Individual and Situational Characteristics of the Occurrence of Cyber Sickness in the Context of Virtually Supported Military Training

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Abstract

Cyber Sickness (CS) is considered a major challenge in the use of virtual reality (VR). This impacts the planned implementation of VR in the training of operational forces. The present work aimed to investigate the prevalence and onset of CS during virtually supported military training using head-mounted displays (HMDs) and explored related predictor variables. For this purpose, a quantitative cross-sectional study was conducted in which German soldiers (N = 100) were exposed to an immersive fifteen-minute VR scenario. We measured CS severity, age, heart rate (HR), and skin conductance (SC). Using newly developed categories to classify CS severity, the results showed a small prevalence (4%) of CS in the studied sample. Susceptibility to CS was the only predictor of the occurrence of CS symptoms. Accordingly, the present work provides evidence that CS may play a minor role in affecting virtually supported operational training. At the same time, the easily detectable susceptibility to CS promises rapid detection of vulnerable users. Implications and further research are discussed to detect, control, and mitigate CS.

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The possibilities of cyberspace promise to fundamentally change people's experiences and behavior (Tachi, 2016). Research in cyberpsychology has been addressing this issue for some time now, and the relevance of this field of research continues to grow (Guitton, 2022). *Virtual reality* (VR) as a tool for creating and applying *virtual training environments* (VTEs) is already frequently used in the development of virtually supported training, for example, operational military or police training (Moskaliuk et al., 2013b). Here, simulators and *head-mounted displays* (HMDs) are common systems to realize VR training safely and cost-effectively (Bertram et al., 2015; Fan & Wen, 2019; Gluck et al., 2020; Moss & Muth, 2011; Yoon et al., 2024).

It has been demonstrated that using VR for educational purposes is effective and facilitates learning transfer (Moskaliuk et al., 2013a). However, *Cyber Sickness* (CS) is known to interfere with or even prevent successful virtually supported training (Diels & Bos, 2015). Despite numerous advancements, CS remains a challenge in digital training (Geyer & Biggs, 2018), potentially jeopardizing training effectiveness. Considering the specific requirements of VTEs for military training purposes, it is important to assess the extent to which CS complicates virtually supported military training. Thus, we accompanied the testing of an HMD-based VR system for military police training in the German Federal Armed Forces (*Bundeswehr*) to observe the impairment CS produces in a sample of soldiers applying the setup for the first time in a typical training situation. Prior research provides various information regarding the occurrence of CS and the impairment it causes in different VR presentations (Sharples et al., 2008). With a postulated prevalence range of 1% to 80%

(Keshavarz et al., 2021), it remains challenging to estimate the occurrence of CS beforehand. Here, we hypothesized the prevalence of CS in soldiers is lower than 20% (Hypothesis 1).

We were also interested in assessing the SOT in our sample to evaluate the point of time in which training managers might have to expect constraints due to CS. Howarth and Hodder (2008) propose that VR users may adapt to CS-inducing simulations through habituation, a process that could be facilitated by incorporating exercises into VR training (Preciado et al., 2018). Therefore, it is important to understand how the onset of CS symptoms manifests in military personnel who are not systematically prepared for VR training purposes. We hypothesized an average SOT above 5 minutes in our sample (Hypothesis 2).

Moreover, we assessed individual, person-related factors of soldiers influencing the extent of CS in our participants. For appliance purposes, it would be vital to assess the risk factors of CS before the launch of larger virtually supported training programs. Individual user factors contribute significantly to the variables influencing CS onset (Davis et al., 2015). Among these, age and subjectively assessed susceptibility to CS are expected to vary considerably among the target population. The role and effect of age on CS sensitivity have not yet been clarified (Golding, 2006; Golding et al., 2021; Keshavarz et al., 2018). Thus, we hypothesized that *age* (Hypothesis 3.1) and *subjectively measured susceptibility to CS* (Hypothesis 3.2) can be regarded as predictors of CS.

Further, we wondered whether psychophysiological variables measurable with the VR equipment used could act as objective predictors of CS. Objective measurements, such as heart rate (HR) and skin conductance (SC), offer insights into CS onset, with prior research (Dennison, 2016; Y. Y. Kim et al., 2005) proposing a link between CS and autonomic nervous system activity. We hypothesized that HR (Hypothesis 4.1) and SC (Hypothesis 4.2) both qualify as predictors for CS.

In this study, we sought to thoroughly explore CS as a significant challenge in implementing VR for military training, with a primary emphasis on proactively managing its associated risks. By delving into the repercussions of CS, our goal was to systematically assess its impact on individuals, thus understanding its broader implications for soldiers' operational effectiveness. Consequently, we investigated CS prevalence, severity, and symptoms among military police personnel engaged in virtually supported military training, categorizing resulting impairments. Furthermore, we examined the potential predictors of age and susceptibility, as well as the psychophysiological markers HR and SC, aiming to elucidate their predictive capacity concerning CS severity.

Cyber Sickness (CS)

If the sense of balance is confused or impaired, the human body reacts with symptoms such as dizziness, nausea, vomiting, pallor, cold sweating, or increased salivation (Kennedy et al., 1993). These physical complaints are often summarized under the term *Motion Sickness* (MS; Descheneaux et al., 2020). A similar phenomenon can be observed in the context of VR use. Besides the notion of CS (Rebenitsch & Owen, 2016), terms such as *Simulator Sickness* (Kennedy et al., 1993), *VR Sickness* (Saredakis et al., 2020), or *Visually induced Motion Sickness* (Keshavarz et al., 2021) are also often used synonymously, despite definitional differences (Descheneaux et al., 2020; Stanney et al., 1997). In this study, the acronym CS is used to refer to this phenomenon.

Theories that have emerged in the context of MS research are most often used to explain the emergence of CS as well (Descheneaux et al., 2020). The Sensory-Conflict

Theory (Reason & Brand, 1975, as cited in Reason, 1978) postulates that conflicts between information processed in the vestibular system, the visual system, or the somatosensory system in humans are primarily responsible for CS. These are either conflicting information from the systems or signals that contradict those of similar situations experienced previously (Bassano et al., 2020; Mittelstädt et al., 2019). Using the associated *neural mismatch model* (Reason, 1978), this involves describing typical situations in which such conflict occurs and in which people often experience corresponding symptoms. For example, many people experience symptoms when they try to read during a car ride. Conflict occurs between two systems of the sense of balance: the vestibular system perceives the acceleration forces of the vehicle, and the visual system signals rigidity by looking at the motionless pages of the book. This ambivalent information triggers confusion in the central nervous system (Golding, 2006a). Similarly, the visual information users receive through an HMD contrasts with the often incongruous proprioceptive stimuli from the body moving little or not at all (Descheneaux et al., 2020). In this situation, visual input induces the appearance of motion, whereas the vestibular input signals stillness. This phenomenon is referred to as *vection* (Bonato et al., 2008). The conflicting information that the central nervous system is trying to integrate appears to be perceived by the body as alien and dangerous. It reacts to this in the same way as to poisoning, with disturbances of consciousness as a warning signal and nausea up to the release of the toxic substance via vomiting, as postulated in the *Poison Theory* from Treisman (1977) which is frequently used to explain the symptoms of CS (Bassano et al., 2020; Davis et al., 2015; Descheneaux et al., 2020).

Kennedy et al. (1993), in the process of creating a measurement instrument for CS, conducted several factor analyses to structure the symptomatology of CS. Finally, 16 symptoms were extracted and classified into three categories. The syndromes of nausea (e.g., nausea, sweating, difficulty concentrating, stomach awareness), oculomotor (e.g., headache, eyestrain, fatigue, blurred vision), and disorientation (e.g., dizziness, vertigo, fullness of head), along with their respective associated symptoms, form a classification of CS (Davis et al., 2015; Kennedy et al., 1993).

Even if the symptoms of CS seem quite ordinary and harmless, they can vary significantly in their severity and latency and can last up to several days in severe cases, leading to restrictions in physical functionality (LaViola, 2000). In the long term, this may lead to problems in many areas of life, for example, when training segments or professional tasks must be managed using VR in the context of advancing digitalization (Saredakis et al., 2020). In addition, CS usually occurs within several minutes, whereas MS often requires more time to occur, for example, when traveling (Y. Y. Kim et al., 2005). Eventually, this might lead to VR abandonment and endanger the introduction of new digital technologies (Nichols, 1999). Therefore, in the following, we will first shed light on how CS occurs as a problem.

