport to the designated areas in their imported model when the full-scale exercise is activated.

When the user has finished setting up the emergency plan within the tabletop functionality, the full-scale exercise can be activated. This exercise will scale the imported tabletop model to real-world dimensions, and the participants can experience the emergency plan in full-scale VR simulation. The participant will have to act according to the role they got assigned to in the tabletop functionality, and their personnel performance will get tracked. The functionality of this exercise should include the ability to execute this exercise with multiple participants at the same time to be able to test the effectiveness of the emergency plan.

According to the knowledge institute for emergency response in the Netherlands (NIBHV, 2020), to evaluate the emergency plan test, the following elements should be logged at the end of every testing session:

- Date of execution exercise
- Type of emergency case
- Present limitations
- Possible limitation solution
- The person responsible for execution limitation solution
- Date of execution solution

To able to log the difference between the effectiveness of the emergency plan and the skillset of the personnel to execute it, the testing data must be divided into two sections. The first section is covering the ability of the personnel to execute an emergency plan by tracking each participant their individual performance. NIBHV (2020) stated that the personnel executing the emergency plan could be divided into three groups:

- Bedrijfshulpverlening (BHV)
- The frontdesk administrator
- Non-trained personnel

The individual performance tracking will need to be based on the role given by the participant in the tabletop functionality. For BHV the execution of a door procedure needs to be tracked, while, for non-trained personnel, this procedure is not taken into consideration for the evaluation.

Product Result

Product focus

The functional exercise concept has not been further developed due to this concept being single user based and the concept being close to the VRBrandveiligheid platform design wise. As stated in the problem definition, for the training simulation in Connec2 to stand out compared to other Virtual Reality-Based Training, the platform should make use of its multi-user functionality. This is why the categories tabletop and full-scale exercise have been developed based on the outcome of the product concept.

General Implementation

For the implementation of the product, the best development method would be to create the product with the game engine Unity3D, as stated in the practical analysis. TVDM has provided 3D models, needed for certain visual aids and other functionality, and I have created additional 3D models in Blender3D. The development of the categories has been done within the same unity project but developed in different scenes. At the end of the development, the tabletop and full-scale exercises were combined.

The base of the interaction design has already been established by using the virtual reality rig TVDM developed for Connec2. This rig enables the user to teleport through the scene by pointing the controller at the designated area the user wants to teleport to. The rig enables the user to interact with the object in the scene by grabbing these as well as pointing at the object with the controller from any distance. The rig also provided the user feedback whenever the user hovers over the object with the controller by highlighting the object. The rig is device agnostic and can so be used with devices like the HTC VIVE and the Oculus Rift. A list with a clear distinction of which assets are provided by the company and which assets had to be made for this product specifically can be found in Appendix E – ***"Asset list"*** in the appendices.

Testing Approach

Because the main weaknesses of the researched Virtual Reality Based Training is the technical barrier, the testing method of this product had to help to secure the ease of use, technical barrier, consistency and general satisfaction of the design of the product. This is the reason why a usability testing method has been chosen. The chosen method is the System Usability Scale (SUS), which can be found in Appendix F: **"*System Usability Scale (SUS), by J. Brooke* "**in the appendices. The SUS scale is used due to it being the industry standard for testing the usability of technology since 1986 (Sauro, 2011). The SUS method has also been used due to its low costs and ease of usage. The SUS is a form which exists out of 10 questions and the answers are based on a 0 to 5 scale. 0 being "totally disagree" and 5 being "totally agree". A questionnaire which covers these questions as well as questions about the opinion of the user about the scale of the 3D tabletop, was needed to improve the tabletop emergency plan editor. The results of the test helped to conclude if the ease of use, technical barrier, consistency and general satisfaction of the design had to be improved for every iteration.

Tabletop Exercise

During the Implementation of the tabletop functionality, the focus was to create the functionality for a user (tabletop instructor) to create and adjust elements on the table and give the user the ability to export the emergency plan. The choice was made to focus on this element because the product concept made clear that the communication and setup elements of the tabletop exercise can be covered with the functionality Connec2 already has. However, creating, adjusting, testing and exporting an emergency plan, cannot be covered with the current functionality in Connec2. To be able to translate the tabletop exercise concept to a tabletop exercise product, the ability of the broad target audience to use the product had to be considered. The tabletop exercise had to have proper user experience and consistent design so users without any prior experience with VR technology would be able to use it. To be able to find out how the interaction had to be designed and secure the ease of use, a suiting testing method had to be found to test the iterations. The testing method has been decided on before the development of the iterations to be able to keep focus on the wanted results and not sidetrack with the development.

Implementation

The tabletop emergency plan editor consists of a 3D tabletop model placed in the middle of the 3D space, as seen in figure 8. The 3D tabletop model has been based on a real 2D emergency plan, which can be found in Appendix D – ***"Tabletop exercise in-depth"*** in the appendices.

All the rooms in the 3D tabletop have been divided in multiple areas. Every area has a separate floor, wall, door and window model. The rooms all have an *AreaBase* and *InteractiveArea* script attached to the floor. The AreaBase script stores the data of the interactive elements placed in these areas while the *InteractiveArea* checks if the user interacts with the designated area and sends the AreaBase data to the *UIManager*. The *UIManager* then displays the gathered information on the instruction board, resulting in the user seeing the information of the interacted room on the instruction board. This information includes the room name, the emergency status and amount of equipment located in the selected area.

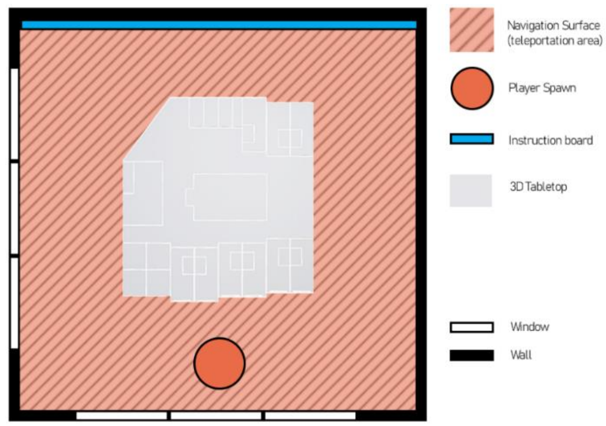


FIGURE 9 – TABLETOP IMPLEMENTATION DESIGN

To test the tabletop usability, the user was given a task. The task for the user was to recreate an 2D emergency plan with the use of the tabletop editor. To make sure the SUS score is reliable, the iterations need to secure that the user understands the given task. For every iteration, the emergency plan which had to be replicated and the editor had to be displayed and explained clearly to the user. For the user to complete the given task, tabletop elements had to be placed at the right locations. The emergency cases also had to be enabled in the right areas. When the participant finished this section, the participant stopped using the VR device and filled in the SUS form (Appendix F: ***"System Usability Scale (SUS), by J. Brooke"***). To make sure the results were consistent, every participant tested the tabletop exercise with an Oculus Rift and each participant got the same assignment to replicate an emergency plan for a hospital. The users testing had different levels of experience with the use of VR technology, this was done to make sure that the score of the usability covers a wide range of potential users with different levels of VR experience.

