TURUN YLIOPISTO

Attitude Processes and User Experiences in Virtual Reality Simulations

Attitude Transitions in Immersive and Non-Virtualized Virtual Reality Machine Gun Simulators

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Abstract

The study aims to measure attitude processes when using simulators and subjective experiences after use by comparing a VR-based immersive simulator and a classic non-immersive simulator. The target groups are the conscripts in the Parola Armored Brigade of the Finnish Defense Forces, who will receive training in using an anti-aircraft machine gun with the help of virtual reality. Both simulators highlighted commendable traits, such as prompt responsiveness to user actions and awareness of control devices. The VR simulator's propensity to induce more pronounced simulator sickness symptoms occurred similarly in both simulators, suggesting common physiological responses across different simulator types. Interestingly, participants in the VR simulator found it easier to control events and manipulate objects, leading to better engagement than in real-life scenarios. These findings illuminate the advantages and limitations of VR training with augmented cues, offering valuable insights for refinement and future research endeavors.

Keywords: simulator, VR-based, immersive, non-immersive, virtual reality, user experience, training, anti-aircraft, machine gun, responsiveness, control devices, sensory feedback, user-friendly.

Table of Contents

Table of Tables

Table of Figures

1 Introduction

The study aims to measure attitude processes when using simulators and subjective experiences after use by comparing a VR-based immersive simulator and a classic non-immersive simulator. The target groups are the conscripts in the Parola Armored Brigade of the Finnish Defense Forces, who will receive training in using an anti-aircraft machine gun with the help of virtual reality. Other characteristics measured are performance and transfer of training). The other aim is to discover if every company or platoon has such a weapon or requires one and how much time is spent on training each conscript on using the gun. A description of the current training practice and the training schedule is needed. Several hypotheses will be presented, and they will be backed up with previous studies and literature review. Examples of existing VR-based simulators in the military world will be provided. The schedule/time frame of this thesis is four months. (September – December 2020)

The next chapter of the thesis will define the different methods and designs used to conduct the study. The study will include two groups, one training for a brief period and the other for a more extended period. One group will train with the classical assault rifle simulator gun and the other with the anti-aircraft VR-based machine gun simulator. The groups will also train without simulators for comparison.

The classical simulator used is the SAAB BT 61 Gunnery Simulation, located at the Parola Armored Brigade of the Finnish Defense Forces and was developed by conscripts. The anti-aircraft machine gun used is the ITKK weapon system, which is belt-fed and has a gas recoil principle. Its fire rate is between 700 to 800 ls/min in theory and 100 ls/min in practice. The SAAB BT 61 Gunnery Simulation is a visual gunnery simulation for indoor and outdoor use, designed to train gunners in using the reflex sight and introduce correct lead-angle and super-elevation. The BT 61 is also meant for training gunners in block shooting and observation of tracers to make fire corrections. The gunner can also be taught to estimate airborne targets' velocity and angles.

The new VR-based simulator consists of a 12.7 ITKK 96 machine gun, two controllers measuring movement and angle attached to it, and VR glasses. The simulator software is based on the Unreal Engine 4 game engine. The simulator user sees a machine gun through the VR glasses, the position and angle of which correspond to the angle of the physical machine gun.

2 Military Conscription Training in Finland

2.1 The Finnish Conscription System

The civil duty defined by Section 2 of the Conscription Act begins at the beginning of the year when a man turns eighteen and continues until the end of the year when he turns sixty. The conscript is in service and later transfers to the reserve. Conscript service is usually performed at the age of 19–20. In exceptional cases, the service starts between 18 and 29. Women can apply for military service voluntarily. (The Finnish Defence Forces, 2022)

The conscript service period is either 165, 255, or 347 days. The service period for conscripts training as non-commissioned officers and demanding tasks in the special forces is 347 days. The service period for those trained for tasks requiring the crew's unique skills and professional competence is 255 days. The service period for those performing unarmed service is 255 or 347 days. Other crew trainees have 165 days of service. Based on the selections made in the corps department, the task for which the conscript will be trained and the length of service according to the task is decided. Most conscripts serve 347 days. (The Finnish Defence Forces, 2022)

The goal of conscript training is to produce troops with superior performance and personnel with suitable skills and operational ability to be placed in the wartime forces of the Defense Forces. In addition, training maintains essential readiness and the ability to increase readiness as needed. (The Finnish Defence Forces, 2022)

2.2 Functional Ability as a Starting Point for Military Training

Functional ability and performance go hand in hand when training individuals to work as part of a high-performance group. The image of warfare today is more demanding and diverse than ever, requiring soldiers to develop all aspects of their operational ability. Operational capability and training are integral parts of the training of all conscripts. It is built from physical, psychological, ethical, and social aspects, all of which interact.

A capable soldier is responsible and can oversee assigned tasks in various situations and environments. They must be able to work independently and as part of a group with initiative, determination, and situational awareness. The critical factor in operational capability is applying knowledge and skills in changing environments and situations.

Physical fitness is critical to bodily functioning, including endurance, strength, speed, and sensory functions. Strong self-confidence and managing challenging situations or environments are essential to mental functioning. It also includes the ability to receive and process information and awareness of the environment, oneself, and activities. A mentally strong soldier is self-confident, able to make decisions and withstand pressure, and motivated to succeed in their mission. (The Finnish Defence Forces, 2022)

Acting ethically requires understanding our values and justifying our actions to ourselves and others. Values related to this area include a sense of responsibility, acceptance of difference, and adherence to the rules of war and the rules governing soldier's behavior. The ability to interact, people skills, and the ability to function as a group member are critical to social functioning. Social functioning includes considering and supporting others, the ability to work in a group, and the so-called "do not leave a friend behind" spirit. Social functioning creates the foundation for group cohesion. (The Finnish Defence Forces, 2022)

2.3 Military Training Systems

Military training systems are customarily divided into three areas (Curry, Price, & Sabin, 2016):

• Live simulations use troops and equipment on natural terrain but with simulated weapon effects. Soldiers are familiar with this training, fighting across areas with blank rounds.

• Virtual simulations use live troops with simulated equipment that engage in virtual combat, akin to a computer game.

•Constructive simulations involve simulated troops and an abstracted environment, similar to a military board game.

Defense training, analysis, and procurement activities worldwide have used modeling and simulation extensively. However, maintaining these systems requires significant capital and revenue expenditures, making them expensive to buy and maintain. They also take a long time, from initial requirements to training applications. The defense community is now interested in using affordable off-the-shelf commercial game technology that provides equivalent defense training capabilities to reduce costs. Game technology is readily available and appealing because it is affordable. (Roman & Brown, 2008).

3 Virtual Reality in Military Simulations

Since the late 1920s, simulators have played a vital role in military training. The Link Company's flight trainers were beneficial in teaching night flying skills. Today, the latest innovation in simulation technology is SIMNET, which electronically connects simulators to create a distributed simulation environment for training and testing combat strategies. (McCarty, Sheasby, Amburn, Stytz, & Switzer, 1993). This innovative development is made possible by the IEEE data protocol standard for distributed interactive simulations, which enables the inclusion of aircraft, land-based vehicles, and ships. (Technology, 1993) HMDs are now being used to reduce the cost of comprehensive field-of-view simulations further (McCarty, Sheasby, Amburn, Stytz, & Switzer, 1993). Head-mounted displays (HMDs) are wearable tech that display high-quality images directly in front of the user's eyes, creating a virtual display that appears to float in mid-air. HMDs can connect to a computer or console or be standalone devices that operate on battery power.

3.1 Virtual Environment

A virtual reality (VR) system aims to immerse users in a virtual world and empower them to interact. VR relies on immersion and interaction to create a user presence in a virtual environment (VE). To achieve this, the elements within the VE must exhibit autonomous behaviors that combine multisensory feedback with behavioral rendering, resulting in an immersive experience. (Bossard, Kermarrec, Buche, & Tisseau, 2008)

Learners are exposed to diverse scenarios and a complex virtual world within a VE. This diversity, driven by the autonomous behavior of certain entities in specific contexts, offers a unique opportunity for knowledge construction through abstraction. Whether the learning is procedural, focused on acquiring skills through direct experience, or declarative, requiring comprehension and applying existing knowledge, systematic and random variation in contexts is essential for abstraction and knowledge transfer. (Mendelsohn P, 1996)

Varied practice, characterized by exposure to different yet analogous situations, can lead to interference between these situations, which, in turn, contributes to the retention of common elements between them. Computer simulations and virtual reality can facilitate effective knowledge transfer through numerous repetitions and autonomous agents. The sensation of presence is achieved when users interact with virtual objects and the coherence of stimulus or number of stimulated senses is high. (Bossard, Kermarrec, Buche, & Tisseau, 2008)

3.2 A Three-Dimensional Virtual Learning Environment

A 3-D virtual environment extends visual information in three dimensions, includes other stimuli, and is interactive. It differs from other VLEs because it is 3-D, has smooth temporal changes and is interactive. This article focuses on "desktop virtual environments," explored with standard PC hardware in schools and homes (Wann & Mon-Williams, 1996). Educators worldwide are utilizing technology to enhance learning. Commercial, off-the-shelf 3-D games are being adapted for classroom use, and educational games are being developed for curricular content (Buchanan, 2003). Despite the hype around 3-D technologies in education, research shows that evidence for their specific learning benefits remains inconclusive.

3.2.1 Distinguishing Characteristics of 3-D VEs

3-D virtual learning environments (VLEs) have unique characteristics distinguishing them from interactive multimedia. One of the most important features is the transparent interface, which allows users to control objects directly within the virtual world. This transparency, increased immersion, fidelity, and active learner participation make VLEs highly effective in delivering a superior learning experience. (Dalgarno & Lee, 2009)

3.3 The Advantages and Disadvantages of Using VR and AR in Military Training

3.3.1 Advantages

Soldiers face risks during military training, and accidents can occur. However, virtual reality technology can offer a solution to this problem. It creates a safe environment for soldiers to practice combat drills without putting them in harm's way. By using portable batteries, VR headsets, and realistic guns, soldiers can simulate different warfare scenarios with the help of AI or their fellow soldiers. By setting up a single facility or platform, soldiers can train more frequently and progress faster. (Velichko, 2019)

Virtual reality applications are highly versatile and can be used for multiple combat missions and environments. This can help reduce the training budget while achieving effective results. VR and AR technology for training also reduces expenses related to transporting soldiers to specialized facilities, maintaining those facilities, fueling ammunition, and other expendables. Soldiers can learn about different vehicle types and environments in detail without any time restrictions. They can examine any vessel or weapon without needing physical access. All the information can be downloaded from a cloud service, making it possible to train from anywhere. (Velichko, 2019)

VR technology provides configurable environments for a variety of scenarios and their combinations. It can recreate nausea-inducing and claustrophobic conditions to help soldiers adapt better without exposing them to actual danger. By using virtual reality, any accidents related to training activities can be eliminated. This technology is wise for optimizing the training budget and boosting efficiency. (Velichko, 2019)

3.3.2 Disadvantages

Virtual Reality (VR) technology enables soldiers to train in a safe environment that can simulate different scenarios. This technology can also recreate situations that can cause nausea or claustrophobia, which helps soldiers adapt to these conditions without any real danger. By using VR, we can avoid any accidents during training, and this technology can help optimize the training budget while boosting efficiency. (Velichko, 2019)