Occurrence and Influences of CS

The prevalence of CS has not been clearly stated in research so far and varies across different studies and simulation types. Prior studies observed a wide range of prevalences and symptoms of CS (Drazich et al., 2023; Keshavarz et al., 2021). Cobb et al. (1999) detected a general occurrence of CS symptoms in 80% of the 200 participants, of which 5% showed very severe symptoms. Mon-Williams et al. (1993) worked with 20 participants and an exposure of 10 minutes in duration. CS symptoms such as eye strain, headache, and nausea were observed in 60%, and impaired visual acuity in 20% of participants. Strabismus was observed in as many as 95% of the participants. In another study by Regan and Price (1994), participants were exposed to 20 minutes of VR via an HMD. CS symptoms were observed in a total of 61%, mainly at the end of the exposure (45%). Once again, the problem of the ambiguous classification of CS symptomology becomes clear: Different authors report different characteristic values, which cannot be compared directly. Lampton et al. (1994) reported a drop-out rate of between 4% and 16% of participants. Sharples et al. (2008) were able to obtain comparable results in their study, concluding that HMD as a VR device elicited the highest prevalence of CS symptoms. This hypothesis was underlined by Yildirim (2020). More recently, Keshavarz et al. (2021) reported a prevalence range of 1% to 80%, depending on individual, device-related, and task factors. The more poorly the technology and tasks are adapted to the needs of the participants, the higher the prevalence of CS symptoms. Sharples et al. (2008) further hypothesized a difference in CS prevalence between soldiers and civilians. This theory arose from the observed severity of CS symptoms, which tend to be lower in military VR studies. However, Johnson (2007), in his summary of military studies investigating CS in soldiers, reported a prevalence of between 13% and 85% for VR conditions.

Davis et al. (2015) stated that people who experience CS are permanently influenced by various psychological and physical influences. They categorize these influences into individual, device-related, and task-depending factors, affecting the user’s susceptibility to CS.

Golding et al. (2021) sought to assess some individual susceptibility factors using a questionnaire, the *Visually Induced Motion Sickness Susceptibility Questionnaire - Short* (VIMSSQ-Short). It specifically asks about experiences with VR systems in childhood and adulthood that involve CS symptoms. This is to assess from the outset which individuals are likely to suffer more from CS during VR use. Further discussion of the VIMSSQ-Short is provided in the Method section.

The influence of individual factors on CS susceptibility has not been clarified yet. Some authors postulate the decrease in susceptibility with increasing age is related to the decrease in visual acuity and adaptation over the lifespan (Bermúdez Rey et al., 2016; Davis et al., 2015; Golding, 2006a; Saredakis et al., 2020). Other authors describe the highest CS susceptibility in late childhood, while it may decrease afterward due to adaptation. A higher susceptibility occurs again in late adulthood due to low experience with VR proprioception (Golding et al., 2021; Keshavarz et al., 2018) or difficulties in operating unknown VR devices (Oh & Son, 2022). Recent studies report very low levels of CS in young children (Tychsen & Foeller, 2020) and in older adults (Drazich et al., 2023). Finally, it is reported that CS susceptibility develops independently of age in general VR content (Oh & Son, 2022). Other personal dispositions like underlying illnesses may further increase the susceptibility of users (Davis et al., 2015).

Device-related factors that influence the perception of CS are described as features or defects of the VR system used. Mostly, these are discrepancies in the simulation compared to similar visual impressions outside VR. For example, the incongruence between actions and the subsequent response of the simulated world, referred to as *lags*, may lead to CS. These could be hand movements that are displayed in the simulation belatedly. Furthermore, technical malfunctions like screen flickering or bad calibration as well as the field of view and unsuitable general ergonomics are considered factors of CS (Davis et al., 2015). In addition to hardware, software components of VR also have an influence. The more detailed the simulation imitates reality, the more stimuli enable the sensory organs to orient themselves accurately (Rebenitsch & Owen, 2016).

Davis et al. (2015) mention task-depending factors as a third category. Within a VR, different simulations can be realized with different options for action. From passive viewing to unlimited interaction with the simulation, people also tend to feel varying degrees of CS.

The better they can anticipate the subsequent actions and reactions of the simulation to their actions, the better the perceptual systems involved can calibrate and avoid conflicts when integrating different stimuli (Sharples et al., 2008; Yildirim, 2020). Task-depending factors of CS are also related to device-related factors, as the level of control, among others, depends on the input devices and the simulated VTE (Davis et al., 2015).

When using VR, the *symptom onset time* (SOT; Howarth & Hodder, 2008) is also of interest. It is postulated that CS symptom severity increases with increasing exposure time (Rebenitsch & Owen, 2016). In their study, Howarth and Hodder (2008) explored adaptation to symptoms of CS using HMDs. SOT was captured by using a scale ranging from 1 (no symptoms) to 4 (moderate symptoms), which was asked of participants once a minute during the 20-minute exposure. SOT was defined as the amount of time until the point at which a participant's score shifted upward. A value of 4 resulted in drop-out. Over several measurement time points, an increasing SOT on the group average, as well as a reduction of subjectively perceived symptoms were detected. Hence, habituation has been proven depending on the number of exposure sessions. Group mean values of SOT increased from approximately 3 to 7 minutes to approximately 7 to 16 minutes (Howarth & Hodder, 2008).

Objective Measures of CS

CS may be measured via (1) observation of the syndrome in an affected person, including a descriptive assessment (Howarth & Hodder, 2008), as well as via (2) widely used self-report instruments, orally and written (Saredakis et al., 2020), or via (3) objective measures of psychophysiological parameters (Descheneaux et al., 2020). The latter involves measuring vegetative responses of the body as biosignal and then using them in numerical form as an indicator to measure a psychological construct that is thought to underlie the physical response (Pugnetti et al., 2001). The approaches of measuring CS via heart rate variability (HRV), skin conductance (SC), electroencephalogram (EEG), or blood pressure may be promising (Descheneaux et al., 2020). Y. Y. Kim et al. (2005) postulate that CS accompanies the pattern changes in the activities of the central and autonomic nervous systems.

In this regard, an indicator of CS is the heart rate (HR). It serves as an important indicator of cardiovascular activity since it signals psychophysiological changes in the state of the body reliably (Keshavarz et al., 2022). Further, some studies already indicated the association of CS symptoms with increased HR (Dennison et al., 2016; Garcia-Agundez et al., 2019; Nalivaiko et al., 2015; Y. Y. Kim et al., 2005).

Y. Y. Kim et al. (2005) also investigated the role of SC as another commonly used marker. SC is positively influenced by the presence of electrodermal activity, i.e., it measures the activity of sweat glands on the body surface, preferably in areas where they are frequently found. In recent studies on CS, the forehead and fingertips were often used for this purpose (Garcia-Agundez et al., 2019; Gavgani et al., 2017). . Sweat gland activity is stimulated by sympathetic nervous system activity, which is the overall activity of the body (Ogorevc et al., 2013). Y. Y. Kim et al. (2005) found an increase in SC with VR exposure in their study. Despite this evidence, the relationship between HR as well as SC, and the expression of CS has not been demonstrated (Dennison et al., 2016; Garcia-Agundez et al., 2019; Gavgani et al., 2017; Y. Y. Kim et al., 2005).

Research Gap and the Present Study

Sharples et al. (2008) assumed a lower incidence and symptom severity in soldiers compared to the reference group of students. Thus, it seems reasonable to examine which severity and how often CS occurs in the target population. As reported in other studies, recent and clear guideline figures on the prevalence of CS in soldiers have not yet been publicly reported (Johnson, 2007). For pragmatic reasons, we expect a prevalence of less than 20% of participants with training impairments due to CS in our sample. From an operational view, a rate above 20% would make parallel alternate VR-independent training for CS-affected individuals unviable, thus making the introduction of VR training appear unreasonable. That is why the following research question and hypotheses are investigated in this regard:

(1) In which prevalence does CS occur in VR-based military training among soldiers?

Hypothesis 1: The prevalence of CS in soldiers is lower than 20%.

Exposure time is positively related to CS symptom severity (Rebenitsch & Owen, 2016). However, users of VR may become accustomed to CS-inducing simulations through habituation (Howarth & Hodder, 2008). This could be achieved with exercises integrated into VR training (Preciado et al., 2018). Thus, it seems worth knowing how the onset of CS symptomatology shows in non-systematically prepared military forces using VR for training purposes and at which duration of VR exposure it causes impairment. We assume that a subjectively noticeable SOT of less than 5 minutes in our sample would be operationally questionable for the introduction of virtually-supported military training, even with habituation methods. The following research question and hypotheses will be investigated in this regard:

(2) At which duration of exposure to VR via HMDs do CS symptoms begin in soldiers?

Hypothesis 2: The average onset of symptomatology during VR exposure in soldiers takes more than 5 minutes.