Implementation Tabletop Iteration #1

The user will be spawned in the area located in figure 8. and will face the instruction board as soon as the tabletop editor has started. The user will be able to only teleport on the navigation surface which is also indicated in figure 8.

Information display

The given task is displayed on the right side of the instruction board, as seen in figure 9.The 2D emergency plan which needs to be recreated is displayed in the middle of the instruction board and the instructions of how the controller works have been displayed on the left side of the instruction board.

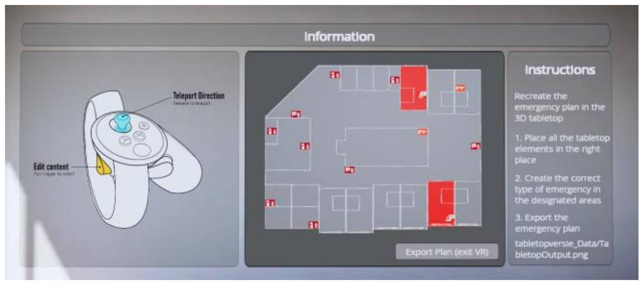


FIGURE 10 – TABLETOP ITERATION #1: INSTRUCTION BOARD

Interaction

The user can point at the designated room in the tabletop. To show where the user points at, an indicator has been added to the hand, as seen in figure 10. The information about this space gets displayed on the wall next to the instruction board in the virtual space. The user can select the pointed at area by pressing the button triggered with the index finger. The area which gets selected turns orange, as shown in figure 10. Selecting the area is needed for the user to change the emergency case in that specific area.

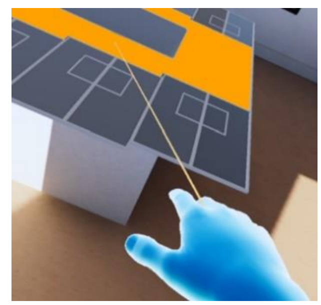


FIGURE 11 - TABLETOP ITERATION #1: VISUAL FEEDBACK

Emergency editing

A menu has been added to the left hand of the user (figure 11). This menu allows the user to edit the tabletop. The menu can be interacted with by pointing at it with your right hand and pressing the button which is triggered by the index finger.

By then selecting the wanted emergency case in the menu, the selected area will turn red, and the icon of the selected emergency case will be displayed. Disabling the emergency case can be done by selecting “no fire” from the dropdown menu. When the user wants to change the emergency case of a different area, the user can simply point at a different area and press the index button again. The dropdown in the menu will update according to the emergency case of the newly selected area.

FIGURE 12 - TABLETOP ITERATION #1: MENU

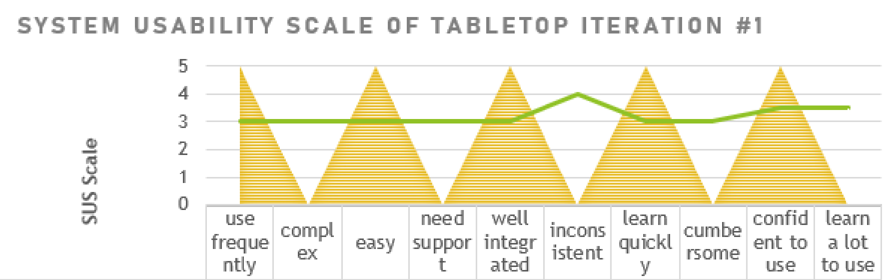
Tabletop elements editing

Editing the tabletop elements can also be done with the menu. The user needs to select the wanted icon by pointing at it and pressing the index finger. By then pointing the icon at the designated area and pressing the index finger again, the icon gets placed onto the 3D tabletop. To delete the icon the user will need to select the “delete” button and select the icon on the tabletop.

Testing Tabletop Iteration #1

Results

The Best Imaginable System Usability Score (BISUS) is indicated with the orange lines. The score of the tabletop V02 is indicated with the green line. The data for every category shows that the opinion of the users was often in the middle, between totally agree and totally disagree. The inconsistent category even scored a 4 out of 5 while the BISUS for this category is 0. The average SUS score resulted in a 47.5, which indicates, according to the SUS, that the usability of this system is graded with an F. This grade indicates that this system usability is not acceptable. The additional questions asked in the questionnaire apart from the SUS questions indicate that the users were able to complete the tasks given entirely and did not experience any bugs which could have influenced the SUS score. Testing this iteration also made clear that the scale of the 3D tabletop was neither too big nor too small.



	use frequently	complex	easy	need support	well integrated	inconsistent	learn quickly	cumbersome	confident to use	learn a lot to use
Best Imaginable SUS Score	5	0	5	0	5	0	5	0	5	0
Tabletop V02	3	3	3	3	3	4	3	3	3.5	3.5

TABLE 2 – SUS RESULTS TABLETOP ITERATION #1

Analysis

This iteration has unfortunately only been tested by two users. One being the client and one being a user who had used VR technology before. The SUS results, however, still gave an overview on what elements need to be improved about the tabletop usability. By observing the testing sessions and looking at the SUS results, the following statements can be made; the users needed time to figure out what the controls are like, resulting in accidentally placing items on the 3D tabletop which confused the user. Placing the tabletop elements was not clear for the users at first, because editing the emergency case worked different compared to placing the emergency elements. This confusion can be an explanation for the bad inconsistent score in the SUS. To be able to justify this conclusion, the editing mechanics in the next iteration should redesigned to be consistent and this design will need to be tested again. Other feedback gathered was about the placement of the “export Plan” button on the instruction board being placed underneath the emergency plan. The placement of the button was unclear to the user.

Implementation Tabletop Iteration #2

UI Design

To make sure the tabletop exercise is consistent in general, the UI design has been based on the dark mode guide UI guide by Chethan KVS (2020). This guide has been followed because it matches the Connec2 UI design most while the guide also states certain design choices based on properly conducted research.