3.4 Mobile Marksmanship Training Simulators

The Army National Guard has introduced a new program called ARNG 4.0 that helps improve combat readiness for all soldiers. The Army National Guard uses a Mobile Marksmanship Training Simulator (MMTS), which Laser Shot, Inc. developed in South Carolina. The MMTS is a firearms simulator that provides basic and advanced training for combat and combat support units. The system uses hit detection camera technology, which employs visible and infrared lasers to detect the location of the lasers emitted from the firearm and transmit the recorded data to the computer system. The system then displays the precise impact location on the screen, which helps in the practical training of soldiers. (Liptak, 2018)

3.5 The Impact of Immersive vs. Non-Immersive Simulators on Performance and Attitude

The utilization of Virtual Reality (VR)--based immersive simulators has proven to be more effective than non-immersive ones in providing a realistic and engaging environment for training tasks. The immersive environment allows users to feel more present, which increases their focus, spatial awareness, and skill development. The level of engagement that users experience with the VR simulator is so realistic that it surpasses that of non-immersive simulators, resulting in improved performance. (Holopainen, et al., 2020)

To measure the effectiveness of both simulators in achieving training objectives, it is essential to evaluate users' performance in the simulated task. Validated metrics such as the ITC-Sense of Presence Inventory can be employed to gauge users' sense of presence and immersive tendencies. These factors significantly influence users' engagement and performance in simulated tasks. (Holopainen, et al., 2020)

However, it is crucial to note that VR-based simulators may cause some users to experience motion sickness due to their immersive nature, which can negatively impact the usability experiences and user satisfaction. It is, therefore, necessary to evaluate the usability experiences by obtaining user feedback on the interface design, ease of use, and comfort during simulation tasks. This will enable the identification of shortcomings and implementing necessary improvements to enhance users' overall experience. (Holopainen, et al., 2020)

3.6 Affordances

According to (Gibson, 1977), affordances are relationships between reality and a user - a relationship exists naturally and is not necessarily visible, known, or desired. (Norman, 1999) Divides the affordances into real and perceived affordances. The perceived affordances are visible and recognizable features and qualities for the users. The user finds these perceived affordances meaningful and valuable with a known outcome. The natural affordances are all the possibilities that the system can potentially deliver. (Holopainen, et al., 2020)

The affordance theory framework will be applied to explain the differences between these virtual learning environments. Based on the results, design principles for VR learning environments will be proposed. The present study aims to employ the affordance theory framework in expounding on the differences among various virtual learning environments. Based on the results obtained, the study will also put forward design principles for VR learning environments. In this regard, the study will consider a range of design principles, including customized learning, multi-sensory effects, immersion, interactivity, 3D-dimensionality, engagement, and motivation towards the content and technology. The study outcomes emphasize the significance of identifying the appropriate technology when designing virtual learning environments. Furthermore, the study demonstrates how virtual environment affordances and equivalent scales can be used to make informed decisions. The study's overarching goal is to determine whether the affordances can inform the creation and explanation of different learning environments, the learning outcomes that different technologies enable, and how these technologies can be employed to build effective learning environments. The study will ultimately propose design principles for VR learning environments based on the results. Based on the results, the design principles may be proposed for VR learning environments. (Holopainen, et al., 2020)

3.6.1 Affordances in a Virtual Learning Environment

In a virtual learning environment (VLE), users are encouraged to actively engage with the content rather than simply receiving it passively. This can be achieved through VR glasses, as demonstrated in a recent study, and an input device, allowing users to interact with the environment and its events. The affordance approach offers a practical framework for studying how VR is integrated into daily routines and how it shapes subsequent patterns of experience. This functional approach is beneficial for defining the reality of knowledge when designing virtual environments. (Dong-Hee Shin, 2017)

3.7 Transfer of Training

Transfer of training measures how well a new skill or a skill in an unfamiliar environment can use what has been learned. A control group learns the target task in its standard setting. This group achieves criterion-level performance after a certain period. The engineering psychologist proposes a new training technique, which will shorten the time needed to learn the target task. A transfer group is given some practice with the latest training technique and then is transferred to the target task. (Witmer & Singer, 1998)

If the groups learn the target task fast enough and save time, information in the training period is carried over to the target task's effective performance or learning. We can say the transfer was positive because of this savings in the learning time. No savings have been made if the training is irrelevant to the target task due to zero transfer. Sometimes, what was learned before the target task may inhibit learning the target skill. In other words, if the groups have learned the target task faster had they had no prior training, then the transfer was negative. The transfer effectiveness ratio (TER) measures the relative efficiency of a transfer performance. The relationship between time in training and transfer effectiveness ratio is known as CTER. CTER stands for "Curriculum, Teaching, Evaluation, and Reflection." It is a framework in education that guides the development of instructional practices and curriculum design. It emphasizes the interplay between curriculum development, teaching methods, assessment strategies, and reflective practices to enhance student learning outcomes. (Witmer & Singer, 1998)

Many real-world tasks involve transferring many different components, and more produce positive rather than negative transfer. Most transfers from one similar task to another are positive. The critical design questions may be focused on those aspects of the difference between training and transfer (or old and new systems) that involve incompatible responses to inappropriate strategies. Care must ensure that a system chosen for analogy training matches the target system's deep structural characteristics, not just its surface features. (Witmer & Singer, 1998)

4 Hypotheses

The aim is to determine how this simulator/virtual reality affects a VR/simulator user and if they are firmly immersed in the virtual world. This will imply whether the better players are more suitable for anti-aircraft positions. According to (Jensen & Konradsen, 2017), VR users who use an immersive HMD (head-mounted display, see Chapter 3) are more engaged, spend more time on learning tasks, and acquire better cognitive, psychomotor, and affective skills (Radianti, Majchrzak, Fromm, & Wohlgenannt, 2019). Immersion would play a significant role here because it would bring attention and focus to the training and result in better scores. (Cummings & Bailenson, 2015) Argue that immersion is an objective measure based on the vividness offered and the extent to which a medium shuts out the outside world. (Meyer, Omdahl, & Makransky, 2018) Furthermore, this study proposes that the HMD and the intuitive interaction through head tracking, typically in immersive VR, lead to increased presence measures. (Meyer, Omdahl, & Makransky, 2018) Immersive tendency is a disposition that can predict the amount of immersion a person can experience. The findings of previous studies support this assumption. They can become involved in different tasks and situations and show a tendency to maintain focus on current activities, such as playing video, computer, or mobile games. (Witmer & Singer, 1998)

Motivation is essential for experiencing presence in a simulated environment. Flow and motivation are interconnected. Highly motivated students have better flow experiences during lectures. Personal traits like immersive tendency and motivation also impact presence and flow. (Weibel & Wissmath, 2011)

Individuals with experience playing video games may exhibit superior performance over novices in virtual reality (VR)--based simulators, albeit only regarding shooting accuracy. The level of experience significantly influences the assessment of shooting accuracy in each simulator platform; however, it appears to have no impact on decision-making performance, regardless of the type of simulator employed. (Blacker, Pettijohn, Grant, & Biggs, 2020)

Thus, the following hypotheses and sub-hypotheses are presented. The most important question this study will answer is whether training with any simulation is the best option to prepare the conscript for battle “in the real world.”

- H1: Training with a VR-based simulator evokes more immersion than training with the traditional simulator.

- H2: Training with a VR-based simulator leads to better performance and user experience in live conditions than training with the traditional simulator.
- H2.1: Several differences in usability, as perceived by the conscripts and in training performance, will be found between the two simulators (VR-based simulator compared to the traditional simulator).
- H3: Training with the classical assault rifle significantly impacts performance.
- H4: A user with high immersive tendencies becomes more absorbed in the simulation.
- H5: The VR-based simulator is better in terms of lower workload.
- H6: The simulation in virtual reality will elicit a more intense emotional response than the non-immersive display modality (traditional simulator).
- H6.1: Differences will be found at a psychological and physiological level.
- H7: A sense of presence in the immersive condition (VR-based simulation) will be more intense compared to the non-immersive condition (traditional simulator).
- H8: An individual's immersive tendency score and performance are related to a high presence in the virtual reality gunnery simulation training environment. High immersive tendencies are linked to a stronger sense of presence using the VR simulator.
- H9: Simulator sickness symptoms are anticipated to be more pronounced in the VR-based simulator compared to the traditional simulator due to immersive conflicts.

4.1 Analyzing the Hypotheses

Theories provide a framework for understanding the world and predicting how things should behave. Hypotheses are specific predictions that can be tested empirically to determine if the data supports them. Hypothesis testing with theoretical models involves using these models to develop and test specific hypotheses. Theoretical models provide a framework for understanding complex phenomena and can be used to generate predictions about how these phenomena should behave under specific conditions. Hypotheses derived from theoretical models can then be tested empirically to determine if the data supports them. This process involves collecting and analyzing data, comparing the results to the predictions of the

Theoretical model, and assessing whether the data provide evidence for or against the hypothesis. (Jhong, 2022)

4.1.1 Theoretical Models

Hypothesis testing with theoretical models is fundamental to scientific inquiry and helps advance our world understanding. This chapter outlines the process of hypothesis testing and the nature of hypotheses.

4.1.1.1 H1: Training with a VR-based simulator evokes more immersion than training with a non-VR-based simulator.

Theoretical Model: Enhancing Immersion in VR-based Training

VR-based training is more immersive than non-VR-based training due to multisensory experiences and cognitive engagement. Metrics like ITC-Sense of Presence Inventory and user feedback can measure immersion.

4.1.1.2 H2: Training with a VR-based simulator leads to better performance and user experience in live conditions than training with the old/traditional simulator.

Theoretical Model: Enhanced Performance and User Experience in VR-based Training for Real-life Situations

VR-based training leads to better performance and user experience in real-life situations due to experiential learning, transfer of knowledge, and performance metrics. User satisfaction and feedback are crucial indicators of effectiveness.

4.1.1.3 H2.1: Several differences in usability will be found between the two simulators (VR-based simulators compared to the old/traditional simulator).

Theoretical Model: Usability Differences Between VR-based and Traditional Simulators

VR-based simulators introduce unique usability factors, and researchers can systematically assess usability in both VR-based and traditional simulators to identify and quantify the specific differences between the two simulator types, informing usability improvements.

4.1.1.4 H3: Training with the classical assault rifle significantly impacts performance.

Theoretical Model: Impact of Classical Assault Rifle Training on Performance

Training with a classical assault rifle improves cognitive and motor skills development, skill acquisition, muscle memory, and weapon handling. Performance metrics post-training are indicative of the impact on performance.

4.1.1.5 H4: A user with high immersive tendencies becomes more absorbed in the simulation.

Users with high immersive tendencies achieve deeper absorption in VR simulations. Researchers can use established measures of absorption to evaluate this hypothesis.

4.1.1.6 H5: The VR-based old simulator is better in terms of lower workload.

Theoretical Model: Workload and Simulator Type

The VR-based old simulator offers advantages in workload management. Researchers can use established workload assessment tools to compare the workload experienced by users in both simulator types.

4.1.1.7 H6: The simulation in virtual reality will elicit a more intense emotional response than the non-immersive display modality (old simulator).

Theoretical Model: Emotional Responses in VR vs. Non-Immersive Display

VR simulations elicit more intense emotional responses than non-immersive display modalities. Researchers can use subjective self-report measures, physiological responses, and facial expression analysis to quantify and compare emotional responses between VR and non-immersive simulations.

4.1.1.8 H6.1: Differences will be found at a psychological and physiological level.

VR simulations induce unique psychological experiences and physiological responses. Researchers can conduct psychological assessments and physiological measurements while users interact with VR and non-immersive simulations to reveal the differences between psychological and physiological levels.

4.1.1.9 H7: A sense of presence in the immersive condition (VR-based simulation) will be more intense compared to the non-immersive condition (old simulator).