Individual user factors account for a substantial proportion of the variables that affect CS onset (Davis et al., 2015). Two individual characteristics that are expected to vary interindividual among the target population are age and subjectively assessed susceptibility to CS of the participants. It is theorized that susceptibility to CS diminishes with advancing age, attributed to the decline in visual acuity and the process of lifelong adaptation (Bermúdez Rey et al., 2016; Davis et al., 2015; Golding, 2006a; Saredakis et al., 2020). Conversely, an opposing perspective posits that susceptibility to CS peaks during late childhood, diminishes through adaptation, and resurfaces in late adulthood owing to limited VR exposure or unfamiliarity with VR devices (Golding et al., 2021; Keshavarz et al., 2018; Oh & Son, 2022). Additionally, the susceptibility to CS exhibits considerable variability due to various individual user characteristics, as stated in the aforementioned research (Davis et al., 2015). Hence, it is imperative to investigate the susceptibility to CS within the context of virtually-supported training, considering these multifaceted factors. Thus, the following research question and hypotheses are examined in this regard:

(3) May the individual characteristics of age and susceptibility to CS predict the occurrence of CS symptoms?

Hypothesis 3.1: Age is a predictor for the occurrence of CS in soldiers.

Hypothesis 3.2: Susceptibility is a predictor for the expression of CS in soldiers.

To date, the possibilities for objective measurement of CS have not been fully explored. New VR systems, however, often offer the possibility of recording psychophysiological measures of participants during use. According to Y. Y. Kim et al. (2005), some of these measures can be used as an objective indication of the individual's perception of CS. HR is a reliable indicator of psychophysiological changes and has been associated with CS symptoms (Keshavarz et al., 2022; Dennison et al., 2016; Garcia-Agundez et al., 2019; Nalivaiko et al., 2015; Y. Y. Kim et al., 2005). Similarly, SC has also been explored in relation to CS, showing an increase with VR exposure, although the direct relationship with CS expression remains unestablished (Y. Y. Kim et al., 2005; Ogorevc et al., 2013; Dennison et al., 2016; Garcia-Agundez et al., 2019; Gavgani et al., 2017).In the present study, the HR and the SC are measured and then tested for their validity as indicating variables of the subjectively perceived CS symptomatology in our sample. The following research question and hypotheses will be investigated in this regard:

(4) Are objective, psychophysiological measures of HR and SC suitable for objective measurement of CS symptomatology?

Hypothesis 4.1: HR is a predictor for the severity of CS in soldiers.

Hypothesis 4.2: SC is a predictor for the severity of CS in soldiers.

Method

Participants and Design

The study was conducted between August and November 2022 with 100 German soldiers (7 female) at the *German Federal Armed Forces' School of Military Police and Staff Service* in Hanover, Germany. The participants were between 18 and 55 years old. The sample was drawn from the population of instructors and trainees in the military police service at this institution, which will be most involved in the implementation and use of VR in military police training in the future. An O-X-O design (Pretest-Treatment-Posttest) was applied in our study to measure CS by the SSQ.

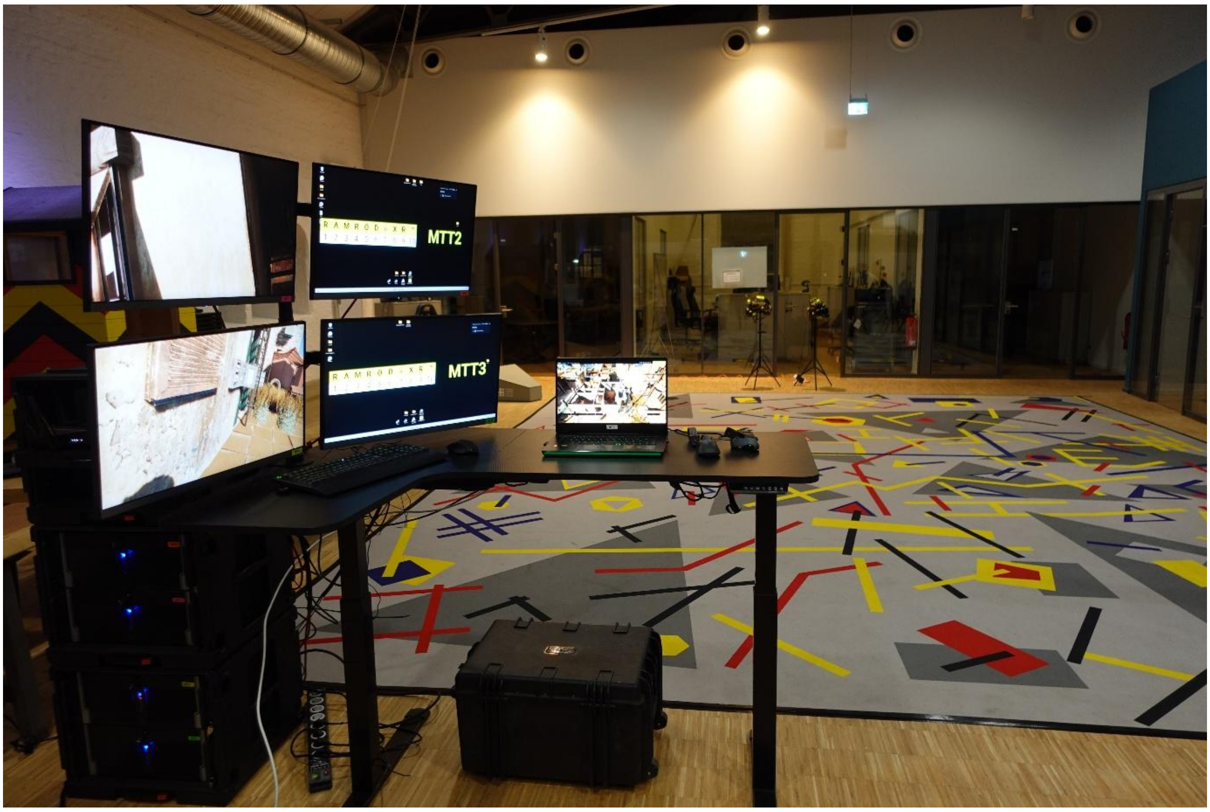
Apparatus and Measures

VTE and VR-Equipment

The VR facility was provided by the company *RAMROD XR* (n. D.), which also independently developed the VTE used. The basic hardware component utilized was the *Mobile Training Team* (MTT), a system consisting of four mainboards with individual screens, MTT 1 to 4, and a laptop for controlling the simulation, called MTT 0 (RAMROD XR, n.d.). The latter provided all control elements related to the VTE, for example, the interspersing of new layers of the scenario. MTTs 1 to 4 were mainly used to connect the personal VR equipment with the software and the sensors. Thus, up to four participants were able to train with each other at the same time. Participants stood on a custom-made carpet during exposure, which serves as a platform for the VTE simulated. This ensured that the VTE was set up the same for all participants and that the real spatial boundaries would be maintained while using the HMD. The MTTs and the carpet are shown in Figure 1.

Figure 1

MTTs and carpet set up in a training facility



Note. MTT-Mainboards on the left, under the associated screens. MTT 0-Laptop on the desk in the middle. Carpet on the ground in the middle.

The VTE consisted of a section of road and a house modeled on those in the Middle East (see Figure 2). The soldiers were able to interact with simulated people. The type of interaction with them and the team's approach in the VTE (e.g., quiet or loud infiltration) does influence the further course of the mission. Scenarios could also be run that unlocked new threats or locations (e.g., the cellar). These were not part of this exposure.

Figure 2

VTE as seen from the bird's-eye-view

Note. Road section on the right. First floor of the building with its rooms and walls in the middle, contains a hallway, a kitchen, a bathroom and a bedroom (upper side) and a living room (lower side).

Personal equipment referred to the devices that are with the person during training in the VTE. This included an HMD, a total of three sensors for measuring psychophysiological measures which are described below, and a *Real Action Marker* (RAM) in the form of an *HK G36 assault rifle*, which is used as a standard rifle in the German Federal Armed Forces (*Bundeswehr*). The controls were similar in their use and operation to that of a real weapon of the corresponding type. The *HTC VIVE Focus 3* (HTC VIVE, 2022) was used as HMD. It was attached to a light combat helmet so that a near-realistic weight rested on the soldiers' heads. The soldiers were able to communicate via built-in headphones and microphones. The *HTC VIVE Focus 3* is one of the most widely used HMDs and was developed for various uses, including training purposes. For the rest, the soldiers wore their combat uniforms during the exposition. Thus, the VTE was considered immersive in the sense of the perception of being surrounded by, included in, and able to interact with VR (Witmer & Singer, 1998).