Tutorial

For the Implementation of the second iteration, the first thing added is a tutorial section. To make sure the user immediately knows what to do, the user will only see the 3D tabletop and tutorial screen in front of them. The user will be limited from taking any actions other than what is displayed on the tutorial screen to avoid confusion as of what happened in iteration #1.

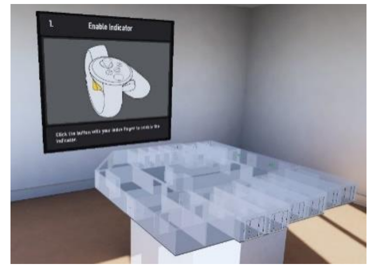


FIGURE 13 – TABLETOP ITERATION #2: TUTORIAL

Task Display

When the tutorial is done, the player will see the task displayed on the instruction board. Here the task is displayed on the left. This choice was made because the user reads from left to right. Thus, placing the task on the left side of the instruction board might help to get a clear overview. The "export plan" button also has been placed underneath the task to make sure the user knows it belongs to one of the steps of the given task.

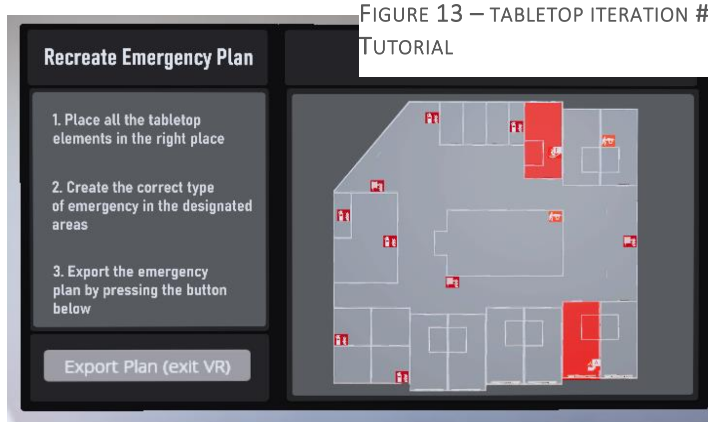


FIGURE 14 – TABLETOP ITERATION #2: TASK DISPLAY

Interaction

Tabletop Editing

To make sure that the tabletop editing is consistent, the menu has been changed. The menu for both tabletop emergency and tabletop elements looks and work similar to each other. The user can press on the wanted icon and can point at the tabletop at the designated area. When the user pressed the index button the icon will be placed. The only difference between the emergency and tabletop elements placement is that the emergency icon will be snapped to the place it belongs in the area. This means that when the user selects a fire class F, which means it is a fire in a pan, that this icon will be placed on the location of the kitchen. The tabletop elements can be placed anywhere in the scene, just through walls or already placed icons. The icon selected in the menu will stay active so that the user can place multiple of the same icons after each other without having to select anything in the menu again. If the user wants to delete the icons, the user will need to select the "delete button" and the user can point and click on the icon which needs to be deleted. This means that the tabletop emergency case also gets deleted this way and the user does not have to press the "no fire" button in the dropdown as was the design in tabletop iteration #1.

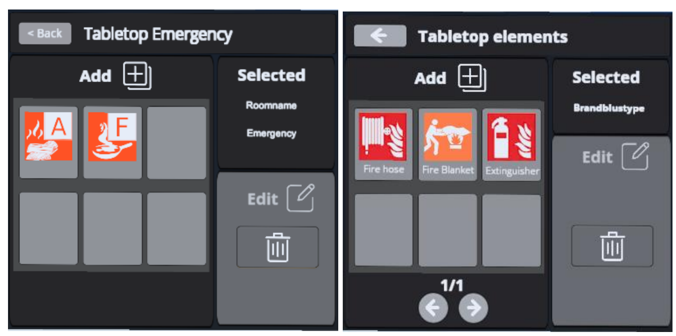


TABLE 3 - TABLETOP ITERATION #2: MENU

Visual Feedback

When the user had one of the editing menus enabled, the walls in the 3D tabletop will be disabled. This results in the user getting a clearer overview of the tabletop.

The selecting color has been changed to a blue. This choice has been made due to the orange selecting color being too close to the indicator color. Blue has been chosen because it's a complementary color to orange.

A square outline the size of the selected icon has been placed at the end of the indicator. This outline is dark blue when the icon can be placed and will be turned red when the icon cannot be placed. The icon cannot be placed when the indicator hovers over walls or already placed icons.

To give the user more feedback about the selected element or emergency case, a corresponding icon had been added to the end of the indicator. This icon has been placed slightly above the end of the indicator so that the placement outline is still visible. When the player presses the index button, the icon will be placed on the board, which results in a visual stamping effect.

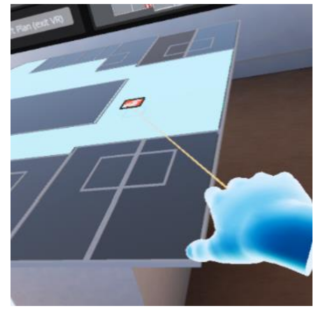
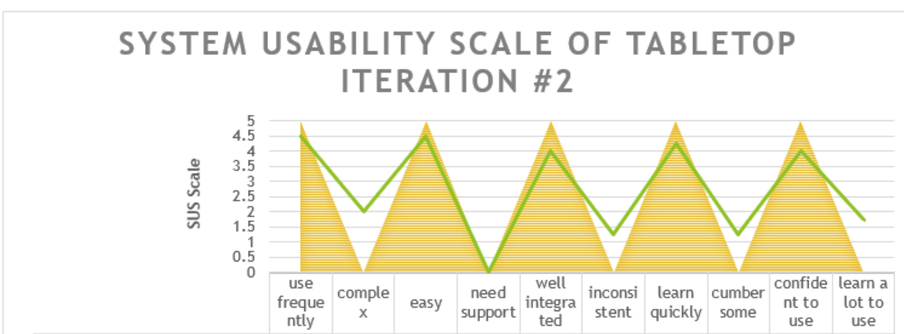


