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THESIS

LEVERAGING AUGMENTED REALITY IN SUPPORT OF AIRCRAFT TOWING EVOLUTIONS

by

Jared R. Marks

June 2023

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This thesis investigated the potential of utilizing augmented reality (AR) as an operational tool to assist tow crew directors in reducing the occurrence of aviation ground mishaps (AGMs) within the fleet. An experiment using experienced tow crew directors in a virtual environment (VE) found improved collision detection rate, mean stopping distance, and user confidence levels amongst all experiment participants across various aviation ground operation scenarios. While the effects did not rise to the level of statistical significance, experiment participants readily recognized and emphasized the potential impact of such a system on a tow crew director's ability to control towing operations effectively and safely with enhanced efficiency. This thesis serves as a compelling proof of concept, providing valuable support to ongoing endeavors to further improve the safety and efficiency of naval aviation enterprise ground operations.

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LEVERAGING AUGMENTED REALITY IN SUPPORT OF AIRCRAFT TOWING EVOLUTIONS

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ABSTRACT

This thesis investigated the potential of utilizing augmented reality (AR) as an operational tool to assist tow crew directors in reducing the occurrence of aviation ground mishaps (AGMs) within the fleet. An experiment using experienced tow crew directors in a virtual environment (VE) found improved collision detection rate, mean stopping distance, and user confidence levels amongst all experiment participants across various aviation ground operation scenarios. While the effects did not rise to the level of statistical significance, experiment participants readily recognized and emphasized the potential impact of such a system on a tow crew director's ability to control towing operations effectively and safely with enhanced efficiency. This thesis serves as a compelling proof of concept, providing valuable support to ongoing endeavors to further improve the safety and efficiency of naval aviation enterprise ground operations.

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LIST OF ACRONYMS AND ABBREVIATIONS

3D	three-dimensional
AGM	aircraft ground mishap
AMB	aircraft mishap board
AMO	assistant aircraft maintenance officer
AMTRP	aviation maintenance training and readiness program
AR	augmented reality
ASM	advanced skills management
ATEAR	aircraft towing enhanced with augmented reality
BAH	Booze Allen Hamilton Consulting Group
BAR	basic and applied research
BR	brake rider
CG	commanding general
CNA	Center of Naval Analysis
CNAF	Commander of Naval Air Forces
CNO	Chief of Naval Operations
DOD	Department of Defense
DODI	Department of Defense Instruction
FM	Flight Mishap
FOD	foreign object damage
FOV	Field of View
FRM	flight related mishap
FY	fiscal year
GSE	ground support equipment
HAZREP	hazardous reports
HMD	head-mounted display
HQMC	Headquarters Marine Corps
IATA	International Air Transport Association

ID	identification number
IMRL	individual material readiness list
IRB	institutional review board
IST	Aviation Maintenance In-Service Training Program
LKE	Lakehurst, New Jersey
MAG	Marine Aircraft Group
MALS	Marine Aviation Logistics squadron
MAW	Marine Air Wing
MCAS	Marine Corps Air Station
MIS	management information system
MO&I	Mission, Operations, & Integration Department
MOP	measure of performance
MOS	military occupational specialty
MOVES	modeling, virtual environments, and simulations institute
MR	mixed reality
NAE	naval aviation enterprise
NAMP	Naval Aviation Maintenance Program
NAS	naval air station
NAVAIR	Naval Air Systems Command
NAVEDTRA	Naval Education and Training Command
NAVSAFCEN	Naval Safety Center
NAWCAD	Naval Air Warfare Center Aircraft Division
NAWCTSD	Naval Air Warfare Center Training Division
NCO	Non-commissioned Officer
NISE	naval innovative science and engineering
NJIT	New Jersey Institute of Technology
NPS	Naval Postgraduate School
NRP	naval research program
ONR	Office of Naval Research

PQS	personnel qualification standard
QPT	qualified and proficient technician
RBA	ready basic aircraft
RISE	Robotic and Intelligent System Engineering Lab
RMI	Risk Management Information
SE	support equipment
SNCO	Staff Non-commissioned Officer
SOP	standard operating procedure
SS	simulator sickness
SSQ	simulator sickness questionnaire
TD	tow crew director
TTD	tow tractor driver
TMT	trail making test
T/M/S	Type/Model/Series
TW	tail walker
USMC	United States Marine Corps
USN	United States Navy
VE	Virtual Environment
VR	Virtual Reality
WESS	web-enabled safety system
WW	wing walker

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Finally, I would like to thank my wife, Jennifer, and my daughter, Madeline, for their unwavering love and support. Their constant encouragement and understanding during the time I spent working on my thesis has been essential to me and my success. I could not have done it without them. I love you both deeply.

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I. INTRODUCTION

This thesis builds upon the work of Major Colton Fetterolf's thesis, "Using Augmented Reality to Enhance Situational Awareness for Aircraft Towing" (2020). Major Fetterolf examined the feasibility of a Virtual Reality (VR) system called "Aircraft Towing Enhanced with Augmented Reality" (ATEAR). His study was designed to help improve the confidence and awareness of the Navy's and Marine Corps' aircraft tow crew directors. This improved confidence and awareness is in regard to the aircraft tow crew director's ability to identify an aircraft's flight surfaces in relation to other objects in the vicinity of the aircraft on a standard flight line, also known as shore-based operations.

