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VISUAL SIGNAL TRAINING FOR DRIVERS AND THEIR GROUND GUIDES

by

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September 2021

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Rising incidents of injuries and mortality rates among Army vehicle occupants is an increasing concern in the Army and the Department of Defense (DOD) as they attempt to improve techniques that avoid unintended harm to Soldiers and government assets. This research analyzes the connection between ground guide visual signal training by computer animations in virtual reality and the accuracy of recognition and recall of those visual signals when demonstrated again by a person. To investigate this, participants were shown combinations of computer animations and prerecorded live action videos in virtual reality, each demonstrating random ground guiding visual signals. After this training, participants were then tested first in virtual reality and then tested again in a follow-up session with an in-person demonstrator. The results indicate the use of visual signals by computer animations in virtual reality will play a significant role in facilitating the training of recognition and recall among participants. This research allows the Army and DOD to better understand computer animations when training personnel on the proper visual signals to be used by ground guides in order to mitigate injury/death.

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VISUAL SIGNAL TRAINING FOR DRIVERS AND THEIR GROUND GUIDES

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ABSTRACT

Rising incidents of injuries and mortality rates among Army vehicle occupants is an increasing concern in the Army and the Department of Defense (DOD) as they attempt to improve techniques that avoid unintended harm to Soldiers and government assets. This research analyzes the connection between ground guide visual signal training by computer animations in virtual reality and the accuracy of recognition and recall of those visual signals when demonstrated again by a person. To investigate this, participants were shown combinations of computer animations and prerecorded live action videos in virtual reality, each demonstrating random ground guiding visual signals. After this training, participants were then tested first in virtual reality and then tested again in a follow-up session with an in-person demonstrator. The results indicate the use of visual signals by computer animations in virtual reality will play a significant role in facilitating the training of recognition and recall among participants. This research allows the Army and DOD to better understand computer animations when training personnel on the proper visual signals to be used by ground guides in order to mitigate injury/death.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAAC	Army Accident Avoidance Course
AR	Army Regulation *or* Augmented Reality
ATP	Army Techniques Publications
CALL	Center for Army Lessons Learned
CCTT	Close Combat Tactical Trainer
DOD	Department of Defense
GAO	Government Accountability Office
JTVSWG	Joint Tactical Vehicle Safety Working Group
ODASAF	Office of the Director of Army Safety
PMCS	Preventive Maintenance Checks and Services
PTN	Pilot Training Next
TC	Training Circular
USACRC	U.S. Army Combat Readiness Center
VE	Virtual Environment
VR	Virtual Reality

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Hooah! Go Army!

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I. INTRODUCTION

A. CONTEXT AND PROBLEM

During fiscal year 2020, half of all Army military fatalities occurring while on duty have involved an Army vehicle (Army motor vehicle, Army combat vehicle, Army operated vehicle or other Army vehicle), according to the U.S. Army Combat Readiness Center (USACRC) & Office of the Director of Army Safety (ODASAF). These on-duty Army vehicle fatalities have steadily increased—by 22%—over the three previous years from FY 2017 to FY 2019 (USACRC) & (ODASA) [1].

Analyzing a more comprehensive period, the U.S. Government Accountability Office (GAO) published a July 2021 report, affirming the Army and Marine Corps "reported 3,753 non-combat accidents resulting in 123 servicemember deaths" from FY 2010 to 2019 from tactical vehicles [2]. The GAO further listed "[d]river inattention, lapses in supervision, and lack of training were among the most common causes of these accidents" [2].

A separate study incorporated information from over 700 tactical vehicle drivers and vehicle commanders over a year. It reviewed characteristics of driver training and evaluations of overall effectiveness. The Deployment and Operations Working Group found:

> [T]actical vehicle mishaps were an important cause of injury to service members while deployed and resulted in cost of damage to vehicles and equipment. Because of the impact on force readiness, they created a sub-group - the Joint Tactical Vehicle Safety Working Group (JTVSWG) - to study and mitigate these mishaps. The JTVSWG identified the need to better understand and evaluate tactical vehicle driver training, and … vehicle driver training program. [3]

The study went on to state while "[t]he Center for Army Lessons Learned (CALL) conducted a survey a number of years ago…there is a lack of current data on this topic despite the improvements in training that have been instituted in the past five years" [3].

Characteristics of this survey show that most drivers were chosen after multiple levels of delegation to mid-grade non-commissioned officers. Once selected, a majority also stated there were no interviews, medical or psychological examinations prior to as well as after being chosen to become a driver. All are required, based on Army regulations. To compound concerns, some stated they did not even receive driver training. Those that did receive at least a portion of driver training, whether in a classroom setting, through practical application, or via a check ride, stated ground guiding visual signals training was not included. Additionally, available training failed to focus on utilizing ground guides in any suggested or required situations [3]. All these highlighted components contribute to military fatalities involving an Army vehicle.

B. POLICY, OPERATIONAL CONSIDERATIONS, AND IMPLICATIONS

Visual signals are significant, as they provide a precise capability to communicate vehicular direction and speed efficiently and effectively. After an exhaustive review of Army publications, no official ground guide training or testing when using visual signals was identified. This is not to be confused with drivers training or drivers testing. Army Regulations (ARs), Army Techniques Publications (ATP), and Army Training Circulars (TCs) show how visual signals of ground guiding techniques and procedures are officially interwoven into driving, as well as drivers training. The limitation is these hand and arm signals are not focused on as a trained, tested, and accredited skill. Army publications stipulate under what conditions to use hand and arm signals, but there is no authorized delivery mechanism to teach them.

1. Drivers

The United States Army Regulation 600-55, Army Driver and Operator Standardization Program is the primary mandate regarding selecting, training, testing, and licensing personnel who drive Army vehicles and equipment.

Potential drivers are required to have an initial interview, physical examination, medical evaluation, and state driver’s license verification if driving off-post. Trainers in charge of these future drivers are appointed in writing or licensed on the specific vehicle or equipment that the trainee is tested on and has technical knowledge and experience of it. They are also certified in writing by their commanders that they have proper knowledge of said subject material. Usable academic material includes driving ranges, hands-on training, simulators, and simulations. The training culminates with a written examination and a driver performance test [4].

As specified in Appendix B, Section G, the road test has three phases: the PMCS test, the vehicle control test, and the driving test. The vehicle control test also covers numerous familiarizing maneuvers [4]. Nowhere during the road test is the focus on ground guiding. If one were to encourage safety through experiential learning proactively, this is a significant necessity. Yet, AR 385-10 does stipulate commanders will provide training and education to prevent motor vehicle accidents. More importantly, it does state either the senior occupant, who "is the senior ranking individual present," or the vehicle commander, "is responsible for the overall safety of the occupants" [5].

2. Senior Occupants and Assistant Drivers

To enforce safety, the senior occupant ensures the vehicle is operated in a safe manner, assists the driver in identifying unsafe mechanical conditions, and identifies road or other driving hazards. The motor vehicle operators are required to use ground guides according to AR 385-10 as well as TC 3-21.60, *Visual Signals,* TC 21-305-20, *Manual for the Wheeled Vehicle Operator,* and TC 21-306, *Tracked Combat Vehicle Driver.*

While senior occupants can perform as the assistant driver, the two are not usually the same. Nevertheless, assistant drivers are specified to "be familiar with the vehicle operations and trained for ground guide duties" [5]. It also mandates that ground guides are required when backing up or when moving within a motor pool or an assembly area. While there is no identified training for this, in a more detailed subsection, common areas are at least identified for using ground guides during rail vehicle transportation, at construction sites, when backing, or when needing to view the area for possible hazards [5].

The Army Traffic Safety Program, AR-385-10, is mentioned as being a requirement for all soldiers, not just drivers and assistant drivers. Appendix B, Section E shows a sample examination of 22 questions. Unfortunately, both ground guides as well as proper hand and arm signals are absent within the entire process and corresponding AR [4].

3. Ground Guides

Upon examination of TC 21-306, listed ground guide procedures specify they are to be used when there is doubt about proper clearance, in cantonments, parking areas, bivouacs sites, when the vehicle is moving in reverse, as well as during limited visibility [6]. TC 21-305-20 identifies similar detailed procedures [7].

While not explicitly identified by the Army Safety Program, *Army Motor Transport Operations: Army Techniques Publication* (ATP) 4-11 is the only publication found that even specifies the assistant driver to assist as the ground guide [8]. These two publications can contradict one another, as the assistant driver may also be the ground guide when necessary.

The abovementioned publications also referenced annual mandatory training of the online Army Accident Avoidance Course (AAAC). This publication, as well, did not cover ground guides. As a side note, on April 18, 2018, the Secretary of the Army published a memo, *Prioritizing Efforts – Readiness and Lethality (Update 2)*, that stated the AAAC is no longer a requirement [9].

Ultimately, the most overlooked component of driver training is the use of ground guiding with visual signals. In many instances, the driver's failure to use a ground guide is the primary cause of these accidents. Standardized common knowledge of ground guiding procedures must be included in unit training and used to a greater extent to "assist equipment operators in identifying potential hazards, obstacles, and personnel they may not otherwise see" [10]. Addressing this problem will give the Army a greater capability to adjust their input and training strategies, improve standardized common knowledge of ground guiding procedures for the selected drivers, and contribute to a more nuanced sustainment training technique to combat current trends in military fatalities.

C. KNOWLEDGE GAP

A review of computer animations in virtual reality has shown that combining the two can maximize learning in this system of communication, with a careful understanding of animation emphasis. In 2015, Patel and MacDorman investigated persuasion effects by computer animation compared to a prerecorded live-action counterpart [11]. They found that the animations can be persuasive even when not human-like in appearance, as long as the animation is portrayed as having authority. In their study, the human in the prerecorded live-action video and the animation both maintained matching appearance, eye contact, and traditional clothing as well as audio tracks (Figure 1). These visualizations influenced their levels of credibility with the viewer [11]. The prerecorded live-action video and the computer animation gave all combinations of responses (identical and contradictory) in four different videos. Participants then assessed ratings for appearance and credibility. Subcategories of appearance were levels of "attractiveness, eeriness, and humanness." Subcategories of credibility were levels of "trustworthiness, competence, and goodwill" [12, p. 7]. Ultimately, a basic understanding is rooted in just how much the avatar can influence people, with the highest quality representation being the most persuasive. The paper states, "computer characters can be more persuasive than a real person while being perceived as less credible" [11, p. 2].

Figure 1. Patel's prerecorded live-action video juxtaposed to the computer animation. Adapted from [11].

Some of the key findings were: (a) any video frame rate issues or blurriness did not seem to affect credibility, goodwill, competence, or trustworthiness; (b) males found male avatars slightly more attractive than the females did other female avatars; (c) males complied with the avatar less when the avatar was female; (d) among both sexes, when motion was not smooth there was less compliance; (e) influence fluctuated based on perceived attractiveness and humanness, but not eeriness; and (f) they found "recall was a significant predictor of eeriness" [11, p. 10]. However, this does not necessarily mean that eeriness is a significant predictor of recall.

Fundamentally, if we can ensure creditability by utilizing proper appearance, eye contact, and audio, we can use computer animation to persuade and train appropriately. In addition, VR training can be equal to or better than equivalent real-world training. An example of this is in other settings, such as teaching children safe road-crossing skills, which have shown slightly better scores than professional human instruction [13]. If the Army can fill this overlooked ground guide training gap to teach hand-and-arm signals using VR, then soldier mortality may decrease.

D. RESEARCH HYPOTHESES

This thesis will focus on the following research hypotheses:

1. Hypothesis 1 (Initial Memory Difference)

Visual signal training using computer animations (CA) in virtual reality will be easier to learn than visual signal training using prerecorded live action (LA) in a virtual reality environment. ($p_{LA} - p_{CA} > 0$).

The aim of this hypothesis is to understand which medium will best provide learning to the participant when identifying specific hand and arm visual signals.

2. Hypothesis 2 (Subsequent Learning)

When attempting to recollect visual signal movements (after second testing), recall will be better for computer animations in virtual reality than prerecorded live action.

The aim of this hypothesis is to understand what level of recollection participants will have based on their training using the two styles. ($\mu_{LA} - \mu_{CL} > 0$).

3. Hypothesis 3 (Reaction Time)

People will identify real-world training movements faster when trained using computer animations in virtual reality compared to prerecorded live-action in virtual reality.

The aim of this hypothesis is to understand if there is a benefit of time to identification hand and arm visual signals depending upon what medium the participants were trained with. ($v_{LA} - v_{CL} > 0$).

E. BENEFITS OF STUDY

The results of this study provide the United States Army, Army Reserve, and Army National Guard with evidence of alternative training capabilities to increase the overall safety of military personnel by using the virtual reality environment. Additionally, this study provides information on the impact of recognition and recall between visual signals. This information, in turn, will guide future training and policy writers for future AR employment, purchasing, and additional development. When training on visual signaling techniques, the United States Army strictly uses live-action training for ground guiding. This does not utilize all current technological capabilities, specifically VR. Exposure to this as a viable resource can speed initial learning, periodic refresher training, and ensure proficiency is maintained for more extended periods.