FIGURE 15 – TABLETOP ITERATION #2: VISUAL FEEDBACK

Testing Tabletop Iteration #2

Results

The data received shows that the BISUS has been reached with the "need support" category. The "complex" category scored the worst out of all the categories with an average of 2, while the BISUS for this category is a 0. The average SUS score resulted in an 80,6 which means that the usability of this system is graded with a B and thus, the system usability is acceptable. Sauro (2011) states that the average SUS score is 68 this means that the current iteration usability scored an above average on the usability scale. The additional questions asked in the questionnaire apart from the SUS questions indicate that the users were able to complete the tasks given entirely and did not experience any bugs which could have influenced the SUS score.



	use frequently	complex	easy	need support	well integrated	inconsistent	learn quickly	cumbersome	confident to use	learn a lot to use
Best Imaginable SUS Score	5	0	5	0	5	0	5	0	5	0
Tabletop V03	4.5	2	4.5	0	4	1.25	4.25	1.25	4	1.75

FIGURE 16 - SUS RESULTS TABLETOP ITERATION #2

Analysis

The inconsistent category has scored a 1.25 out of 5 while the BISUS is a 0. This means that the change in the tabletop editing design has been improved comparing this result to the results gathered in iteration #1, which scored a 4 out of 5.

Final Product

The final product can be described as a method used to test the trainee's knowledge of an emergency procedure. This will be an emergency case based on the emergency exercise created by an instructor.

The final product includes the best scoring tabletop iteration. Due to the feedback gathered from tabletop iteration #2, the menu location has been changed. It has been decided to place this menu on the wall, next to the instruction board, instead of it being attached the users left hand. This is done to prevent the user from getting an overload of information.

The final product also includes a full-scale exercise. This full-scale exercise allows the user to experience the 3D tabletop in a realistic human-size scaled virtual simulation. This 3D environment is a detailed representation of the 3D tabletop model.

In the final product, the user starts with the tabletop editor. Here the user can recreate an emergency plan similar to the other tabletop iterations. The user now has an extra option to test the emergency plan. The user can place emergency elements and enable two types of fires in specific areas in the 3D tabletop. When the user presses the "start simulation" button, displayed on the instruction wall, the full-scale exercise will start. Starting the Full-scale exercise will spawn the user in the designated area and the selected emergency cases will be spawned in the corresponding places. For the full-scale exercise, the user can walk in the simulation version of the tabletop where the emergency cases are enabled.

The testing approach of the final product has been done by using the SUS scaling again. This was done to be able to compare all the usability scores from the iterations and the final product.

To test the final product the user was given an instructional video on how to perform a door procedure in real life. The user then starts the tutorial in VR. The user will recreate the plan displayed on the instruction board which asks the user to enable one emergency case in the 3D tabletop. The next step taken by the user is to press the "start exercise" button. The user will now spawn in the full-scale exercise and performs the previously taught door procedure. When this procedure has been finished, the user will go back to the tabletop, and the personal performance of the door procedure will be gathered by the system and displayed on the instruction board. The final product can be found in **Appendix A:** "Graduation Product – Multi-user Training Simulation in Virtual Reality" in the appendixes.

Testing Results

Results

For the final product, the need of support category has scored the worst when comparing it to tabletop iteration #2. The SUS score also indicates that the user finds the final product a bit harder to use compared to the previous tabletop iteration. The result of the remaining categories ended up being quite close to the results of tabletop iteration #2. The average SUS score of the final product results in a 76, this means that the product's usability is graded with a B, which means that the usability of this product is acceptable.

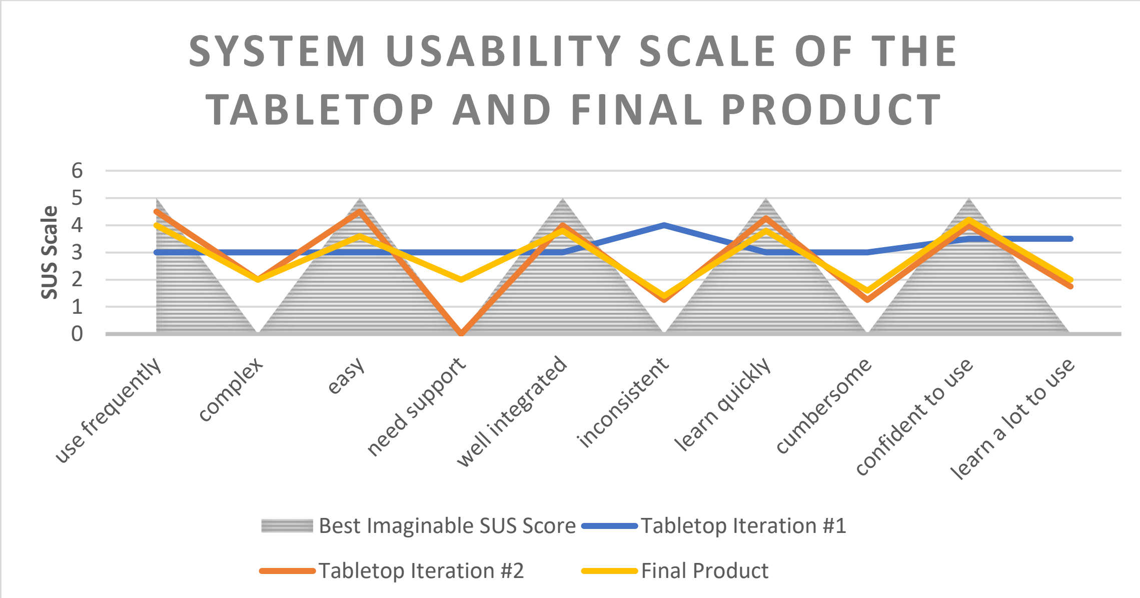


FIGURE 17 - SUS RESULTS TABLETOP FINAL PRODUCT

Analysis

The only difference between the tabletop iteration #2 and the tabletop design in the final product is the change of position of the menu, which is now located on the wall. An explanation for the SUS score being slightly worse compared to the SUS scale of tabletop iteration #2 could be the implementation of the additional full-scale exercise. This full-scale exercise had not been tested on its usability before it had been added to the final product.

Conclusion

Discussion

The discussion chapter is covering the approach of the research and states whether certain decisions could have been approached better.

Product Approach

Due to my lack of knowledge of programming in Unity3D, the initial product had to be scaled down. By making the decision earlier on in the development of the product, could have resulted in the full-scale exercises being more developed and tested in depth.

Testing Approach

Testing the product with industry professionals, which means emergency trainees and trainers, would have been a better fitting testing audience, due to these participants being familiar with emergency training methods like the tabletop method. The iterations and product have been tested by a total amount of 11 participants. Increasing the number of testers would have resulted in a more accurate SUS score. Increasing the number of testers was hardly possible during this time due to Covid19. Testing the usability with more participants would have resulted in more reliable testing result.

