# Cybersickness Considerations for Curricula using Virtual Reality Training Systems

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## ABSTRACT

Virtual Reality (VR) training systems are reaching higher levels of maturity and military schoolhouses are moving forward with incorporation into classroom training and curricula. VR training is proven effective at teaching general and specific skills receiving significant enthusiasm and support through many hype cycles over the years. Unfortunately, with current VR technology users still experience adverse effects, such as cybersickness (CyS) and follow-on aftereffects. The work quantifying effective durations and cumulative timeframes for use is not accessible, mature or effective for curriculum managers (CM) who are not VR experts. VR technology manufacturer's guidelines for usage protocols are appropriate for personal usage but are not sufficient to meet the duty of care required for a classroom environment. This lack of fidelity and maturity prevents effective Head Mounted Display (HMD) VR training system integration into curricula.

This paper surveyed the currently available literature on CyS and VR, identifying existing recommendations for HMD VR incorporation within military classrooms. The paper provides a basic understanding of VR's hype, CyS, the limits of VR and VR usage protocols. Current VR usage protocols are examined, and the US Navy's Visual Identification VR training system is provided as a representative example.

VR can become one of the most useful training mediums for the military, but clear guidance is required for effective employment. VR is a still new technology which lacks clear direction on effective use. This is especially true in the provision of usage protocols and strategies to minimize the effects of CyS and prevent the loss of training effectiveness. The paper recommends a threefold approach for military leadership to provide the required governance to maximize VR training effectiveness.

## ABOUT THE AUTHOR

**LCDR Nicholas Adriaanse** is a Royal Australian Navy (RAN) Weapons Electrical Engineer Officer acting in a Personnel Exchange Program (PEP) Position at NSWCDD DNA. He joined the RAN as an Undergraduate Entry Officer and has served on HMA Ships *Toowoomba*, *ANZAC* and *Brisbane*. His significant engineering experience includes involvement in *ANZAC*'s Anti-Ship Missile Defence Upgrade and *Brisbane's* Post Delivery Upgrade. This is his second US tour after completing a PEP role at AEGIS Training and Readiness Center (ATRC) as the Class Advisor, Course Supervisor, Instructor and Laboratory Lead for the United States Navy (USN) Combat System Officer Baseline 7 course. In *Brisbane* he participated in live missile firing, Exercises Pacific Vanguard and Talisman Sabre and a regional presence deployment. At NSWCDD DNA he is the Product Owner for Visual Identification Virtual Reality (VIDVR), a billet that involves significant stakeholder liaison and project management activities.

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## INTRODUCTION

Militaries around the world use simulation in a multitude of areas, and many newer systems utilize head-mounted displays (HMDs). This paper grew out of the experiences of the author overseeing the development of just such a system. As a Royal Australian Navy officer working on exchange with the U.S. Navy, the author is assigned as product owner for the Visual Identification Virtual Reality (VIDVR) Training System Software. The Naval Surface Warfare Center Dahlgren Division Dam Neck Activity (NSWCDD DNA) built VIDVR to support training for Navy boatswain's mates (BM) at Naval Training Command (NTC) Great Lakes, Chicago. VIDVR provides early-career sailors with experiences they could not be exposed to in the real world due to constraints such as safety, cost or availability, which were the drivers in deciding to develop the training system in virtual reality (VR). VIDVR is shown in Figure 1.

**Figure 1. User's View in VIDVR Helm Trainer**

There are many advantages to conducting training virtually including repetition of tasks and repositioning of students in world without wasting training time (Johnson, 2005). VR training comes with significant cost savings, as an example DDG hourly cost is approximately $10,000 based on an $80 million/year operating cost per vessel (Congressional Budget Office, 2021). this generates a cost saving ratio of approximately 80:1 assuming a VIDVR experience cost of $121/hour, based on 2 E-6 personnel acting as instructors (DoD, 2022) (Office of Secretary of Defense, 2023) and ignoring initial acquisition costs of both systems. This estimate also ignores the availability disparity although it is acknowledged that simulators can be between 10 to 30 times more available than the platform they simulate significantly increasing the value of a virtual system (Johnson, 2005).

VIDVR allows students to participate in individual training utilizing virtual environments (VEs), realistic tools, hand tracking, voice recognition and text-to-speech technology to provide repeatable, evaluable scenarios. Each scenario progresses at the student's own pace with instructor oversight. This repeatable and cost-effective training aims to improve performance of bridge teams throughout the fleet by increasing initial training quality and achieving standardization of training outcomes. Students have access to training on Port Lookout, Starboard Lookout, Aft Lookout, Helm and Lee Helm watchstations. Each of the watchstations provides students with tools that will be available to them in real-world, shipboard environments, as well as helpful training aids and scenario interactions. The scenarios focus on familiarization, training students to correctly use watchstation tools and communicate using appropriate vernacular and syntax. Using VIDVR, schoolhouses are able to realize a 1:15 student instructor ratio and significantly increase repetitions of practice over previous methods, with reduced instructional time.