F. SCOPE

This thesis utilized the following 11 hand-and-arm signals that control vehicle drivers/crews and investigated whether animated visual signals were comparable or better to live-action visual signals within a virtual environment.

1. Attention
2. I am ready; Are you ready?
3. Start engine or prepare to move
4. Move forward
5. Halt or stop
6. Increase speed
7. Slow down
8. Move in reverse

9. Advance, move out, or follow me
10. Turn vehicle
11. Turn while backing

This research is meant to effectively assess the cognitive trainability of soldiers, as they distinguish between live and virtual, using recall and recognition. These findings ultimately benefit Army decisions and improve the trainability of visual signaling techniques. This stands to be capitalized upon at multiple echelons and, therefore, advance training techniques and doctrinal adjustments found in Army regulations. This study was not meant to capture all potential visual signaling hand-and-arm signals for ground vehicles that could be utilized or provide training for mechanized movement techniques, traffic control, convoy control, firing range, or flag signals. This thesis also did not evaluate a particular vendor's equipment or examine any specific environmental assessments.

G. THESIS OUTLINE

The remainder of this thesis is structured as follows:

Chapter II outlines ground guiding procedures, practical military usage of ground and flight simulators and simulations, considerations of nonverbal communications using virtual environments (VE), and experiential learning based upon these conditions.

Chapter III examines the design methodology and task analysis conducted for ground guiding and details the ground guide VR prototype development.

Chapter IV presents the corresponding results, analysis, and the demographics of the study participants.

Chapter V summarizes the conclusions and provides recommendations for future research.

II. LITERATURE REVIEW

This review is divided into four parts; the first part provides an appropriate context of ground guide procedures for use in conjunction with tactical wheeled vehicles, followed by an examination into U.S. military uses of simulations and simulators. The third part discusses decisive nonverbal communication considerations using VR, and then the final section is a review segment of exploiting learning by utilizing virtual reality.

A. GROUND GUIDING PROCEDURES

The United States Army Training Circular (TC) 3-21.60 is the primary reference manual regarding commonly used visual signals, which superseded FM 21-60, 30SEP 1987. This publication applies to the Army, Army Reserve, and Army National Guard and is used for effective and quick coordination and control. TC 3-21.60 identifies signals for mounted and dismounted operations, aircraft, and pyrotechnics. The hand and arm signals for guiding tactical wheeled vehicles are located in the mounted operations subsection [14].

Each signal is provided with verbal and visual clarification, as seen below in Figures 2 through 11. The 11th approved hand and arm signal for guiding tactical wheeled vehicles, "Turn while backing" is not presented as it is a combination of "Move in reverse" and "Turn" signals. See Figures 9 and 11. All illustrations shown below are used during daytime hours. Furthermore, the signaler always faces the intended recipient when signaling.

Figure 2 illustrates "Attention." This movement requires the arm to be fully extended out sideways beyond parallel with the palm facing out forward. The arm is then waived up to the head and back down to the starting position, repeating.

Figure 2. Attention. Source: [14].

Figure 3 illustrates “I am ready; Are you ready?” In the direction of the individual being signaled, the palm is outwardly faced with an open hand slightly raised above the horizontal plane. This movement requires the arm to be fully extended to approximately 20 degrees above the ground surface.

Figure 3. I am ready; Are you ready? Source: [14].

Figure 4 illustrates “Start engine or prepare to move.” This movement requires the armed be fully extended, with the hand in a fist. At waist height, the fist will travel in a circular motion.

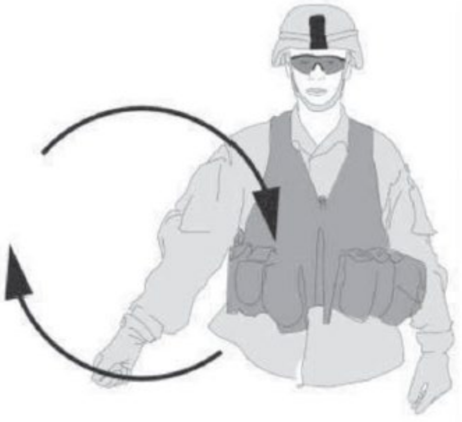

Figure 4. Start engine or prepare to move. Source: [14].

Figure 5 illustrates “Move forward.” This movement requires the hands to be open, with the backs of the hands and forearms in the direction of the individual being signaled. The action occurs only at the elbows, with the forearms and hands moving back and forth in unison between slightly below parallel to the ground and back up approximately 55 degrees in the direction of the signaler’s chest and lower face.

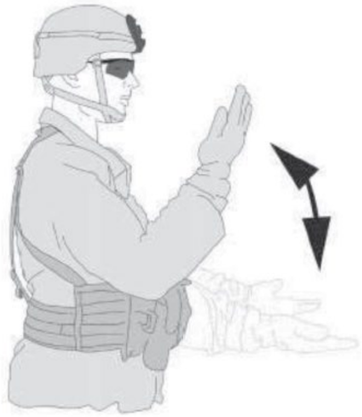

Figure 5. Move forward. Source: [14].

Figure 6 illustrates “Halt or stop.” This movement requires the arm and hand to be fully extended to approximately 65 degrees with the palm facing forward in the direction of the intended recipient. This position is maintained until verification of the signal is recognized.

Figure 6. Halt or stop. Source: [14].

Figure 7 illustrates “Increase speed.” This signal requires the hand to maintain a fist during its entirety. Movement is made at the elbow and shoulder joints. The arm is raised to approximately 65 degrees, With return movement of the elbow back to the side and the fist back to shoulder level. This movement is required to be repeated several times at a rapid pace.

Figure 7. Increase speed. Source: [14].

Figure 8 illustrates “Slow down.” This movement requires the arm to be fully extended to the user’s side with the palm facing the ground. The straight arm is then waived from approximately 10 degrees to –20 degrees from parallel to the ground multiple times.

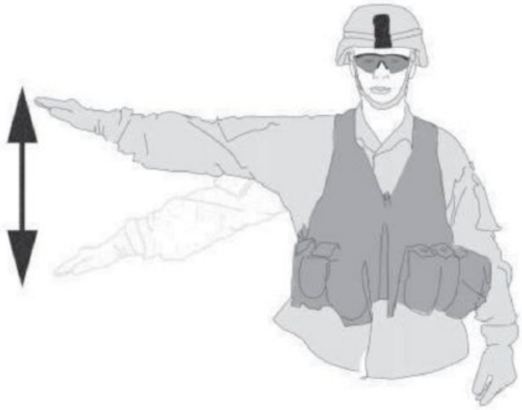

Figure 8. Slow down. Source: [14].

Figure 9 illustrates “Move in reverse.” This movement requires the palms of the hands to face forward in the direction of the intended recipient. Hands and elbows are brought in the direction of the torso and then, repeatedly, fully extended back out to approximately 10 degrees above the ground.

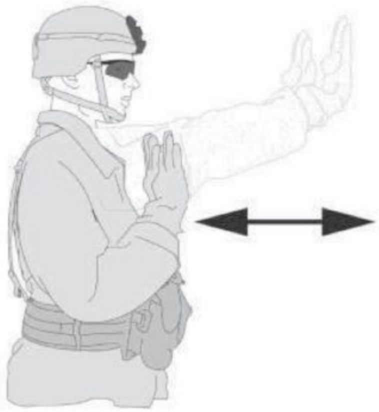

Figure 9. Move in reverse. Source: [14].

Figure 10 illustrates “Advance, move out, or follow me.” The starting position begins with the arm at approximately 120 degrees overhead, with the arm then pushing forward to around 10 degrees above parallel from the ground in the direction of forward movement. This movement requires the arm to be fully extended with the palm facing forward. The arm moves only at the shoulder joint during the entire duration.

Figure 10. Advance, move out, or follow me. Source: [14].

Figure 11 illustrates “Turn vehicle.” The arm is at a 0- or 180-degree lateral angle from the body, indicating the direction of the turn. This movement is maintained in a static position and requires the arm to be fully extended with the palm open and towards the recipient.

Figure 11. Turn vehicle. Source: [14].

B. MILITARY USE

The military uses a wide variety of simulations and simulators. There are a few pertinent items in the air and ground domains that show emergent technologies that deal with various training aspects. Some concrete elements of simulations and simulators show both current thinking and use related to overarching training in this area.

1. Flight

VR has effectively accelerated training involving some of the hardest-to-learn aircraft platforms. The Air Force Air Education and Training Command started the Pilot Training Next (PTN) (Figure 12) program in April 2018. Their initial attempts to decrease pilot training time on numerous platforms such as the Navy F/A-18 Hornet, T-6 Texan trainer, H-60 helicopter, F-35, C-130, and others using the HTC VIVE Pro VR headsets, saw pilot training and certification/graduation time decrease from one year to four months [15]. Consequently, they have also found themselves less inclined to spend money on legacy simulators that cost more than ten times the amount ($4.5 million) of the VR simulator bay setup ($300,000) [15]. Arguably, this change ultimately increased efficiency of training, time, overall budget, and a positive increase in student to instructor personnel ratios permitting more trained students per iteration.

Due to the expansion of the Air Force into VR simulators, the Air Force Academy cadets also showed cumulative improvement in aviation training. Utilizing the 16 immersive VR training devices at their disposal, cadets without any aviation training claimed to have increased muscle memory and better self-confidence. This additional capability increased repetition and showed a “positive correlation between early participants in the VR training and live-flight performance in powered flight” [16]. Subsequently, Capt. Bryan Rhoades, the powered flight program flight commander, stated because of heightened repetition, “cadets are showing up a lot more prepared and knowledgeable about radio calls and traffic patterns” when arriving for training [16].

Figure 12. Flying a virtual-reality training sortie during a Pilot Training Next program at the PTN Armed Forces Reserve Center. Source: [17].

Success with the VR-centric PTN program has provided significant practical worth. Lt. Col. Robert Knapp, Detachment 24 operations officer, stated, “There is no doubt that there is great benefit in the use of immersive training devices” [17]. Knapp’s reasoning is grounded in the fact these training devices produce more individualized and earlier access to learning. Subsequently, Defense Innovation Unit is revising the PTN program by maintaining the VR nucleus and partnering with industry to integrate A.I., cloud infrastructure, and cybersecurity [18], [19]. Consequently, by preserving the VR component and consolidating these additional capabilities with it, VR has proven valuable as a learning tool.

2. Ground

While the Air Force is primarily focusing on simulations, the Army focuses more on simulators. The Close Combat Tactical Trainer (CCTT) and associated Reconfigurable Vehicle Tactical Trainer (RVTT) subsystem have begun system divestment, as of 1QFY21 with completion before 1QFY24 [20]. Their replacement is the Common Driver Trainer (CDT) Virtual Product Line (VPL), produced by Leidos [21]. With this program upgrade, focus shifts to driver training capabilities. Despite the CDT VPL being likely a positive advancement, it only addresses a part of the problem.

Accordingly, the U.S. Army's effort is on how to train for war, simulating bloodless fights via tank battles, convoys, and smaller patrols. The simulators can do a great deal, with a singular focus on combat. The CDT systems provide training on the Mine-Resistant Ambush-Protected platform, tanks (and their variants), Stryker (Figure 13), and Tactical Wheeled Variant, such as the HMMWV [21]. In addition, PEO STRI stated the cab variants are "interchangeable and reconfigurable… [able to] conduct basic, intermediate and advanced driver's training tasks" using a mobile platform that incorporates six degrees of freedom and multiple scenario databases [22]. This transition from the CCTT to the CDT will help reduce downtime and remain current with newer model variants. Noticeably, we have a point of need before combat that is not identified.

Figure 13. CDT setup for Stryker training. Source: [21].

After reviewing multiple videos and various demo manuals, the trainees' focus is apparently on the deliberate training challenges such as navigating obstacles (cones, barricades, enemies) or targeting (munition trajectories). None of the simulators or simulations showed or used a visual ground guide, including when loading a vehicle into an aircraft (Figure 14) [23]. One must ask, "When and where does the mission start?" It starts with the rehearsals. Accordingly, an overlooked and ingrained gap in training exists.