Subjective Measures

The *Simulator Sickness Questionnaire* (SSQ; Kennedy et al., 1993) was applied in a translated German research version to measure CS (two of the authors and one colleague, see Appendix B). It is the oldest and most widely used instrument for assessing CS (Descheneaux et al., 2020). It consisted of sixteen items, each of which asked about a typical symptom of CS. The participants were asked to self-assess their feelings on a scale from 0 (symptom not perceived at all) to 3 (symptom strongly perceived). For scoring, scale scores were summed by cluster and multiplied by a scaling factor. For the total CS score, all item scores were summed and multiplied by another scaling factor. The scaling factor for nausea was 9.54, for oculomotor symptoms 7.58, for disorientation 13.92, and for the total CS score 3.74. Thus, across all scales, there were minimum values of 0 and maximum values of 200.34 for nausea, 159.18 for oculomotor symptoms, 292.32 for disorientation, and 235.62 for the total CS score, called SSQ-TS (Y. Y. Kim et al., 2005). The higher the scores, the higher the subjective perception of CS or individual symptom clusters, respectively (Bimberg et al., 2020). In this study, the SSQ was assessed once before and once after exposure, as recommended by Bimberg et al. (2020). For a practice-oriented classification of the measured symptom severities about the scenario run by the participants, new value categories were postulated to correctly assess the actual limitations due to CS in the use of HMDs. The degrees of impairment played a role: a score of 0 described no impairment (category 0), scores >0 to 25 resulted in insignificant impairment (category 1), scores >25 to 50 resulted in mild impairment (category 2), scores >50 to 75 resulted in moderate impairment (category 3), scores >75 to 150 resulted in severe impairment (category 4), and with scores >150 to 235.62 (category 5) participants were classified as incapable of exposure because impairment at such high levels would most likely be accompanied by severe physical symptoms due to CS symptomatology.

Susceptibility to CS was assessed using the VIMSSQ-Short (Golding et al., 2021) in a translated German research version (two of the authors and one colleague, see Appendix C). It originated from the *Motion Sickness Susceptibility Questionnaire* (MSSQ) by Golding (2006b), which was originally developed to measure susceptibility to MS. The VIMSSQ-Short was developed on this basis specifically to measure CS susceptibility and therefore primarily inquired about negative experiences during adulthood while using VR. Thus, possible electronic devices, for example, smartphones, tablets, and HMDs, were mentioned first, before the participants were asked whether they experienced any of the five CS symptoms while using them. The symptoms were nausea, headache, fatigue, dizziness, and eyestrain. On a scale of 0 (Never) to 3 (Often), participants then rated how often they experienced these symptoms while using these electronic devices. The second part asked about possible triggered avoidance behaviors related to the electronic devices that may have caused the symptoms. If this was answered as true, participants were asked to name these devices in question 3. Total values from 0 to 18 were possible, which were obtained by adding up the item values. A classification of the individual sum values was made in the present work as follows: A value of 0 corresponded to no susceptibility, a value between 1 and 6 to low susceptibility, between 7 and 12 to medium susceptibility, and between 13 and 18 to high susceptibility. The VIMSSQ-Short was also used to collect data about the age of the participants in years.

The SOT was measured by interviewing the participants during the exposure. The methodology of Howarth and Hodder (2008) was followed. In their study, participants rated their symptoms during exposure on levels 1 (no symptoms), 2 (mild symptoms), 3 (moderately severe symptoms), and 4 (severe symptoms). SOT was defined as the elapsed time by which there is a change on the four-point scale, most commonly from 1 to 2. For simplicity, participants were instructed to self-report if they felt a change in symptom severity. The participants in question were then asked every minute to which extent they felt that their symptoms had changed. For the time before the first report and for the participants who gave no information about the change in their symptoms, the value 0 was entered. The participants were briefed on this procedure before the start of the exposure.

Objective Measurements

A total of three sensors were used to measure the psychophysiological measures. The Polar Verity Sense (Polar, n.d.), one on every forearm, was used to record HR. HR was recorded in the unit of measure *heartbeats per minute* (bpm). To record SC, the Shimmer 3 sensor (Shimmer Research Ltd., 2022) was attached to the hand, always against handedness. Using finger cuffs around the index and ring fingers, SC was measured directly on the hands. Skin resistance was measured in kiloohms (kΩ) and was then converted to microsiemens (µS), as the unit of measurement for SC, using the formula $\mu S = (1/k\Omega) \times 1000$. The sensors were connected to the related MTT via Bluetooth signal for data transmission. After the survey was completed, data were analyzed with Microsoft Excel (Version 2021) and IBM SPSS Statistics (Version 27).

Procedure

The procedure is based on the outline by Nichols et al. (2000), who described an optimal CS investigation in four phases: (1) pre-exposure questionnaires, (2) pre-exposure assessment, (3) observation during exposure, and (4) post-exposure assessment. The following description of this study is divided into these four phases.

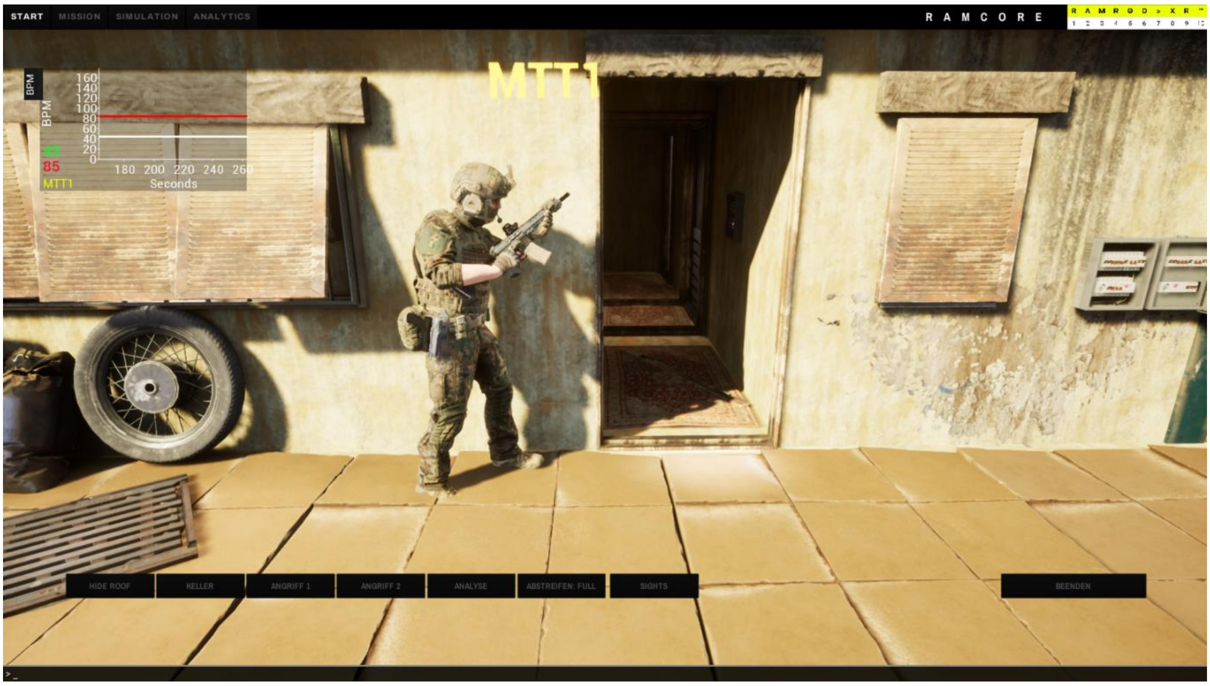
(1) Upon the arrival of the participants, they were first briefed on the procedures of the study, instructed, and asked to give informed consent (see Appendix A). All the participant's questions were answered. Thus, it was first described to them that they were undergoing a psychological examination and that its purpose was to find out more about the effect of VR-assisted training on military personnel. The process described hereafter was briefly explained to them. A total time of approximately 60 minutes was stated. Participants were told that they could stop the exposure at any time, without giving any reason or consequences, and that they were able to contact the test administration at any time for this or any other questions or comments. Lastly, it was asked whether everyone felt ready for the investigation described; if anyone did not, the participant was dismissed.

(2) Following consent, two questionnaires were administered to the participants. First, the pre-exposure SSQ was completed, followed by the VIMSSQ. In preparation, this was followed by attaching the sensors and picking up the equipment, consisting of a combat helmet (instead of HMD) and RAM. A baseline survey was then conducted in which the participants moved around the room for three minutes with full equipment. During this, they walked at a walking pace, squatted, stretched, and generally maintained a mild level of arousal comparable to that in the exposure. HR and SC were already recorded during this process. The combat helmet was then removed, and the HMD-helmet was put on. Participants were aligned at the starting point of the VTE, and they were instructed to report immediately if CS symptoms occurred. Subsequently, the simulation was started.