As product owner, the author facilitated a pilot program to introduce VIDVR to two courses: Surface Professional Apprentice Career Track (SPACT) and BM A School. Although NTC was enthusiastic about the use of VIDVR, on completion of the pilot, trainers at NTC requested guidance on integration of the VIDVR training system into the curriculum, specifically requesting answers to these questions:

1. How long can students use VR per session?
2. How many VR sessions per day can students do safely?
3. How many VR sessions are needed to achieve the learning outcomes (LOs)?

When the author reviewed the available material regarding classroom VR training systems and cybersickness (CyS), he realized there are still challenges to be addressed by the published science regarding these questions. In fact, attempting to answer the trainers' questions provided few solid answers but rather raised significantly more questions:

1. What is the maximum individual period that students can be engaged in a head-mounted display (HMD) VR session before adverse effects are experienced?
2. What is the maximum individual period that students can be engaged in an HMD VR session before learning deteriorates? Is this the same period as the above question?
3. What is the maximum cumulative period of HMD VR sessions over a defined period of time that students can engage in before adverse effects are experienced?
4. What is the maximum cumulative period of HMD VR sessions over a defined period of time that students can engage in before learning deteriorates? Is this the same period as the above question?
5. How long are adverse effects expected to last?
6. What percentage of students are likely to be unable to participate in VR due to severe reactions?
7. Are there potential mitigations which reduce the likelihood of adverse effects occurring for students that can be applied in a classroom environment or through curriculum controls, such as habituation, breaks, etc.?
8. How should the trainers treat and manage adverse effects in students?
9. What is the minimum period of exposure for learning to occur? (curriculum specific)
10. What is the minimum number of sessions required for all curriculum specific LOs to be achieved?
11. How are the impacts of VR on students measured?
12. How are LOs achieved for students that are unable to participate in VR?

Some of these questions were answered, but for many, it became clear that the answers were too often "It depends," or "There are no clear answers available in the scientific literature."

## PURPOSE OF THIS PAPER

The purpose of this paper is to two-fold. The first is to provide curriculum managers (CM) tasked with integrating classroom-based HMD VR simulators into a curriculum with clear answers to the above questions where they exist. These personnel are often chosen for their abilities in warfighting specialties as opposed to their technical or scientific knowledge, and should not be expected to be able to  The second purpose of this paper is to list the questions where no clear answers exist, so that research agencies can conduct research to answer them.

## BACKGROUND

### Virtual Reality

VR is a technology that immerses users in digitally simulated environments, providing multisensory experiences which can replicate the real world or simulate places where humans cannot reach, such as fantasy worlds or the interiors of equipment. Users perceive a 3D visual environment often provided by an HMD, but can be provided by other display technologies, such as large screens, as in a CAVE Automatic Virtual Environment. Normally, clues for other senses, such as sounds via earphones/speakers or tactile effects via haptic devices, are provided. Many VR environments react to user's motions as the interface, attempting to make the experience as natural as possible and provide a feeling of presence within the simulation. This immersion is often achieved by tracking head and body movements, adjusting visual display in real-time, and incorporating hand controllers or other input devices for user engagement. Because of the unparalleled level of engagement provided, a wide range of fields utilize VR applications, including gaming, education, training, healthcare, architecture, and entertainment. For more information on VR, (Lowood, 2023) provides a good primer.

### Hype Cycles

Most technologies experience a roller coaster of peaks and valleys as they progress from being the "latest and greatest" technology through maturation to wide usage and eventually reach the point where many people don't remember life without it. Desktop and laptop computers, smart phones, the internet, VHS/DVD/Blu-ray players, and many other technologies, have all progressed to near ubiquity. However, many promising technologies never reach this point.

A good way to examine this rise and fall of technological advancements is through the Gartner Hype Cycle. Every year since 1995, Gartner Consulting has published a report that lists between ten and thirty technologies that it believes are important to its clients and where these technologies are on the development cycle (Gartner Consulting, 2023). Their cycle, which is outlined in Figure 2, shows where Gartner feels each technology is and estimates how long it will be until the technology reaches the fifth and final stage of the curve, "the Plateau of Productivity." The stages, along with a brief stage description, are listed in Table 1.