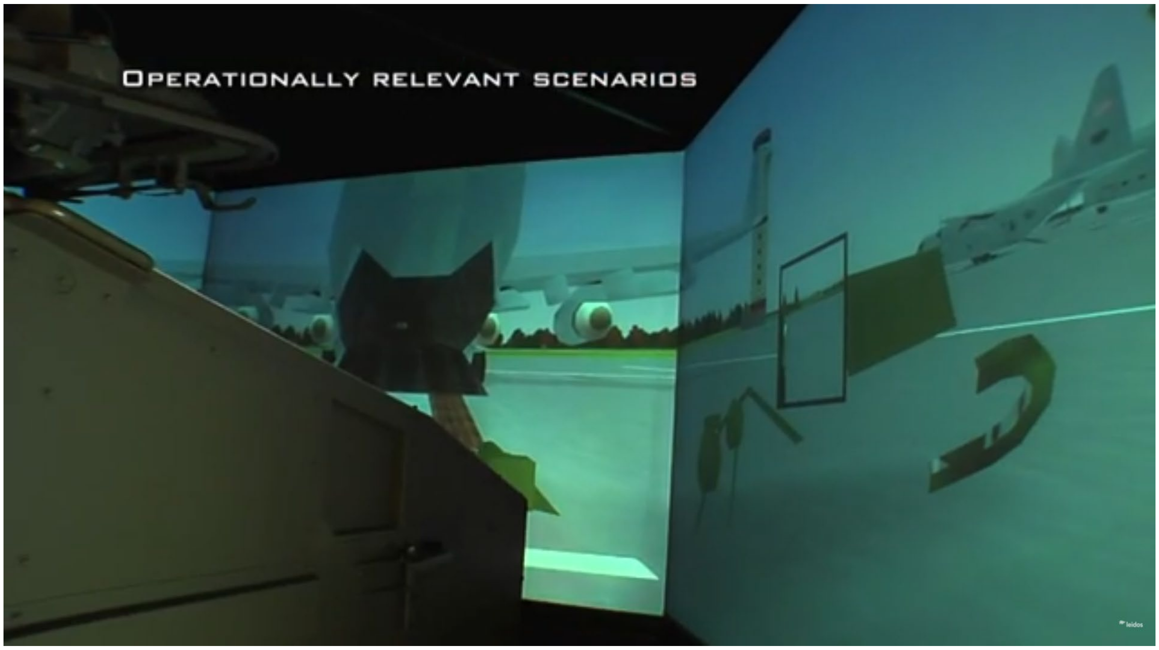

Figure 14. CDT screenshot of loading vehicle into aircraft without a ground guide. Source: [23].

Training changes behavior. When unsafe behavior is met with consequences, one can develop good habits and techniques. Superimposing the gaps found in Army simulators with the Air Force's success with VR leads us to think about integrating them. Once combined, specific individual strengths of both realms of training will then complement each other and minimize gaps.

C. CONSIDERATIONS OF NONVERBAL COMMUNICATION USING VR

In 1970, Masahiro Mori defined the uncanny valley as "the proposed relation between the human likeness of an entity and the perceiver's affinity for it" [24]. Essentially, Mori referenced the emotional uneasiness felt when one realizes that something is not human, even though it was designed to attain a human likeness. While Mori referred to an animatronic hand's size, texture, and skin, the uncanny valley concept has become all-encompassing when referencing the human body, and most noticeably, the face. As human likeness increases, it continues to move along a path of imitation towards the viewer's conception of becoming a normal person. The more realistic the avatar becomes, the greater the chance for eeriness prior to similarities no longer being differentiated between the two.

As this eeriness decreases the probability of learning effectively from human-like robots and VR avatars, four main areas stand out when researching the uncanny valley: natural expressions, characteristics of self, emotions, and realism.

1. Conformity to Natural Expression

While attempting to verify that this negative perception extends to both male and female avatars, Tinwell focused on substantiating anatomical locations of perceived lack of facial animations, specifically in the upper areas of the face [25]. After looking at facial expressions, a general thought that there are multiple contributors to uncanny movements and visual effects upon the viewer exists. Specific information from previous studies measured an increase of fear and surprise in the uncanny valley when manipulating male avatars' facial expressions as described [25]. It was found that specific areas that attribute greatly to this were the limited movements in general areas extending from the eyelids to the top of the forehead [25]. Accepted studies have also shown lip movements that are not synchronized with speech can also trigger this trait [25].

Another subconscious bias, rooted in biological legitimacy, shows how the level of participants' emotional attachment fluctuates. Mousas referenced "positive reactions" specifically to the average, "low amplitude" male avatars, not strictly negative stimuli associated with the low or high amplitude zombie male avatars [26]. While this shows a similar intercorporeality between the viewer and the avatar, it prompts the same justification as it does for the perception of others from a phenomenological perspective. Merleau-Ponty wrote about the experience:

> In perceiving the other, my body and his are coupled, resulting in a sort of action which pairs them. This conduct which I am able only to see, I live somehow from a distance. I make it mine; I recover it or comprehend it. Reciprocally I know that the gestures I make myself can be the objects of another's intention. [27]

Equally important to those perceptions are the cognitive beliefs, traits, goals, abilities, and cognitive self-schemas that one might expect.

2. Characteristics of Self

Avatars represent how we see ourselves and how we want others to see us as well. Novak's key observation is that when given a choice to choose an avatar to represent them, participants were more likely to select the same gender as themselves [28]. In addition, they opted to choose avatars with more gender-specific hyper-masculine or hyper-feminine qualities [28]. Viewers also mentally assigned to the avatars a certain level of competence as well as trustworthiness. Additionally, those participants selected avatars that also conveyed self-characteristics of the participants' own emotions [28]. These are distinguishing characteristics, but simple demographics such as age and gender demonstrate a broader deviation spectrum.

Age plays a factor in immersive virtual reality. Results suggest younger adults were the most successful at separating virtual reality from reality, based on their scoring to various stimuli [26]. Not only that, but the inverse is also true when directly compared to virtual reality sickness. Older adults were less prone to virtual reality sickness (or cybersickness), but this tendency has been equalized as VR technology has improved [29], [30].

Mousas identified other gender differences with this study. Females had a higher emotional reactivity to all the virtual avatars. Females had a more negative response than their male counterparts when viewing all avatars [26]. This could be due to sociocultural factors, gender stereotypes, or social expectations [26]. The explanation is not definitive, as scholars have no explicit agreement as the research intersects neurological, psychological, and cultural norms that all offer unique perspectives [12]. Nonetheless, emotional reactivity should also be considered when attempting to define broader concerns of communicative dissonance.

3. Emotions

A lack of emotional recognition, usually found within the uncanny valley, can disrupt an exemplary learning state due to negative aversions of the observed avatar. Fear and surprise are two undesirable emotions that participants recognized, with a rate above 90%. For those avatars with limited facial animations, recognition rates decreased to 62%

for male avatars and 70% for female avatars [25]. Recognition rates were higher or lower based on the gender of the participant. Nonetheless, we can detect negative traits or characteristics in avatars with limited facial mobility. Having those traits does not necessarily predict how uncanny they are, merely the participants' association of perception of uncanny features.

A study attempted to measure the emotional intensity of participants under experimental conditions in response to virtual characters to include any measurable difference among genders related to aversive avatars and suggests that the two psychological conditions of emotional valance and intensity are essential in doing so [26]. Emotional valences describe the extent to which an emotion is positive or negative. Emotional intensity is the measurable amount or quality of that property. By ranking the likeability of face, body, locomotion, and size for the four different avatars, greater negative emotional reactivity was found toward high-intensity zombie male avatars compared to low-intensity male zombie avatars. In addition, females maintained greater negative emotional intensity in comparison to their male counterparts. Furthermore, viewers showed more hostile emotional reactivity toward the high amplitude male avatar than the low amplitude male avatar, especially when his body size, motion, and overall appearance matched expectations [26].

In game design, the combination of aesthetics and mechanics and their dynamics is of the utmost importance to discern for the following reasons: 3D immersion compared to other media is better at analyzing emotional responses. When attempting to study emotional reactions, the ability to evaluate faces holds a comparative advantage when referencing virtual designs compared to pictures or videos [26]. Cardoso evaluated emotional reactivity, stating, "[w]hile mechanics define the game's functionality, dynamics are the player's interaction with and response to the mechanics, and the aesthetics are the player's emotional response to the mechanics and dynamics" [31, p. 4]. These three conditions cannot be acquired through 2D illustrations. They further demonstrate users' complex emotional connectivity.

4. Realism

To ensure participants remain calm, realistic body animation is equally important all by itself without any specific concerns of facial animations. Makled studied the impact between head and body movement in relation to the comfortability and realism of avatars in virtual reality [32]. Viewers conveyed that the avatars' presence was more significant when body movement was assessed, specifically as a requirement for heightened VR engagement. Noticeably, more than a third (37.5%) of the participants did not detect any physical omissions of animation for the head, as it moved when focusing on the body [32]. Subconsciously, realistic movement is tracked by the brain's premotor cortex, which is essential to realizing both "self-awareness as well as… the felt embodiment of observed body parts" as they move and rotate [12, p. 6].

The assessment of various avatars is also influenced on a conscious level. Anthropomorphism traits are human characteristics or behaviors that humans imbue to a creature or object. Homophily is the propensity for people to be attracted to others who are like themselves. A key feature identified in the study shows that the more anthropomorphic an avatar is, the fewer abnormal features it has. It also tends to be more pleasing to the eye [28]. This ingrained assessment helps provide an additional evaluation of how realistic the avatar is. Based on this, "there is a high correlation between credibility ratings and homophily and social attraction" [28, p. 53]. When this occurs, trust and competence increase in human perception of the avatar due to homophily. In addition, the various features of the avatar could perhaps also change other differently held perceptions and show a decrease in the quality of their interaction [28].

D. MAXIMIZING LEARNING WITH VIRTUAL REALITY

Utilizing Kolb's experiential learning theory, explaining that people learn using active or reflective observations, one can improve their knowledge and understanding of that instruction if provided standardized training iterations [33]. This can be accomplished through a static training mechanism of experience, reflection, conceptualization, and decision making. Upon building knowledge and skill thru participation, these interactions standardize repetitive iterations and reinforce learning styles. Virtual reality may well be an essential element of the learning process, capable of maximizing instruction and behavior.

VR can be tailored to meet all styles of learning. There are eight major learning styles: visual/spatial, aural, physical/tactile, verbal, logical/analytical, social/linguistic, solo, natural. Each can be predictably productive regardless of preference or blended learning styles [34]. With virtual learning environments becoming more prevalent in higher education, it appears to support a combination of effects; students receive better grades, there is an increased level of satisfaction between the learner and instructor. Autonomous learning increases. Also, the capability to learn anytime/anywhere is becoming the preference over a peer learning interaction [35]. Possible reasoning behind this is due to "virtual reality [being] more effective than similar activities without simulations and sensors…and promote [18] deep and coherent learning" [35, p. 4-5].

Kolb's active learning through immersion and interaction defines the stimulation required to exploit learning at the uppermost capacity. VR channels the mechanisms of physical, self, and social versions of one's presence to experience and interact with other participants, the environment, objects, reality, and fantasy [36].

E. SUMMARY

This chapter gave us a foundational understanding of available literature regarding the standards of hand and arm visual signals, how both the Army and Air Force training tools can complement each other, based on training proficiencies, and how we must address specific human predispositions in the VR world to create a learning setting. It is imperative to know the exact instructions for each ground guiding procedure to establish the correct reference point. We reviewed positive changes in Air Force training that utilizes VR simulations, identifying comparative advances in time, money, safety, muscle memory, self-confidence, and overall knowledge. We also identified positive Army training changes that utilize VR simulator capabilities by identifying interchangeable and reconfigurable variants that maximize scenario databases. Combining the two services' capabilities and ensuring the Army trains participants with the proper hand and arm visual signals, we also identified any specific hindrances to learning. Virtual reality has been shown to have numerous pitfalls and biases that can hinder learning. We were able to identify concerns regarding the uncanny valley, overall facial expressions, gender preferences, emotional responses, and irritations that can stand in the way of learning. Finally, we discussed how people learn and specifically identified that VR is a reputable vehicle to facilitate learning.

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III. METHODOLOGY

A. PARTICIPANTS

The population of interest in this study was active-duty military members of various times in service and in the age range between 18 and 65. There were no restrictions regarding gender or demographics. The requested sample size was between 20 and 35 subjects based on the power analysis results and taking into account some variability due to potential difficulties in recruitment with current COVID conditions. A total of 35 participants from Naval Postgraduate School in Monterey, California, volunteered to participate in this study. Of the 35 participants, 27 (77%) were male, and 8 (23%) were female. Twenty-two indicated some form of previous ground guide training. Five indicated they have ground guided in the past with no prior training. Eight specified they neither received ground guide training nor ground guided before. Of the 35 participants, 16 took part in both initial and follow-up testing.

B. DESIGN OVERVIEW

The experiment was designed for two phases, an initial session to learn signals, followed by testing. The second session was only to test memory for the signals after a few days. The initial test was formatted to determine if people would identify real-world visual signals faster when trained using computer animations in virtual reality compared to prerecorded live-action in virtual reality. The initial test used only the virtual avatar.

In the follow-up testing, we wanted to discover, when attempting to recollect visual signal movements, if recall is improved for computer animations or prerecorded live-action when both were shown in virtual reality. Participants who took part in the follow-up testing iteration were tested using only in-person hand and arms signals. In both iterations, participants were evaluated based on the number of times they were able to identify the correct hand and arm visual signal and the speed at which they did so.

The training order of the hand and arm signals were randomized and split into two collections. The first group of participants received training beginning with five animations then five live-action. The second group received training beginning with five live-action then five animations (see Figure 15). After training, participants completed a post questionnaire survey used to identify when—given a choice between training using prerecorded live-action or computer animations, both shown in virtual reality—which option people prefer (see Appendix B, Section C).