(3) Subsequently, after the start of the VR simulation, the infiltration and investigation of the presented VTE was conducted with up to four participants each. In the VTE, they were also able to see each other simulated in their combat uniforms and realistically observe their own and others' movements (Figure 3). In the ego-perspective, the soldiers started on the road section (see Figure 2 and 4) and then went into the hallway of the building to secure all the rooms leading off from there. The latter were first to be secured and then thoroughly inspected. Thereby, the encountered rooms and places should be exactly memorized, thus higher attention should be paid to the perception of the VTE all the time. Simulated persons appearing were to be considered hostile but could be forced to surrender by shining the flashlight attached to the simulated weapon. The soldiers had to be careful, as the simulated people were often hiding, and the rooms were darkened. Further, emphasis was placed on ensuring that participants were aware of their condition concerning possible CS symptoms. After 15 minutes, the exposure period ended. There was no use of the weapons through firing.

Figure 3

Soldier in the VTE viewed from the Third-Person-Perspective



Note. The avatar of a participant stands in the center, to the left of the entrance door to the building. The rooms to be infiltrated lead off from there.

Figure 4

Operator View in the VTE from the First-Person-Perspective

Note. A scene taken from the First-Person-Perspective on the road section near the building. Participants were able to see and use the simulated weapon and their hands on it realistically.

(4) Post-exposure SSQ was presented immediately afterward. The equipment was then cleaned and stored ready for use. Once all test booklets were checked for completeness the final instruction followed. First, participants were asked if they all felt that they were still well and fit for duty. If not, it was pointed out that the participants should continue to pay attention to the symptoms in the follow-up and that they should immediately consult a doctor in case of any disabilities. Further questions and comments could be asked directly or via the contact data provided. Finally, the participants were thanked and dismissed.

Results

Firstly, we performed descriptive analysis to examine CS as well as SOT in the sample. A regression model was set up hereafter to analyze the relationship between the predictor variables and CS.

Descriptive Analysis

As Bimberg et al. (2020) recommended, mean, standard deviation, and median are reported for the SSQ measures. In the pre-exposure measurement, the mean of the SSQ-TS was 7.11 with a standard deviation of 10.23. The median was 3.74. Among the subscales, the oculomotor symptom cluster had the highest value of $M = 7.27$, moreover, a standard deviation of 10.44. The median was 0. This was followed by disorientation with $M = 5.43$, $SD = 10.45$ as well as a median of 0, nausea with $M = 5.15$, $SD = 10.28$, and a median of 0. Maximum values of 41.14 for the SSQ-TS, 57.24 for the nausea subscale, 45.48 for the oculomotor subscale, and 41.76 for the disorientation subscale were shown in the SSQ scores. In the post-exposure measure, SSQ-TS showed a mean of 18.63, $SD = 15.06$ with a median of 14.96. Disorientation showed the highest mean score of 20.88, also $SD = 21.45$, and a median of 13.92. This was followed by nausea with $M = 15.65$, $SD = 14.19$, and a median of 14.96, and the oculomotor cluster with $M = 14.40$, $SD = 14.75$, and a median of 7.58. Maximum values of 74.80 for SSQ-TS, 85.86 for nausea, 68.22 for oculomotor, and 83.25 for disorientation were observed. Thus, the mean differences between pre- and post-measurements, with descending magnitude, were 15.45 for disorientation, 11.52 for SSQ-TS, 10.50 for nausea, and 7.31 for oculomotor. SSQ-TS scores were significantly higher after exposure, $t(99) = 7.67$, $p = < .001$, as well as nausea scores ($t(99) = 7.33$, $p = < .001$), oculomotor scores ($t(99) = 5.06$, $p = < .001$) and disorientation scores ($t(99) = 7.07$, $p = < .001$). Cronbach's alpha values are reported between .94 and .95 for SSQ-TS, between .84 and .85 for nausea, between .91 and .93 for oculomotor, and between .88 and .90 for disorientation (Sevinc & Berkman, 2020).

In the present study, we used the self-defined SSQ value categories described above. Category 1 (Insignificant impairments) occurred most frequently, with *N* = 63, corresponding to a relative frequency of 63%. Category 2 (Slight impairments) was found in *N* = 26 participants, corresponding to a relative frequency of 26%. Category 0 (No impairments) was found in 7 participants or 7% of the sample. 4 Participants were assigned to Category 3 (Moderate impairments), or 4% of the sample. Therefore, 4 participants (4%) were found to be affected by CS according to our categorization.

Another purpose of this survey was to use oral feedback from the participants about the SOT of CS symptoms to determine the average exposure time that soldiers spent in VTE before they became aware of the symptoms. In our study, none of the participants took the opportunity to verbally communicate regarding perceived CS. Thus, each participant was registered with a score of 0. Further discussion is provided below.

The participants in the sample had a mean age of 34.35 years, with a standard deviation of 8.91 and a median of 34. They were between 18 and 55 years old. VIMSSQ susceptibility scores yielded *M* = 2.15, *SD* = 3.25, and *Mdn* = 1.5, with a minimum of 0, and a maximum of 11. Golding et al. (2021) reported a Cronbach's Alpha of .84 for the questionnaire.

HR and SC were collected continuously during the 3-minute baseline condition and the 15-minute VR exposure. The values were then averaged for the baseline survey and intervals of one minute each at the beginning (minutes 0 to 1), middle (minutes 7 to 8), and end (minutes 14 to 15) of the exposure (Y. Y. Kim et al., 2005). The mean values are shown along with their standard deviations in Table 1. Within the baseline survey, the sample has an

HR of 94.12 bpm on average with a standard deviation of 11.03. In the first minute of exposure (minutes 0-1), measures were *M* = 89.92 bpm, *SD* = 14.34, in the middle minute (minutes 7-8), measures were *M* = 93.73 bpm, *SD* = 14.90, in the last minute (minutes 14-15), measures were *M* = 99.20 bpm, *SD* = 16.52, and over the entire exposure period, measures were *M* = 94.05 bpm, *SD* = 14.03. A repeated measures ANOVA determined that mean bpm levels showed a statistically significant difference between measurement time points, $F(2, 198) = 53.53$, $p < .001$, partial $\eta^2 = .35$. Bonferroni-adjusted post-hoc analysis revealed significantly ($p < .001$) higher bpm scores in the middle minute than in the first minute ($M_{\text{Diff}} = 3.81$, 95%-CI[2.19, 5.43]) as well as significantly ($p < .001$) higher bpm scores in the last minute than in the middle minute ($M_{\text{Diff}} = 5.48$, 95%-CI[3.19, 7.76]). For SC, a mean of 3.52 µS with a standard deviation of 9.21 was obtained in the baseline survey. Furthermore, the first minute of exposure showed *M* = 3.23 µS, *SD* = 2.72, the middle minute *M* = 3.64 µS, *SD* = 2.97, the last minute *M* = 3.99 µS, *SD* = 2.99, and over the entire exposure *M* = 3.64 µS, *SD* = 2.89 were measured. A repeated measures ANOVA determined that mean µS levels showed a statistically significant difference between measurement time points, $F(2, 198) = 38.89$, $p < .001$, partial $\eta^2 = .28$. Bonferroni-adjusted post-hoc analysis revealed significantly ($p < .001$) higher µS scores in the middle minute than in the first minute ($M_{\text{Diff}} = .41$, 95%-CI[.22, .60]) as well as significantly ($p < .001$) higher µS scores in the last minute than in the middle minute ($M_{\text{Diff}} = .35$, 95%-CI[.17, .54]).

Table 1

Mean values (standard deviations) of HR and SC measurements of all participants over different measurement time points during exposure

Variable	Baseline	0-1 min	7-8 min	14-15 min	Total
HR (bpm)	94.12	89.92	93.73	99.20	94.05
	(11.03)	(14.34)	(14.90)	(16.52)	(14.03)
SC (μS)	3.52	3.23	3.64	3.99	3.64
	(9.21)	(2.72)	(2.97)	(2.99)	(2.89)

Note. Baseline = Measured over three minutes before exposure, 0-1 min = First minute of exposure, 7-8 min = Middle minute of exposure, 14-15 min = Last minute of exposure, Total = Mean over entire exposure. Total *N* = 100.