A. RESEARCH PROBLEM AND MOTIVATION

The driving force behind this thesis was to decrease the number of Aviation Ground Mishaps (AGMs) within the Naval Aviation Enterprise (NAE) and advocate for the fielding of technologies that support aviation ground operations. While there are various categories of AGMs, this research focuses explicitly on aircraft collisions while being towed. Despite being acknowledged as a serious problem by NAE leadership, the collision rate remains alarmingly high, resulting in damages and repairs that have cost the NAE millions of dollars. Studies conducted by the Naval Safety Center (NAVSAFCN), Head Quarters Marine Corps (HQMC), and other consulting and analysis firms have identified multiple potential contributing factors to the increase in AGMs, with maintainer inexperience as the primary issue (Glueck, 2017; Department of Defense Aviation, 2018; Nguyen, 2018). This thesis will further investigate and test other factors, including maintainer contrast sensitivity or the visibility of flight control surfaces, and maintainer cognitive processing speed or the ability to process information and react to potential collisions (Fetterolf, 2020).

This thesis will continue the work established in Major Fetterolf's study by experimenting on qualified aircraft maintainers in a simulated operational environment within ATEAR. The experiment will assess maintainers' ability to react and identify potential aircraft collisions with and without Augmented Reality (AR) supplementation within the virtual environment of ATEAR. The data collected from the experiment will provide NAE leaders with the information needed to determine if an AR system can effectively reduce the number of AGMs within the NAE. Additionally, this thesis will directly support NAVSAFCN initiatives and the Naval Air Warfare Center Aircraft Division (NAWCAD) in developing and fielding AR technologies to help support the NAE mission.

B. RESEARCH QUESTIONS

The work in this thesis will focus on the following research questions initially addressed in Major Fetterolf's (2020) work:

1. How can AR be utilized to prevent aircraft collisions during towing evolutions?
2. To what extent does AR enhance situational awareness for a tow crew director?

C. HYPOTHESIS

Similar to Major Fetterolf's hypotheses, the following null hypothesis and alternative hypothesis have been established to address the research questions:

1. Hypothesis 1

- Null Hypothesis $H1_0$: There is no difference in collision detection rate between the standard view and the AR view, $d_{ps} - {}_{pAR} = 0$
- Alternative Hypothesis $H1_A$: There is a difference in collision detection rate between the standard view and the AR view, $d_{ps} - {}_{pAR} \neq 0$

2. Hypothesis 2

- Null Hypothesis $H2_0$: There is no difference in mean stopping distance between the standard view and the AR view, $\mu d = 0$
- Alternative Hypothesis $H2_A$: There is a difference in mean stopping distance between the standard view and the AR view, $\mu d \neq 0$

3. Hypothesis 3

- Null Hypothesis $H3_0$: There is no difference in confidence levels between the standard view and AR view, $\mu d = 0$

- Alternative Hypothesis $H3_A$: There is a difference in confidence levels between the standard view and AR view, $\mu d \neq 0$

D. RESEARCH OBJECTIVES

- Collaborate with NAWCAD Lakehurst Mission Operations and Integration (MO&I) Department to implement an AR interface that provides additional detection information to a aircraft tow crew director. Specifically, an aircraft's proximity to other objects within a simulated environment.

- Integrate the NAWCAD AR overlay into the ATEAR system and carry out the designed experiment on maintainers from Marine Aircraft Group 11 (MAG), III Marine Aircraft Wing (MAW). The experiment will gather objective and subjective data on the research questions, clarify the potential of AR in this specific domain, and assist NAWCAD in developing and fielding AR support equipment to alleviate towing collisions and support the NAE mission.

E. BENEFITS OF STUDY

This research intends to draw attention to the issue of towing collisions and to reduce the number of AGMs caused by aircraft collisions within the NAE. Moreover, this research will support the efforts of NAWCAD's "Wing Walker" initiative, which aims to provide maintainers with collision detection AR capabilities. The development and fielding of AR collision detection support equipment will elevate the maintainers' confidence and situational awareness while carrying out towing operations and address the AGM problem identified by NAVSAFCN and HQMC, ultimately saving the NAE millions of dollars.

F. SCOPE OF THESIS

This thesis is divided into four main areas of investigation:

1. The first area is to examine and review the historical data analyzed in previous efforts. The historical mishap data evaluates the problem's overall impact and supports the problem statement. By obtaining current mishap data, this thesis will further support the problem statement by comparing it to historical data. This data will include the cost of damage and repairs and the operational impact on squadrons.

2. The second area will analyze the current training, qualifications, and towing procedures for aircraft tow crews within the NAE, including USN and USMC aviation.

3. The third area will explore current AR and VR technologies, evaluate their advantages, and examine various use cases in the industrial and military domains.

4. The fourth area will focus on experimenting with qualified aircraft maintainers from VMFAT-101. The assessment of each individual's performance will be gauged on three distinct parameters, namely their ability to detect collisions, the average distance between the aircraft and potential collision points once the towing operation has stopped, and their confidence in detecting potential collision within their field of view (FOV). The subjects will experience an equal number of scenarios of varying difficulty, with and without using an AR supplementation. The subject will conduct one set of scenarios utilizing NAWCAD's collision detection interface. The data gathered will be analyzed by comparing each subject's performance with and without AR supplementation in each scenario within the VE. Subjects will also take contrast sensitivity and cognitive processing speed tests between scenario sets. These tests will assist in analyzing subject performance in a collision scenario and if

contrast sensitivity or cognitive processing speed could be potential causal factors.