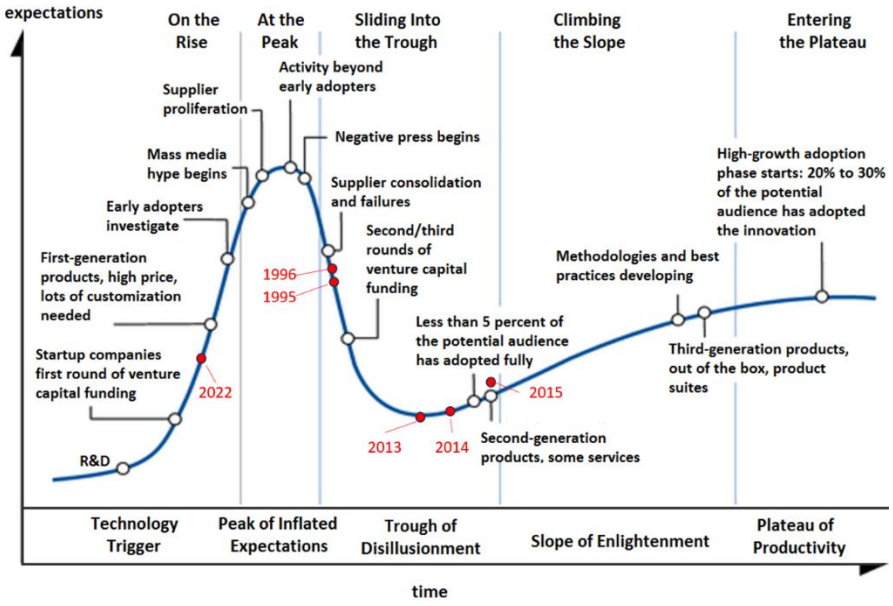


**Figure 2. Gartner Hype Cycle. Red dots show year/position VR appeared. 2022 was labeled "Metaverse"**

**Table 1. Phases of Gartner's Hype Cycle (Gartner Consulting, 2023)**

| | |
|---|---|
| Innovation Trigger | A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven. |
| Peak of Inflated Expectations | Early publicity produces a number of success stories — often accompanied by scores of failures. Some companies take action; many do not. |
| Trough of Disillusionment | Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters. |
| Slope of Enlightenment | More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious. |
| Plateau of Productivity | Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology's broad market applicability and relevance are clearly paying off. |

The Gartner Hype Cycle reflects the fact that few technologies have a smooth path from conception to ubiquity. Most undergo periods of exuberance for the promise of the technologies when evangelists would make elevated claims about their promises and capabilities which are followed by fallow times when users realize technology's capabilities fail to live up to the evangelists' hype, causing a drop from the "Peak of Inflated Expectations" to the "Trough of

Disillusionment." The technology might continue to improve slowly and eventually cross the "Slope of Enlightenment" and reach the "Plateau of Productivity."

However, for some technologies, the path to productivity is not so smooth. Rather than smoothly passing through enlightenment to productivity, the technology wallows with relatively few people using it or predicting its emergence. Instead, a smaller group of true believers works to overcome the shortcomings which prevented adoption. If this happens, generally one of two things will occur: the technology will die out, or those working on it will make advancements and it will once again be considered an up-and-coming technology. When that happens, advocates again arise and sing the praises of the technology, including how the previous failures have been overcome by the latest work, and the technology (sometimes with a different name) begins its journey on the Hype Cycle anew. As an example, in 2023, artificial intelligence (AI) which is the current exceptionally hot technology, sits at the height of the "Peak of Inflated Expectations." Despite recent excitement around machine learning and large language models, this has happened several times previously in the history of AI (Thompson, 2022). In AI's case, the future will determine whether its effects are as earthshattering as proponents claim or it too will reenter the "Trough of Disillusionment" yet again.

**The Hype of Virtual Reality**

In 1995, the initial Gartner Hype Cycle already had VR sliding into the "Trough of Disillusionment," as did the next year's chart. (Figure 2 shows the six years that VR has appeared on the Hype Cycle.) From 2013-2015, VR appears as moving slowly up the slope of enlightenment toward the "Plateau of Productivity" so it is interesting to see the acknowledgment of the challenges in placing the metaverse back on the rise toward the "Peak of Inflated expectations." In 2022 Gartner put "Metaverse" as one of the technologies, which was included here as encompassing VR. Ben Delaney, a journalist who covered VR in the 1990's, said of the hype around the advances of the 2010's, "I've been really, really getting a chuckle out of reading the hype about the Oculus, because it just feels like they're recycling the same old press releases and nonsense that people were talking about 20 years ago" (Robertson & Zelenko, 2014).