Regression Model of CS

First, a regression model was calculated using the Enter method (Liu et al., 2003). For the regression model, the variables age, susceptibility, the mean values of HR during exposure, and the mean values of SC during exposure were set as predictors, and the SSQ-TS in the post-measurement (perceived CS) was set as the statistical criterion. The regression model was calculated after testing the statistical requirements (Olsen et al., 2020). Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern (Age, Tolerance = .90, VIF = 1.11; Susceptibility, Tolerance = .99, VIF = 1.01; HR, Tolerance = .95, VIF = 1.05; SC, Tolerance = .94, VIF = 1.07). Normal distribution of the residuals could not be assumed, so bootstrapping with 10,000 samples was used (Hesterberg, 2011). The regression model showed an *R-value* of .44, which, according to Cohen's (1988) conventions, indicated a medium correlation between actual and predicted values. The model showed a medium fit with R^2 = .2 (corrected R^2 = .16) (Cohen, 1988). Significance testing by

ANOVA with a significance level of .50 revealed that the predictors age, susceptibility, mean HR, and mean SC significantly predicted the statistical criterion Post-SSQ-TS, F (4,91) = 5.58, p < .001 (Hoyt et al., 2006). Table 2 shows the coefficients of this model. Susceptibility was identified as a predictor of CS symptom expression, β = .42, t (91) = 4.40, p < .001. Age was not significantly identified as a predictor, β = .08, t (91) = .81, p = .445, as well as HR, β = .05, t (91) = .53, p = .584, and SC, β = -.13, t (91) = -1.36, p = .176 (Hoyt et al., 2006).

Table 2

Coefficients of the regression model of this study

				Bootstrap[a]			
						BCa 95% CI	
Predictor	*b*	β	*t*	*SE*	*p*	*LL*	*UL*
Constant	6.13		.56	10.86	.573	-15.09	28.25
Age	.12	.08	.82	.15	.445	-.18	.40
Susceptibility	2.25	.42	4.4	.49	< .001	1.36	3.34
SC	-.66	-.13	-1.36	.43	.116	-1.47	.20
HR	.05	.05	.53	.09	.584	-.12	.21

Note. BCa = bias-corrected and accelerated; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.
a Unless stated otherwise, bootstrap results are based on 10,000 bootstrap samples.

Next, another regression model was calculated using a stepwise selection of predictors (Liu et al., 2003), inclusion criterion probability of F value ≤ .05, and an exclusion criterion was F probability ≥ .1. The model indicated the inclusion of the variable susceptibility, with β = .41, t (91) = 4.34, p < .001. The variables age with β = .10, t (91) = 1.08, p = .281, HR with β = .04, *t* (91) = .39, *p* = .697, and SC with β = -.15, *t* (91) = -1.63, *p* = .11 were excluded. The regression model shows an *R-value* of .41, which is indicative of a medium correlation between actual and predicted values according to the conventions of Cohen (1988). The model has a medium fit with R^2 = .17 (corrected R^2 = .16) (Cohen, 1988). Significance testing by ANOVA with a significance level of .05 revealed that the predictors age, susceptibility, mean HR, and mean SC statistically significantly predicted criterion CS, F (1,94) = 18.83, $p < .001$ (Hoyt et al., 2006).

Discussion

The purpose of this study was to examine the prevalence, severity, and SOT of CS in a sample of military police personnel undergoing virtually supported military training and to classify the impairments this imposes on training. In addition, possible predictors (age and susceptibility to CS) and psychophysiological markers (HR and SC) were examined in terms of their predictive power regarding CS. A prevalence lower than 20% was suspected. Across all SSQ scales, results showed an increase in averaged CS symptom severity over all times of measurement. Some participants also reported CS symptoms during pre-measurement, which may be attributed to their individual physical complaints (Bimberg et al., 2020). Also, in 10 cases, there was less CS reported in post-measures than in pre-measures. The VIMSSQ scores of these participants were lower on average (*M* = 1.70, *SE* = 1.50, *Mdn* = 1, Min = 0, Max = 4) compared to the total sample. We assume that the participants already showed up for the examination with CS-like symptoms that dissipated during the exposure. Because no positive effect of VR exposure was assumed, no negative effect was postulated instead (Bimberg et al., 2020). Usually, VR exposure came with higher CS values.

To capture prevalence, a separate category system of SSQ-TS at post-measurement was developed for this study. The goal was to assess the degree to which military VR training was impaired by the CS that occurred. Based on our comprehensive literature review, we discovered a notable absence of any publicly accessible classification system for SSQ-TS values to assess the degree of impairment resulting from varying levels of CS severity. Following the observations in the sample, categories to classify this impairment were arranged. The participants were found to report CS symptom severities qualifying for categories 0 (no impairment) to 3 (moderate impairment). While 93% of the participants reported CS symptoms, 4% of the sample were assigned to category 3 and therefore labeled as affected symptoms. None of the participants orally reported problems related to subjective CS symptomatology, so it was presumed that consciously noticeable issues in our sample would have become apparent only when SSQ-TS exceeded 50. Therefore, as previously formulated in Hypothesis 1.1, less than 20% prevalence is assumed for soldiers. Additionally, we assume that no VR-independent alternate training is needed for the 4% of CS-affected participants. An SSQ-TS exceeding 50 seems quite high in comparison with the value ranges according to Stanney et al. (1997) but indicates that CS encompasses higher value ranges than the phenomenon Simulator Sickness postulated by these authors. This assumption is supported by the fact that HMDs tend to elicit higher CS scores than the flight simulators used by Stanney et al. (1997) (Rebenitsch & Owen, 2016). Categories 4 (severe impairment) and 5 (exposure inability) were not found in the sample. Scores of >75 to 150 would be estimated to cause severe impairments in participants that would impede VR training, which did not happen during this study. Further, SSQ-TS of 75 or higher are reported rarely and under impeding circumstances (Kennedy et al., 1993; So et al., 2001). However, it is assumed that hereafter, further exposure to VR would seem impossible and an endeavor would thus have to be aborted. Such high values in a realistic VTE also seem unlikely (Rebenitsch & Owen, 2016).

The significant role of locomotion is discussed as a reason for the low reported symptom severities (Sharples et al., 2008; Yildirim, 2020). Less triggered sensory conflicts between visual and vestibular systems due to the modern, ergonomically adapted equipment used in this study may also be a contributing factor (Rebenitsch & Owen, 2016; Saredakis et al., 2020). In addition, the participants' task of closely examining VTE may have been a distraction from symptoms (Tärning et al., 2019; Zhou et al., 2019).

Despite partly elevated SSQ scores at pre- and post-measurement, none of the participants verbally expressed complaints regarding symptom severity during SOT measures. Several reasons may be suggested as to why the participants only noticed the symptoms afterward. Firstly, the onset of CS symptoms is usually not salient to those affected (Kim & Park, 2020). Moreover, the participants felt pressure in the context of social inhibition (Guerin, 1989). The above-mentioned influences due to a high level of locomotion (Sharples et al., 2008; Yildirim, 2020) and distraction (Tärning et al., 2019; Zhou et al., 2019) might play a role as well. Increased stress levels associated with exposure to VR, often for the first time, may have negatively impacted the functioning of participants' working memory during exposure (Luers et al., 2020). In addition, the increased arousal may have enhanced the sensation of CS during pre- and post-measurement via SSQ (H. Kim et al., 2021). Further, priming of CS-like perceptions by the items of SSQ (Bimberg et al., 2020), expectancy effects triggered by the questionnaire (Keshavarz & Hecht, 2011) as well as the possible VR aftereffect, which describes the continuity of felt CS symptoms after VR exposure might have been involved in completing the SSQ (Descheneaux et al., 2020; Mittelstädt et al., 2019). In Hypothesis 2.1, an average SOT of more than 5 minutes was expected. Determining a SOT is not reasonably feasible in this study due to the lack of measured data. Further research should consider the discussed constraints above in doing so.

As suggested predictors of CS, age (Hypothesis 3.1), and susceptibility as measured by the VIMSSQ-Short (Hypothesis 3.2), together with the psychophysiological markers HR (Hypothesis 4.1) and SC (Hypothesis 4.2) were tested in two regression models. Both achieved a medium fit (Cohen, 1988) and were considered statistically significant. However, only susceptibility was recognized as a significant predictor. These findings may underline the research of Golding et al. (2021), according to which the VIMSSQ-Short reliably measures susceptibility to CS. However, as noted by the authors, the true proportions of variance explained are likely to be smaller due to expected multicollinearity between predictors (Golding et al., 2021).

The results of the regression models exclude age as a useful predictor in our study. While some researchers postulate that CS symptomatology decreases over the life course (Davis et al., 2015), others observed that susceptibility to CS develops in middle childhood, then decreases, and again shows an increase in late adulthood (Golding et al., 2021). Neither theory could be affirmed here, thus the direction of the association between these two variables remains unresolved. It is possible that sex, as another influential variable, may have reduced the contribution of age to variance resolution (Descheneaux et al., 2020; Golding et. al, 2021).