G. THESIS STRUCTURE

- Chapter I provides an overview of the problem statement, objectives, and methodology.
- Chapter II reviews the documents and policies that define Mishaps within the Department of Defense (DOD), expound upon the effects of towing incidents on naval aviation, and review the current training, composition, and procedures for NAE tow crews.
- Chapter III includes a review of literature on topics related to AR and VR, as well as an examination of AR and VR use cases and technologies with a focus on aviation ground operations and maintenance fields within the civilian and military domains.
- Chapter IV reviews the simulation development, design and development of the different AR interfaces and the captured performance measures. Specifically, a review of NAWCAD's collaboration with the New Jersey Institute of Technology (NJIT) on the design and development of the Wing Walker System collision detection interface is conducted.
- Chapter V reviews the methodology and experiment design.
- Chapter VI covers the results and analysis of the experiment.
- Chapter VII concludes the research questions, provides future work recommendations to include continued collaboration to improve and field the Wing Walker system, and elaborates on how similar AR systems can vastly improve the NAE mission and objectives.

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II. TOWING MISHAP REVIEW

Aircraft towing is a critical component within the NAE, allowing for the efficient and safe movement of aircraft around the flight deck, hangar deck, and maintenance spaces. However, towing operations can be complex and potentially hazardous, involving coordinating multiple personnel and operating specialized equipment. As a result, aircraft towing mishaps can occur, significantly impacting the NAE both monetarily and operationally.

This chapter will provide an overview of aircraft towing mishaps in the NAE, including the impacts of these mishaps, the various studies conducted about them, and the staffing and composition of an Aircraft Tow Crew. Additionally, this chapter will discuss the procedures involved in aircraft towing, including the various equipment used and the specific protocols that must be followed to ensure safety and efficiency. Finally, this chapter will explore the training and management of Aircraft Tow Crews, including the current requirements and qualifications for personnel involved in towing operations.

Overall, this chapter will demonstrate the importance of aircraft towing within the NAE while highlighting the potential risks involved and the critical need for proper procedures and training to ensure safe and efficient operations.

A. DOD MISHAP CLASSIFICATIONS

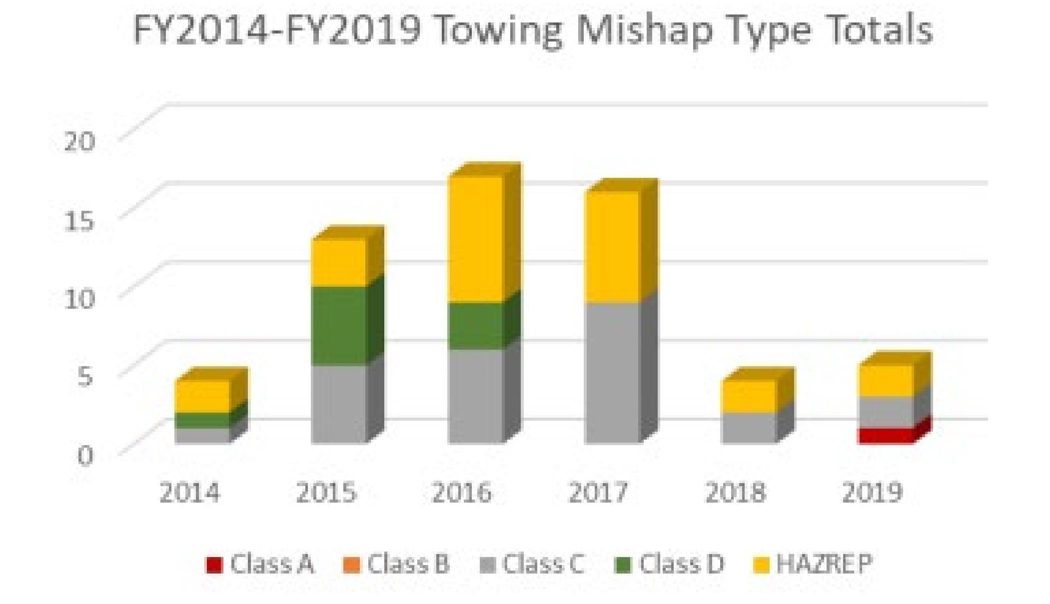
As previously stated in Major Fetterolf's thesis (2020), a naval aviation mishap is an event that involves government equipment and results in damage, injury, or illness. The DOD assigns a classification to each mishap based on its severity, the injuries sustained by those involved, and the cost to the government. The Department of Defense (DOD) relies on the policy guidelines laid out in DOD Instruction (DODI) 6055.07 to steer its mishap classification system, which sets out the protocols for mishap notification, investigation, reporting, and record-keeping for each of its military branches (Office of the Secretary of Defense, 2018). The mishap definitions and reporting procedures for the United States Navy (USN) are also directed by the Naval Aviation Safety Management System (OPNAVINST3750.6S). Mishaps are classified according to their cost, ranging from "A" to "D," with "A" denoting over $2,000,000 and "D" denoting between $20,000 and $50,000. Moreover, the U.S. Navy categorizes mishaps into subcategories, such as flight mishaps (FM), flight-related mishaps (FRM), and AGM, based on how they happened, as stated by the Chief of Naval Operations (2014).

B. IMPLICATIONS OF TOWING RELATED AGMS

The implications discussed in this section will focus on the monetary and operational impacts of towing-related AGMs on the NAE. As highlighted by previous studies, there has been a notable surge in towing-related Aviation Ground Mishaps (AGMs) since Fiscal Year (FY) 2014. This concerning trend is largely attributed to the mishandling of aircraft by maintainers, leading to collisions with typical items, buildings, and support equipment that can be found on a standard operational flight line. As we will see in the following section, the USN collects the data and analyses AGMs utilizing their primary aircraft reporting system. The FY2014-2019 data utilized in this thesis was retrieved by Major Fetterolf (2020) and is from the USN's web-enabled safety system (WESS). The Risk Management Information (RMI) system has now replaced the WESS, and any data reviewed past 2019 will be data retrieved from the RMI system..