Config 1 Training	**Config 2 Training**	**Config 3 Training**	**Config 4 Training**	**Config 5 Training**
Attention	Turn vehicle	Advance, move out, or follow me	Move in reverse	Slow down
I am Ready; Are you Ready?	Attention	Start engine or prepare to move	Advance, move out, or follow me	Move in reverse
Start engine or prepare to move	Move forward	I am Ready; Are you Ready?	Turn vehicle	Attention
Move forward	Start engine or prepare to move	Attention	I am Ready; Are you Ready?	Turn vehicle
Halt or Stop	I am Ready; Are you Ready?	Turn vehicle	Attention	Advance, move out, or follow me
Increase speed	Halt or Stop	Move forward	Start engine or prepare to move	I am Ready; Are you Ready?
Slow down	Increase speed	Move in reverse	Halt or Stop	Move forward
Move in reverse	Advance, move out, or follow me	Halt or Stop	Slow down	Increase speed
Advance, move out, or follow me	Move in reverse	Slow down	Increase speed	Start engine or prepare to move
Turn vehicle	Slow down	Increase speed	Move forward	Halt or Stop
Config 6 Training	**Config 7 Training**	**Config 8 Training**	**Config 9 Training**	**Config 10 Training**
Increase speed	Halt or Stop	Move forward	Start engine or prepare to move	I am Ready; Are you Ready?
Slow down	Increase speed	Move in reverse	Halt or Stop	Move forward
Move in reverse	Advance, move out, or follow me	Halt or Stop	Slow down	Increase speed
Advance, move out, or follow me	Move in reverse	Slow down	Increase speed	Start engine or prepare to move
Turn vehicle	Slow down	Increase speed	Move forward	Halt or Stop
Attention	Turn vehicle	Advance, move out, or follow me	Move in reverse	Slow down
I am Ready; Are you Ready?	Attention	Start engine or prepare to move	Advance, move out, or follow me	Move in reverse
Start engine or prepare to move	Move forward	I am Ready; Are you Ready?	Turn vehicle	Attention
Move forward	Start engine or prepare to move	Attention	I am Ready; Are you Ready?	Turn vehicle
Halt or Stop	I am Ready; Are you Ready?	Turn vehicle	Attention	Advance, move out, or follow me
Config 1 Testing	**Config 2 Testing**	**Config 3 Testing**	**Config 4 Testing**	**Config 5 Testing**
Start engine or prepare to move	Move forward	I am Ready; Are you Ready?	Turn vehicle	Attention
Attention	Turn vehicle	Advance, move out, or follow me	Move in reverse	Slow down
Halt or Stop	I am Ready; Are you Ready?	Turn vehicle	Attention	Advance, move out, or follow me
I am Ready; Are you Ready?	Attention	Start engine or prepare to move	Advance, move out, or follow me	Move in reverse
Move forward	Start engine or prepare to move	Attention	I am Ready; Are you Ready?	Turn vehicle
Move in reverse	Advance, move out, or follow me	Halt or Stop	Slow down	Increase speed
Increase speed	Halt or Stop	Move forward	Start engine or prepare to move	I am Ready; Are you Ready?
Turn vehicle	Slow down	Increase speed	Move forward	Halt or Stop
Slow down	Increase speed	Move in reverse	Halt or Stop	Move forward
Advance, move out, or follow me	Move in reverse	Slow down	Increase speed	Start engine or prepare to move
Config 6 Testing	**Config 7 Testing**	**Config 8 Testing**	**Config 9 Testing**	**Config 10 Testing**
Advance, move out, or follow me	Slow down	Move in reverse	Halt or Stop	Increase speed
Increase speed	Halt or Stop	Move forward	Start engine or prepare to move	I am Ready; Are you Ready?
Slow down	Move in reverse	Increase speed	Move forward	Start engine or prepare to move
Turn vehicle	Increase speed	Halt or Stop	Slow down	Move forward
Move in reverse	Advance, move out, or follow me	Slow down	Increase speed	Halt or Stop
Move forward	I am Ready; Are you Ready?	Start engine or prepare to move	Turn vehicle	Attention
Attention	Turn vehicle	Advance, move out, or follow me	Move in reverse	Slow down
I am Ready; Are you Ready?	Start engine or prepare to move	Attention	Advance, move out, or follow me	Move in reverse
Start engine or prepare to move	Attention	Turn vehicle	I am Ready; Are you Ready?	Advance, move out, or follow me
Halt or Stop	Move forward	I am Ready; Are you Ready?	Attention	Turn vehicle

Legend		
Virtual avatar viewed	Live-action video viewed	Note: Testing configurations remain the same during both first and second testing iterations.

Figure 15. Training and testing configurations.

The NPS Institutional Review Board approved this study (see Appendix A). This process required a combination of the thesis proposal, conflict of interest forms, questionnaires, simulator sickness questionnaires, and data collection sheets, and scientific review form. In addition, all personnel and writers of the research team completed required Collaborative Institutional Training Initiative ethics training.

C. MATERIALS

1. Live-Action Videos

All live-action videos used during training and initial testing were segments of one video downloaded from the U.S. Army Combat Readiness Center. The video was uploaded by "Army Safety" on June 4, 2014 [37]. This video is the only supported professional ground guiding video found, with an unmatched level of fidelity and credibility to ensure proper hand and arm signals. The footage was segmented into ten individual hand and arm signals, each with individual labeling by Army Safety at the Combat Readiness Center (Figure 16). All sound was removed from the video in order to eliminate possible confounding data.

Figure 16. Army safety video. Source: [37].

2. Software

The MOVES Institute's FutureTech team created all virtual reality 3D backgrounds, animations, and assets using the Unity game engine version 2020.1.8f1. Like the live-action videos, animation sequences contained no sound.

3. Hardware

The computer used was an X64-based PC, HP EliteDesk 800 G4 TWR WS. The operating system installed was Windows 10 Pro, version 10.0.19042 Build 19042. The processor was an Intel(R) core (TM) i7-8700 CPU @ 3.20GHz, 3192 MHz, 6 Core. Installed physical memory was 16.0 GB. The graphics card was an NVIDIA GeForce RTX 2080, driver version 27.21.14.5749 with 1.0 GB of RAM. The keyboard was an MSI gaming PS/2 Keyboard. The monitor was an Acer XB241H Predator. The camera was a Microsoft autofocus H.D. widescreen.

The VR headset was a Lenovo Oculus Rift S. Resolution to 2560 x 1440 (1280x1440 per eye). Pixel density is approximately 600ppi—refresh rate 80Hz. The field of view is 115 degrees. The VR headset requires an Intel i3-6100 or AMD Ryzen 3 1200, 8GB RAM, Nvidia GTX 1050Ti or AMD Radeon RX 470, and one USB 3.0 Port [38]. The desktop tower met all Oculus manufacturer requirements.

D. PROCEDURE

1. Setup

The experiment took place at the Naval Postgraduate School in Monterey, California. Data collection occurred on two separate days, between three to seven days apart. The experiment location was identified based on proximity to the participants and attaining a controlled environment, not utilized by others. The exclusive use of the lab was beneficial and approved in accordance with COVID safety protocols. Before each participant's arrival, the lab and all devices were sterilized. Devices and software were verified to be in working order, and any necessary calibrations were made. The computer initialization was prepared ahead of time to ensure a smooth iteration based on the required training or testing configuration (Figure 17). Standard widgets were used for the initial graphical user interface for speed and simplicity.

Figure 17. Initialization start screen.

2. Initial Brief

Upon participant arrival, all participants verbally acknowledged they were not suffering from COVID-related illness or had any symptoms of cyber sickness, such as nausea, dizziness, or discomfort. Once verified, participants sat at an extended table to ensure proper social distancing when available. All participants were asked to mute their phones so that sounds would not interfere with participants' concentration during the experiment. All participants were then required to use hand sanitizer before any further actions. The instructor notified all participants that cleaning procedures were conducted after each participant using a combination of Lysol disinfectant spray, Clorox, and alcohol wipes, and that proper distancing and observing mask guidance by the CDC, DOD, the state of California, Monterey County, and NPS would be enforced, with the exception of masks while in VR as they fog up the VR display, but the mask exception was only to pull it below the nose, and this was done after the researcher was six feet away from the participant. After COVID protocols were discussed, participants received the requisite consent and directions form to complete. The form provided an introduction brief to the study as well as consent to participate. In conjunction with this form, the instructor notified all participants that all data collected would be anonymized after completed data collection. In addition, participants were told that if they had any questions during the appointment, to please ask.

3. Training

Upon completing the introduction brief, participants moved to the computer to sit at a computer table. Before wearing the VR headset, the presenter explained the participant would watch a visual signal at full speed. It would then repeat at half speed before moving on to a new visual signal. The instructor told participants to remember the visual signal names with their corresponding action(s).

After participants put the VR headset on, they were allowed as much time as they needed in order to familiarize themselves with the VR environment prior to beginning the training. Participants ready to being the training module began with a view of the proceed screen (Figure 18).

Press SPACE to proceed with the experiment

Figure 18. Proceed screen.

Anyone who was not familiar with the VR headset received training on making all suitable adjustments. Some were able to turn and see mountains beyond the bay doors in the simulation. Other participants received the simulation with the X and Y axes locked, so that the participants looked squarely at the training and testing events (center screen) at all times. The locking and unlocking of the X and Y axes were not planned and were intermittent anomalies. Once the training began, participants saw either the live-action or the animation visual signals (Figures 19 & 20).

Figure 19. Training segment: "Start Engine" command using live-action. Adapted from [37].

Figure 20. Training segment: "Slow down" command using animation.

The presenter supervised the gaze and overall training of the participant using the external monitor. This observation helped validate system performance and subject attention (Figure 21).

Figure 21. External view of participant conducting training segment.

4. Computer Testing

All participants were notified that they would watch ten separate animations. As before, once they pressed the spacebar, the awaiting animation began the hand and arm movement. In addition, participants were instructed that as soon as they recognized the hand and arm movement, they were required to press the spacebar again immediately. Upon doing so, participants verbally stated which signal they thought was displayed. Participants who did not know the visual signal were instructed to say either "I don't know" or could still guess, as they would not be penalized for incorrect answers. Prior to testing, the presenter clarified to all participants that the experiment was about testing the medium for learning, not about the participant's individual performance. Participants were notified incorrect answers would not be negatively assessed. The presenter actively encouraged all to provide a guess. As testing continued and they said what the movement was, their answers were recorded (Figure 22). When ready, participants were then able to press the spacebar and continue to each successive animation. Participants were allowed to modify their response(s) at any time during the test.

Figure 22. Testing segment: “Reverse” command.

5. Follow-up Live-Action Testing

All participants were requested to take part in the voluntary follow-up iteration of testing. Before the agreement, the pool of participants was reminded that a video camera would help score the testing. Those who agreed to the follow-up testing received the same ten live-action hand and arm signals in the same order as previously tested. Likewise, participants used the same room for follow-up testing as in the previous iteration.

Participants sat in a corner chair and watched the visual signals at a distance of approximately 15 feet. Beforehand, they received instructions that once the specific hand

and arm movement began, they should speak clearly enough for the microphone to capture their answer as soon as they recognized it. The camera recorded only their voice and the presenter's hand and arm movements to reflect the level of accuracy and identification time in seconds. Finally, participants were told to answer as soon as they recognized the signal. Like initial testing, participants acknowledged incorrect answers would not be negatively assessed. The presenter actively encouraged all to provide a guess. Participants were allowed to modify their response(s) at any time during the test.

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IV. RESULTS OF ANALYSIS

Paired t-Tests were used for all hypotheses because this was a within-subjects design so that all participants were exposed to both conditions. However, when comparing between naturally occurring groups, independent samples t-tests were used.

A. STATISTICAL ANALYSIS

(1) Animated and Live Initial Memory Difference

The difference in initial memory recall between animated and live-action was reviewed. One hypothesis identified the possibility that there would be a difference in initial memory recall. The Paired t-Test fails to reject the null hypothesis as there was not a significant difference between initial memory scores of computer animation (M = 0.84, SD = 0.151, CI_{95}[0.79, 0.89]) to live-action (M = 0.82, SD = 0.177, CI_{95}[0.758, 0.876]), t(34) = 0.597, p = 0.554, d = 0.122.

(2) Received Ground Guide Training

Results were compared to identify whether there was a difference on initial memory recall between those that received ground guide training to those that had not. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference between prior training scores from the group that had no ground guide training (M = 0.81, SD = 0.132, CI_{95}[0.736, 0.88]) to the group that had previous ground guide training (M = 0.84, SD = 0.114, CI_{95}[0.793, 0.889]), t(33) = -0.785, p = 0.438, d = 0.243.

(3) Ground Guided Before

Focus was placed on comparing those that had previously ground guided with those that had not on initial memory recall. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference between ground guiding scores from one group that never ground guided (M = 0.79, SD = 0.138, CI_{95}[0.714, 0.87]) compared to the group that had ground guided before (M = 0.85, SD = 0.108, CI_{95}[0.804, 0.892]), t(33) = -1.326, p = 0.194, d = 0.484.

(4) Operated a Tactical Vehicle

Further comparisons reviewed groups that operated a tactical vehicle previously with those that had not on initial memory recall. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference between those that have not operated a tactical vehicle (M = 0.80, SD = 0.149, CI_{95}[0.708, 0.892]) to those that have operated a tactical vehicle (M = 0.84, SD = 0.108, CI_{95}[0.798, 0.882]), t(33) = -0.886, p = 0.382, d = 0.307.