Despite apparently approaching the "Plateau of Productivity" in 2015, VR has not yet realized the benefits and it has not seized the market share its most ardent advocates predict. Compare VR usage with the game industry that many have predicted VR will replace. In 2015, 81% of teens had a game console and 72% routinely played games on their consoles or mobile devices (Lenhart, 2015). Contrast that with VR usage: in 2023, only 29% of teens owned a VR device and only 14% used it weekly (Steensland, 2023).

After acquiring HMD maker Oculus in 2014, META became the primary company pushing the adoption of VR. On MIT researcher Lex Fridman's podcast, the CEO of META Mark Zuckerberg said,

> "A lot of people think that the metaverse is about a place, but one definition of this is it's about a time when basically immersive digital worlds become the primary way that we live our lives and spend our time." (Fridman, 2022, 17:02-17:12)

In the same interview, Zuckerberg listed all the items that need to be done

> "Temperature, olfactory… We're working on haptic gloves, the sense that you want to be able to put your hands down and feel some pressure from the table. All these things… are going be really critical to be able to keep up this illusion that you are in a world and that you're fully present in this world… It's amazing how much you're just going be able to build with software that sort of masks some of these things." (Fridman, 2022, 09:42-10:20)

However, in that interview, while describing all the technology innovations necessary for large-scale adoption of VR or the metaverse, Zuckerberg omitted one of the biggest stumbling block: people don't like to use it for long periods, if at all, due to the discomfort that many humans feel when using it (META, 2020).

**Cybersickness**

The malady known as CyS, VR sickness, VE adaptation syndrome, or by several other names, is a phenomenon that occurs when individuals experience symptoms (see Table 2) while using some sort of simulation technology. This

discomfort is akin to the motion sickness experienced during real-world travel, such as in cars or boats. The causes of CyS are multifaceted and stem from a combination of factors related to human perception, technology limitations, and the nature of immersive virtual experiences. VR optimists, such as Zuckerberg, believe that technological advancements will mitigate the effects of CyS, but Rebenitsch and Owen (2016) reported that CyS did not decrease with technological advancements. This section will cover many of the causes of CyS, and the mitigations to reduce the incidence and effects of CyS upon users will be covered in later sections.

**Table 2. Symptoms of CyS**

| | | |
|---|---|---|
| Headache | Disorientation | Stomach Awareness/Nausea |
| Cold Sweating | Eye Strain | Postural instability (ataxia) |
| General Discomfort | Fatigue | Vomiting (rarely) |

While many people utilize the catch-all term "cybersickness" to refer to any sickness experienced when using a computer-driven experience, such as VR, augmented reality, or simulator sickness, research has shown that the causes of VR sickness and simulator sickness are significantly different. In simulator sickness, oculomotor symptoms predominated, followed by nausea and disorientation as the least felt system. However, with VR sickness, the effects are reversed – disorientation was the most prevalent symptom while oculomotor was the least. Additionally, the severity of the effects were three times greater in VR sickness than simulator sickness (Stanney et al., 1997).

There are many causes of CyS. One of the primary causes of CyS is a mismatch between sensory inputs. A human's brain is always comparing the multitude of sensory inputs it receives, and when two inputs apparently disagree, it creates issues. When a person uses a VE, their visual system perceives motion and movement cues, while their vestibular system in the inner ear does not sense corresponding physical motion. This sensory disconnect confuses the brain, leading to the feelings of disorientation and discomfort. In natural settings, our sensory inputs are usually synchronized, but VR can disrupt this harmony, resulting in CyS. The issues stem from the physiological responses (vestibular and visual perception) which are mostly driven by aspects outside of the system designer's control (LaViola, 2000).

Vection, which is the illusory self-motion in the absence of physical self-motion through space, produces some of the largest mismatches between the visual and vestibular systems and thus causes some of the most significant CyS effects. In fact, Hettinger et al (1990) posit that vection is a necessary condition for CyS to occur. The sense of vection increases with a higher rate of optical flow (McCauley & Sharkey, 1992), which increases as the user's speed increases and distance from objects in the world decreases. Even though a low-flying helicopter is much slower than a jet at 35,000 feet, the proximity of the ground increases the optical flow and therefore vection, and therefore the likelihood and severity of CyS.

Content design is crucial when discussing the causes of CyS (Tian et al., 2022). Some VEs incorporate rapid and erratic movements, sudden changes in perspective, or intense visual effects. These elements can overload the senses and contribute to feelings of nausea and disorientation. Designers need to consider these factors when creating VR experiences to minimize the risk of CyS. Research has indicated that reducing locomotion with teleportation reduces the CyS symptoms (Clifton & Palmisano, 2020). Many VR games have begun using teleportation vice locomotion to move throughout the virtual world.