1. Review of FY 2014–2019 WESS Data

It is important to note that the data analysis conducted in this section was conducted by Major Fetterolf (2020). Additionally, the data in this section and the subsequent section utilize the search function in Excel as the primary means of review. Due to the functionality of WESS, the outputs delineating the types of incidents can be vague and not well-defined. So, because of this vagueness, a thorough search of the incident narratives was performed, resulting in 59 incidents involving towing. The incidents are further categorized, see Figure 1, into Class A mishaps (1 incident), Class C mishaps (25 incidents), Class D mishaps (9 incidents), and HAZREPs (24 incidents). These incidents occurred among all aircraft type/ model/series (T/M/S) within the NAE, most of which occurred during FY2015-2017. The reason for this significant increase in incidents during this period is unknown (Fetterolf, 2020).



Data source: Naval Safety Center, raw unpublished data received by Capt Colton Fetterolf via email, Mar. 19, 2020.

Figure 1. Number of Towing Incidents FY2014–FY2019. Source: Fetterolf (2020).

Major Fetterolf (2020) utilizes Table 1 to provide more information about when these incidents occurred. He noted that 59.3% of mishaps occurred during the day, 3.4% during dusk, and 37.3% during nighttime operations. The data was also divided into incidents during ashore and afloat operations, with 71.2% occurring while units were ashore and 28.8% occurring during afloat or shipboard operations. With visibility being much lower at night and the dynamic nature of shipboard operations, Major Fetterolf annotated that these observations are surprising and go against common expectations.

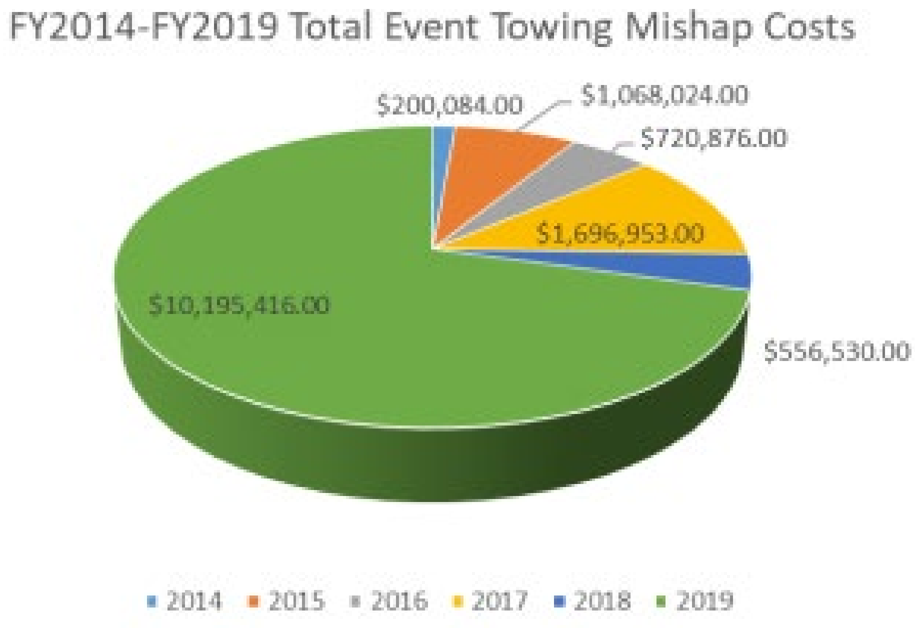
Table 1. FY2014–FY2019 Towing Incident Overview. Source: Fetterolf (2020).

FY	Mishap Classification																
	A			B			C			D			H			Total	Total Event Cost
	Day	Dusk	Night	Day	Dusk	Night	Day	Dusk	Night	Day	Dusk	Night	Day	Dusk	Night		
2014							1					1	1	1		4	$ 200,084.00
2015							5			2		3	3			13	$ 1,068,024.00
2016							4		2	1	1	1	5		3	17	$ 720,876.00
2017							4		5				3		4	16	$ 1,696,953.00
2018							2						1		1	4	$ 556,530.00
2019			1				2						1		1	5	$ 10,195,416.00
Time of Day	0	0	1	0	0	0	18	0	7	3	1	5	14	1	9	Day 35 Dusk 2 Night 22	$ 14,437,883.00
Mishap Type Total	1			0			25			9			24			59	
Ashore	1			0			17			8			16			42	
Afloat	0			0			8			1			8			17	

Data source: Naval Safety Center, raw unpublished data received by Capt Colton Fetterolf via email, Mar. 19, 2020.

a. Monetary Impacts

Along with the review of the FY2014-2019 WESS data, Major Fetterolf (2020) also analyzed the monetary impacts associated with that time period. He noted that the cost of towing-related incidents within the NAE from FY2014 to FY2019 was $14,437,883, as reported in Table 1 and Figure 2. The task of evaluating the cost of aircraft and property damage resulting from a mishap falls on the aircraft mishap board (AMB), with injury expenses added by NAVSAFECEN, according to the Chief of Naval Operations (2014). However, Major Fetterolf (2020) clarifies that the estimated cost of mishaps may not fully encompass the entire expense. He notes that the AMB is instructed by OPNAVINST 3750.6S to omit the man-hours used in damage inspection, commercial equipment rentals or space fees, and further damages incurred during rescue or salvage operations. The total cost of mishaps in FY2019, the year with the second-lowest number of incidents, amounted to $10.2 million due to a costly class-A mishap. The second and third most expensive years were FY2017 and FY2015, respectively, costing approximately $1.7 million and $1.1 million, as reported by Fetterolf (2020).