(5) Percentage Correct Depending on Condition – Whether They Started with Animated or Live

The data was analyzed utilizing the condition that participants having begun with either animated training or live action training might show a correlation based on order. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference in scores when starting with animations (M = 0.82, SD = 0.120, CI_{95}[0.768, 0.872]) as opposed to live-action (M = 0.84, SD = 0.124, CI_{95}[0.777, 0.903]), t(33) = -0.482, p = 0.663, d = 0.164.

(6) X and Y Axis

Comparisons were made in initial recall between groups that participated in the simulation when the X and Y axis were locked in comparison to those that were able to look around 360 degrees in the simulation. This task was completed to ensure no confounding variables were present. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference in scores between the group with unlocked axes (M = 0.82, SD = 0.122, CI_{95}[0.759, 0.879]) compared to locked axes (M = 0.84, SD = 0.121, CI_{95}[0.776, 0.884]), t(33) = -0.438, p = 0.664, d = 0.165.

(7) Transformed Time Stats

Response time data were transformed due to a non-normal distribution that was highly skewed with a high kurtosis. After the transformation, the data were reviewed to ensure there were no significant outliers. One outlier was removed due to being outside 2.5 standard deviations.

b. *Difference in Response Time for Part 1*

Further analysis reviewed the difference in mean response time between those live and animated regardless of what training module they received first. The Paired t-Test fails to reject the null hypothesis as there was not a significant difference between response time scores of computer animation (M = 1.03, SD = 0.442, CI_{95}[0.882, 1.175]) o live-action (M = 1.09, SD = 0.386, CI_{95}[0.967, 1.223]), t(34) = -0.845, p = 0.404, d = 0.145.

c. *X and Y Difference in Time*

To make sure there were no confounding elements, we tested to make sure locking the X and Y axis did not have an effect on the experiment. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference in response times between the group with unlocked axes (M = 1.09, SD = 0.136, CI_{95}[0.929, 1.258]) compared to locked axes (M = 1.04, SD = 0.359, CI_{95}[0.874, 1.196]), t(33) = 0.495, p = 0.624, d = 0.184.

d. *Time Difference Between Conditions – Whether They Received Animated or Live First*

The groups were analyzed to see if there was a difference in response time based on the order participants received the training, whether it was the animated version or the live version first. The Independent Samples t-Test fails to reject the null hypothesis as there was not a significant difference in response times between computer animation (M = 1.10, SD = 0.409, CI_{95}[0.919, 1.278]) to live-action (M = 1.01, SD = 0.235, CI_{95}[0.893, 1.131]), t(33) = 0.731, p = 0.470, d = 0.0003.

(8) **Recall Accuracy Between Animated and Live in Part 2**

Analysis of the percentage correct based on Part 2 of the experiment between animated and live action was made. The Paired t-Test fails to reject the null hypothesis as there was not a significant difference in scores between computer animation (M = 0.81, SD = 0.213, CI_{95}[0.708, 0.917]) to live-action (M = 0.83, SD = 0.177, CI_{95}[0.738, 0.912]), t(15) = -0.187, p = 0.855, d = 0.102.

(9) Difference Correct Between Part 1 and Part 2

Further, examination was made to understand if there was a difference in the number of correct answers from Part 1 to Part 2. The Paired t-Test fails to reject the null hypothesis as there was not a significant difference between Part 1 test scores (M = 0.83, SD = 0.139, CI_{95}[0.757, 0.893]) to Part 2 test scores (M = 0.82, SD = 0.142, CI_{95}[0.749, 0.889]), t(15) = 0.164, p = 0.872, d = 0.071.

(10) Accuracy among Videos – Part 1

A repeated measures ANOVA was used to see if there was a difference in accuracy among the videos (Table 1). A significant difference was found such that accuracy differed among the videos, $F(8,27) = 2.87$, $p < 0.001$, $\eta_p^2 = 0.72$. Pairwise comparisons were examined to see where the differences were.

Table 1. Descriptive statistics, part 1

	Mean	Std. Deviation
P1 Attention	.80	.406
P1 Are you ready	.43	.502
P1 Start engine	.91	.284
P1 Forward	.97	.169
P1 Stop	.54	.505
P1 Increase Spd	.86	.355
P1 Slow	.80	.406
P1 Reverse	1.00	.000
P1 Follow	.97	.169
P1 Turn	1.00	.000

Upon review, the correlation between each individual visual signal was found to have a surprising number of significances (highlighted) between them (Table 2). The signals are coded as follows: 1 is “Attention.” 2 is “I am ready; Are you ready?” 3 is “Start your engine.” 4 is” Move forward.” 5 is “Halt or stop.” 6 is “Increase speed.” 7 is “Slow down.” 8 is “Move in reverse.” 9 is “Advance, move out, or follow me.” 10 is “Turn vehicle.”

Table 2. Visual signal correlation significance levels

	1	2	3	4	5	6	7	8	9	10
1	-	0.003	0.211	0.012	0.037	0.535	1.000	0.006	0.032	0.006
2	0.003	-	0.000	0.000	0.160	0.000	0.003	0.000	0.000	0.000
3	0.211	0.000	-	0.324	0.000	0.487	0.160	0.083	0.324	0.083
4	0.012	0.000	0.324	-	0.000	0.103	0.012	0.324	1.000	0.324
5	0.037	0.160	0.000	0.000	-	0.003	0.027	0.000	0.000	0.000
6	0.535	0.000	0.487	0.103	0.003	-	0.422	0.023	0.103	0.023
7	1.000	0.003	0.160	0.012	0.027	0.422	-	0.006	0.032	0.006
8	0.006	0.000	0.083	0.324	0.000	0.023	0.006	-	0.324	N/A
9	0.032	0.000	0.324	1.000	0.000	0.103	0.032	0.324	-	0.000
10	0.006	0.000	0.083	0.324	0.000	0.023	0.006	N/A	0.324	-

(11) Accuracy among the Videos – Part 2

The correct scores based on part two of the experiment were analyzed, but there were not sufficient numbers to make any meaningful conclusions. A significant difference was not found among the videos, $F(8,7) = 8.55$, $p = 0.091$, $\eta_p^2 = 0.77$. (Table 3)..

Table 3. Descriptive statistics, part 2

	Mean	Std. Deviation
P1 Attention	.80	.414
P1 Are you ready	.40	.507
P1 Start engine	.93	.258
P1 Forward	.87	.352
P1 Stop	.47	.516
P1 Increase Spd	.80	.414
P1 Slow	.93	.258
P1 Reverse	.93	.258
P1 Follow	1.00	.000
P1 Turn	1.93	.258

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V. DISCUSSION, FUTURE RESEARCH, AND CONCLUSION

A. DISCUSSION

This research found no difference between the conditions of visual signal training in virtual reality using computer animations and those using prerecorded live-action. The participants' levels of learning showed similar recall, regardless of group placement. In addition, participants identified training movements at similar speeds regardless of independent variable group placement. Ultimately, all available data analyzed did not support the *a priori* hypotheses.

Consequently, this inability to reject the null hypotheses supports this learning medium's validity in virtual reality training of hand and arm visual signals. Participants exhibited an 83% overall accuracy when recalling these signals. If the two commands, "I am ready; Are you ready" and "Halt or stop" are removed, the level of accuracy increased to 91%. Overall, these very high rates indicate that this is a viable learning option. Almost all other signals achieved between 86% and 97% accuracy. "Move in reverse" was the only visual signal to receive 100%. The learning rates overall are very high. Comparing the data after Part 2 of testing, the accuracy of the numbers does seem to follow the same pattern as Part 1.

The variety of scores dictates the military must identify what minimum threshold should be the standard. Is 80% accuracy sufficient for ground guides or drivers? Likewise, there is another concern. "I am ready; Are you ready?" was only accurately identified 43% of the time. "Halt or stop" was mildly better at 47% accuracy. These scores have a high correlation, providing support that the visual signals were misidentified as the other. Due to this significant finding, a visual assessment was made of the two signals, confirming the similarities.

Low accuracy scores indicate a significant problem as the probability of chance is at least 50% accuracy. These numbers are insufficient when the objective is a disciplined, fighting force. Higher accuracy when correctly identifying correct visual signals is definitely attainable. The low accuracy scores do support the need for further training. This should be endorsed immediately by proper channels.

B. FUTURE RESEARCH

This thesis helps put focus on preventable injuries, deaths, and subsequent organizational breaches in the written directives that military personnel follow to ground guide vehicles. Amending regulations and procedures must conform to the changing technological implementation of tomorrow. The value of VR technology to promote learning and validation that we will use to ensure the safety of military personnel in all settings is critical. Emphasis should be on problems in multi-domain realism, lack of training repetitions, associated training costs, and training consistency. These suggestions include:

- Add a live demo to learn from as a training condition.
- Add different hand and arm signals, encompassing mechanized movement techniques, traffic control, and convoy control.
- Incorporate auditory white noise to identify at what volume or frequencies learning is most effective, absent sound.
- Integrate performance-based scoring to identify appropriate learning gratification.
- Utilize a broader age demographic to assess VR as a reliable training source and assess technological biases.
- Conduct a more time-intensive study comparing retention and recollection over an extended period.
- Adjust initial training playback speeds to various amounts for calculation of ideal learning speeds and requisite intervals.
- Intensify training iterations employing duration or repetition to reinforce learning before the testing phase.

Hopefully, the above recommendations will improve both the research and extend the current knowledge base in the field of ground guiding safety.

C. LIMITATIONS

This thesis dealt with three limitations. First, there was an insufficient number of participants for Part 2 of the testing. A total of 16 completed the second phase. In order to statistically prove significance, additional personnel are required. Second, the unplanned locking and unlocking of the X and Y axes, creating an intermittent anomaly not allowing the participant to look around the VR space, did not affect testing. Finally, there was a level of inconsistency regarding participants' time between completion of Part 1 and Part 2. Equal spacing would have been ideal, but some participants' schedules dictated a wider completion window that spanned three to seven days.

D. CONCLUSION

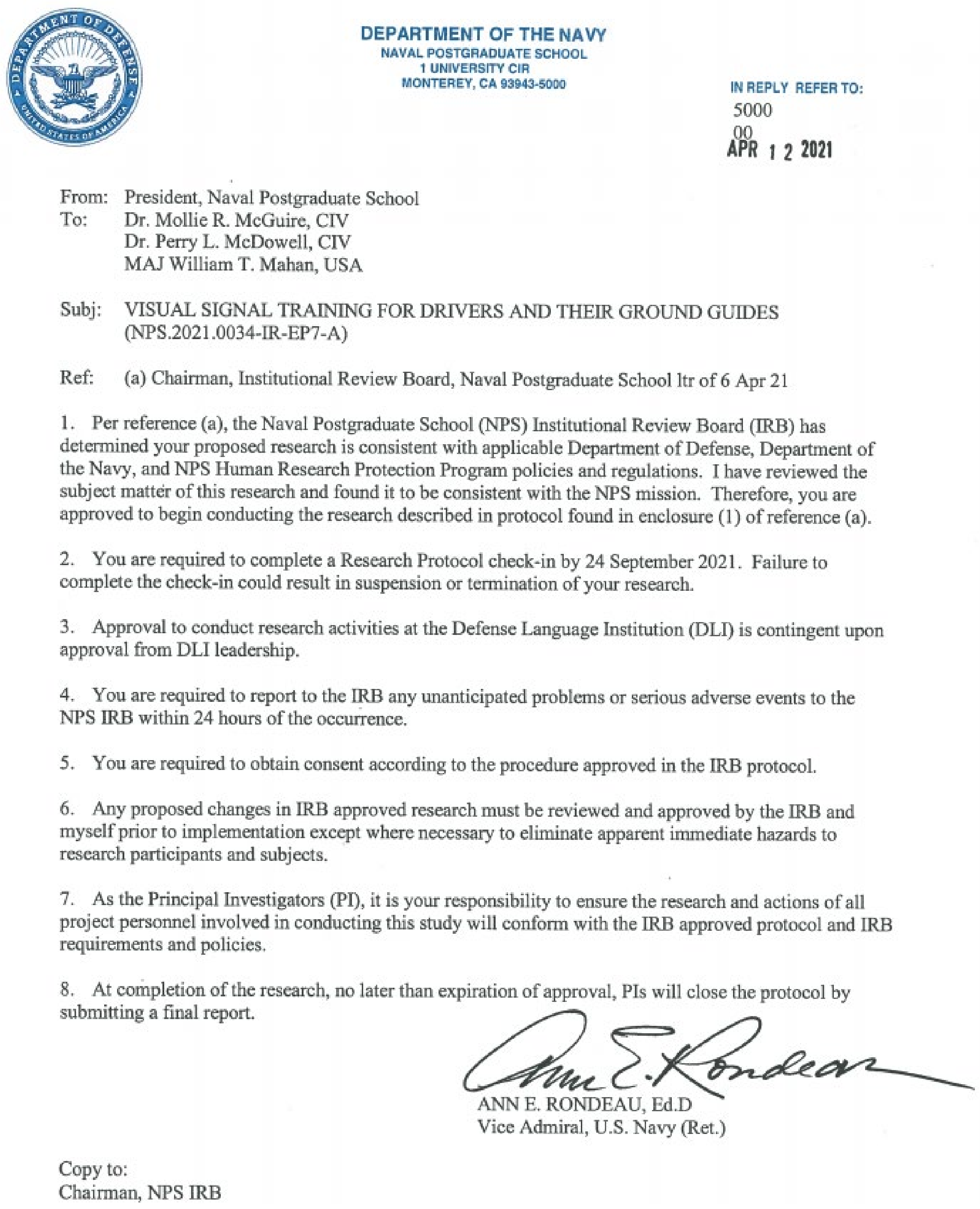
This thesis sought to evaluate the capabilities of personnel learning ground guide visual signals in virtual reality. Specifically, we endeavored to answer whether virtual reality or prerecorded live-action visual signals would facilitate learning quicker, and would participants recall hand and arm signals with a higher degree of accuracy utilizing virtual reality than they would using prerecorded live-action. The results show significant findings.