Another cause of CyS is latency, the delay between a user's action and the corresponding response in the VE. When there's a noticeable delay in the VR system's response to the user's movements, it can lead to a discordance between what the user expects and what they perceive, further exacerbating feelings of nausea and discomfort (Stauffert, Niebling, & Latoschik, 2018).

The field of view (FOV) in virtual reality is another crucial factor in causing CyS. While many predicted that improving the FOV would reduce CyS, several studies have shown that increased FOV is correlated with higher instances of CyS (Lin et al., 2002) (Saredakis, et al., 2020) (Rebenitsch & Owen, 2016). Many attribute this to the fact that peripheral movement causes more distress than central movement and is more prevalent in wider FOV systems. Several mitigation techniques for CyS actually involve limiting FOV for users, which is detrimental to training value in many VR training systems.

Individual susceptibility is an important variable in the onset of CyS. Just as some people are more prone to motion sickness during traditional travel, certain individuals are more susceptible to CyS (Tian et al., 2022). Factors such as age, previous history of motion sickness, and individual differences in sensory processing can influence how people respond to virtual reality environments. Because of the wide variation among users, generalizing guidelines may be impossible.

In recent years, advancements in virtual reality technology have aimed to address these causes of CyS. Many potential solutions have been investigated such as motion platforms, direct vestibular stimulation, rest frames, and adaptation, (Davis, 2014) calibration of inter-pupillary distance (IPD), ergonomics, and control with copious advice provided for system designers. High-resolution displays, improved tracking systems, higher frame rates, and reduced latency have all contributed to more comfortable and immersive VR experiences. Additionally, research into adaptive content design and locomotion techniques has sought to minimize the likelihood of inducing discomfort. One of the challenges for system users however is the difficulty of prediction which prevents an individual from knowing the effects they will experiencing without experimentation (LaViola, 2000).

## RECOMMENDATIONS FROM LITERATURE TO REDUCE THE EFFECT OF CYS

Studies have shown that there is a high likelihood of a VR user experiencing the effects of CyS (LaViola, 2000) – therefore recommendations that minimize the effect of CyS will contribute significantly to learning effectiveness from a VR training system. These recommendations should be considered in the context of the curriculum being taught and the specifics of the VR training system being integrated. Occasionally it may be acceptable for students to experience a level of discomfort in order to achieve the LOs due to the critical nature of the learning outcomes. In other cases, it may be completely unacceptable for students to experience any level of discomfort.

The five step VR Usage Protocol (Stanney et al., 2014) requires the following steps:

1. Design VE stimulus to minimize adverse effects.
2. Quantify VE stimulus intensity.
3. Quantify VE aftereffects of target system.
4. Identify individual capacity of target user population to resist adverse effects of VE exposure.
5. Provide warnings for those with severe susceptibility to issues.

The limited steps of the protocol obscure the challenges of actually applying these steps for CM and other curriculum designers who are not already VR experts. The outputs of the steps do not necessarily answer the questions outlined earlier in this paper. Manufacturer's guidelines regarding VR usage protocols are sufficient for entertainment devices operated in personal homes however do not provide enough guidance for a classroom environment where a higher duty of care for students exist. Many manufacturer's manuals acknowledge the effects that are outlined in this paper (HTC, 2021) (Sony, 2016), (META, 2020) (Hewlett Packard, 2018) however their recommendations lack the fidelity required to be effective in a classroom environment.

### Design VE Stimulus to Minimize Adverse Effects

This portion of the protocol requires designers and system developers to follow multiple design guidelines available to minimize the impact of VE on users. There are many published works available to validate and inform design and development decisions.

Specific efforts identified in the VR Usage Protocol include:

1. Ensuring that system lags/latencies are stable
2. Using high quality HMDs to minimize display/phase lags
3. Optimized frame rates
4. Adjustable Interpupillary Distance IPD
5. Low Levels of Vection
6. Reduced spatial frequency
7. Provision of spatial audio to increase presence and minimize sensory conflict
8. User position choice

Many of these factors are controlled by the designer and developer of the HMD and not necessarily the training system designer. Those aspects have received significant development attention since 2014, as HMD designers have solved many technical problems, such as display/phase lags, FOV and others. Unfortunately solving these problems has not eliminated the physiological effects and aftereffects of VR on users and effort is still required from the training system developers to minimize effects and aftereffects through conscious design decisions (Tian et al., 2022).