Theoretical Model: Intensity of Presence in Immersive vs. Non-Immersive Conditions

VR-based simulations provide a heightened sense of presence due to multisensory inputs, contributing to immersion. Non-immersive simulations lack the depth of immersion and sensory stimuli characteristic of VR environments.

4.1.1.10 H8: An individual's immersive tendency score and performance are related to a high presence in the virtual reality gunnery simulation training environment. High immersive tendencies are linked to a stronger sense of presence using the VR simulator.

Individuals with high immersive tendencies experience a stronger sense of presence during VR-based gunnery simulation training, improving performance outcomes. Measuring immersive tendencies and sense of presence can establish correlations between immersive tendencies, presence, and performance.

4.1.1.11 H9: Simulator sickness symptoms are anticipated to be more pronounced in the VR-based simulator compared to the traditional simulator due to immersive conflicts.

Simulator sickness symptoms are more pronounced in VR-based simulators due to conflicts between visual perception and physical senses. Symptoms include discomfort, eye strain, headache, nausea, vomiting, and disorientation. Simulator sickness is significant in simulator training, reducing trainees' time, focus, and effectiveness due to discomfort. VR sickness specifically results from mismatches between visual and vestibular signals, hindering the immersive experience and affecting user comfort in virtual reality settings. (Aaltonen, 2022)

4.1.2 Enhancing Training with VR-Based Simulators: A Theoretical Analysis

Virtual Reality (VR) has emerged as a powerful tool in education and training, offering immersive experiences that closely mimic real-world scenarios. This chapter explores three hypotheses about using VR-based simulators in training contexts, providing theoretical models to support each hypothesis.

4.1.2.1 H1: Training with a VR-based simulator evokes more immersion than training with a non-VR-based simulator.

VR-based simulators offer a heightened immersion in rough multisensory experiences, leading to cognitive engagement and interaction with the virtual world. Researchers can validate this through well-established metrics for measuring immersion.

4.1.2.2 H2: Training with a VR-based simulator leads to better performance and user experience in live conditions than training with a traditional simulator.

VR-based training facilitates knowledge transfer to real-life situations, leading to better performance and user experience. Researchers can assess performance metrics in live conditions to compare them with traditional training simulators.

4.1.2.3 H2.1: Several differences in usability will be found between the two simulators (VR-based simulators compared to the old simulator).

Both VR-based and traditional simulators have their unique usability factors. Researchers can systematically assess usability using established methods like heuristic evaluation, usability testing, and user surveys to identify and quantify the specific usability differences between the two simulator types.

4.1.2.4 H3: Training with the classical assault rifle significantly impacts performance.

Training with a classical assault rifle is foundational to skill acquisition and performance enhancement. This regimen involves honing cognitive skills such as attention, memory, and decision-making processes pertinent to firearm operation. Repeated practice sessions cultivate motor skills crucial for accuracy and swift handling during simulated or real combat situations. Post-training performance metrics, including accuracy in target shooting, speed of weapon handling, and overall task completion time, are essential benchmarks reflecting the impact of classical assault rifle training on performance.

4.1.3 Exploring the Impacts of VR-Based Simulations: Further Hypotheses and Theoretical Models

As the adoption of Virtual Reality (VR) technology continues to grow across various domains, it is crucial to investigate its multifaceted effects and advantages compared to non-immersive display modalities. In this essay, we delve into several hypotheses related to VR-based simulators, providing theoretical models to support each hypothesis and offering insights into the potential psychological and physiological differences that may arise.

4.1.3.1 H4: A user with high immersive tendencies becomes more absorbed in the simulation.

Users with high immersive tendencies will become more absorbed in VR simulations than others. Researchers can use established metrics such as the Tellegen Absorption Scale (TAS) or user feedback to measure the level of immersion experienced by users.

4.1.3.2 H5: The VR-based old simulator is better in terms of lower workload.

VR-based simulations will lower users' workload than traditional non-VR simulations. Workload refers to the cognitive and physical demands placed on users during their interactions, and established assessment tools such as the NASA Task Load Index (NASA-TLX) can be used to measure and compare workload in both simulator types. Researchers can measure workload using established assessment tools such as the NASA Task Load Index (NASA-TLX) to quantify and compare the workload experienced in both simulator types.

4.1.3.3 H6: The simulation in virtual reality will elicit a more intense emotional response than the non-immersive display modality (old simulator).

Hypothesis 6 suggests that VR simulations elicit a more intense emotional response than non-immersive display modalities. Researchers can measure emotional reactions through self-report measures, physiological responses (e.g., heart rate, skin conductance), and facial expression analysis to quantify and compare emotional reactions. Researchers can measure emotional responses through self-report measures, physiological responses (e.g., heart rate, skin conductance), and facial expression analysis to quantify and compare emotional reactions.

4.1.3.4 H6.1: Differences will be found at a psychological and physiological level.

Differences will be found at both psychological and physiological levels due to the unique psychological experiences and physiological responses induced by VR simulations. Researchers can conduct psychological assessments (e.g., cognitive tests, questionnaires) and physiological measurements (e.g., monitoring heart rate and skin conductance) to compare the results and reveal differences at both levels.

4.1.4 Exploring the Impact of Training and Immersive Environments on Performance in Military Gunnery Simulation

The efficacy of different simulation environments and training methodologies holds significant importance in military training. This study delves into the multifaceted dynamics of training with classical assault rifles, the immersion levels in varying simulator conditions, and their influence on performance outcomes. Theoretical models are employed to substantiate the hypotheses posited within this study.

4.1.4.1 H7: A sense of presence in the immersive condition (VR-based simulation) will be more intense compared to the non-immersive condition (old simulator).

The immersive quality of Virtual Reality (VR)-based simulations creates a heightened sense of presence due to realistic multisensory inputs, creating an environment that closely mimics real-world scenarios. This contrasts with non-immersive simulators, which lack the depth of immersion and sensory stimuli characteristic of VR environments. Measuring the sense of presence through validated tools and user feedback enables a quantification of immersion experienced in both VR and non-VR conditions, indicating the intensity of presence in each simulator environment.

4.1.4.2 H8: An individual's immersive tendency score and performance are related to a high presence in the virtual reality gunnery simulation training environment. High immersive tendencies are linked to a stronger sense of presence using the VR simulator.

Individuals with high immersive tendencies engage more deeply in VR-based simulations, leading to a stronger sense of presence. This improves VR-based gunnery simulation training performance due to increased focus, spatial awareness, and engagement. Empirical validation is necessary to substantiate these models within military training simulations.

4.1.5 Comparative Analysis of Simulator Sickness: Traditional vs. VR-Based Simulators

4.1.5.1 H9: Simulator sickness symptoms are anticipated to be more pronounced in the VR-based simulator compared to the traditional simulator due to immersive conflicts.

Simulator sickness and VR sickness both cause discomfort, nausea, and disorientation. Simulator sickness affects virtual reality, in-flight simulators, and video games, while VR sickness is specific to virtual reality. Simulator sickness can be triggered by motion perception and has oculomotor disturbances. Conflicts between visual and vestibular signals cause VR sickness. Understanding the differences is crucial for mitigating discomfort in immersive simulations and enhancing user experiences and training outcomes. Simulator and VR sickness have similar symptoms but differ in triggers and manifestations. Understanding these distinctions is crucial to enhancing immersive simulation user experiences and training outcomes. (Wikipedia contributors;, 2023)

In conclusion, these hypotheses and theoretical models provide valuable insights into VR-based simulations' diverse effects and advantages compared to non-immersive display modalities. Empirical research and data collection are essential to validate these models and thoroughly investigate the psychological and physiological differences that may emerge. Understanding these nuances is pivotal in harnessing the full potential of VR technology across various domains, from education to healthcare and beyond.

5 Measures

The different traits, such as immersive tendencies, technology readiness, previous experience with virtual reality and games, state, the sense of presence in the VR environment, subjective experiences, and system usability, will be measured in this research.

5.1 Presence

Presence is a subjective feeling of existing in a specific place or environment, even if someone is physically located elsewhere. In virtual environments (VEs), presence refers to the experience of a computer-generated environment instead of the physical location. To achieve presence, a combination of sensory stimulation and environmental factors must encourage involvement, immersion, and internal tendencies to become engaged. (Witmer & Singer, 1998)

A Presence Questionnaire (PQ) is a tool employed to assess the level of presence experienced by users in Virtual Environments (VEs). On the other hand, the Immersive Tendency Questionnaire (ITQ) is used to gauge the differences in individuals' proclivity to experience presence. Notably, presence in VEs does not necessarily require complete displacement of attention from the physical environment to the VE. Instead, it depends on how much users shift their attention from the physical environment to the VE. (Witmer & Singer, 1998)

The degree of engagement of users in the VE and their reported level of presence is contingent upon the extent to which they focus their attention on the VE. Selective attention is the ability to focus on selected information that is meaningful and of interest to the individual. It plays a vital role in how users report presence in a VE. (Witmer & Singer, 1998)

5.1.1 Enhancing Learning in Virtual Reality through the Sense of Presence

Virtual Reality (VR) technology is reshaping online education by immersing users in lifelike digital environments. By crafting these immersive worlds, VR fosters a sense of "presence," blurring the boundary between reality and simulation. This feeling of presence is crucial for effective learning as it enhances engagement and blurs the lines between real and virtual experiences.

Presence is a blend of physical and emotional connection to the virtual environment, enhancing learning effectiveness. Engaged learners exhibit heightened attention, improved retention, and a better grasp of spatial and contextual concepts. Through intensified emotional experiences, VR facilitates stronger connections with virtual scenarios and characters, aiding in memory retention.

Furthermore, VR serves as a valuable tool for military personnel to practice handling challenging scenarios in a safe, controlled setting. VR surpasses traditional training methods by allowing individuals to make decisions and observe outcomes. This technology has the potential to transform military training by providing realistic simulations without real-life risks, equipping personnel with essential skills for effective duty performance.

5.2 Involvement

Involvement is a psychological state experienced when an individual focuses their energy and attention on a coherent set of stimuli or activities that are meaningfully related. The level of involvement is influenced by the significance or meaning the individual attaches to the stimuli or activities they engage in. As users become more immersed in the virtual environment (VE) stimuli, they become more involved in the VE experience, increasing their sense of presence. (Witmer & Singer, 1998)

5.2.1 Training Time and Necessity of Weapon Implementation

Analyzing the time spent training with each simulator helps determine the learning efficiency with immersive and non-immersive training methods. The VR-based simulator might offer more efficient training due to its immersive nature, potentially reducing the overall training time required for proficiency. Evaluating whether each company or platoon has or requires the specific weapon being trained on provides insights into the necessity of implementing such weaponry.

Understanding the need for the weapon in different units informs decisions on resource allocation and training priorities. Describing the existing training practices and schedules offers a comprehensive view of how training is conducted, providing context for incorporating new weapon training into existing programs.

Referencing previous studies and literature on training duration and the effectiveness of VR-based versus non-immersive training in military settings can support hypotheses on training time and the necessity for weapon implementation. These theoretical models provide a framework for evaluating the performance, attitude processes, training efficiency, and necessity of implementing new weaponry in military training using both immersive and non-immersive simulators. Empirical analysis, supported by data collection and thorough literature reviews, will validate these models and hypotheses.