The results of the SUS score of the final product do not fit the expectations, the expectations were that this SUS score would score higher compared to previous iterations due to the feedback applied. with the theory that…The SUS score of the final product was worse compared to the best tested tabletop iteration. Testing the usability of the full-scale exercise prior to adding this exercise in the product and creating an additional iteration of the full-scale exercise could have resulted in a better SUS scale of the product.

Conclusion

This research aimed to identify what elements are needed for Connec2, a multi-user virtual reality platform, to also function as a training simulation. Based on the theoretical analysis, conducted at the start of this research, the currently most used training methods and their limitations have been collected. It can be concluded that the desired training simulation needs to contain the functionality to teach trainees and reflect on their progress as well as the functionality to create, adjust and test emergency plans. Based on this research the sub questions had been formulated which are answered in this chapter.

> *Sub Question - “How should the exercises be designed to communicate specified learning elements to the trainees and ensure this skill transfer?”*

A functional exercise answers this question, by teaching the trainee procedural skills. Research conducted about skill transfer of procedural skills in VR has shown that the use of observational learning, guidance aids, high cognitive fidelity as well as high physical fidelity can reduce the training time drastically. The functional exercise concept describes how the already implemented functionality in Connec2 can be used to secure this skill transfer.

To design exercises to communicate specified learning elements and ensure skill transfer, the exercise should be single user based and enable observational learning. The design should also include the limited accessibility of guidance aids, to enforce the user to recall the steps which ensures skill transfer to the user.

> Sub Question - “*How can the training simulation provide opportunities to create and adjust emergency and test plans?”*

A researched method is the Tabletop exercise which is an interesting method because it is the industry standard to test emergency plans. The Tabletop was selected because it is easy to set up and helps the trainee visually observe the building space. The only main limitation with these exercises is the lack of immersion. To offer added value, this tabletop exercise must provide a realistic representation of an emergency scenario. This reason being because this element is missing in physical tabletop exercises. The immersion can be achieved by adding a full-scale exercise functionality so that the user can be given the opportunity to practice an exercise in a realistic environment.

The training simulation can provide opportunities to create and adjust emergency plans by being able to place and remove emergency elements on the 3D tabletop. The testing can be done by providing the user the ability to add specific emergency cases to the tabletop. These cases should then be tested in the full-scale exercise which provides opportunities to test and adjust these emergency plans.

> *Sub Question - "How should the training simulation be designed to decrease the technical barrier and so increase the usability of the emergency simulator?"*

VR technology creates a technical barrier when it comes to new users due to the overload of information which can overwhelm these users. This also causes the usability of VR to be quite low for a new user. To counter these difficulties, multiple iterations of a tabletop exercises have been developed and tested based on a usability score survey. Proper visual feedback helps the user understand what they are doing within the simulation, such as highlighting the selected objects whenever it is interactable.

Testing these iterations have shown that a step by step tutorial can be added to decrease the technical barrier and increase the usability of the simulation. The testing results have also shown that the consistency of the mechanics adds to an increased usability as well.

> Main Question – "*What are important elements for the design of an Emergency Training Simulation for a Multi-User Virtual Reality Platform to teach trainees emergency protocols and create, adjust and test emergency plans?"*

The product concept describes that important elements to teach trainees emergency protocols are the assurance of skill transfer and proper user experience in VR. This includes design considerations like adding observational learning elements, high cognitive fidelity, and tracking the trainee's performance. To be able to create, adjust and test emergency plans, a tabletop exercise should be translated to the VR simulation. The tabletop exercise enables the user to create and adjust elements while a full-scale exercise enables the user to test the emergency plan in a realistic immersive environment. Every element in the training simulation should keep the usability in mind to limit the technical boundary of VR, which is a common problem with new users of VR. The usability can be improved by limiting the information provided in the simulation to avoid information overload. Adding a step by step tutorial will not only increase the usability of the simulator but can also be used to increase the skill transfer.

Recommendations

Considering how Connec2 had very positive results from its first stress test executed with potential users and other experts in VR technology, the market opportunities for Connec2 are growing. Therefore, a training simulation that overcomes the limitations of currently used training methods can be an addition to the current uses of Connec2. This research has shown that Virtual Reality-Based Training often lack the multi-user functionality; therefore, a training simulation in Connec2 is possibly filling a market-gap. Thereby reaching new target audiences, and thus expanding its possible sales market. Considering TVDM has already developed Connec2 and VR Brandveiligheid and with use of the results and product from this research, TVDM can expand Connec2 and reduce the development cost of the desired training simulation.

For the tabletop exercise it is recommended to create standard exercises which are based on the training regulations in the Netherlands (*Appendix B* - “Emergency Training in The Netherlands”). As stated in this appendix, all companies in the Netherlands need to have a certain number of employees trained in emergency exercises. If the tabletop exercise covers the functionality needed to train these employees, and adding an immersive experience to the tabletop, can result in this tabletop exercise to be a possible addition to the market.

Making use of the SUS testing method is recommended for testing the different iteration on a system usability due to it being easy to set up and it being cost-effective. By displaying the data like how I have done it in table 3, will create a clear overview not only of the potential weaknesses of the system but also the problem importance by looking at how steep the line is.

For the design of the functional exercise, as described in the product concept, this design can be a potentially interesting addition to the simulation if it is developed in such a way that it can function as a tool whereby the user can put together a training by themselves. Designing the exercise like this fits the broad use case of Connec2, due to having the user be in control.

By adding the possibility for the user to import their own created functional exercise into the tabletop/ full scale exercise will lower the maintenance of the tabletop exercise by not having to develop specific training exercises.

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Appendix

Appendix A: Product – Multi-user Training Simulation in Virtual Reality. The final product can be found by following this link (to YouTube): https://youtu.be/T2JPMJx5JUY

Appendix B: Reflection

1. Technical research and analysis.

Basic skillset of programming was required to be able to start the development of the product. Because I had no experience with programming prior to this graduation internship, this skill level had to be obtained first. Although I had used Unity3D before during this study, I had never delved deeper into the technical side of the engine. Programming specific functionality has been more challenging than I had initially anticipated and the lack of knowledge of programming at the start of the project resulted in me being a bit too ambitious about the product results. By pushing myself to still create a valuable product, I have managed to improve my technical skillset in the Unity engine drastically. This project gave me the opportunity to also update my knowledge about lighting and other settings in unity, due to me not having used the engine in 1 year.