**Quantify VE Stimulus Intensity**

This is largely the most challenging portion of the assessment of a VR training system for incorporation into any curriculum, as it necessarily involves subjective measures regarding the VE provided by the training system. The VR Usage protocol (Stanney et al., 2014) specifies the following steps:

1. Initial Estimate
2. Observe
3. First hand assessment
4. Measure dropout rate
5. Measure sickness
6. Measure aftereffects
7. Compare to other VE systems
8. Report
9. Expect dropouts

According to Australian research approximately 67 percent of people were unable to complete a 14 minute roller coaster ride, which the authors suggest places a limit on high motion content of approx. 7 minutes for any initial VR session (Nesbitt, Davis, Blackmore, & Nalivaiko, 2017). Longer exposure times result in higher reported CyS (Saredakis, et al., 2020).

The available data presents somewhat of an answer toward question 1 regarding how long students can spend in VR, although it remains the fact that duration depends on VR stimulus intensity which does not have a quantitative measure. This data generally only speaks to student discomfort and does not cover the learning effectiveness of a training system. It could be feasible that a system has a such a high level of learning effectiveness that even though it causes students to experience significant CyS and aftereffects it is still worth pursuing the training system, albeit in a controlled manner.

Comparative analysis is achieved across 3 subscales providing quartiles of sickness and is based on 29 studies (all completed before 2014) (Stanney et al., 2014). This allows comparison of VE stimulus as Low, Moderate, Medium, High or Extreme as compared to other VE systems (Stanney et al., 2014), this remains a subjective measure though and requires exposure to a system in order to provide a rating.

**Quantify VE Aftereffects of Target System**

A number of specific aftereffects of VEs have been identified including (Stanney & Kennedy, 1998):

- Degraded hand-eye coordination
- Postural instability
- Vestibulo-ocular reflex changes
- Sensorimotor adaptation
- Ataxia
- Degraded visual acuity

Research suggests these aftereffects are expected to be negatively correlated with users' experience of CyS (Weech et al., 2019). In addition findings suggest that only 50% or less of users will experience aftereffects, however they will last longer than the exposure and are not proportional to the exposure (Stanney et al., 2014). These aspects of aftereffects are concerning for a training environment, as those students who have the best experience of training may be the most impacted outside of the classroom. Two options are proposed for re-adaption to the real world: natural decay and active re-calibration (Stanney et al., 2014). It is suggested that the natural recovery time is proportional to

exposure time – therefore this has been a common method of re-adaptation (Stanney et al., 2014). Unfortunately, studies have shown that aftereffects can last up to 24 hours and therefore the US Navy has put in place regulations to prevent pilots from flying aircraft post simulator exposure (U.S. Department of the Navy, 2022)– this suggests that natural recovery may not be the best form of recovery for a training system as it may render students unable to participate in subsequent training or other activities for significant periods.

One method for ensuring that student's aftereffects are effectively controlled is to use previously published visual, proprioceptive, postural measures (Stanney et al., 2014) to capture data on aftereffects. The major concerns for a schoolhouse would be the costs of conducting, analyzing and managing this test battery, combined with the cost of training educational staff to administer and evaluate this testing regime which may be excessive when compared with the cost of acquiring the VR training system. Having a body of data that would allow better management of the impact on students.

Many device manufacturers specify breaks of varying lengths to mitigate the aftereffects of utilizing VR, unfortunately the data does not support this conclusion (Szpak et al., 2022). In fact the taking of breaks may impact the student's perception of the VE negatively due to the repeated adaptation and re-adaptation.

**Identify individual capacity of target user population to resist adverse effects of VE exposure**

VR effects and aftereffects can influence individuals differently due to a number of factors, such as:

- Age
- Gender
- Anthropometrics
- Health status
- Substance influence
- Adaptation (Experience)

A review in 2022 indicated that individual susceptibility to CyS may be the largest factor in an individual's VE perception (Tian et al., 2022). Interestingly, the exposure capacity of an individual can vary due to circumstance, as well as a population of individuals having varying capacities (Stanney et al., 2014). This capacity is reduced through increasing intensity of exposure, influence of substances and enhanced via adaptation through repeated exposure (Stanney et al., 2014).

The generic capacity of individuals can be generally described in the following manner; people are most susceptible to sickness at approximately age 12, after which susceptibility decreases until older age when it increases again (Stanney et al., 2014).

There is good evidence for user habituation to VR meaning that more and longer sessions should be effective over a longer period (Kennedy et al., 2000). Exposure time and repeated exposure is linearly related to CyS effects experienced (Stanney et al., 2014) which influences the recommendations for scheduling VR sessions. The data suggests adaptation occurs with 4 to 6 exposures with 2 to 5 days between exposures (Kennedy et al., 2000). Much of the available data is based on aviation simulators mostly helicopter as they are more "provocative" than fixed wing (Kennedy et al., 2000). There is definitely room for further study in this area on VR training systems that do not pose the same vection challenges as aviation simulation.