HR and SC were not identified as valid predictors in this study either. A continuous increase in mean scores could be detected across the different measurement time points, but this increase was not due to changes in CS symptomatology in this study. Lower mean values in the first minute of exposure compared with the baseline measurement can be explained by a drop in physical activity when attaching the equipment, comparable to the research of Y. Y.

Kim et al. (2005). In addition, it should be noted that attention related to the VTE, which Dennison et al. (2016) postulated as the basis of increased SC values during VR exposure, affects psychophysiological markers. Also, stress, which may result from exposure to the most unfamiliar environment and provide increased values in HR and SC because of the psychophysiological response, may play a role here (Dennison et al., 2016). Presumably, the movement of the participants also increased the values of the psychophysiological variables (Dirican & Göktürk, 2011).

Overall, of the predictors hypothesized at the outset, only susceptibility measured by VIMSSQ-Short was significant. The relationship between the variables age, HR, and SC remains controversial; however, based on previous and future research, a relationship with CS may be assumed and therefore should be investigated further (Y. Y. Kim et al., 2005; Saredakis et al., 2020).

Limitations

Regarding the findings on CS prevalence, the main challenge was the lack of categories to classify SSQ-TS values (Bimberg et al., 2020). The categorization proposed in this paper represents a way of looking at it, intending to capture the impairment level perceived by the participants. Thus, the categorization chosen here may have limited generalizability, also considering the postulate that soldiers are considered less susceptible to CS (Sharples et al., 2008; Stanney et al., 1997).

Moreover, it should be noted that the SSQ is a subjective measure that merely reflects the participant's assessment of their symptomatology, so statements about the actual extent of CS in this survey cannot be made accurately (Bimberg et al., 2020). Additionally, the pre-measurement could prime participants' perception of CS symptoms through its items and thus somatically activate them. At the same time, the numerical comparability of the subscales among each other is challenging, because the weighting factors in the score calculation are different between SSQ scales. Some items are also used among two scales (Bimberg et al., 2020). Developing new categories to classify the SSQ-TS or exploring other measures of CS, particularly with the use of HMDs, are areas of future research in this area (Bimberg et al., 2020; Stanney et al., 1997). Likewise, it should be emphasized that susceptibility to CS in this study is a subjective measure and was investigated based on the VIMMSQ-Short, which was developed recently and is recommended for use in combination with the MSSQ (Golding, 2006b; Golding et al., 2021). The latter was not implemented in this study for the convenience of the survey.

The SOT investigation proceeded with an unexpectedly low response. The simplification of the original survey procedure by Keshavarz and Hecht (2011) and Howarth and Hodder (2008), which required participants to self-report noticing symptoms in this study, may have reduced the response. It may be necessary to address the participants personally and regularly during exposure (Howarth & Hodder, 2008; Keshavarz & Hecht, 2011).

Moreover, the psychophysiological measurements used in this study have limitations. Psychophysiological measures are also influenced by variables other than CS, such as arousal caused by movement or excitement as well as inter-individual differences between the arousal levels of users (Dennison et al., 2016; Martin et al., 2020). In addition, delayed onset effects can be expected with CS, which in some cases may not be detected in a study (Martin et al., 2020; Mittelstädt et al., 2019). In the future, it should therefore be checked how psychophysiological measures can be accurately assigned to other physical arousal or CS symptoms (Descheneaux et al., 2020).

For technical reasons, our measurement of SC took place on the fingers, but is recommended on the forehead in the context of CS measures (Dennison et al., 2016). Garcia-Agundez et al. (2019) conclude from their study that the broadest possible combination of the various psychophysiological markers increases the accuracy of the CS measurement. The increase in SC values can be related to a higher CS symptom severity.

Further impairments of the investigation were found in the use of VR technology, which was procured specifically for this purpose and is still in a state of development. Associated with this, there were technical malfunctions during the survey, which in some cases led to longer waiting times or connection errors between the sensors and the computer systems. Therefore, some measures needed to be repeated. This is particularly common with new types of VR systems (Ivanova, 2018).

Furthermore, multicollinearity between potential predictors and their variance decomposition should be explicitly inspected while performing the statistical examinations (Grömping, 2007), thus finding parameters discriminatively attributable to CS symptomatology (Descheneaux et al., 2020). A follow-up survey would have been useful to provide information on the existence of a VR aftereffect (Y. Y. Kim et al., 2005; Mittelstädt et al., 2019).

Conclusion and Future Research

This study aimed to investigate the occurrence and progression of CS in soldiers and to examine the variables of age, susceptibility to CS, HR, and SC for their suitability as predictors of CS. A new categorization system was postulated for application to the SSQ-TS to assess impairment by CS. A CS prevalence of 4% was found. SOT was not determined. Only susceptibility was significantly categorized as a predictor of CS in the regression model setup. Further research on the occurrence, progression, and possible predictor variables of CS, particularly in the context of operational forces, is needed to better assess the problems caused by CS in VR-based military training (Descheneaux et al., 2020; Rebenitsch & Owen, 2016; Saredakis et al., 2020).

Results imply that CS-related symptoms are common but rarely result in impairment. The introduction of VR into military training is possible and advisable judging by its potential for long-term effort savings and financial relief (Bertram et al., 2015). Especially the utilization of VR in military training offers notable advantages, including enhanced flexibility in scenario creation and utilization of VTEs across diverse training situations. This approach comes with high acquisition costs but also yields substantial cost savings by reducing expenses associated with construction, travel, and catering for exercises, particularly when conducted at home training locations (Gluck et al., 2020). In addition, the effectiveness of virtual-assisted military training for team-based tasks has already been demonstrated in various training situations (Yoon et al., 2024). Through positive feedback and constructive criticism from the soldiers in our study, we perceived them to be open to technology and receptive to VR. Impressions of joy about otherwise rare training opportunities and improved teamwork (Yoon et al., 2024) were also noticeable in our study.

In the future, CS scores may be predicted in part by measured vulnerability, so potential problems may be anticipated through appropriate questionnaires or oral questioning (Golding et al., 2021).As technology advances, VR technologies will be continuously improved ergonomically (Diels & Bos, 2015), while task-related factors must be based on real-world operational situations in the context of military training (Moskaliuk et al., 2013b). Individual factors can only be influenced to a limited extent, yet the symptomatology of CS can be contained by various measures that still need to be evaluated in the future. Examples include medications such as antihistamines, habituation to VR scenarios, or vestibular stimulation (Descheneaux et al., 2020; Howarth & Hodder, 2008). Thus, the implementation of VR in everyday operational training seems to be possible, as some pilot projects have already demonstrated (Moskaliuk et al., 2013b). The present study underlines this view from the CS research perspective.

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Appendix A: Information und Einwilligungserklärung

Zum wissenschaftlichen Forschungsvorhaben *Das Auftreten des Phänomens Cyber Sickness unter Berücksichtigung von Personen- und situativen Merkmalen im Rahmen virtuell unterstützter Ausbildung im Feldjägerwesen der Bundeswehr*

Werte Kameradinnen und Kameraden,

vielen Dank für Ihre Bereitschaft zur Teilnahme an der wissenschaftlichen Untersuchung zur Überprüfung der Eignung von Virtual Reality (VR) zur Nutzung in der Ausbildung von Stresskompetenzen. Im nachfolgenden erhalten Sie Informationen zum Inhalt und Ablauf sowie zu den erhobenen Daten.

Inhalt des Forschungsvorhabens. Die nachfolgende wissenschaftliche Untersuchung dient der Feststellung, in welchem Maße körperliche Reaktionen auf die Anwendung von VR das Ausbildungsgeschehen beeinträchtigen können. Das Ziel ist es, VR in die Ausbildung im FJgWesBw zu implementieren. Dazu soll mittels dieser Untersuchung festgestellt werden, ob sich VR dafür eignet.

Ablauf. Die Teilnahme an dieser wissenschaftlichen Untersuchung wird etwa eine Stunde in Anspruch nehmen. Zunächst werden Sie in die Untersuchung eingewiesen und befüllen anschließend Fragebögen zu Ihrem derzeitigen Befinden. Dann begehen Sie mittels der zur Verfügung gestellten VR-Ausrüstung ein virtuelles Gebäude, welches Sie näher untersuchen sollen. *Es handelt sich um eine reine Beobachtung. Der Einsatz der Waffe ist hierbei ausdrücklich verboten.* Im Anschluss wird erneut ein Fragebogen zu Ihrem Befinden ausgefüllt. Es können Ihnen während der Untersuchung keine Schäden entstehen. Im Anschluss folgen weitere Fragen zur Ihrer Techniknutzung, Ihrem Befinden und die Möglichkeit Fragen zu stellen.