Virtual reality and prerecorded live-action positively increased learning with similar pace and accuracy and maintained high retention levels. There was no significant difference between which facilitated higher learning rates: retention or speed of visual signal identification. These findings are significant when taken as a whole, as the data supports two certainties.

First, scores between groups were similar across the board, regardless of the driver's or the ground guide's prior experience. The finding that there was no difference between those with ground guiding experience and those without indicates that those with experience had no advantage or better knowledge than those without it, and further supports the reality that lack of knowedge in ground guiding visual signals is a problem in the military. On the other hand, it also gives us better insight into how we can train to fix the discrepancy. Using virtual reality to train hand and arm visual signals is equally viable as using the live-action medium. We have shown that training can be done quickly, with extremely low overhead, and subjects can maintain retention of this learning in the near term. The training is also standardized for each trainee, creating the same level of knowledge across the service.

Training on ground guide signals should be implemented to save lives. This study has shown that the use of virtual reality for training is an effective means to administer this training. Vitual reality and the standardization of ground guide training should be implemented for the safety of all those in military ground transportation.

APPENDIX A. INSTITUTIONAL REVIEW BOARDS APPROVALS



DEPARTMENT OF THE NAVY
NAVAL POSTGRADUATE SCHOOL
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MONTEREY, CA 93943-5000

IN REPLY REFER TO:
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APR 1 2 2021

From: President, Naval Postgraduate School
To: Dr. Mollie R. McGuire, CIV
Dr. Perry L. McDowell, CIV
MAJ William T. Mahan, USA

Subj: VISUAL SIGNAL TRAINING FOR DRIVERS AND THEIR GROUND GUIDES (NPS.2021.0034-IR-EP7-A)

Ref: (a) Chairman, Institutional Review Board, Naval Postgraduate School ltr of 6 Apr 21

1. Per reference (a), the Naval Postgraduate School (NPS) Institutional Review Board (IRB) has determined your proposed research is consistent with applicable Department of Defense, Department of the Navy, and NPS Human Research Protection Program policies and regulations. I have reviewed the subject matter of this research and found it to be consistent with the NPS mission. Therefore, you are approved to begin conducting the research described in protocol found in enclosure (1) of reference (a).

2. You are required to complete a Research Protocol check-in by 24 September 2021. Failure to complete the check-in could result in suspension or termination of your research.

3. Approval to conduct research activities at the Defense Language Institution (DLI) is contingent upon approval from DLI leadership.

4. You are required to report to the IRB any unanticipated problems or serious adverse events to the NPS IRB within 24 hours of the occurrence.

5. You are required to obtain consent according to the procedure approved in the IRB protocol.

6. Any proposed changes in IRB approved research must be reviewed and approved by the IRB and myself prior to implementation except where necessary to eliminate apparent immediate hazards to research participants and subjects.

7. As the Principal Investigators (PI), it is your responsibility to ensure the research and actions of all project personnel involved in conducting this study will conform with the IRB approved protocol and IRB requirements and policies.

8. At completion of the research, no later than expiration of approval, PIs will close the protocol by submitting a final report.

Ann E. Rondeau

ANN E. RONDEAU, Ed.D
Vice Admiral, U.S. Navy (Ret.)

Copy to:
Chairman, NPS IRB

Figure 23. President, Naval Postgraduate School approval.

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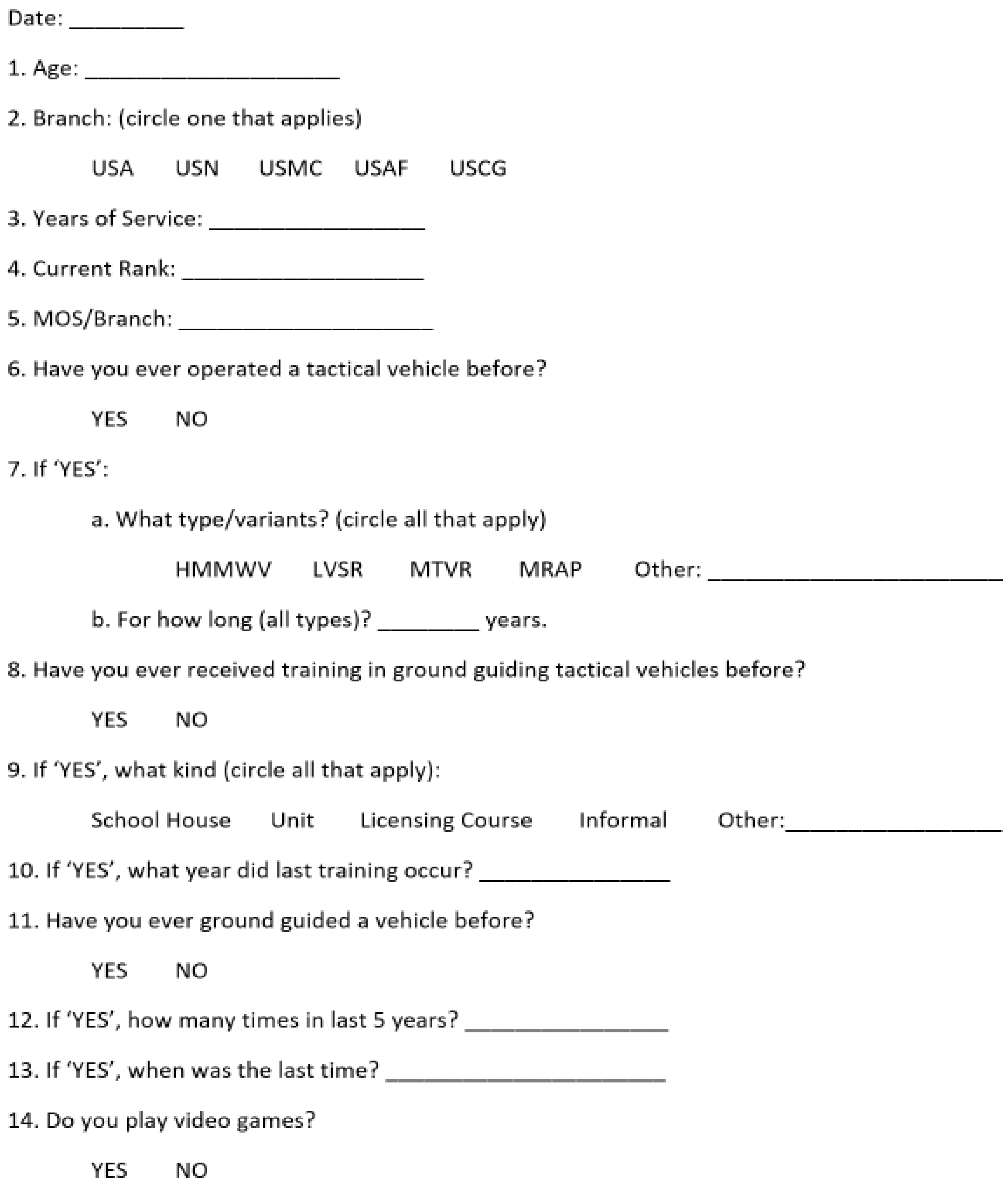
APPENDIX B. EXPERIMENT SUPPLEMENTALS

A. DEMOGRAPHIC SURVEY



Date: _________

1. Age: ____________________

2. Branch: (circle one that applies)

    USA USN USMC USAF USCG

3. Years of Service: _________________

4. Current Rank: ___________________

5. MOS/Branch: ____________________

6. Have you ever operated a tactical vehicle before?

    YES NO

7. If 'YES':

    a. What type/variants? (circle all that apply)

        HMMWV LVSR MTVR MRAP Other: ________________________

    b. For how long (all types)? ________ years.

8. Have you ever received training in ground guiding tactical vehicles before?

    YES NO

9. If 'YES', what kind (circle all that apply):

    School House Unit Licensing Course Informal Other:_________________

10. If 'YES', what year did last training occur? _______________

11. Have you ever ground guided a vehicle before?

    YES NO

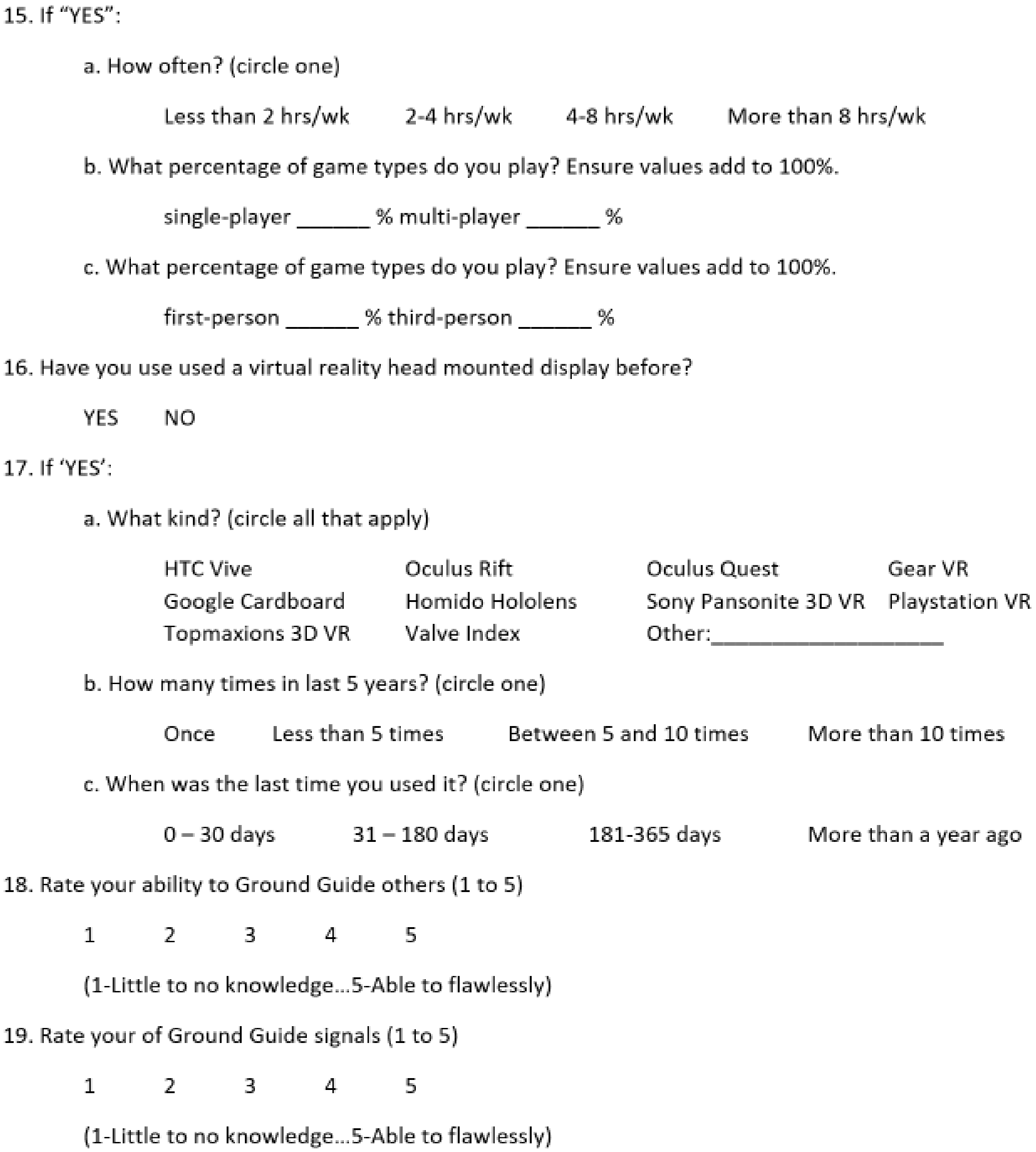
12. If 'YES', how many times in last 5 years? ________________

13. If 'YES', when was the last time? ______________________

14. Do you play video games?

    YES NO

Figure 24. Demographic survey, questions 1-14.