The VIMSSQ can be used to assess susceptibility and potentially remove those students that would be most impacted by the exposure (Golding, 2021). A baseline level VIMSSQ score would allow instructors to remove individuals from exposure to VE if it is determined their risk is too high. These individuals could follow the original instruction and assessment method to achieve the LOs.

**Treatment and Management of Adverse Effects**

VE users who experience adverse effects should receive first aid treatment as required. Some users will immediately recover with little more than a break from VE exposure. Others may require longer breaks, water or medical attention. If a user does not experience symptoms that does not preclude them from experiencing aftereffects that may impact

their performance in critical activities in the period following VE exposure. The effects of breaks to mitigate CyS and aftereffects for students may not be as effective as originally proposed (Clark, 2021).

**Provide warnings for those with severe susceptibility to issues**

Stanney et al. (2014) are clear that all users of VE's need to receive guidance on the effects and aftereffects of VR. This should be incorporated into the system design to ensure that the warnings are available to all students and not dependent on instructor training and knowledge. As a system matures, a catalogue of effects and aftereffects collated from survey responses will ensure that these warnings and briefs remain relevant and provide effective mitigation against adverse outcomes.

## VIDVR ANALYSIS

This paper seeks to apply the discussed VR usage protocol to the VIDVR training system. The courses, within which VIDVR is utilized, are 15 (SPACT) and 25 (BM A) instructional days long. This course length includes 6 hours of time allocated to the practical learning and assessment of the material that VIDVR presents

**Design VE stimulus to minimize adverse effects**

VIDVR was developed following current literature recommendations to minimize effects and aftereffects on users. As a result this paper will assume that the effects from design and development have been mitigated to their maximum and all remaining issues are required to be managed via usage protocols for the system.

Specific efforts identified in the VR Usage Protocol addressed by VIDVR include:

1. Ensuring system lags/latencies are stable – important in VIDVR's screen mirroring capability
2. Using high quality HMDs (HP G2 Reverb) to minimize display/phase lags
3. Optimized frame rates for HMD utilizing powerful GPUs in computer stations
4. Adjustable Interpupillary Distance IPD – a feature of chosen HMD
5. Low Levels of Vection
6. Reduced spatial frequency – specifically removal of direct simulation of ocean wave effects on the ship to reduce motion likely to induce sickness
7. Provision of spatial audio (ocean noise) to increase presence and minimize sensory conflict
8. Choice of seated or standing position for user – but no traversing movement required within environment during events minimizing sensory conflicts

VIDVR is designed to be significantly less provocative than aviation simulators and although standard ship motion tends to be associated with motion sickness, these elements of motion (ship pitch and roll) have been intentionally removed to improve the user experience.

**Quantify VE stimulus intensity**

VIDVR's lookout capability received the following feedback from informal surveys conducted during the pilot activity:

- 34 students participated in the pilot
- 27 found VIDVR to be comfortable
- 7 found VIDVR to be uncomfortable and each experienced some of the following symptoms: CyS, blurry eyes, sore eyes, sore head, headache, nausea and discomfort

This is a 20.6% rate of discomfort. The pilot training sessions were conducted over a period of 4.5 hours with students spending up to 15 minutes in VR at any one time. Students were given guidance to remove the headset and take breaks if necessary during the session. VIDVR's helm training capability is yet to be fielded, however presents a similar visual experience to students.

VIDVR does not have high motion content, therefore VIDVR's stimulus intensity is evaluated as within the Low to Moderate range based on the available data and first hand assessments of the system. Anecdotal evidence suggests that some users are comfortable up to at least 60 minute sessions, while others are limited to 15 minutes.

**Quantify VE Aftereffects of Target System**

So far no studies have been completed for VIDVR on aftereffects though this is highly recommended to develop an understanding of the impact of VIDVR sessions on students.

**Identify individual capacity of target user population to resist adverse effects of VE exposure**

As the population of expected users for VIDVR is in the range of 18-25, age related susceptibility is likely to be minimal.

**Treatment and Management of Adverse Effects**

VE users who experienced adverse effects during the VIDVR received breaks and were excused from training if required. It is recommended that development of an active re-calibration program based on VIDVR's aftereffects is pursued to ensure that students leave the classroom in the same state they arrived.

**Provide warnings for those with severe susceptibility to issues**

During VIDVR pilot courses these warnings were provided verbally. Incorporation of warnings into the design of VIDVR was proposed to ensure warnings are available to all students and not dependent on instructor training and knowledge. As VIDVR continues to mature as a system, a catalogue of effects and aftereffects collated from SSQ responses will ensure these warnings and briefs remain relevant and provide effective mitigation against adverse outcomes.