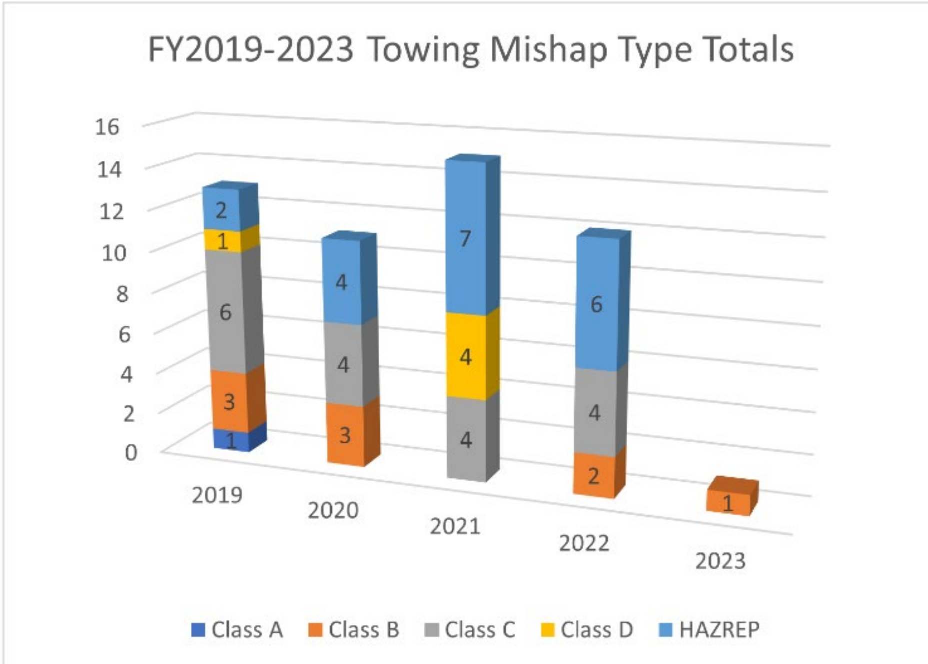
Data source: Naval Safety Center, raw unpublished data received by Capt Colton Fetterolf via email, Mar. 19, 2020.

Figure 2. Event Cost Totals for FY2014–FY2019. Source: Fetterolf (2020).

2. Review of FY 2020–2023 RMI Data

a. Monetary Impacts

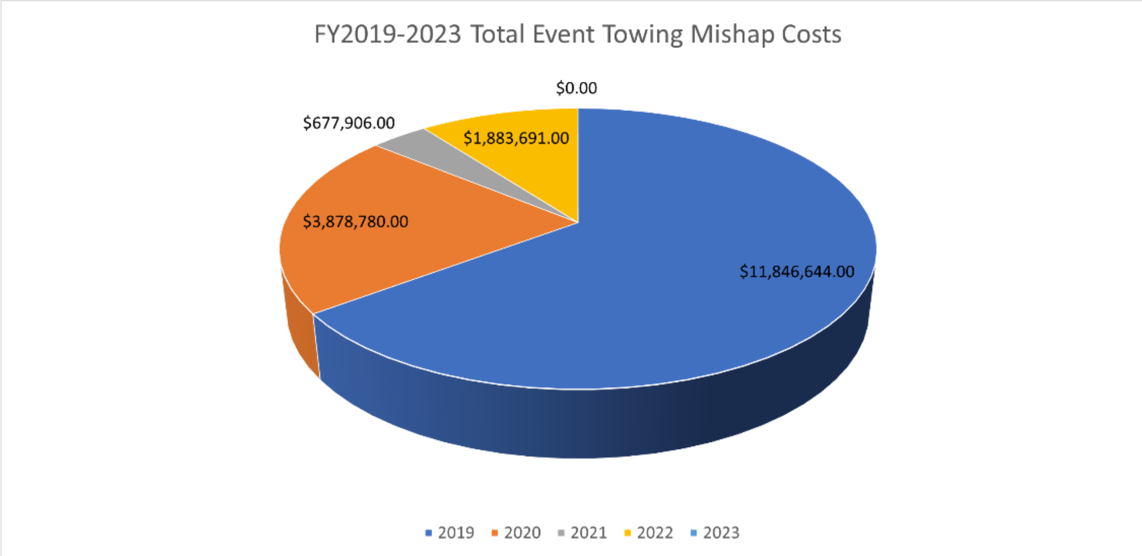
After thoroughly searching the incident narratives, the FY2019-FY2023 RMI data annotates 52 incidents involving towing. The incidents are further categorized, see Figure 3, into Class A mishaps (1 incident), Class B Mishaps (9 incidents), Class C mishaps (18 incidents), Class D mishaps (5 incidents), and HAZREPs (19 incidents). These incidents occurred among all aircraft type/model/series (T/M/S) within the NAE, most of which occurred during FY2019 and FY2021. Unfortunately, unlike the WESS data, the RMI data could not produce additional information like the time of incident occurrence or whether the incident occurred ashore or afloat.



Data source: Naval Safety Center, raw unpublished data received via email on Oct. 3, 2022.

Figure 3. Number of Towing Incidents FY2019–FY2023

The cost of towing-related incidents within the NAE from FY2019 to FY2023 was $18,287,021, as reported in Figure 4. From this data, FY2019 accumulated an additional eight mishaps and $ 1.6 million from the previous data pulled by Major Fetterolf, accounting for $11.8 million. Although FY2021 had the most mishaps happen within the year, it was the least costly of the other years. FY2023, one Class B mishap occurred during the data pull, but no financial information. Therefore, the AMB is most likely still investigating and calculating the total loss of the mishap.