5.3 Immersion

The state of immersion occurs when an individual becomes fully engaged and actively participates in their surroundings. This sensation is achieved through a steady flow of stimuli and experiences the environment provides. The level of immersion is directly linked to the degree of presence felt in the virtual environment (VE). Several factors contribute to immersion, such as detachment from the physical environment, self-inclusion in the VE, natural modes of interaction and control, and perception of self-movement. The VE should effectively isolate users from their physical surroundings to enhance immersion, typically through helmet-mounted displays (HMD). Both immersion and involvement are essential to experiencing a sense of presence, which entails focusing one's attention and energy on a coherent set of VE stimuli. Presence is a subjective experience that cannot be objectively defined or measured. (Witmer & Singer, 1998)

6 Methods

The next chapter of the thesis will define the different methods and designs used to conduct the study. The first group will train for a brief period and the other for a more extended period. One of the groups will train with the classical assault rifle simulator gun and the other with the anti-aircraft VR-based machine gun simulator. The groups will also train without simulators to compare the test results.

The classical simulator is the SAAB BT 61 Gunnery Simulation, found at the Parola Armored Brigade of the Finnish Defense Forces and was developed by conscripts. The administrator of the virtual training environment of the Finnish Defense Forces and the director of the Simulator Sector / VK Department is Engineering Major Lasse Lahdenmaa.

6.1 Contributing Factors

Based on conceptual similarities, the contributing factors are divided into the following major categories: Control Factors, Sensory Factors, Distraction Factors, and Realism Factors (Table 1). Control Factors may affect immersion but not involvement, while Realism Factors should affect involvement but not immersion. Sensory and Distraction Factors might affect immersion and participation (

Table 2). (Witmer & Singer, 1998)

Table 1. Factors Hypothesized to Contribute to a Sense of Presence. (Witmer & Singer, 1998)

Major Factor Category: CF: Control Factors, SF: Sensory Factors, DF: Distraction Factors, RF: Realism Factors

Control Factors	Sensory Factors	Distraction Factors	Realism Factors
Degree of control	Sensory modality	Isolation	Scene realism
Immediacy of control	Environmental richness	Selective attention	Information consistent with the objective world
Anticipation of events	Multimodal presentation	Interface awareness	Meaningfulness of experience
Mode of control	Consistency of multimodal information		Separation anxiety/ disorientation
Physical environment modifiability	Degree of movement perception Active search		

Table 2. Presence Questionnaire Item Stems. (Witmer & Singer, 1998)

Item	Stems Factors
1. How much were you able to control events?	CF
2. How responsive was the environment to actions that you initiated (or performed)?	CF
3. How natural did your interactions with the environment seem?	CF
4. How completely were all your senses engaged?	SF
5. How much did the visual aspects of the environment involve you?	SF
6. How much did the auditory aspects of the environment involve you?	SF
7. How natural was the mechanism which controlled movement through the environment?	CF
8. How aware were you of events occurring in the real world around you?	DF
9. How aware were you of your display and control devices?	DF
10. How compelling was your sense of objects moving through space?	SF
11. How inconsistent or disconnected was the information coming from your various senses?	RF
12. How much did your experiences in the virtual environment seem consistent with your real-world experiences?	RF, CF
13. Were you able to anticipate what would happen next in response to the actions that you performed?	CF
14. How completely could you actively survey or search the environment using vision?	RF, CF, SF
15. How well could you identify sounds?	RF, SF
16. How well could you localize sounds?	RF, SF
17. How well could you actively survey or search the virtual environment using touch?	RF, SF
18. How compelling was your sense of moving around inside the virtual environment?	SF
19. How closely were you able to examine objects?	SF
20. How well could you examine objects from multiple viewpoints?	SF

Item	Stems Factors
21. How well could you move or manipulate objects in the virtual environment?	CF
22. To what degree did you feel confused or disoriented at the beginning of breaks or the end of the experimental session?	RF
23. How involved were you in the virtual environment experience?	
24. How distracting was the control mechanism?	DF
25. How much delay did you experience between your actions and expected outcomes?	CF
26. How quickly did you adjust to the virtual environment experience?	CF
27. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?	CF
28. How much did the visual display quality interfere with or distract you from performing assigned tasks or required activities?	DF
29. How much did the control devices interfere with the performance of assigned tasks or with other activities?	DF, CF
30. How well could you concentrate on the assigned tasks or required activities rather than the mechanisms used to perform those tasks or activities?	DF
31. Did you learn new techniques that enabled you to improve your performance?	CF
32. Were you involved in the experimental task to the extent that you lost track of time?	

6.1.1 Immersive Tendencies Questionnaire (ITQ)

The Immersive Tendencies Questionnaire (ITQ) measures a person's tendency to get involved or immersed in a situation. On the other hand, the Presence Questionnaire (PQ) measures the extent to which a person feels present in a virtual environment and the factors that contribute to this experience (Table 3) (Rózsa, et al., 2022).

PQ items were based on the factors derived from a review of the existing literature and created by examining various factors present in the literature. The PQ items assess both involvement and immersion, two aspects of presence. The ITQ items were designed to identify individual differences that may affect the level of presence experienced in any situation. These items evaluate an individual's tendency to become involved in everyday activities and their ability to focus on a task. The ITQ items measure both involvement and immersion. (Witmer & Singer, 1998)

Table 3. The factor structure of the 18-item version of the ITQ. (Rózsa, et al., 2022)

ITQ items	Original subscale
1. Do you quickly become deeply involved in movies or TV dramas?	Focus
2. Do you ever become so involved in a TV program or book that people have problems getting your attention?	Involvement
3. How mentally alert do you feel at present?	Focus
4. Do you ever become so involved in a movie that you are unaware of things happening around you?	Involvement
5. How frequently do you identify closely with the characters in a storyline?	Involvement
6. Do you ever become so involved in a video game that it is like you are inside the game rather than moving a joystick and watching the screen?	Games
7. How physically fit do you feel today?	Focus
8. How good are you at blocking out external distractions when involved in something?	Focus
9. While watching sports, do you ever become so involved in the game that you react as if you were one of the players?	
10. Do you ever become so involved in a daydream that you are unaware of things happening around you?	Involvement
11. Do you ever have dreams so real that you feel disoriented when you wake up? Involvement	
12. While playing sports, do you become so involved in the game that you lose track of time?	Focus
13. How well do you concentrate on enjoyable activities?	
14. How often do you play arcades or video games? (The term "often" should be taken to mean every day or every two days, on average.)	Games
15. Have you ever got excited during a chase or fight scene on TV or in the movies?	Focus
16. Have you ever been scared by something happening on a TV show or in a movie?	Involvement
17. Have you ever remained apprehensive or fearful long after watching a scary movie?	Involvement

ITQ items	Original subscale
18. Do you ever get so involved in doing something that you lose all track of time?	Focus

6.2 Subjects/Participants

The participants of this study were twenty-six conscripts recruited on-site between the ages of 19-26, out of which twenty-one were male and five were female. They served in the Parola Armored Brigade of the Finnish Defense Forces and received training in using an anti-aircraft machine gun with the help of virtual reality.

Statistics of the conscripts, such as age, gender, education, and military rank, were collected. Each subject was given a subject number, and their answers were identified only with that number and not with any other personal info, such as name.

6.3 Design

The study compares a VR-based immersive simulator and a classic non-immersive simulator. The participants were divided into two groups, and both groups were trained with simulators. The first group typically learned the target task with the classical SAAB BT 61 assault rifle simulator with an external screen. The second group trained with an anti-aircraft machine gun virtual reality-based simulator. Then, the groups switched. Both simulator games aim to shoot as many helicopters as possible in five minutes. There are three rounds, and each round has nine helicopters. Both groups' performance and attitude processes were compared, and an analysis was made. The final scoring will determine the performance of the task measurement. The factors measured were performance, scoring, sense of presence, psychological and immersive tendencies, and virtual and system usability experiences. Personality, NASA TLX factors (cognitive workload, frustration, performance, effort), and simulator sickness were also measured.

6.3.1 Data Collected

The conscripts filled in a survey at the end of each use to collect the following information:

- Background information, including:
    - Age, gender, education, military rank, military unit

  - Previous gaming experience playing, particularly VR-based and shooting games.
  - Individual differences related to personality and different media usage experiences (Gosling, Rentfrow, & Swann, 2003)
  - Immersive tendencies (Witmer & Singer, 1998)
- Regarding the simulators used during the study:
  - Performance in a simulator (helicopters shot in five minutes)
  - The NASA Task Load Index (Hart & Staveland, 1988)
  - Subjective User Experiences (Lewis, Maher, & Utesch, 2013)
  - Simulator sickness (Kallinen, 2020)
  - Presence (Witmer & Singer, 1998)

In addition, during the simulations, the following physiological signals were measured with the Empatica E4 wristband: electrical conductivity of the skin, heart rate, temperature, and acceleration of the hand movement.

7 Apparatus and Weapon Simulators

7.1 The ITKK weapon system: Anti-Aircraft Machine Gun

The 157-centimeter-long anti-aircraft machine gun 96 is belt-fed with a gas recoil principle, is a functioning automatic firearm with a 12.7 x 108 caliber, and weighs 25 kilograms. It has a belt box of fifty cartridges weighing 11.1 kilograms, an elastic cradle weighing twenty kilograms, and a base stand of twenty-four kilograms. Theoretically, the fire rate is between 700 and 800 lbs./min. In practice, it is 100 ls/min, considering belt changes.

The weapon system includes a barrel, a flexible cradle, an erectable base stand, a reflective sight, and equipment. A gun with flexible cords is attached to a perimeter platform in a vehicle. Pressing the trigger of the tuned rifle's flexible cradle releases the slide with its locks from the tuning position. The slide slides forward, taking the detached cartridge from the belt into the cartridge housing, and the buckle striker ignites the detonator. Gunpowder gas forces the slider to retreat, causing the shot cartridge to exit the cartridge housing. In the return movement, the lock pushes the new cartridge into the case. At the same time, the core pusher pushes the core out of the gun. Shooting is interrupted by releasing the cradle release handle to the front, leaving the slide in the rear position.

7.2 SAAB BT 61 Gunnery Simulation

BT 61 is a visual gunnery simulation adopted for 12.7 mm MG for indoor and outdoor use. The purpose of BT 61 is to train gunners in using the reflex sight and introduce correct lead-angle and super-elevation (Figure 1). The BT 61 is also meant for training gunners in block shooting (fire busts) and observation of tracers to make fire corrections.

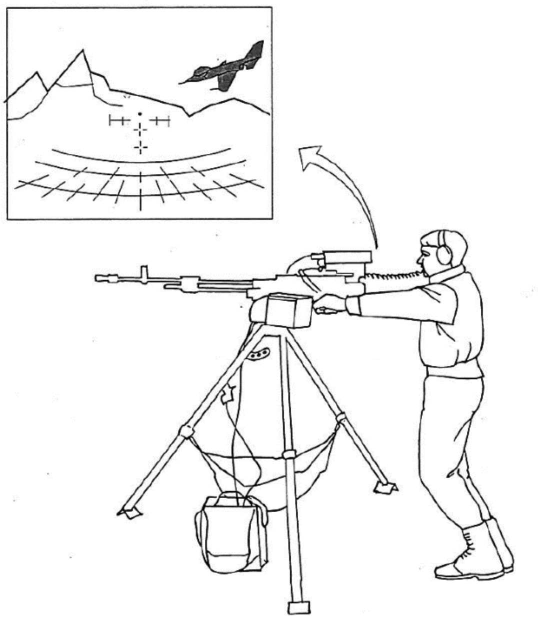

Fig 1. The SAAB BT 61 mounted on a 12.7 mm MG

Figure 1. The SAAB BT 61 is Mounted on a 12.7 mm MG.