## RECOMMENDATIONS

In order to achieve this effectively students should commence their course with a familiarization session and then schedule sessions every 3 days to maximize the adaptation of individuals (Duzmanska et al., 2018). Additionally the initial familiarization session should be for 30 minutes (as recommended for Low Intensity stimulus) with the following sessions being up to 60 minutes (that would enable the following total immersion hours: 15 instructional days, 5.5hours and 25 instructional days, 9.5hours), which is aligned with the allowed curriculum periods. This answers questions 1 and 2 for a CM.

A future effort should be conducted to quantify the effects of VIDVR on users using a larger experimental population, prediction questionnaires using the Visually Induced Motion Sickness Susceptibility Questionnaire (VIMSSQ), formal Simulator Sickness Questionnaires (SSQs), capturing better population data and following strict experimental conduct guidelines. This will better capture sickness impacts of session duration, dropout rates and cumulative exposure effects as outlined in the VR usage protocol.

In addition to specific efforts to quantify VIDVRs effects this usage protocol should be analyzed and adjusted over time based on data collected from the students. To ensure that adequate data is collected to enable effective refinement of the usage protocol the school house should administer surveys pre-VE session, post-VE session, pre-course and post-course. These surveys should use simple rating scales such as the SSQ and VIMSSQ to capture valid data that measure CyS effects (Golding, 2021).These surveys will validate the stimulus intensity evaluation in a quantitative manner and inform adjustments to the schedule. This answers question 16 for a CM in regard to specific effects during a VE, but leaves aftereffects unanswered.

Other methods could be used to break the exposure for students including limiting exposure lengths to 15 or 30 minutes and interspersing them with classroom training. Which raises the question; what other issues arise as a consequence?

The recommendation is that students do not undertake risky activities, such as flight, without consulting a doctor within the 24 hours following exposure that has caused VR aftereffects in line with current Naval Aviation policy. In

addition it is recommended that students spend 2 hours per hour (2:1) of exposure post VR training session in a supervised environment to ensure that any adverse effects have dissipated before departure. This could easily be achieved by scheduling the VR exposures early in the day.

It is recommended that once the aftereffects of VIDVR have effectively been studied that an active recalibration program be developed that will assist in returning users to their baseline states. If this calibration program can be developed effectively it may enable the deployment of VIDVR at sea or at the waterfront, although there are other considerations that may impact these deployments. Students should be prevented from departing the supervised location until they are returned to a baseline level condition.

For VIDVR, this will be holding familiarization sessions on the first day of the course and then conducting sessions every third day which maximizes the adaptation for users along with providing enough time within the training system to achieve the LOs for the course.

All students participating in VR should be required to undertake pre and post session surveys (VIMSSQ) and testing to determine the effects of VR on their body. The surveys conducted prior to student exposure will identify those with higher susceptibility to CyS and enable removal from the VR training pipeline. Those students must be provided with alternative options for achieving the LOs from the curriculum.

Students should be briefed on the effects of VR and provided guidance and direction to effectively manage their own time within the bounds of the session limits. It is critical that students understand that self-reporting CyS symptoms and aftereffects will not result in adverse action. Data should be collected on dropout rates, to better inform future usage guidance.

## CONCLUSION

VR can become one of the most useful training mediums for the military. However, just as it has not reached the level of adoption by the general public that its advocates expected, it is not ready for widespread usage by the military training community without additional groundwork. VR is still a new technology, one which still lacks clear guidance on how to use it most effectively. This is especially true in the area of designing VR environments and providing utilization strategies to prevent loss of training effectiveness due to user's negative physiological reactions. This lack of guidelines forces those in the military tasked with implementing VR training solutions to interpret the overwhelming breadth of scientific literature on the subject, which is something many CMs are not equipped to do. The result of this is that VR solutions are not consistently designed, developed, and implemented to minimize the likelihood of negatively impacting training outcomes.

Military leadership needs to produce a threefold plan to maximize the utilization of VR for training. The first part of the plan is to perform an in-depth study, similar to this paper but at a greater level of detail, to determine the current state of the art in methods to reduce/prevent CyS, and identify areas which require further research to mitigate the effects of CyS. The next two parts arise from the results of the first part. One is to convert the scientific findings from the first part into clear and actionable guidance to be followed when creating and implementing these systems by all those involved, such as CMs, instructional system developers, VR designers. The final part of the plan takes the results of part one and funds a research program to find technologies and practices to reduce CyS and maximize the effectiveness of VR training systems.

VR has the ability to be a game-changing technology and provide the military with training that cannot be delivered any other way. It is up to military leadership to guide its employment in such a way that it reaches the "Plateau of Productivity" and not remain stuck in the "Trough of Disillusionment."

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