2. Designing and prototyping.

Based on the preliminary experiment, literature research and desk research, I have formulated multiple product concepts. These concepts describe the design and how the functionality in Connec2 can be applied to get to achieve these results. Doing this has created a fundamental base for the prototyping phase of the project and helped to decide what the scope of the project would be. The most suitable prototyping method was by developing the product concepts in the Unity3D engine. Multiple prototype iterations (CMD method) have been made to be able to create the final product. This method was the most suitable because it fits the company's methodology most. Regular contact with the stakeholders has resulted in the iterations being pushed into the right direction, by frequently discussing the product results and focus. The method used to get feedback from the user (usability testing) has been suitable due to the result of these testing sessions giving a clear overview of what elements needed improvement. That this testing method has been suitable for the product result can be seen by how the iterations have improved drastically after applying the feedback gathered from the testing sessions.

3. Testing and rolling out

To be able to detect problems with the design of the product, a usability test has been executed for every iteration of the product. As stated in the research, a weakness of VR bases training simulations includes the high technological barrier. The technological barrier can be decreased by testing if the user understands and likes to use the system. Therefore, using a usability test has been the best suitable testing method. Unfortunately, the most suitable testing audience (emergency trainees) could not test the iterations due to the limitations Covid19 gave. I decided to instead test the usability of the product with experienced but also non experienced users with VR technology. This due to the product needing to be usable by every type of user with any type of experience with VR technology. By creating additional questions to the usability survey, limitations which could influence the usability score have been made clear. These questions included if the user experienced any bugs in the system. The system tested spoke for itself by giving the user a task and instructions on how to achieve the task.

4. Investigation and analysis

By first defining the problem behind the problem I have been able to look at the problem in a more general way. Meaning that I didn't fully focuses on the requested approach of the client and so being able to approach the research in a more flexible way. Because non-VR training methods had to be translated to VR, The CMD methods for literature study have been used to gather more information about the translation of the product concept to the product design. By researching how skill transfer and user experience in VR can be created and secured, has resulted in a clearer overview of what the product design should eventually look like. Multiple research directions have been explored by not only having done literature research but also having created a preliminary experiment. This experiment has been very useful due to the resulting list of design requirements as well as technical challenges and boundaries. The result of this experiment has helped to create new ideas and potential concepts for the product.

5. Conceptualizing

Multiple product concepts have been formulated within this research based on the conducted research. These concepts have all been based on research conducted about the subject. Due to programming being a new skill for me, I have been struggling to determine what I was capable of. Because of my limiting programming skills, I have not been able to develop all the most promising concepts. This because the approach of the implementation of certain ideas was a too challenging. I have however been able to develop the tabletop and functional exercise which was the most important direction due to this functionality being an uncovered area for TVDM.

6. Designing

This competence is a bit hard to answer due to this product never being intended to be market ready. The goal of this project was to function as a preliminary research for the development of a somewhat huge extension for the platform. Although the product not having to be market ready, the product still functions as a proof of concept for TVDM. I was able to create a product which is usable for users with and without VR knowledge, which shows that the design in general has been properly done. The product is also consistent considering functionality as well as the visual representation. The choices of the product design are however totally backed up by either conducted research results or the usability testing results.

7. 8. Enterprising competences

The functionality of the previously created platforms by the client have been taken into consideration in how the eventual design of the product could look like. This was done to give the client an overview of what functionality can be reused. Doing this has showed that the technical or financial feasibility of the client has been taken into consideration and has been justified. Due to the conducted research being about general currently used training methods, this research has given an inside of what the possible market opportunities are for Connec2.

9. Working in a project-based way

I showed that I can work within a team, although this project was not team based, I have still attended most of the meetings of the VR team of TVDM. During these meetings I would communicate about my progress of this project and I would ask for help whenever needed. I have adapted to the agile development methodology of the team without any issues.

10. Communication

I have followed the guideline written in the manual of the graduation, with APA references. I hope my report conveys information about my topic which is creating a training simulation for a multi-user platform. I also took the time and effort to make the layout of the report more appealing for the reader.

11. Learning ability and reflectivity

I think I have scored well on this competency due to me discovering a whole new skillset. This skillset has been a huge challenge for me to deal with, but I enjoyed it a lot. Combining my weaknesses and strengths during this project is what makes me score well on this competency.

12. Responsibility

I took responsibility on learning how to code, setting up the entire 3D set in VR and planning out my workload for myself. I guided myself throughout this whole project and asked for feedback and advice from colleagues when I needed it most. Any requirements for this graduation I have met accordingly. I believe this product will be useful for the final product of TVDMs training simulator.

Appendix C: “Prototype 1 – Assuring TVDM their objectives and getting familiar with the TVDM assets”

Prototype 1 | 24/02/2020 - 02/03/2020
Goal: Make sure I understand TVDM their objectives by creating a basic table top functionality in Unity working with the TVDM VR rig.

Main objectives TVDM are to develop a Multi-user training simulation which has a tabletop and first person simulation functionality. This experiment should contain interactivity with objects, including placing and adjusting elements. To be able to make it usable for new users, the instructions must be clear and the interactivity and navigation should be easy to use.The objectives of the TableTop experiment are to test the right scaling of the map and its correcsponding visuals to achieve a clear overview of the situation.

Prototype 1 functionality:

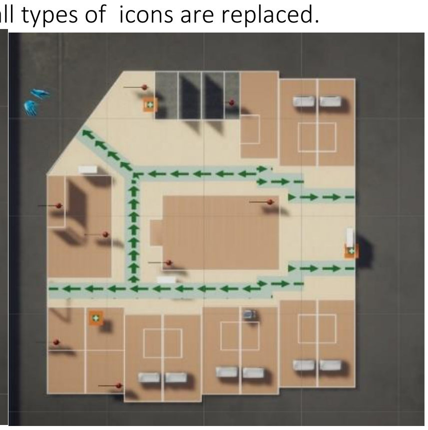
1. Interactivity with objects by pointing at these.
    a) Adjusting objects
    b) placing in the right spot
    a) Instructions on instruction board

    b) Navigation from TVDM VR rig
    c) Interactivity by pointing at object with feedback (objects shows ray and highlight on focus)
2. Switching between first person and tabletop
. scaling difference
3. Visuals
. Walls in tabletop have transparency
    a) Use of real map (hospital)

Prototype 1 goals in game:

4. Replace all 8 2D fire extinguishers icons with 3D fire extinguisher models

5. When the right object gets placed close to the right icon a blue version of the object will show and if the user releases the button at this moment the blue object will be replaced. The icon on the floor will now disappear
6. 1 and 2 gets repeated until all types of icons are replaced.