The gunner can also be trained to estimate airborne targets' velocity and angles. The BT 61 is mounted on the actual weapon, with the BT 61 Sight Display mounted where the reflect sight is typically placed (Figure 2 and Figure 3). A sensor on the gun senses the weapon's movements and a trigger sense when the weapon is fired. During training, the gunner investigates the Sight Display instead of looking into the actual sight of the gun.

Figure 2. The Sight Display of the Old SAAB Simulator. Picture: Elias Lehtonen.

In the Sight Display, the gunner can see an image combining a photographed terrain area and different moving three-dimensional targets. Crosshairs (reticles) with range marks and other information that can be caught in the real reflex sight are also visible in the Sight Display.

Figure 3. Side Profile View of the Old SAAB Simulator (Side Profile). Picture: Elias Lehtonen.

When the gunner moves the weapon, the image in the Sight Display changes just like the actual terrain would look when looking at a real sight (Figure 4); the projectile simulation is realistic and accurate.

Figure 4. The Old SAAB Simulator Display. Picture: Elias Lehtonen.

7.3 The New VR-based Simulator

The ITKK VR simulator (Figure 11 and Figure 12) was developed mainly for the training of anti-aircraft crews during the study by Conscript Eljas Lehtonen at the Parola Armored Brigade of the Finnish Defense Forces. The simulator consists of a 12.7 ITKK 96 machine gun (Figure 10), two controllers measuring movement and angle attached to it, and VR glasses (Figure 5 and Figure 6). The simulator software is based on the Unreal Engine 4 game engine.

Figure 5. A Conscript Operating the New VR-based Simulator. Picture: Elias Lehtonen.

The simulator user sees a machine gun through the VR glasses, whose position and angle correspond to the physical machine gun (Figure 7). The simulator shoots various moving or stationary targets, such as combat helicopters and assault tanks (Figure 8 and Figure 9). One of the key objectives of the simulator is to teach its user how to aim a machine gun. (Lehtonen, 2020)

Figure 6. A Conscript Operating the New VR-based Simulator. Picture: Elias Lehtonen.

Figure 7. The New VR-based Simulator Display. Picture: Elias Lehtonen.

Figure 8. The New VR-based Simulator Display. Picture: Elias Lehtonen.

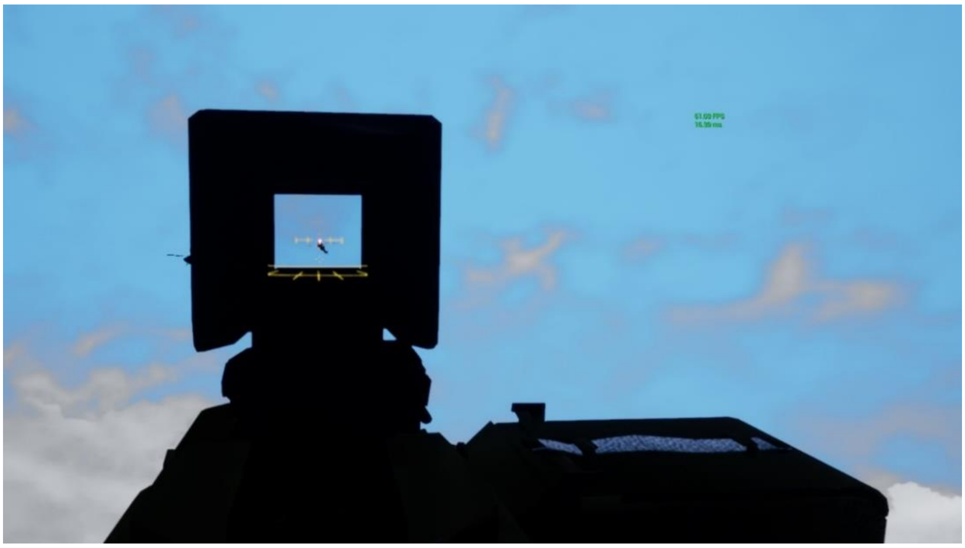

Figure 9. The New VR-based Simulator Display. Picture: Elias Lehtonen.

7.3.1 Technical Features

Below is a simulator description, along with the design constraints and characteristics. (Lahdenmaa, 2020)

Figure 10. Left Profile View of the New VR-based Simulator. Picture: Elias Lehtonen.

- Speed: variable, random
- Limited cartridge
- three laps, nine helicopters in five minutes, the last lap incomplete
- five bullets in one helicopter before dropping/being fired

- Speed min. 2500 cm / s
- Speed max. 3500 cm / s
- Spawn radius: 5
- Spawn interval: 5
- Active time: 60
- Health = 100 (5 bullets)
- Coded with Unreal Editor

Figure 11. Top View of the New VR-based Simulator with VR Glasses. Picture: Elias Lehtonen.

Figure 12. The New VR-based Simulator with VR Glasses. Picture: Elias Lehtonen.

8 Results

The following code performs a Wilcoxon signed-rank test on related samples. The test is performed on six variables: physical, temporal, performance, effort, frustration, and mental. The code also includes a nonparametric test for related samples. The results of the tests are summarized in a table that shows the Z-score and P-value for each variable.

Additionally, the code includes a usability study that compares two simulators. The study consists of nine variables: ease of use, technician support, and confidence. The study results are summarized in a table showing each variable's Z-score and P-value.

Finally, the code includes a sickness study that compares the effects of the two simulators on different symptoms, such as blurred vision, dizziness, and nausea. The study's results are summarized in a table showing each symptom's Z-score and P-value. The code comprehensively analyzes the two simulators and their effects on users.

The sense of immersion in virtual reality (VR) environments can be measured with validated tools and user feedback. This provides a way to quantify the depth of immersion in VR compared to non-immersive simulators. High immersive tendencies in individuals positively correlate with a stronger sense of presence in VR environments. This increases engagement and immersion and improves VR-based gunnery simulation training performance.

Theoretical models have been developed to outline the complex interplay between classical assault rifle training, sense of presence in immersive environments, immersive tendencies, and performance outcomes. Empirical validation is necessary to substantiate these models and hypotheses within the context of military training simulations.

8.1 Wilcoxon Signed Rank-Test

The Wilcoxon signed-rank test is a non-parametric test used to compare two related samples. It is commonly used for repeated measures designs where the same subjects are evaluated under different conditions. It is an alternative to the dependent samples t-test when its assumptions are unmet. The test is calculated by summing the positive and negative order numbers; the smaller value is the R-test variable. (Nummenmaa, 2004)

8.1.1 One-sided vs. Two-sided Tests

The p-value in a t-test is calculated based on the t ratio and degrees of freedom (sample size minus 1). A two-tailed test is assumed by default, checking for differences in both directions. The one-tail p-value is half of the two-tail value. One-tail tests focus on differences in one direction, offering more statistical power. Significance levels commonly used include < 0.05 (5%), < 0.01 (1%), and < 0.001 (0.1%). It is almost statistically significant if the significance level is less than 0.05 ($\alpha = 5\%$). < 0.01 ($\alpha = 1\%$) stands for statistically significant and <0.001 ($\alpha = 0.1\%$) is highly statistically significant.

Choosing between one- and two-tailed tests depends on the specificity of the alternative hypothesis (H_1). If H_1 is specific, a one-tail test is appropriate; if non-specific, a two-tail test is suitable. In SPSS, a two-sided test was conducted, but p-values were halved to reflect a one-sided test due to clear and concise hypotheses.

8.2 NASA TLX

Table 4. Results of the NASA-task load index

Effects (NASA TLX)	VR Simulator	Traditional Simulator	Z-score	P-value
Mental	2.5(0.68)	3.0(0.84)	2.00	0.25
Physical	1.9(0.77)	3.0(1.07)	3.56	**0.005**
Temporal	2.9(0.98)	2.8(1.02)	-0.25	0.401
Performance	2.8(1.02)	2.9(1.20)	0.34	0.369
Effort	1.9(0.77)	2.7(0.98)	3.15	**0.001**
Frustration	2.0(1.02)	2.5(1.11)	1.85	0.32

8.2.1 NASA TLX results

Adhering to hypotheses H2[1] and H3[2], the average for the VR simulator's physical, temporal, performance, effort, and frustration is 2.3, and the traditional simulator is 2.8. From these results and Table 4 above, it can be concluded that the effort (z=3.15, p=0.001) and physical (z=3.56, p=0.005) effects are statistically significant (see Chapter 8.1.1), as the p-value is less than 0.01. The rest of the impact, such as mental, temporal, performance, and frustration, is insignificant because the p-value is more than 0.05. The z-score for the NASA TLX composite is 3.204, and the p-value is .001, as seen in Table 8 the Appendix Figure 17.

[1] See (4.1.1.2)
[2] See (4.1.1.4)

8.3 Usability

Table 5. Results of the Usability Index

Usability	VR Simulator	Traditional Simulator	Z-score	P-value
Use often	3.2(1.17)	3.4(1.40)	0.72	0.237
Complicated	1.4(0.50)	1.8(0.98)	2.23	**0.013**
Easy to use	4.3(0.71)	4.0(1.10)	-1.51	0.066
Support from technician	2.0(0.82)	2.0(1.04)	-0.06	0.477
Similar properties	3.3(0.77)	3.6(9.5)	1.48	**0.07**
Inconsistencies	1.9(0.69)	1.6(0.68)	-1.75	**0.004**
Learn quickly	4.4(0.62)	4.1(0.96)	-1.20	0.115
Difficult to use	1.5(0.58)	1.8(1.06)	1.634	**0.05**
Confidence	3.4(0.92)	3.3(1.24)	-0.730	0.233
Study before use	1.6(0.62)	1.9(0.77)	1.886	**0.030**

8.3.1 Usability Results

Per the hypotheses (H2[3] and H2.1[4]), the VR simulator received statistically better evaluations in the simulator having inconsistencies (z=-1.75, p=0.004). This factor has a p-value under 0.01, as seen in Table 5, and is statistically significant. However, contrary to the hypotheses, the simulator received worse evaluations for being complicated (z=2.23, p=0.013) and requiring studying it before use (1.886=0.030). These are almost statistically significant, as they have a p-value under 0.05. The factor challenging to use (z=1.886, p=0.05) can also be considered almost statistically significant, as the p-value is precisely 0.05. There were no differences regarding these factors: easy to use (z=-1.51, p=0.066), having similar properties (z=1.48, p=0.07), having support from technicians (z=-0.06, p=0.477), used often (z=0.72, p=0.237), learning quickly (z=-1.20, p=0.115), and confidence (z=-0.730, p=0.233). These are not statistically significant, as the p-value of these factors is over 0.05.

[3] See 4.1.1.2
[4] See 4.1.1.3

8.4 Simulator Sickness

Table 6. Results of the Sickness Index

Sickness	VR Simulator	Traditional Simulator	Z-score	P-value
Blurred vision	0.4(0.83)	0.3(0.73)	-0.61	0.951
Dizziness with eyes open	0.1(0.42)	0.0(.00)	-1.342	0.180
Dizziness with eyes closed	0.0(0.19)	0.0(.00)	-1.000	0.317
Vertigo	0.0(0.19)	0.0(.00)	-1.000	0.317
Abdominal symptoms	0.0(0.19)	0.0(.00)	-1.000	0.317
Perspiration	0.1(0.31)	0.4(0.79)	2.111	0.35
Nausea	0.0(0.19)	0.0(0.19)	0.000	1.000
Difficulty concentrating	0.2(0.50)	0.1(0.36)	-0.707	0.480
Intracranial hypertension	0.2(0.48)	0.1(0.36)	-0.447	0.655
Malaise	0.4(0.50)	1.9(0.77)	4.481	**<0.001**
Fatigue	0.3(0.71)	0.3(0.65)	-0.447	0.655
Headache	0.1(0.36)	0.1(0.26)	-0.1000	0.317
Eye strain	0.4(0.74)	0.3(0.66)	-0.452	0.651
Accommodative dysfunction	0.6(0.84)	0.4(0.73)	-0.1.144	0.253

8.4.1 Simulator Sickness Results

According to Table 6 hypothesis H9[5], only malaise (z=4.481. p=<0.001) is statistically highly significant out of all these simulator sickness effects. This is because the p-value is less than 0.001.