15. If "YES":

a. How often? (circle one)

Less than 2 hrs/wk   2-4 hrs/wk   4-8 hrs/wk   More than 8 hrs/wk

b. What percentage of game types do you play? Ensure values add to 100%.

single-player ______ % multi-player ______ %

c. What percentage of game types do you play? Ensure values add to 100%.

first-person ______ % third-person ______ %

16. Have you use used a virtual reality head mounted display before?

YES   NO

17. If 'YES':

a. What kind? (circle all that apply)

HTC Vive   Oculus Rift   Oculus Quest   Gear VR
Google Cardboard   Homido Hololens   Sony Pansonite 3D VR   Playstation VR
Topmaxions 3D VR   Valve Index   Other:____________________

b. How many times in last 5 years? (circle one)

Once   Less than 5 times   Between 5 and 10 times   More than 10 times

c. When was the last time you used it? (circle one)

0 – 30 days   31 – 180 days   181-365 days   More than a year ago

18. Rate your ability to Ground Guide others (1 to 5)

1   2   3   4   5

(1-Little to no knowledge...5-Able to flawlessly)

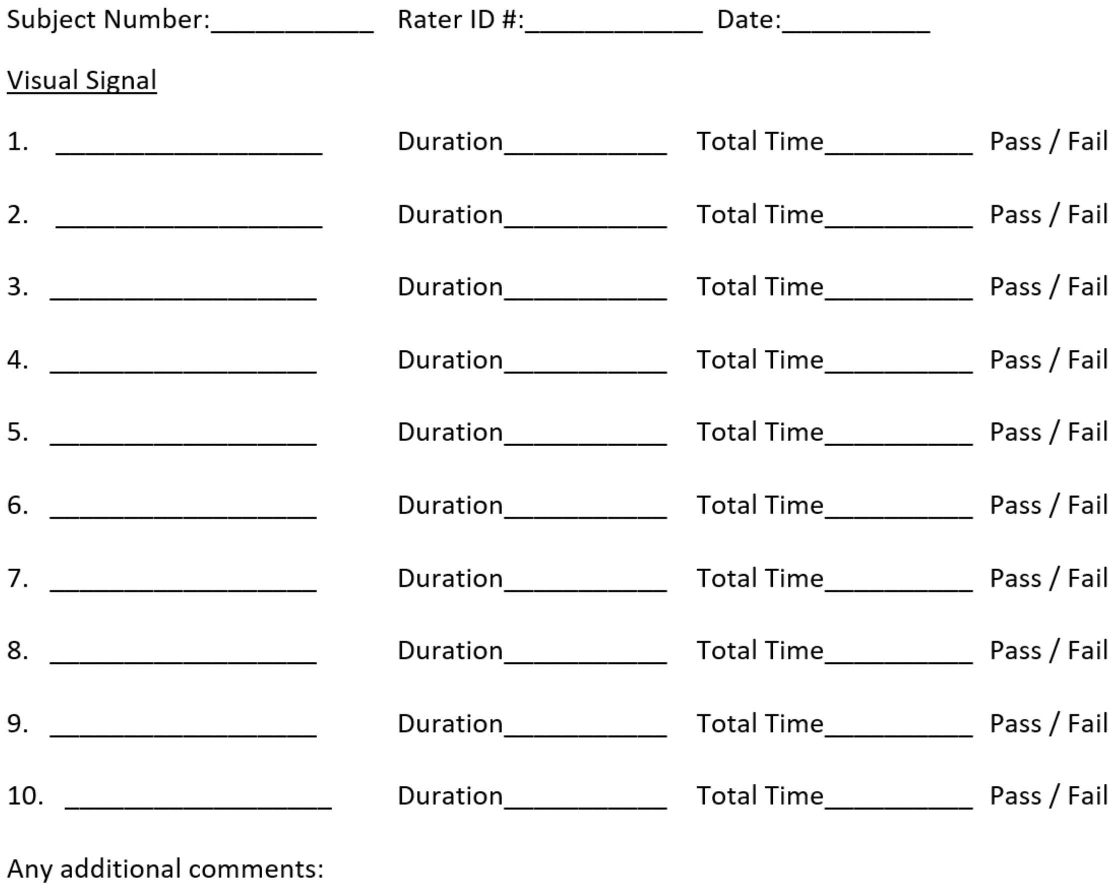
19. Rate your of Ground Guide signals (1 to 5)

1   2   3   4   5

(1-Little to no knowledge...5-Able to flawlessly)

Figure 25. Demographic survey, questions 15-19.

B. PASS/FAIL SCORING SHEET



Subject Number:____________ Rater ID #:_____________ Date:___________

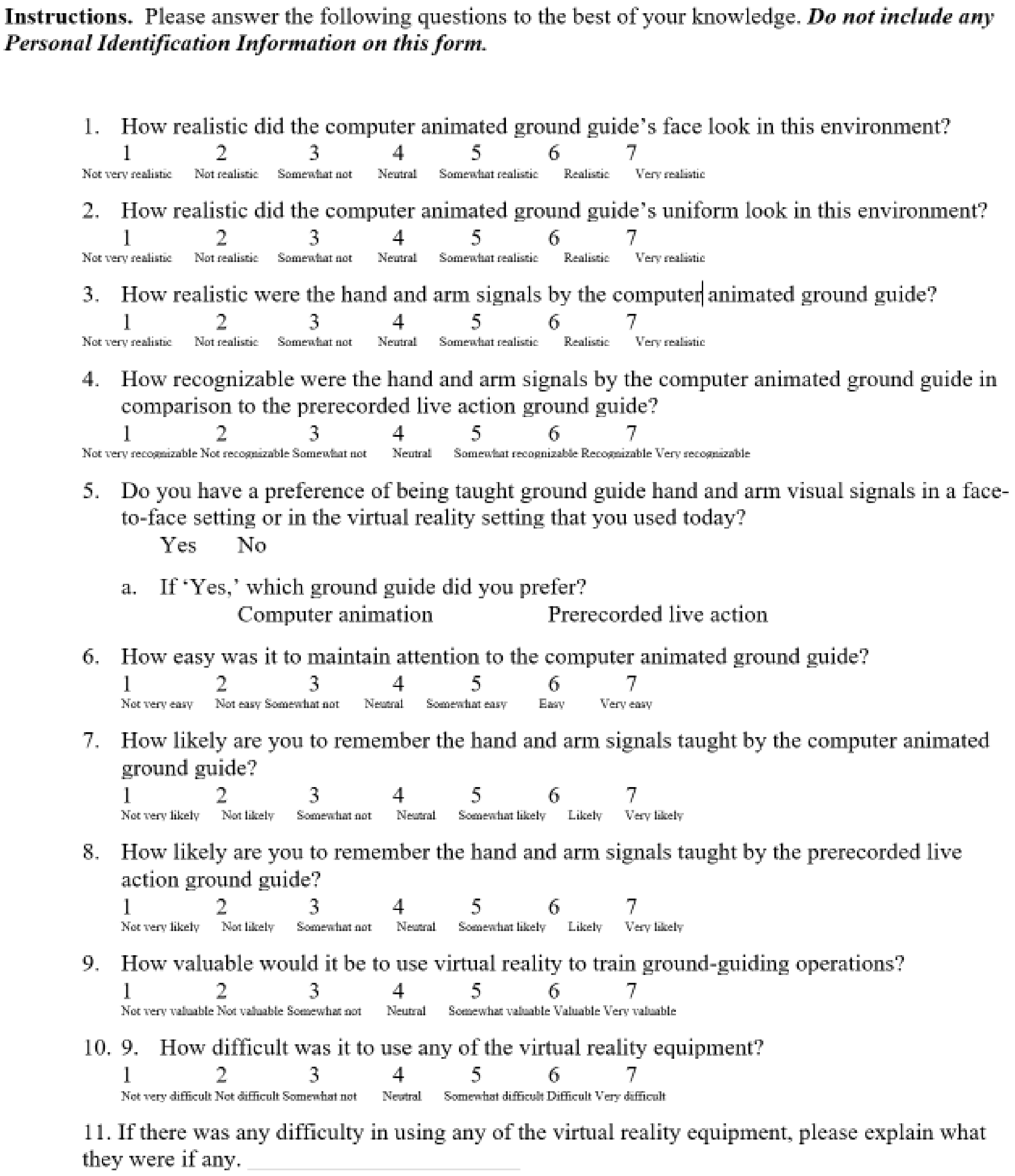
Visual Signal

1. ____________________ Duration____________ Total Time___________ Pass / Fail
2. ____________________ Duration____________ Total Time___________ Pass / Fail
3. ____________________ Duration____________ Total Time___________ Pass / Fail
4. ____________________ Duration____________ Total Time___________ Pass / Fail
5. ____________________ Duration____________ Total Time___________ Pass / Fail
6. ____________________ Duration____________ Total Time___________ Pass / Fail
7. ____________________ Duration____________ Total Time___________ Pass / Fail
8. ____________________ Duration____________ Total Time___________ Pass / Fail
9. ____________________ Duration____________ Total Time___________ Pass / Fail
10. ____________________ Duration____________ Total Time___________ Pass / Fail

Any additional comments:

Figure 26. Visual signal pass/fail scoring sheet.

C. POST QUESTIONNAIRE



Instructions. Please answer the following questions to the best of your knowledge. ***Do not include any Personal Identification Information on this form.***

1. How realistic did the computer animated ground guide's face look in this environment?

1	2	3	4	5	6	7
Not very realistic	Not realistic	Somewhat not	Neutral	Somewhat realistic	Realistic	Very realistic

2. How realistic did the computer animated ground guide's uniform look in this environment?

1	2	3	4	5	6	7
Not very realistic	Not realistic	Somewhat not	Neutral	Somewhat realistic	Realistic	Very realistic

3. How realistic were the hand and arm signals by the computer animated ground guide?

1	2	3	4	5	6	7
Not very realistic	Not realistic	Somewhat not	Neutral	Somewhat realistic	Realistic	Very realistic

4. How recognizable were the hand and arm signals by the computer animated ground guide in comparison to the prerecorded live action ground guide?

1	2	3	4	5	6	7
Not very recognizable	Not recognizable	Somewhat not	Neutral	Somewhat recognizable	Recognizable	Very recognizable

5. Do you have a preference of being taught ground guide hand and arm visual signals in a face-to-face setting or in the virtual reality setting that you used today?

   Yes No

   a. If 'Yes,' which ground guide did you prefer?

      Computer animation Prerecorded live action

6. How easy was it to maintain attention to the computer animated ground guide?

1	2	3	4	5	6	7
Not very easy	Not easy	Somewhat not	Neutral	Somewhat easy	Easy	Very easy

7. How likely are you to remember the hand and arm signals taught by the computer animated ground guide?

1	2	3	4	5	6	7
Not very likely	Not likely	Somewhat not	Neutral	Somewhat likely	Likely	Very likely

8. How likely are you to remember the hand and arm signals taught by the prerecorded live action ground guide?

1	2	3	4	5	6	7
Not very likely	Not likely	Somewhat not	Neutral	Somewhat likely	Likely	Very likely

9. How valuable would it be to use virtual reality to train ground-guiding operations?

1	2	3	4	5	6	7
Not very valuable	Not valuable	Somewhat not	Neutral	Somewhat valuable	Valuable	Very valuable

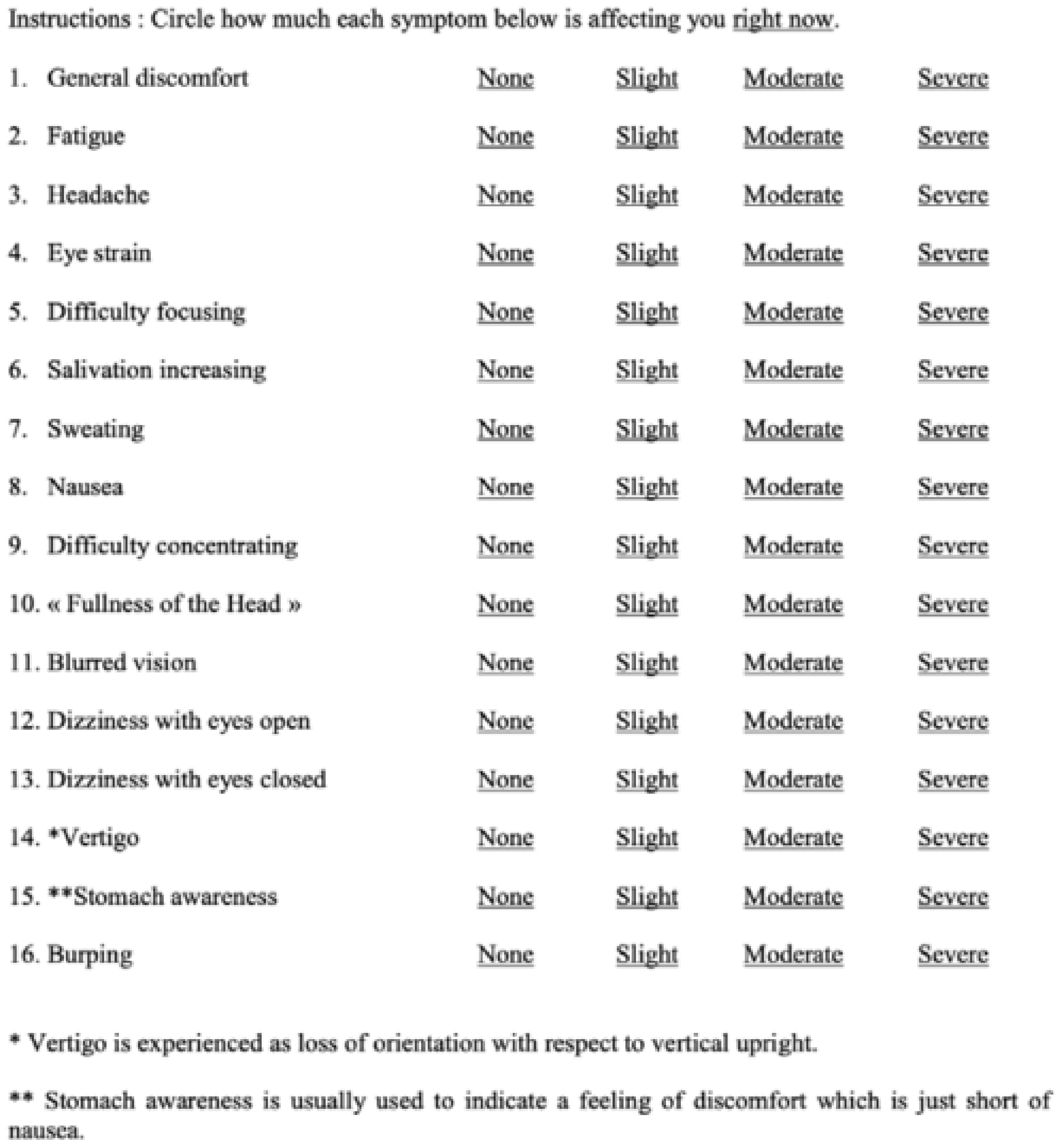
10. 9. How difficult was it to use any of the virtual reality equipment?