Data source: Naval Safety Center, raw unpublished data received via email on Oct. 3, 2022.

Figure 4. Event Cost Totals for FY2019–FY2023

3. Operational Impacts

Towing incidents impact a squadron's ability to meet flight-hour targets and aircraft availability for missions. These effects do not have immediate financial consequences but are related. For example, suppose an aircraft is damaged during a towing incident and requires maintenance. In this case, it may be "down" for maintenance for an extended time, reducing the number of available aircraft for the daily schedule and missions. Additionally, the maintenance required to repair the damaged aircraft is more complex or time-consuming than anticipated leading to the daily flight schedule being disrupted and causing second and third-order effects on the monthly and annual flight hour goals (Eckstein, 2016). If a squadron cannot reach its flight hour goals, it could also decrease the budget and allocation of flight hours for the next fiscal year. In sum, towing incidents can negatively impact the squadron's operational goals by reducing aircraft availability for missions, disrupting the daily flight schedule, and potentially leading to a decrease in the budget for flight hours and training events (Fetterolf, 2020).

4. Other AGM Studies

In recent years, the surge in towing incidents and other Aviation Ground Mishaps (AGMs) has been a critical topic of discussion among NAE leadership. In 2016, the USN and USMC turned to consulting and organic analysis agencies like Booz Allen Hamilton (BAH) and the Center of Naval Analysis (CNA) to independently review mishap data, practices, and procedures. The studies from both CNA and BAH attributed the increase in AGMs to inexperienced maintainers (Fetterolf, 2020).

A more comprehensive study on the rise of AGMs in USMC aviation was conducted by BAH, focusing on seven essential variables, including leadership, standardization, training, culture, resources, facilities, and operational tempo (Glueck, 2017). The same study conducted by BAH identified the need for more technical expertise between the ranks of E4 and E6 and that there is inadequate maintenance safety expertise and leadership outside of the maintenance department. These factors increased the pressure on maintenance staff and, consequently, the likelihood of AGMs. In addition, the BAH study also found that the expeditionary maintenance mindset, which prioritizes mission completion at all costs, was also found to contribute to the increase in AGMs

C. TOW CREW STAFFING AND RESPONSIBILITIES

Per the Aircraft Securing and Handling Procedures with Aircraft Restraining Devices and Related Components (NAVAIR 17–1-537), a tow crew is staffed with six-members for standard operating procedures, consisting of a tow director (TD), tow tractor driver (TTD), brake rider (BR), two wing walkers (WW), and a tail walker (TW) (Department of the Navy, 2017). In addition, NAVAIR 17–1-537 annotates that all members of the tow crew are required to be familiar with the aircraft handling signals detailed in the Aircraft Signals NATOPS Manual (NAVAIR 00–80T-113) and to carry a whistle throughout the duration of the aircraft movement.

1. Staffing

Per the Naval Aviation Maintenance Program (NAMP) 4790.2D and NAVAIR 17–1-537, no rank restrictions exist on personnel filling any tow crew position. Based on common practices seen in both the USN and USMC, tow crew staffing typically reserved for E-6 and below with the Senior NCO being the director and the majority of the crew being more junior and with less experience. Additionally, Figure 5 references the positioning of tow crew members in association with the aircraft.

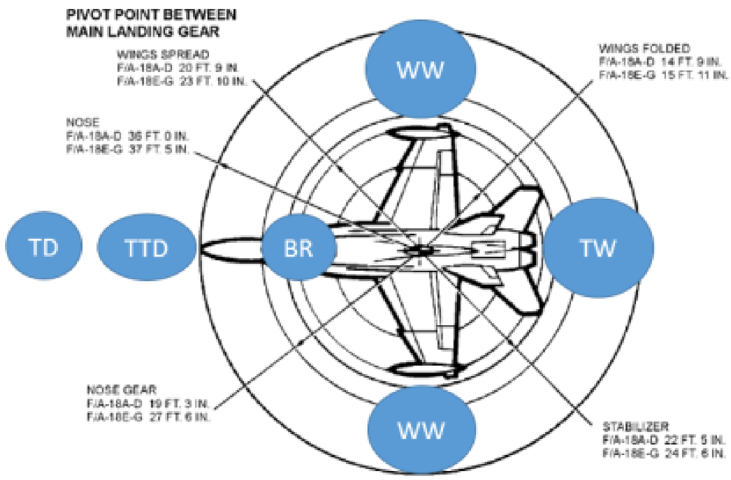


Figure 5. Aircraft Tow Crew Positioning. Adapted from USN (2017). Source: Fetterolf (2020).

2. Responsibilities

The NAVAIR 17–1-537 publication outlines crew members' responsibilities during aircraft towing operations. Each standard six-person tow crew member has clearly defined roles to ensure a safe and successful evolution. The TD supervises the process, monitors the aircraft's position, and directs the TTD, who operates the tow tractor, using verbal communication and hand signals. If the TTD loses control, the BR initiates the brakes. The presence of two WWs stationed parallel to the wingtips and the TW at the aft of the aircraft ensures the safety of the aircraft. Additionally, two CWs are added to the tow crew if the aircraft's braking system is inoperable, responsible for placing wheel chocks to control the aircraft's movement. All tow crew members must be familiar with aircraft handling signals, carry a whistle, and be prepared to perform their roles to prevent incidents from occurring (Department of the Navy, 2017).