[5] See 4.1.1.11

8.5 Presence

Table 7. Results of the Presence Index

Presence	VR Simulator	Traditional Simulator	Z-score	P-value
Controlling events	2.1(0.54)	1.8(0.80)	-2.183	**0.015**
Environment responsive to initiated actions	1.9(0.65)	1.9(0.77)	0.456	0.324
Natural interactions with the environment	1.6(0.57)	1.8(0.80)	0.951	0.086
All senses engaged	1.6(7.3)	2.0(0.90)	1.567	0.059
Visual aspects of the environment	1.6(0.74)	1.8(0.79)	1.107	0.134
Auditory aspects of the environment	1.6(0.73)	1.7(0.86)	0.214	0.416
Mechanism controlling movements	1.4(6.3)	1.7(7.1)	1.856	**0.032**
Awareness of events	1.5(0.65)	1.4(0.70)	-0.884	0.189
Awareness of display and control devices	1.9(0.73)	1.9(0.81)	-0.037	0.486
Sense of objects moving through space	1.8(0.84)	2.4(1.54)	1.941	**0.026**
Disconnected sensory information	1.4(0.78)	1.4(0.88)	0.258	0.398
Experiences in VE compared to real-life	1.1(0.86)	0.9(0.86)	-0.762	0.223
Anticipation of actions	1.4(0.83)	1.7(0.85)	1.403	0.081
Survey environment using vision	1.5(0.88)	1.5(0.84)	0.268	0.394
Identification of sounds	1.3(0.78)	1.5(0.84)	1.008	0.157
Localization of sounds	1.1(0.92)	1.4(0.79)	1.651	**0.05**
Actively survey or search VE using touch	1.5(0.75)	1.9(0.80)	1.831	**0.034**
Sense of movement inside VE	0.9(0.86)	0.9(0.82)	-0.460	0.323
Examination of objects closely	2.4(0.74)	2.3(0.80)	-1.082	0.14

Presence	VR Simulator	Traditional Simulator	Z-score	P-value
Examination of objects from multiple viewpoints	1.7(0.71)	1.60(0.87)	-0.455	0.325
Move or manipulate objects in VE	1.2(0.94)	0.9(0.88)	-1.161	0.123
Disorientation or confusion during breaks	0.8(.69)	0.9(.89)	0.292	0.385
Involvement in the VE experience	2.2(0.83)	2.0(0.77)	-1.414	0.079
Distracting control mechanism	1.6(0.68)	1.9(0.85)	1.166	0.122
Delay between actions and outcomes	0.6(0.62)	0.6(0.68)	0.000	0.5
Adjustment to VE	1.4(0.98)	2.0(1.07)	2.463	**0.007**
Proficiency in interaction with VE	1.3(1.03)	1.6(1.07)	1.485	0.069
Interference of visual display quality and distraction from tasks	1.2(0.80)	1.5(0.84)	1.662	**0.048**
Interference of control devices with the performance of tasks	2.1(1.00)	2.0(1.00)	-0.775	0.22
Concentration on tasks instead of mechanisms	2.4(0.63)	2.3(0.59)	-0.660	0.255
Learning new techniques for improved performance	2.0(0.48)	1.9(0.86)	-0.440	0.33

8.5.1 Presence Results

Per hypotheses H1, H4, H6,[6] and H6.1[7] and Table 7, the VR simulator received statistically better evaluations in adjustment to VE (z=2.463, p=0.007). It is statistically significant, as the p-value is less than 0.01. Contrary to the hypotheses, it was worse in controlling events (z=-2.183, p=0.015), sense of objects moving through space (z=1.941, p=0.026), mechanism

[6] See 4.1.1.7
[7] See 4.1.1.8

controlling movements (z=1.856, p=0.032), actively survey or search VE using touch (z=1.831, p=0.034), and interference of visual display quality and distraction from tasks (z=1.662, p=0.048) and localization of sounds (z=1.651, p=0.05). This is because the p-values were less than 0.5. These effects are statistically almost significant, as their p-values are less than 0.05. The simulators had no differences regarding these factors: delay between actions and outcomes.

8.6 Composites

Table 8. Results of the Composite Index

Composites	VR Simulator	Traditional Simulator	Z-score	P-value
Workload (NASATLX)	2.348(0.3572)	2.804(0.6070)	3.204	**<0.001**
Scoring (Usability)	75.268(10.0540)	72.857(19.4807)	-0.060	0.476
Presence (Control Factor)	19.286(4.4875)	18.607(5.4728)	-0.649	0.258
Presence (Sensory Factor)	17.000(4.9591)	18.821(5.4776)	1.523	0.064
Presence (Distraction Factor)	10.286(2.6923)	10.607(3.7052)	0.468	0.314
Presence (Realism Factor)	8.536 (3.3608)	9.464(3.7955)	1.147	0.125

8.6.1 Results of the Composites

Contrary to Hypotheses H5[8] and complying with Hypotheses H3[9], the NASA TLX workload was lower in the VR simulator than in the traditional simulator (Table 4. Results of the NASA-task load index). As can be seen from Table 8, the workload (z= 3.204, p= <0.001) composite was lower in the VR simulator than in the traditional one. It is highly statistically significant, as the p-value is less than 0.001. Per Hypotheses H7[10] and H8[11], the presence control factor was higher in the VR Simulator and almost statistically significant.

Table 9 Moreover, Table 10 it depicts the calculated mean with a 95% confidence interval of each composite for both the VR-based and traditional simulators. Confidence intervals help estimate the precision of statistics compared to the sampled population. They represent a range of values for a parameter, in this case, the mean, with a specified degree of confidence to indicate our level of certainty.

Table 9. A Comparison of the Means of All Composites for the VR-based Simulator

[8] See 4.1.1.6
[9] See 4.1.1.4
[10] See 4.1.1.9
[11] See 4.1.1.10

VR Simulator	NASA TLX	Scoring	Control Factor	Sensory Factor	Distraction Factor	Realism Factor
Mean	2,3476	75,2679	19,2857	17,0000	10,2857	8,5357
N	28	28	28	28	28	28
Std. Deviation	,35722	10,05400	4,48749	4,95909	2,69234	3,36080

Table 10. A Comparison of the Means of All Composites for the Traditional Simulator

Traditional Simulator	NASA TLX	Scoring	Control Factor	Sensory Factor	Distraction Factor	Realism Factor
Mean	2,8036	72,8571	18,6071	18,8214	10,6071	9,4643
N	28	28	28	28	28	28
Std. Deviation	,60698	19,48069	5,47276	5,47759	3,70524	3,79553

The “NASA TLX” or “Workload” composite has the lowest mean value for both simulators, and the “Scoring” composite has the lowest, according to Figure 13.

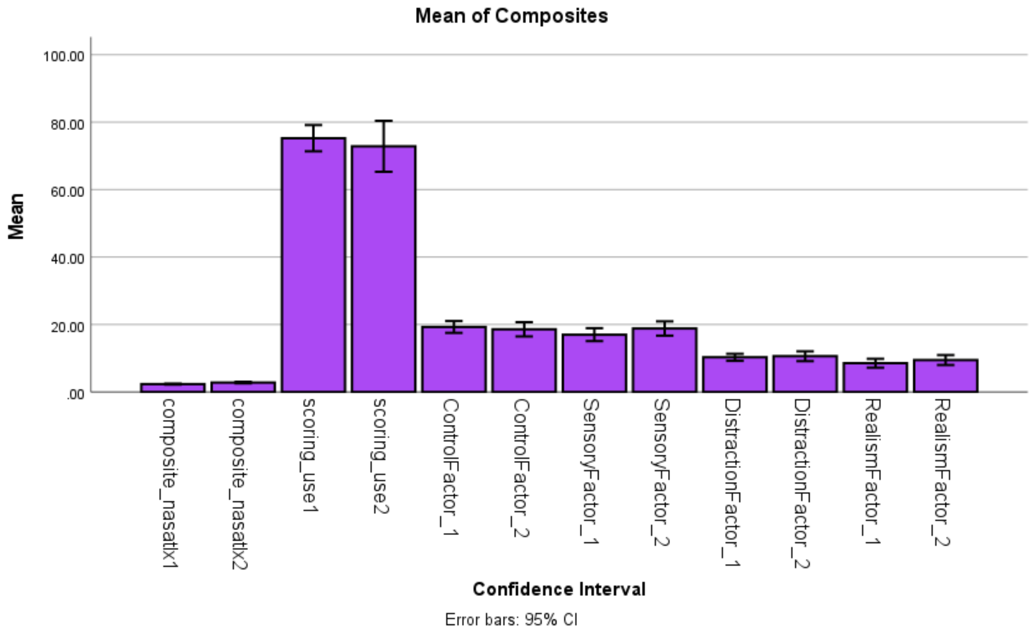

Figure 13. Bar Graph with Error Bars of the Mean of Composites of Both Simulators

8.7 Immersion

8.7.1.1 Immersion Results

Table 11. Immersive Tendencies score

Subscale	Sum	Median	Mean	Standard Deviation
Focus	439	15.68	14.5	0.09
Involvement	352	12.57	13	0.11
Games	118	4.21	4	0.17
Immersive Tendencies	909	32.46	31.5	0.37

The score for all three subscales (see Table 3. The factor structure of the 18-item version of the ITQ.) was calculated by adding the points for each question belonging to that subscale. The Immersive Tendencies score was calculated by adding the sum of all the subscales, as seen in Table 11. The results prove the point of hypothesis H4[12].

[12] See 4.1.1.5

9 Summary

Participants in the VR simulator experienced heightened control and agency within the virtual environment, facilitating seamless task navigation and object manipulation from diverse angles. However, moments of disorientation during breaks and intermittent distractions from the control mechanism detracted from immersion. Conversely, the traditional simulator offered an intuitive interface engaging multiple senses, but occasional visual display issues and task distractions affected the overall experience.

Both simulators demonstrated prompt responsiveness and device awareness but encountered challenges like disconnected sensory feedback and delays between actions and outcomes. Participants found the traditional simulator more suited for frequent use but perceived it as intricate, requiring more learning time. In contrast, the VR simulator was seen as more user-friendly despite displaying typical inconsistencies associated with VR environments, affecting factors like time estimation. Nevertheless, robust technical support optimizes user experiences in both immersive environments. Consistent with hypotheses H2 and H3 and the NASA TLX results, the VR simulator showed statistically significantly lower effort and physical effects than the traditional simulator. Mental, temporal, performance, and frustration effects did not show statistically significant differences between the two simulators.

The VR simulator received statistically better usability evaluations for having inconsistencies. However, it received worse evaluations for being complicated and requiring study before use. These usability factors were almost statistically significant. Factors like ease of use, having equivalent properties, technician support, frequency of use, quick learning, and confidence did not show statistically significant differences. Malaise was highly statistically significant out of all the simulator sickness factors, with pronounced symptoms in the VR simulator compared to the traditional one.