1	2	3	4	5	6	7
Not very difficult	Not difficult	Somewhat not	Neutral	Somewhat difficult	Difficult	Very difficult

11. If there was any difficulty in using any of the virtual reality equipment, please explain what they were if any. ____________________

Figure 27. Post questionnaire

D. SIMULATOR SICKNESS QUESTIONNAIRE



Instructions : Circle how much each symptom below is affecting you right now.

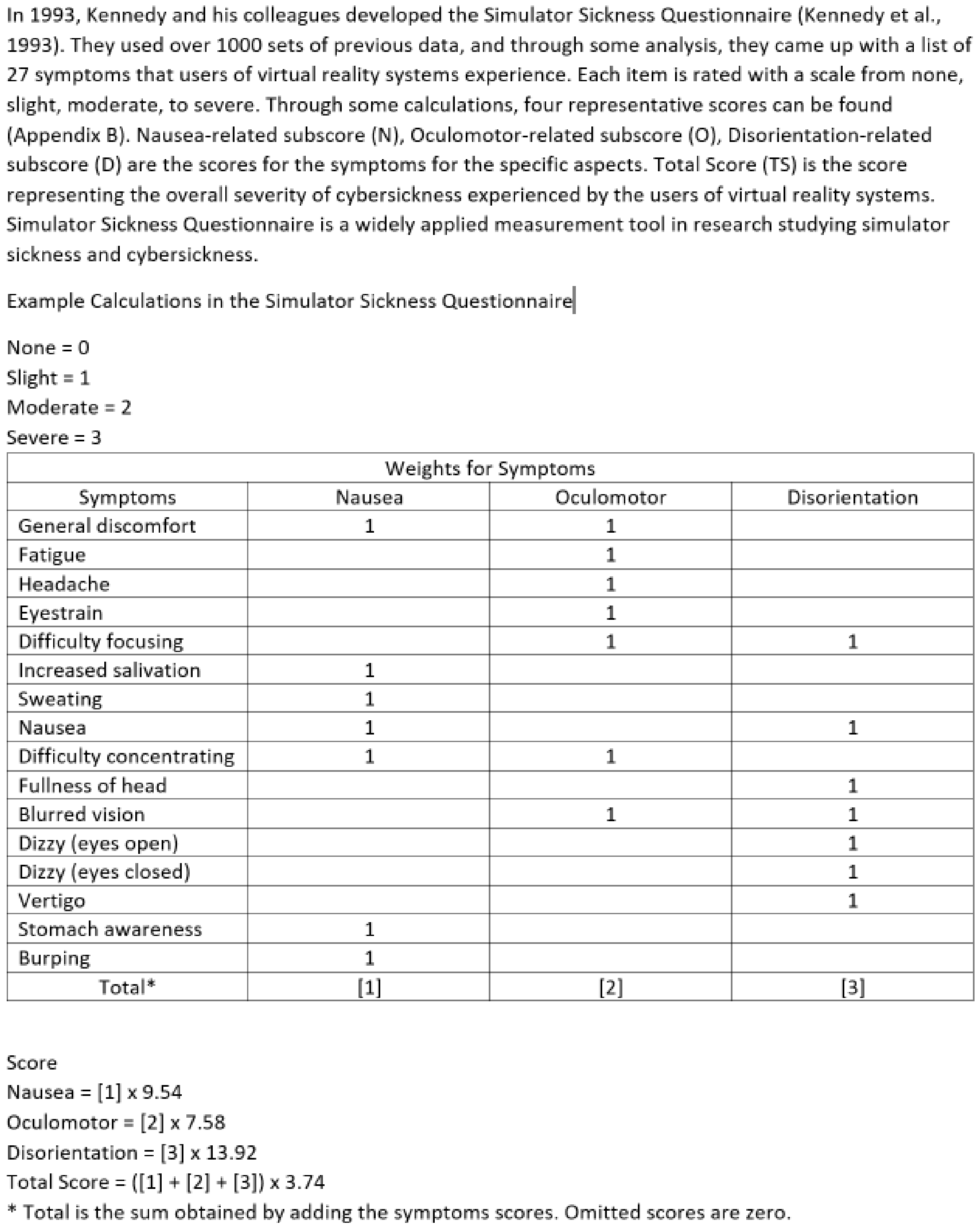
1. General discomfort	None	Slight	Moderate	Severe
2. Fatigue	None	Slight	Moderate	Severe
3. Headache	None	Slight	Moderate	Severe
4. Eye strain	None	Slight	Moderate	Severe
5. Difficulty focusing	None	Slight	Moderate	Severe
6. Salivation increasing	None	Slight	Moderate	Severe
7. Sweating	None	Slight	Moderate	Severe
8. Nausea	None	Slight	Moderate	Severe
9. Difficulty concentrating	None	Slight	Moderate	Severe
10. « Fullness of the Head »	None	Slight	Moderate	Severe
11. Blurred vision	None	Slight	Moderate	Severe
12. Dizziness with eyes open	None	Slight	Moderate	Severe
13. Dizziness with eyes closed	None	Slight	Moderate	Severe
14. *Vertigo	None	Slight	Moderate	Severe
15. **Stomach awareness	None	Slight	Moderate	Severe
16. Burping	None	Slight	Moderate	Severe

* Vertigo is experienced as loss of orientation with respect to vertical upright.

** Stomach awareness is usually used to indicate a feeling of discomfort which is just short of nausea.

Figure 28. Simulator sickness questionnaire. Source: [39].

E. SIMULATOR SICKNESS QUESTIONNAIRE SCORING



In 1993, Kennedy and his colleagues developed the Simulator Sickness Questionnaire (Kennedy et al., 1993). They used over 1000 sets of previous data, and through some analysis, they came up with a list of 27 symptoms that users of virtual reality systems experience. Each item is rated with a scale from none, slight, moderate, to severe. Through some calculations, four representative scores can be found (Appendix B). Nausea-related subscore (N), Oculomotor-related subscore (O), Disorientation-related subscore (D) are the scores for the symptoms for the specific aspects. Total Score (TS) is the score representing the overall severity of cybersickness experienced by the users of virtual reality systems. Simulator Sickness Questionnaire is a widely applied measurement tool in research studying simulator sickness and cybersickness.

Example Calculations in the Simulator Sickness Questionnaire

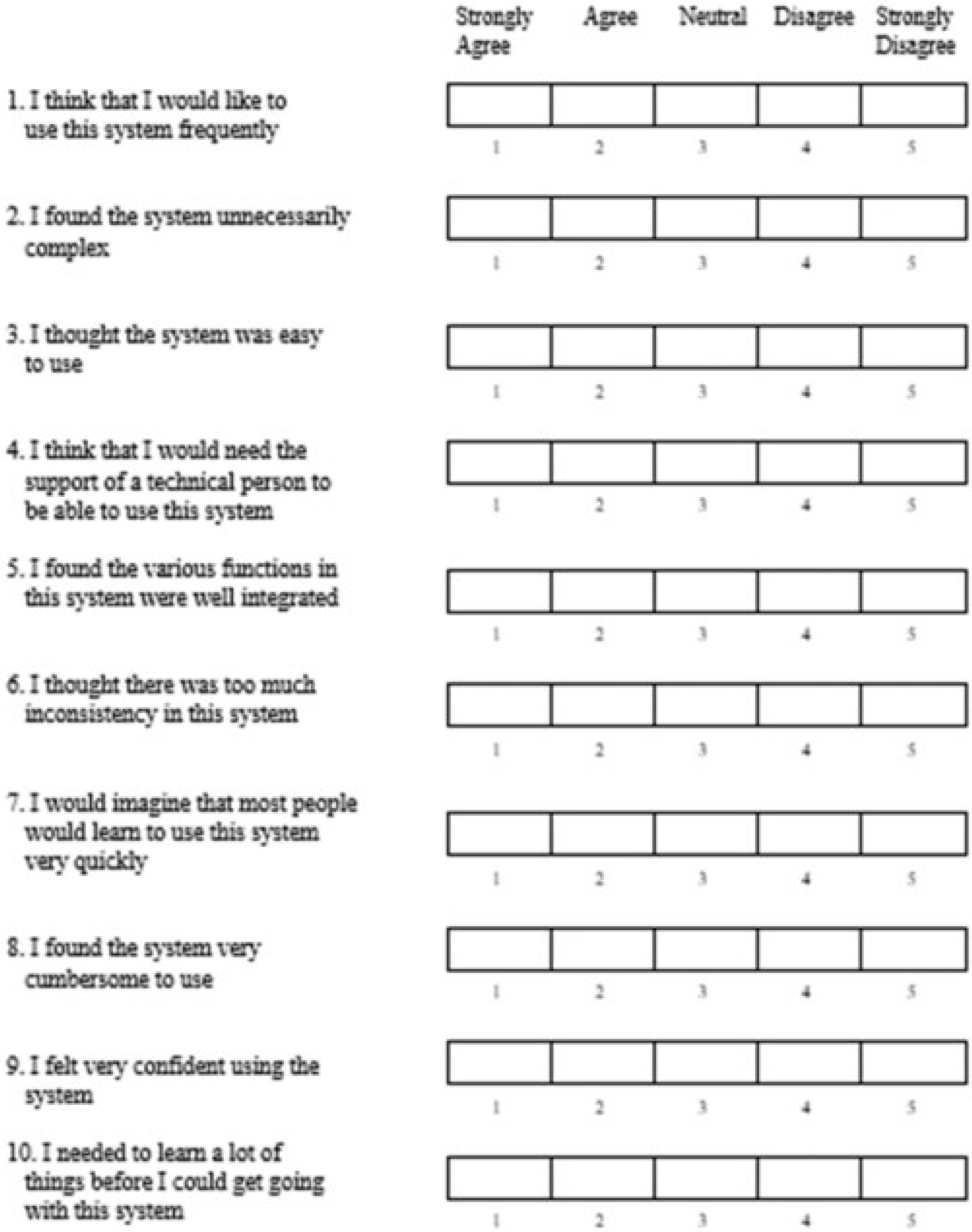
None = 0
Slight = 1
Moderate = 2
Severe = 3

Weights for Symptoms			
Symptoms	Nausea	Oculomotor	Disorientation
General discomfort	1	1	
Fatigue		1	
Headache		1	
Eyestrain		1	
Difficulty focusing		1	1
Increased salivation	1		
Sweating	1		
Nausea	1		1
Difficulty concentrating	1	1	
Fullness of head			1
Blurred vision		1	1
Dizzy (eyes open)			1
Dizzy (eyes closed)			1
Vertigo			1
Stomach awareness	1		
Burping	1		
Total*	[1]	[2]	[3]

Score
Nausea = [1] x 9.54
Oculomotor = [2] x 7.58
Disorientation = [3] x 13.92
Total Score = ([1] + [2] + [3]) x 3.74
* Total is the sum obtained by adding the symptoms scores. Omitted scores are zero.

Figure 29. Simulator sickness questionnaire scoring. Source: [39].

F. SYSTEM USABILITY SCALE



	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I think that I would like to use this system frequently	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
2. I found the system unnecessarily complex	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
3. I thought the system was easy to use	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
4. I think that I would need the support of a technical person to be able to use this system	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
5. I found the various functions in this system were well integrated	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
6. I thought there was too much inconsistency in this system	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
7. I would imagine that most people would learn to use this system very quickly	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
8. I found the system very cumbersome to use	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
9. I felt very confident using the system	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
10. I needed to learn a lot of things before I could get going with this system	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5

Figure 30. System usability scale

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