3. Summary

The frequency of towing-related incidents within the areas of responsibility of the WWs and TW highlights the critical role they play in a towing operation. Furthermore, the lack of readiness and attention demonstrated by less experienced crew members and the distance of the wing tips and horizontal stabilizers from the TD pose a challenge in monitoring and avoiding collisions. Thus, it can be argued that having experienced personnel for all positions in the tow crew is crucial for safe and successful towing operations. These observations align with the recommendations provided by the CNA and BAH reports, emphasizing the importance of addressing staffing and experience levels of the entire tow crew to enhance towing safety.

D. AIRCRAFT TOWING PROCEDURES

The process for towing aircraft is a standardized procedure within the NAE and is outlined in NAVAIR 17–1-537. Maintenance control initiates the towing operation by assigning a TD. The TD then gathers the tow crew and provides a briefing on the aircraft being towed, which includes the destination, reasons for towing, aircraft limitations, and the assignments of WWs and TWs. Per NAVAIR 17–1-537, tow crew members, excluding the TTD and BR, carry a standard sports whistle, which they can use to stop the towing process when necessary. After the briefing, the tow tractor and tow bar are connected to the aircraft. Then, using hand and arm signals detailed in NAVAIR 00–80T-113, the TTD moves the aircraft to its desired location under the TD's direction. While the aircraft is towed, WWs and TWs walk alongside to prevent and identify potential collisions. If they believe the aircraft is in danger, the TW or WWs will use their whistle to signal the TTD to stop. Once the whistle is blown, the TTD halts movement so the TD can evaluate the situation. If the towing is completed without any safety concerns, the aircraft is secured, and the tow tractor and tow bar are disconnected. The tow bar's disconnection signifies the evolution's end, and the crew is sent back to their respective work centers. (Department of the Navy, 2017).

E. TOW CREW TRAINING AND MANAGEMENT

This section will explore the training requirements for USN and USMC personnel involved in aircraft towing operations, as it falls under the NAMP. Specifically, the section will focus on the training management system used by naval aviation maintenance professionals, the maintenance training program, and the current qualifications held by members of a F/A-18 tow crew. The NAMP is a comprehensive system designed to ensure the safe and effective maintenance of naval aircraft and includes requirements for training and certification of maintenance personnel. As a preliminary note, the current training for tow crew personnel remains the same for the USN and the USMC.

1. The Naval Aviation Maintenance Program

The NAMP is a comprehensive system designed to ensure safe and effective maintenance practices within the NAE. The program covers all aspects of maintenance, including planning, scheduling, and execution, and is designed to ensure that aircraft are maintained to the highest safety and reliability standards.

The NAMP is based on standard operating procedures (SOPs) and guidelines used by all naval aviation maintenance personnel. These procedures cover everything from pre-flight inspections to major repairs and are designed to ensure that all maintenance work is performed consistently and to the same high standards. The NAMP is divided into organizational, intermediate, and depot-level maintenance. Each level of maintenance has its own set of procedures and guidelines and is responsible for different aspects of aircraft maintenance.

Specifically related to this research, the NAMP includes requirements for training and certification of maintenance personnel, as well as for the documentation of maintenance work and the tracking of maintenance and training records for aircraft and personnel. (COMNAVAIRFOR, 2022)

2. Aviation Maintenance In-Service Training Program

As previously discussed, the NAMP is responsible for implementing aviation maintenance-related training in the squadron, overseen by the In-Service Training Program

(IST). The squadron's Assistance Aircraft Maintenance Officer (AMO) is accountable for the IST program. The AMO's responsibilities include scheduling maintainers for external training, enforcing a weekly technical training plan, and ensuring that military occupational specialty (MOS) requirements are fulfilled (COMNAVAIRFOR, 2022). In addition, the AMO typically manages the GSE training and licensing program, which focuses on qualifications specific to aircraft GSE, i.e., the A/S32A-45, also known as the tow tractor (COMNAVAIRFOR, 2022).

3. Advanced Skills Management

The Advanced Skills Management (ASM) system is integral to the NAMP. It tracks and manages the training and qualification status of USN and USMC aviation maintenance personnel. According to the Commander, Naval Air Forces (COMNAVAIRFOR), ASM is an "unclassified management information system (MIS) that contains job task requirements, documents completed training, qualifications, certifications, duty or billet assignments, and tracks personnel progress in completing [qualified and proficient technician] QPT or [aviation maintenance training and readiness program] AMTRP" (COMNAVAIRFOR, 2022).

As stated by Fetterolf (2020), "a maintainer's profile within ASM is comprised of all previous and current qualifications, including the current status of qualifications the maintainer is in the process of completing." This profile helps to ensure that all personnel have the necessary skills and knowledge to perform their jobs safely and effectively and that each individual receives the required training to maintain their qualifications and advance in their career.

4. Tow Crew Qualifications

Aircraft tow crew personnel must meet specific training and qualification requirements per the NAMP. The requirements for tow crew personnel vary depending on their roles and responsibilities. As mentioned in Chapter II.B, a tow crew comprises six individuals: a tow crew director, a tow tractor driver, a brake rider, two wing walkers, and a tail walker. Of these individuals, only three receive formal qualifications and training through the IST: the TD, TTD, and BR. The formal qualification for the TD training syllabus and the basic Aircraft Towing Qualification can be found in Appendix A. Training syllabi for the TTD and BR are similar to that of a TD. Still, they have different requirements specific to their qualifications (COMNAVAIRFOR, 2022). It is important to note that these syllabi may differ based on T/M/S. Aircraft with tires/wheels utilize BRs as a redundant safety measure, while T/M/S with no tires/wheels, like the A/H1, do not have that luxury (Fetterolf, 2020).