The present results indicate that adjustment to the virtual environment was statistically better in the VR simulator. However, controlling events and other factors related to presence were worse in the VR simulator, showing statistically significant differences. The delay between actions and outcomes did not show statistically significant differences.

Contrary to hypothesis H5, the workload composite was lower in the VR simulator, aligning with hypothesis H3. The presence control factor was higher in the VR simulator, almost statistically significant, supporting H7 and H8.

Below is a detailed breakdown analysis of how the results support the theory of the hypotheses evaluated for this study.

- H1: Training with a VR-based simulator evokes more immersion than training with the old simulator.

Supported: The VR simulator received statistically better evaluations for adjustment to the virtual environment, indicating a higher sense of immersion.

- H2: Training with a VR-based simulator leads to better performance and user experience in live conditions than training with the old/traditional simulator.

Partial Support: The VR simulator showed lower effort, physical effects, and workload, which could contribute to a better user experience. However, it also displayed challenges in usability and control, suggesting a mixed outcome.

- H2.1: Several differences in usability, as perceived by the conscripts and in training performance, will be found between the two simulators (VR-based simulator compared to the old/traditional simulator).

Supported (Partially): The VR simulator did show significant differences in usability, both positive and negative, compared to the traditional simulator.

- H3: Training with the classical assault rifle significantly impacts performance.

Supported: The workload was lower in the VR simulator, indicating a potential impact on performance.

- H4: A user with high immersive tendencies becomes more absorbed in the simulation.

Partially Supported: While adjustment to the virtual environment was better in the VR simulator, other aspects of presence showed challenges.

- H5: The VR-based simulator is better in terms of lower workload.

Supported: The workload was indeed lower in the VR simulator.

- H6: The simulation in virtual reality will elicit a more intense emotional response than the non-immersive display modality (old/traditional simulator).

Unsupported: Emotional response was not explicitly measured in the provided results.

- H6.1: Differences will be found at a psychological and physiological level.

Unsupported: The results provided did not explicitly measure psychological and physiological differences.

- H7: A sense of presence in the immersive condition (VR-based simulation) will be more intense compared to the non-immersive condition (old/traditional simulator).

Mixed Support: While adjustment to the virtual environment was better, controlling events and some aspects of presence were worse in the VR simulator.

- H8: An individual's immersive tendency score and performance are related to a high presence in the virtual reality gunnery simulation training environment. High immersive tendencies are linked to a stronger sense of presence using the VR simulator.

Unsupported: The provided results did not explicitly measure the direct relationship between immersive tendencies and presence.

- H9: Simulator sickness symptoms are anticipated to be more pronounced in the VR-based simulator compared to the traditional simulator due to immersive conflicts.

Supported: Simulator sickness symptoms, particularly malaise, were more pronounced in the VR simulator.

While some hypotheses received explicit support from the results, others showed mixed outcomes or were not fully addressed. The findings provide valuable insights into the strengths and limitations of the VR-based simulator compared to the traditional one, highlighting areas for improvement and further investigation. In summary, participants in the VR simulator found it easier to control events and manipulate objects, leading to better engagement than in real life. However, they experienced moments of disorientation and distractions from the control mechanism.

The traditional simulator engaged multiple senses effectively but had occasional visual display issues and task distractions. Both simulators shared positive traits like responsiveness and device awareness but faced challenges such as disconnected sensory feedback and action-outcome delays.

10 Discussion and Conclusion

The analysis of the results reveals nuanced insights into how the hypotheses regarding the VR-based simulator's performance align with the observed outcomes. Training with the VR-based simulator fostered a heightened sense of immersion, as evidenced by the simulator's superior evaluations for adjusting to the virtual environment. While expectations of a lower workload in the VR setting were confirmed, challenges in usability and control detracted from an unequivocally superior user experience.

Moreover, the impact of training with the simulator on performance was substantiated by a significantly reduced workload in the VR simulator. However, the link between high immersive tendencies and more robust presence in the VR environment remains inconclusive, warranting further investigation. Notably, the VR simulator's propensity to induce more pronounced simulator sickness symptoms was evident, posing a notable concern for user comfort and engagement. Although emotional responses and psychological-physiological differences were not explicitly measured, the mixed outcomes surrounding presence underscore the complexity of user experiences within immersive environments. These findings illuminate both the advantages and limitations of the VR-based simulator, offering valuable insights for refinement and future research endeavors.

In the VR simulator, participants reported an enhanced sense of control and agency within the virtual space. They adeptly navigated tasks and manipulated objects, enjoying a comprehensive understanding facilitated by the ability to examine items from various angles. Despite these advantages, participants faced occasional moments of disorientation, particularly during breaks, which interrupted their immersive experience. Furthermore, distractions from the control mechanism occasionally affected their engagement during tasks.

On the other hand, the traditional simulator offered a unique yet valuable experience, featuring an intuitive interface that engaged multiple senses through superior visual and auditory components. However, intermittent visual display issues and occasional task distractions slightly affected the overall user experience.

Both simulators demonstrated commendable traits, such as prompt responsiveness to user actions and awareness of control devices. Nonetheless, they encountered similar challenges, including disconnected sensory feedback and noticeable delays between initiating actions and observing outcomes, which impacted the seamless interaction within the simulations.

During the usability analysis, participants noted some distinctions between the two simulators. The traditional simulator appeared better suited for frequent use, although participants perceived it as more intricate, demanding additional time for comprehension and proficiency before practical use. Conversely, the VR simulator received praise for its user-friendly interface, instilling confidence in users despite marginal differences in results between the two platforms.

However, the VR simulator displayed typical inconsistencies associated with virtual reality environments. These inconsistencies, particularly in aspects like prospective time estimation sensitive to environmental factors, contributed to nuanced user experience differences observed between the simulators.

Despite these variations, robust technical support significantly contributed to both simulators' performance, ensuring smooth operation and effective troubleshooting. This underscores the importance of reliable technical assistance in optimizing user experiences within these immersive environments.

Due to its immersive visual nature, the study revealed that symptoms like blurred vision, dizziness with eyes open, and accommodative dysfunction were more prominent in the VR simulator. Conversely, perspiration and malaise were more evident in the traditional simulator. Interestingly, shared symptoms, including dizziness with eyes closed, vertigo, abdominal discomfort, nausea, fatigue, and headaches, occurred similarly, suggesting common physiological responses across different simulator types. Further investigation could unveil underlying mechanisms behind these shared symptoms in immersive environments.

In summary, participants in the VR simulator found it easier to control events and manipulate objects, leading to better engagement than in real-life scenarios. However, they encountered occasional disorientation and distractions from the control mechanism. The traditional simulator effectively engaged multiple senses but had intermittent visual display issues and occasional task distractions. Both simulators showcased positive responsiveness and device awareness traits and challenges, such as disconnected sensory feedback and action-outcome delays, impacting the overall user experience.

The study did not measure affordances as intended, which could benefit future experiments. Based on the research, VR training with augmented cues improved performance, enhanced user experience in the virtual environment, and better actual task performance. The study found that participants who underwent VR training performed better on the task than those who did not receive prior VR training. Furthermore, the VR-based simulator group with augmented cues achieved more significant gains during the task than the classic non-immersive simulator group using the SAAB BT 61 Gunnery Simulation. This supports the hypothesis that multisensory cues that are augmented and informationally enriched contribute to enhanced learning outcomes and transfer to natural environments despite reducing overall fidelity during the training phase in the virtual environment. (Cooper, et al., 2018)

Bibliography

Aaltonen, S. (2022, September 27). *Training in VR and XR: Simulator Sickness Explained (And Eliminated)*. Retrieved from Varjo Insider: https://varjo.com/vr-lab/training-in-vr-and-xr-simulator-sickness-explained-and-eliminated/

Baumann, J. (Jim Baumann). *Military applications of virtual reality*. Retrieved from Human Interface Technology Laboratory: http://www.hitl.washington.edu/research/knowledge_base/virtual-worlds/oldscivw/EVE/II.G.Military.html

Blacker, K. J., Pettijohn, K. A., Grant, R., & Biggs, A. T. (2020, April 16). *Measuring Lethal Force Performance in the Lab: The Effects of Simulator Realism and Participant Experience*. Retrieved from Sage Journals: https://journals.sagepub.com/doi/10.1177/0018720820916975

Bossard, C., Kermarrec, G., Buche, C., & Tisseau, J. (2008, September). *Transfer of learning in virtual environments: A new challenge?* Retrieved from Research Gate: https://www.researchgate.net/publication/220530372_Transfer_of_learning_in_virtual_environments_A_new_challenge

Buchanan, K. (2003, January). *Opportunity knocking: Co-opting and games.* Retrieved from Researchgate: https://www.researchgate.net/publication/285658716_Opportunity_knocking_Co-opting_and_games

Cooper N, M. F. (2021, Marrch 24). *Transfer of training—Virtual reality training with augmented multisensory cues improves user experience during training and task performance in the real world.* Retrieved from https://doi.org/10.1371/journal.

Cooper, N., Milella, F., Pinto, C., Cant, I., White, M., & Meyer, G. (2018). The effects of substitute multisensory feedback on task performance and the sense of presence in a virtual reality environment. *PLOS ONE*, 25.

Cummings, J. J., & Bailenson, J. N. (2015, May 15). How Immersive Is Enough? A Meta-Analysis of the Effect of Immersive Technology on User Presence. *Taylor & Francis Online*, pp. 272-309.

Curry, J., Price, T., & Sabin, P. (2016). *Commercial-off-the shelf-technology in UK military training. Simulation & Gaming, 47 (1).* Retrieved from Research Space: https://researchspace.bathspa.ac.uk/8332/1/8332.pdf

Dalgarno, B., & Lee, M. J. (2009, December 20). *What are the learning affordances of 3-D virtual environments?* Retrieved from Bera Journals: https://bera-journals.onlinelibrary.wiley.com/doi/10.1111/j.1467-8535.2009.01038.x

Dong-Hee Shin. (2017). *The role of affordance in the experience of virtual reality learning: Technological and affective affordances in virtual reality, Volume 34, Issue 8,.* Retrieved from Science Direct: https://www.sciencedirect.com/science/article/pii/S0736585317301223

Field, M. J. (1996). *Telemedicine: A guide to assessing telecommunications for health care.* National Academies Press.

Gibson, J. J. (1977). *The theory of affordances.* USA.

Gosling, S. D., Rentfrow, P. J., & Swann, W. B. (2003). A very brief measure of the Big-Five personality domains. . *Journal of Research in Personality, 37(6)*, 504–528.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock, & N. Meshkati, *Advances in psychology, 52. Human mental workload* (pp. 139-183). North-Holland.

Holopainen, J., Lähtevänoja, A., Mattila, O., Södervik, I., Pöyry, E., & Parvinen, P. (2020). Exploring the Learning Outcomes with Various Technologies - Proposing Design Principles for Virtual Reality Learning Environments. *Proceedings of the 53rd Hawaii International Conference on System Sciences 2020*, (pp. 1-10). Hawaii.

Jensen, L. X., & Konradsen, F. (2017). A review of the use of virtual reality head-mounted displays in education and training. *Education and Information Technologies*, 1-18.

Jhong, K. Y. (2022). *Evaluating Artificial Intelligence for Operations in the Informative Environment*. Retrieved from https://core.ac.uk/download/554154034.pdf.

Kallinen, S. R. (2020). The Finnish Defence Research Agency, Human Performance Division.

Krause, M., & Conti, A. (n.d.). *Arduino DRT.* Retrieved from Detection Response Task: https://detection-response-task.com/

Lahdenmaa, L. (2020, November). Finnish Defence Forces and the director of the Simulator Sector / VK Department. Parol Armored Brigade, Parolannumi, Finland: Finnish Defence Forces.