7. At the end all icons are replaced with the right 3D models

Prototype 1 testing results:

(2 Users testing from VR team, TVDM)

1. Interactivity
    a) Pointing at objects is too complicated/annoying
    b) Placing objects in the wrong spot should show feedback
2. Usability for new users

. Instructions on board are clear
    a) navigation is clear
    b) interactivity too complicated
3. Switching between first person and tabletop
. scaling is too big, map should be higher placed
4. Visuals
. Bloom is too much
    a) transparency on tabletop walls make the map more clear
    b) transparency can make the tabletop less clear when it is more complicated

Requirements product

Tabletop Technical boundaries/challenges	MoSCoW	Solution Provided by TVDM	
Use of multi-user functionality	S	✓	
switching from tabletop to simulation scene and transferring information	M		
Storing area data	M		
Enabling the using to change the area data	S		
Requirements Tabletop Design	MoSCoW	Solution Provided by TVDM	
Navigation user through virtual space	M	✓	
Simplified 3D Visualization of training area with correct scaling	M		
Navigation and editing instructions for user	S		
Visual representation of user in simulation	S	✓	
Simplified visual representation of emergency case	M		
Transparency in walls tabletop	S		
Visual feedback by highlighting objects	S		
Detailed 3D visualization of training area with correct scaling	M		
Detailed visual representation of emergency case	S		

Appendix D - “Emergency Training in The Netherlands”

In the Netherlands every company needs to be prepared for emergency situations according to the Arbeidsomstandighedenwet, 2017, article 15. The law states that every company needs to set up a bedrijfshulpverlening organization (BHV organization) to secure the health, safety, and wellbeing of employers and employees.

A specified number of employers/employees at a company will need to be trained with the basics of emergency response, these employers and employees are called bedrijfshulpverleners (BHVers). Every company needs to secure that this set number of BHVers are always present at the company. A BHV organization ensures that the company is prepared for any calamities and emergencies within the company. With a BHV organization the company needs to identify the risks of the workplace by setting up a Risk Inventory and Evaluation (RI&E) document. The company also needs to provide adequately trained emergency responders (BHVers) and organize an annual emergency response session. BHVers must have the correct BHV and first aid equipment like fire extinguishers, first aid kits, emergency response vests, walkie-talkies (Arbeidsomstandighedenwet, 2017, article 15).

Bhv.nl. (n.d.).

Step 0: Communication exercise - This phase is a theoretical communication exercise in which we go through the evacuation plan with the emergency response organization. In addition, we make a tour through the building together to draw attention to the preventive facilities.

Step 1: Physical eviction - Before this exercise, we have a preliminary discussion with the organizer of this exercise in your organization, for example the head of FAFS. We discuss as many details as possible. During the exercise we perform the evacuation under the guidance of our instructor. We recommend this phase, for example, if your organization is new or if you have recently moved. This often involves only part of your employees, for example a specific department or part of the building.

Step 2: Physical eviction Day or week is announced, but not the exact time. Here too we will have a preliminary discussion with your contact person, and we will agree on exactly what the exercise will look like: which scenarios do we practice and when do we do that, who are involved, etc. During the exercise, our instructor has a less leading, but more acting role.

Step 3: Physical eviction Day or week is not announced in advance An evacuation situation is carried out as realistically as possible at this stage, so there is no preliminary discussion. Our instructor comes to your organization unannounced and unobtrusive, that is to say not recognizable as an employee of BHV.NL, and starts the exercise. He mainly has an observer role this day. You can choose to use a lotus victim in this exercise. The evacuation is carried out by your emergency response organization.

Step 4: Physical eviction External emergency services are involved. Also in this phase our instructor has an observer role and deployment of a lotus victim is possible.
Perception - Do you prefer the planning and organization of the evacuation drill in your own hands, but would you like to have an objective assessment of how the evacuation drill works? Then you can choose to use one or more observers, depending on the size of the organization. In this way, the emergency response officers can fully concentrate on the evacuation exercise and they do not have to be involved in the course of the process.

Appendix C – "Training Set-Up"

To be able to start the development of the product, a better understanding of the setup of training programs had to researched. According to Wilson's (2000), an excellent comprehensive training program consists of several elements. Wilson's (2000), divided these elements into seven steps to creating a basic training setup schematic;

1. Identify the training needs
2. Identify those who need training
3. Identify the training method to be used
4. Prepare the training materials
5. Deliver the training program
6. Evaluate the effectiveness
7. Audit the process for future modification

This list can help to cover the information needed to setup specific training. The topic which needs to be trained is defined, the target audience gets identified, and the effectiveness already gets evaluated. By following this schematic, the training can be designed and analyzed. If the results are ineffective, steps 3-6 can be repeated.

1) Training Subject:
    - *a)* Fire safety
2) Target group:
3) Used training method(s):
    - a) Tabletop exercise
    - b) Physical exercise
    - c) full- scale exercise
4) Needed training materials:
    - a) Tabletop materials
        - i) Fire extinguisher icon
        - *ii)* Fire alarm icon
        - *iii)* Evacuation route
    - b) Physical exercise
        - i) Door procedure
        - ii) Extinguishing fire
5) Deliver the training program
6) Evaluate the effectiveness
    - a) Emergency plan
    - b) Personnel executing the plan based on individual roles
7) Audit the process for future modification

Appendix E– *"Tabletop exercise in depth"*

To be able to create a tabletop exercise in Virtual Reality, a better understanding of the overall design of a real-life tabletop exercise will need to be made clear.

Within tabletop the participants can have different roles;

Player – These are the general participants who get assigned to a pawn and are so being part of the exercise.
Observer - They answer questions or give feedback as if needed.

Facilitator - Facilitators control the pace and flow of the exercise and steer the ongoing discussion to the desired direction.
Evaluator - Evaluators should report on the strengths they observed and what areas can be improved next time (Alertmedia, 2019, p.1).

Actiz. (2015) explains step by step how a Tabletop exercise is performed;
Step 1: At the start of a Tabletop exercise, the locations of the following elements are being discussed;

- emergency exits
- fire hose(s)
- fire extinguishers
- fire detector(s)
- assembly point(s)

This is often done by placing the corresponding pictograms on the blueprint while the meaning and purpose of that specific equipment are being explained.