Freiwilligkeit. Ihre Teilnahme an der wissenschaftlichen Untersuchung ist freiwillig. Es steht Ihnen zu jedem Zeitpunkt frei, Ihre Teilnahme abzubrechen, ohne Angabe von Gründen und ohne dass Ihnen daraus Nachteile entstehen.

Datenerhebung. Im Rahmen der Untersuchung werden folgende Daten von Ihnen erhoben: Soziodemografische Daten (Alter, Geschlecht) und Projektdaten, d.h. im Rahmen des wissenschaftlichen Forschungsvorhabens erhobene Informationen zu Ihrer Person, wie insbesondere: Ausgefüllte Fragebögen und Biofeedbackdaten (Herzrate, Hautleitfähigkeit).

Anonymität. Die Teilnahme an dieser Erhebung ist ohne Nennung Ihres Namens möglich. Ihre Daten werden vertraulich behandelt und in anonymisierter Form erhoben und verarbeitet, das heißt ein Rückschluss auf Ihre Person ist nicht möglich. Demographische Angaben wie Alter oder Geschlecht lassen keinen Rückschluss auf Ihre Person zu. Es wird keinen anderen Personen als denen mit der Durchführung und Auswertung der Erhebung Betrauten, Zugang zu diesen Daten gewährt. Die Originaldaten werden gemäß Leitlinien mindestens 1 Jahr lang aufbewahrt und anschließend gelöscht, soweit gesetzliche Vorgaben nicht längere Archivierungspflichten vorsehen.

Die Ergebnisse der Erhebung werden im Rahmen einer Bachelor-Arbeit an der Helmut-Schmidt-Universität/Universität der Bundeswehr Hamburg veröffentlicht. Dies geschieht ebenfalls in anonymisierter Form, das heißt ohne dass Ihre Daten Ihrer Person zugeordnet werden können. Die erhobenen Daten werden ausschließlich für wissenschaftliche Zwecke genutzt.

Information und Einwilligungserklärung

Zum wissenschaftlichen Forschungsvorhaben *Das Auftreten des Phänomens Cyber Sickness unter Berücksichtigung von Personen- und situativen Merkmalen im Rahmen virtuell unterstützter Ausbildung im Feldjägerwesen der Bundeswehr*

Einwilligungserklärung zur Teilnahme

Ich habe die schriftliche Information zu dem wissenschaftlichen Forschungsvorhaben erhalten. Ich habe beide Dokumente gelesen und verstanden. Ich wurde ausführlich - mündlich und schriftlich - über das Ziel und den Verlauf des Forschungsvorhabens sowie meine Rechte und Pflichten informiert. Ich hatte Gelegenheit Fragen zu stellen. Diese wurden zufriedenstellend und vollständig beantwortet.

Ich erkläre hiermit meine Teilnahme an dem wissenschaftlichen Forschungsvorhaben. Ich wurde darauf hingewiesen, dass meine Teilnahme an dem Forschungsvorhaben freiwillig ist und dass ich das Recht habe, dieses jederzeit ohne Angaben von Gründen zu beenden, ohne dass mir dadurch Nachteile entstehen.

Ja **Nein**

Datenschutzrechtliche Einwilligungserklärung

Ich bin mit der Verarbeitung und Speicherung meiner erhobenen personenbezogenen Projektdaten, nämlich der Fragebogendaten und der eigenen Herzfrequenz sowie der Hautleitfähigkeit, im Rahmen des wissenschaftlichen Forschungsvorhabens einverstanden, insbesondere auch mit der Verarbeitung besonderer Kategorien meiner personenbezogenen Daten, hier Gesundheitsdaten.

Ja **Nein**

____

Vor- und Nachname

____________________ ________________________

Ort und Datum Unterschrift

Nummer/ID____________________ Datum______________

Appendix B: Fragebogen zur Simulatorkrankheit

In Anlehnung an: Kennedy, Lane, Berbaum & Lilienthal (1993)[1]

Auftrag: Kreisen Sie ein, in welchem Ausmaß Sie jedes der aufgelisteten Symptome **gerade jetzt** beeinträchtigt.

1. Allgemeines Unwohlsein	Gar nicht	Leicht	Mittelmäßig	Stark
2. Erschöpfung	Gar nicht	Leicht	Mittelmäßig	Stark
3. Kopfschmerzen	Gar nicht	Leicht	Mittelmäßig	Stark
4. Überanstrengung der Augen	Gar nicht	Leicht	Mittelmäßig	Stark
5. Schwierigkeiten beim Scharfsehen	Gar nicht	Leicht	Mittelmäßig	Stark
6. Erhöhter Speichelfluss	Gar nicht	Leicht	Mittelmäßig	Stark
7. Schwitzen	Gar nicht	Leicht	Mittelmäßig	Stark
8. Übelkeit	Gar nicht	Leicht	Mittelmäßig	Stark
9. Konzentrationsschwierigkeiten	Gar nicht	Leicht	Mittelmäßig	Stark
10. Kopfdruck	Gar nicht	Leicht	Mittelmäßig	Stark
11. Verschwommene Sicht	Gar nicht	Leicht	Mittelmäßig	Stark
12. Schwindel (Augen geöffnet)	Gar nicht	Leicht	Mittelmäßig	Stark
13. Schwindel (Augen geschlossen)	Gar nicht	Leicht	Mittelmäßig	Stark
14. Gleichgewichtsstörungen	Gar nicht	Leicht	Mittelmäßig	Stark
15. Mulmiges Gefühl im Bauch	Gar nicht	Leicht	Mittelmäßig	Stark
16. Aufstoßen	Gar nicht	Leicht	Mittelmäßig	Stark

[1] Kennedy, R.S., Lane, N.E., Berbaum, K.S., & Lilienthal, M.G. (1993). Simulator Sickness Questionnaire: An enhanced method for quantifying simulator sickness. *International Journal of Aviation Psychology, 3(3)*, 203-220. https://www.doi.org/10.1207/s15327108ijap0303_3

Nummer/ID_______________ Datum _______________

Appendix C: Fragebogen zur Anfälligkeit für visuell-induzierte Bewegungskrankheit (VIMSSQ) (Golding et al., 2021)[2]

1. Bitte geben Sie Ihr Alter an: ………. Jahre

2. Bitte geben Sie Ihr Geschlecht an: [ ] männlich [ ] weiblich [ ] divers
   1111111111111111111111 1 2 3

Dieser Fragebogen ist konzipiert worden, um Ihre Erfahrungen mit verschiedenen Arten von elektronischen Anzeigen und Unterhaltungsgeräten zu erfassen, und, ob diese bei Ihnen jemals Unwohlsein ausgelöst haben.

Zu den angesprochenen Geräten/Einrichtungen gehören:

- **Kinoleinwände**
- **Filme/ Videospiele auf Smartphones & Tablets**
- **Videospiele**
- **VR-Brillen**
- **Große elektronische Werbetafeln mit sich bewegenden Animationen**
- **Elektronische Informationstafeln**

Bitte beantworten Sie diese Fragen immer nur in Bezug auf Ihre Erfahrungen als Erwachsener (nach dem 18. Geburtstag)!

1. Wie häufig haben Sie jedes der folgenden Symptome bei Verwendung eines der oben genannten Geräte oder Einrichtungen verspürt? Bitte umkreisen Sie Ihre Antworten.

Übelkeit	Nie	Selten	Manchmal	Oft
Kopfschmerzen	Nie	Selten	Manchmal	Oft
Schwindel	Nie	Selten	Manchmal	Oft
Erschöpfung	Nie	Selten	Manchmal	Oft
Überanstrengung der Augen	Nie	Selten	Manchmal	Oft
	0	1	2	3

2. Hat Sie eines dieser Symptome jemals davor gestoppt, eines dieser Geräte oder Einrichtungen zu verwenden oder dazu gebracht, diese zu vermeiden? Bitte umkreisen Sie Ihre Antwort.

Nie	Selten	Manchmal	Oft
0	1	2	3

3. Sollten Sie jemals durch Symptome gestoppt oder zur Vermeidung gebracht worden sein, bitte listen Sie im Folgenden die Geräte und Einrichtungen auf, bei denen dies passiert ist (Hinweis: Von der Auflistung oben):

[2] Golding, J. F., Rafiq, A. & Keshavarz, B. (2021). Predicting Individual Susceptibility to Visually Induced Motion Sickness by Questionnaire. *Frontiers in Virtual Reality, 2*, Artikel 576871. https://doi.org/10.3389/frvir.2021.576871