Lehtonen, E. (2020, December 01). Interview with the Concript Developing the VR-SImulator. (F. Bhuiyan, Interviewer)

Lewis, J., Maher, D., & Utesch, B. (2013). *UMUX-LITE: when there's no time for the SUS*. Retrieved from Researchgate: https://www.researchgate.net/publication/262344995_UMUXLITE_when_there's_no_time_for_the_SUS

Liptak, M. (2018). On Point and On Target. *Citizen Soldier*, pp. 30-31.

McCarty, W. D., Sheasby, S., Amburn, P., Stytz, M., & Switzer, C. (1993, September 30). *A Virtual Cockpit for a Distributed Interactive Simulation Environment, unpublished paper, 30 September 1993.* Air Force Institute of Technology.

Mendelsohn P. (1996). Le concept de transfert. In *Le transfert des connaissances en formation* (pp. 11-19). Lyon.

Meyer, O. A., Omdahl, M. K., & Makransky, G. (2018). *Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment.* Copenhagen: Science Direct.

Nangalia, V., Prytherch, D. R., & Smith, G. B. (2010). Health technology assessment review: Remote monitoring of vital signs - current status and future challenges. *Crit Care, vol. 14,5*.

Norman, D. A. (1999). *Affordance, conventions, and design, interactions, 6(3).*

Nummenmaa, L. (2004). *Käyttäytymistieteiden Tilastolliset Menetelmät.* Helsinki: Tammi.

Radianti, J., Majchrzak, T. A., Fromm, J., & Wohlgenannt, I. (2019). *A systematic review of immersive virtual reality applications for higher education: Design elements, lessons learned, and research agenda.* Kristiansand, Duisburg, Vaduz: Science Direct.

Roman, P., & Brown, D. (2008). Games—Just how serious are they? Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC). Kingston, Ontario, Canada.

Rózsa, S., Hargitai, R., Láng, A., Osváth, A., Hupuczi, E., Tamás, I., & Kállai, J. (2022, July 14). *Measuring Immersion, Involvement, and Attention Focusing Tendencies in the Mediated Environment: The Applicability of the Immersive Tendencies Questionnaire. Front Psychol*. Retrieved from National Library of Medicine: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9333092/

Smith, G., Parry, D., Farrell, S., Woodward, L., Prytherch, D., Harrison, S., & Hirsch, N. (2008). Validation of a novel radar-based breathing rate measurement device in human volunteers. *Resuscitation, vol. 77*, 14-15.

Technology, I. S. (1993). *Protocols for Distributed Interactive Simulation Applications.*

The Finnish Defence Forces. (2022). *Varusmies 2023 - Opas varusmiespalvelukseen valmistautuvalle.* Mikkeli: PunaMusta2022.

Velichko, M. (2019). *VR Military Training – the Next Step of Combat Evolution*. Retrieved from Jasoren: https://jasoren.com/vr-military-training-the-next-step-of-combat-evolution/

Wann, J. P., & Mon-Williams, M. (1996). What does virtual reality NEED? Human factors issues in the design of three-dimensional computer environments. *International Journal of Human–Studies*, 44, 6, 829–847.

Weibel, D., & Wissmath, B. (2011). *International Journal of Computer Games Technology, Article ID 282345*, p. 14 pages.

Wikipedia contributors;. (2023, December 26). *Virtual reality sickness*. Retrieved from Wikipedia Encyclopedia: https://en.wikipedia.org/w/index.php?title=Virtual_reality_sickness&oldid=1191548566

Witmer, B. G., & Singer, M. J. (1998, June). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators and Virtual Environments, Vol. 7, No. 3*, pp. 225-240.

Appendices

Below are bar graphs depicting the raw data results of the NASA TLX composites for both simulators generated by the SPSS statistical analysis software. 45

Appendix 1. Related-Sample Friedman's Two-Way Analysis of Variance by Ranks of NASA-TLX

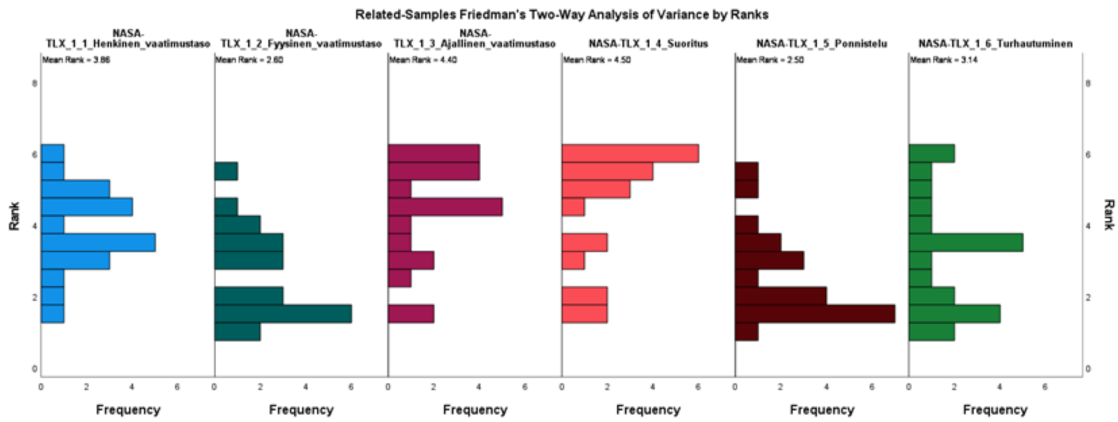

Figure 14. Two-Way Analysis of Variance by Ranks (VR-based simulator). Picture: SPSS.

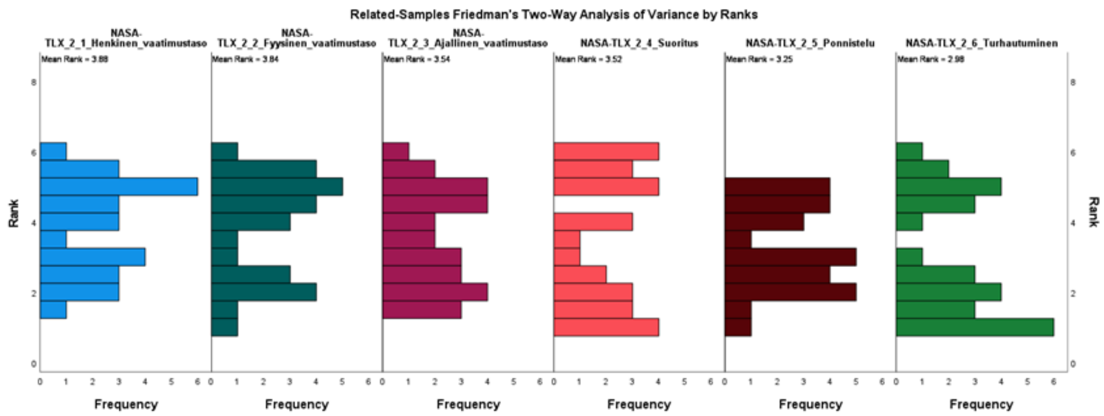

Figure 15. Two-Way Analysis of Variance by Ranks (traditional simulator). Picture: SPSS.

Appendix 2. The Continuous Field Information for the NASA-TLX composites

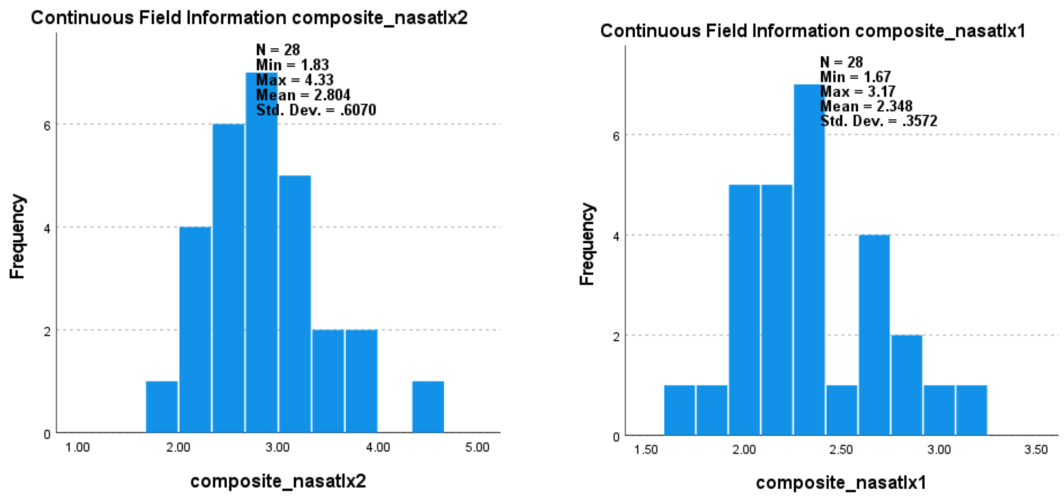

Figure 16. The frequency for the NASA-TLX composites. Picture: SPSS.

The mean, min, max, standard deviation, and frequency of the NASA-TLX composites for both the traditional (composite_nasatlx1) and VR-based (composite_nasatlx2) simulators. Below are samples of Friedman's two-way analysis of variance by ranks summary. As seen from the table below (Figure 17), the total sample size (total N) is 21; the test statistic is 27.117, the degree of freedom is 5, and the asymptotic significance or p-value is less than 0.001.

Related-Samples Friedman's Two-Way Analysis of Variance by Ranks Summary

Total N	21
Test Statistic	27.117
Degree Of Freedom	5
Asymptotic Sig.(2-sided test)	<.001

Figure 17. The Two-Way Analysis of Variance by Ranks Summary of NASA-TLX. Picture: SPSS.

Appendix 3: Code samples of the Nonparametric Tests for NASA-TLX

NASA_TLX

```
* Encoding: UTF-8.


DATASET ACTIVATE DataSet5.

*Nonparametric Tests: Related Samples.

NPTESTS

  /RELATED TEST(NASATLX_1_1_Henkinen_vaatimustaso NASATLX_2_1_Henkinen_vaatimustaso)
WILCOXON

  /MISSING SCOPE=ANALYSIS USERMISSING=EXCLUDE

  /CRITERIA ALPHA=0.05  CILEVEL=95.


*Nonparametric Tests: Related Samples.

NPTESTS

   /RELATED TEST(NASATLX_1_2_Fyysinen_vaatimustaso NASATLX_2_2_Fyysinen_vaatimustaso)
WILCOXON

  /MISSING SCOPE=ANALYSIS USERMISSING=EXCLUDE

  /CRITERIA ALPHA=0.05  CILEVEL=95.


*Nonparametric Tests: Related Samples.

NPTESTS

  /RELATED TEST(NASATLX_1_3_Ajallinen_vaatimustaso NASATLX_2_3_Ajallinen_vaatimustaso)
WILCOXON

  /MISSING SCOPE=ANALYSIS USERMISSING=EXCLUDE

  /CRITERIA ALPHA=0.05  CILEVEL=95.


*Nonparametric Tests: Related Samples.

NPTESTS

  /RELATED TEST(NASATLX_1_4_Suoritus NASATLX_2_4_Suoritus) WILCOXON

  /MISSING SCOPE=ANALYSIS USERMISSING=EXCLUDE

  /CRITERIA ALPHA=0.05  CILEVEL=95.
```

Figure 18. SPSS Coding for the NASA-TLX nonparametric tests, including datasets. Picture: SPSS.