Step 2: Each participant then receives a (Playmobil or Lego) pawn that represents them, and their individual role gets specified.

Step 3: The emergency case now gets explained, and each participant must place their pawn at the location on the blueprint they would logically be located during the time of the occurring emergency.

Step 4: The participants can now indicate and discuss what they think they should do in this emergency. This is the moment the participants will have to work together.

Step 5: The performance of participants is discussed with all participants, and recommendation for improvement of the program can be discussed.

LEGO BHV Table Top suitcase - Office
Complete case with all the essentials for a Table Top Meeting with a floor plan to play an evacuation drill within an office environment.
The case contains the following parts:
- LEGO Fire Truck - simple version (x1)
- LEGO Minifig, BHV Team leader, incl. First aid kit and walkie-talkie (x2)
- LEGO Minifig, emergency response member, including walkie-talkie (x8)
- LEGO MiniFig Ambulance Brother - NL (x2)
- LEGO MiniFig Fireman - NL (x6)
- LEGO MiniFig Policeman - NL (x2)
- LEGO Minifig Assorted [6 different MiniFigs] (x4 = 24 pcs)
- LEGO Minifig Assorted [3 different children] (x4 = 12 pcs)
- LEGO Fire Extinguisher, small (x10)
- LEGO Fire Extinguisher, large (x2)
- LEGO Flames (x10)
- LEGO Fireproof Separation (red bar 1 x 8 studs] (x10)
- LEGO Fireproof Separation (red bar 1 x 4 studs) (x10)

The signal boards below are based on NEN 1414:
- LEGO BHV Signal stone [manual call point] (x5)
- LEGO BHV Signal stone [fire extinguisher] (x5)

- LEGO BHV Signal stone [fire hose reel] (x5)
- LEGO BHV Signal stone [fire blanket] (x1)
- LEGO BHV Signal stone [assembly point] (x2)
- LEGO BHV Signal Brick [AED] (x1)
- LEGO BHV Signal Brick [First Aid] (x1)
- LEGO BHV Signal Brick [Exit] (x5)
- LEGO BHV Signal stone [Emergency exit - route] (x5)
- LEGO AED Kit (x1)
- LEGO Desk / conference table with chair (x30)
- LEGO Computer Desk (x5)
- LEGO Wheelchair (x1)
- LEGO Water Cooler (x1)
- LEGO Canteen table with 4 chairs (x4)
- LEGO Planter (x2)

Appendix F: *System Usability Scale (SUS), by J. Brooke*

To calculate the SUS score, first sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1,3,5,7,and 9 the score contribution is the scale position minus 1. For items 2,4,6,8 and 10, the contribution is 5 minus the scale position. Multiply the sum of the scores by 2.5 to obtain the overall value of SU.

SUS RANGE	GRADE	PERCENT RANGE
84.1–100	A+	96–100
80.8–84	A	90–95
78.9–80.7	A–	85–89
77.2–78.8	B+	80–84
74.1–77.1	B	70–79
72.6–74	B–	65–69
71.1–72.5	C+	60–64
65–71	C	41–59
62.7–64.9	C–	35–40
51.7–62.6	D	15–34
0–51.7	F	0–14

FIGURE 18GRADING SCALE INTERPRETATION TABLE FOR SUS SCORE. SOURCE: ADAPTED FROM TABLE 8.6, PAGE 204 FROM (SAURO AND LEWIS, 2012).ING

Usability testing questionaire

Testing Usability of a Virtual Reality Tabletop Simulation

This questionnaire reflects on the usability of the tabletop functionality for a multi-user training simulation (Connec2). This functionality gives the user the ability to create, adjust and test emergency plans.

Version tested (name of folder) *

- ◯ Tabletop_V01_UsabilityTest
- ◯ Tabletop_V02_UsabilityTest
- ◯ Tabletop_V03_UsabilityTest

Age

- ◯ under 21 years
- ◯ between 21-35 years
- ◯ over 35 years

I am experienced with Virtual Reality Technology *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I have used Connec2 before *

- ◯ Yes
- ◯ No

I think that I would like to use this system again. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I found the system unnecessarily complex. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I thought the system was easy to use. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I think that I would need the support of a technical person to be able to use this system. *

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly agree

I found the various functions in this system were well integrated. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I thought there was too much inconsistency in this system. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I would imagine that most people would learn to use this system very quickly. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I found the system very hard to use. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I felt very confident using the system. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

I needed to learn a lot of things before I could get going with this system. *

	1	2	3	4	5	
Strongly disagree	○	○	○	○	○	Strongly agree

Usability testing results

Time stamp	Version tested	I think	I found	I thought	I think	I found	I thought	I would	I found	I felt w	I need	SUS Raw Score	SUS Final Score	Grade	Acceptability
27-5-2020 17:14:50	Tabletop_V01_	4	2	3	2	3	4	4	3	4	3	24	60	F	Not Acceptable
29-5-2020 14:26:34	Tabletop_V01_	2	4	3	4	3	4	2	3	3	4	14	35	D	Marginal High
											Average	19	47,5	F	Not Acceptable
31-5-2020 14:56:30	Tabletop_V02_	4	2	4	2	4	1	3	1	3	1	31	77,5	C	Acceptable
31-5-2020 15:40:47	Tabletop_V02_	4	2	4	4	4	2	4	2	4	2	28	70	C	Acceptable
31-5-2020 16:10:30	Tabletop_V02_	5	2	5	2	4	1	5	1	4	2	35	87,5	B	Acceptable
31-5-2020 16:27:23	Tabletop_V02_	5	2	5	3	4	1	5	1	5	2	35	87,5	B	Acceptable
											Average	32,25	80,625	B	Acceptable
15-6-2020 14:25:44	Tabletop_V03_	5	2	4	3	4	1	4	2	5	3	31	77,5	B	Acceptable
15-6-2020 14:58:26	Tabletop_V03_	3	2	3	3	4	2	4	3	2	1	25	62,5	C	Marginal High
15-6-2020 16:32:01	Tabletop_V03_	4	2	4	1	4	1	4	1	4	2	33	82,5	B	Acceptable
15-6-2020 17:04:58	Tabletop_V03_	4	2	3	2	4	2	4	1	5	2	31	77,5	B	Acceptable
15-6-2020 18:04:59	Tabletop_V03_	4	2	4	1	3	1	3	1	5	2	32	80	B	Acceptable
											Average	29,66666667	76	B	Acceptable