F. SUMMARY

This chapter overviews the DOD mishap classifications and focuses on the implications of aircraft towing-related mishaps. In addition, the chapter reviews data related to towing-related mishaps, the monetary and operational impacts of these mishaps, and studies related to aviation ground-related mishaps. This chapter also reviews tow crew structure, responsibilities, training, and training management. Overall, this chapter highlights the importance of aircraft towing safety and the need for ongoing training and attention to detail in this critical aspect of towing operations.

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III. VIRTUAL ENVIRONMENT BACKGROUND

Virtual environments have become increasingly prevalent in many domains, from entertainment and education to military and maintenance applications. This chapter introduces the virtual environment background and discusses the reality-virtuality continuum, VR, and AR. VR refers to a computer-generated simulation that immerses the user in an artificial environment, while AR overlays digital information onto the user's view of the real world. These technologies have numerous applications in the military and maintenance domains, including training, simulation, maintenance and repair, and mission planning. This chapter will explore some of the current use cases and technologies in these domains. Overall, this chapter aims to provide a foundation for the subsequent chapters by introducing the key concepts and technologies that underpin virtual environments and discussing their potential applications in the military and maintenance domains.

A. THE REALITY-VIRTUALITY CONTINUUM

The Reality-Virtuality Continuum model describes the relationship between the real world and virtual environments (VEs). The model proposes a spectrum, or continuum, between the real world and fully immersive VEs, with various levels of reality and virtuality in between, as seen in Figure 6 (Milgram et al., 1995).

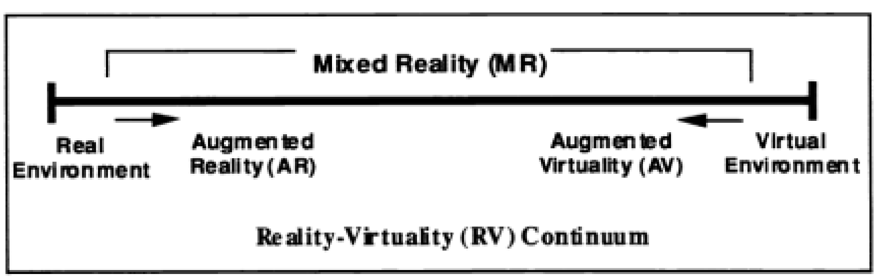


Figure 6. Reality-Virtuality Continuum. Source: Milgram et al. (1995).

The real world represents the most concrete and tangible experience at one end of the continuum. Moving along the continuum, we encounter AR, which overlays digital information onto the real world, adding a layer of virtuality. Mixed reality (MR), which blends digital and real-world elements to create a more immersive experience, lies anywhere along the middle of the continuum where VE and the real-world meet. Finally, at the far end of the continuum, we find fully immersive virtual environments that can provide users with experiences that are impossible to achieve in the real world. As we move along the continuum closer to the VE end, VR allows the system user to interact and have a heightened sense of presence within the VE (Brooks, 1999).

The Reality-Virtuality Continuum helps users understand the different types of VEs and how they relate to the real world. In military and maintenance domains, the continuum can be used to select the appropriate continuum type for a given application. For example, an AR system might be suitable for providing maintenance personnel with real-time information about equipment, while a VR simulation might be used for training soldiers in dangerous combat scenarios.

In the military, virtual environments are used for training and simulation purposes. For example, virtual training environments enable DOD members to engage in realistic training scenarios. This allows them to develop skills and practice in a safe and controlled environment, including virtual combat training, vehicle simulations, and even medical training for military medics.

Different continuum types also support maintenance activities in the maintenance domain by providing realistic simulations of complex systems. This can include the use of VR, MR, and AR to support maintenance activities such as repair, assembly, and troubleshooting. By using these technologies, maintenance personnel can access detailed information about equipment and systems, allowing them to identify and address issues more quickly and effectively.

Within the Continuum, VR and AR are rapidly evolving technologies with numerous applications across various industries. As these technologies advance, users can expect to see more innovative uses and applications emerge. In addition, users will likely see significant developments in VR and AR hardware, software, and content in the coming years, further enhancing their capabilities and usability. By exploring these technologies more deeply, users can better understand their potential and how they can be leveraged to provide immersive experiences, enhance training, and support maintenance activities, including aircraft towing operations.

1. Virtual Reality

Dr. Fredrick Brooks (1999), was the department founder of the 3D interactive computer graphics; human-computer interaction; virtual worlds; computer architecture; and the design process at the University of North Carolina Chapel Hill and defined VR as follows:

> Virtual reality is a way for humans to visualize, manipulate and interact with computers and extremely complex data. It is a three-dimensional, interactive, computer-generated environment. Users are immersed in and able to interact with a simulated world through the use of VR devices and typically wear a headset to experience the environment. They can manipulate objects, interact with others in the virtual environment, and move around the space they are immersed in. (Brooks, 1999)

The user is immersed in the virtual environment and can interact with it through VR devices such as headsets, allowing for a sense of presence in the virtual world. In VR, users can manipulate objects, interact with other users in the virtual environment, and move around the space in which they are immersed.

a. VR Use-Cases and Technologies

VR has emerged as a valuable tool in various fields, including military, maintenance, and aviation. In the military domain, VR is primarily utilized for combat training, medical training, and vehicle and equipment simulations. Applications and programs such as Virtual Battlespace 3 (Bohemia Interactive Simulations, n.d.) and VirtaMed (VirtaMed, n.d.) provide realistic environments that allow personnel to practice procedures and develop skills in a safe, controlled environment. In the maintenance domain, VR is used for maintenance simulations, assembly simulations, and remote support utilizing platforms such as Oculus and HoloLens. These platforms provide realistic simulations and real-time guidance and assistance to maintenance personnel. Finally, in the aviation domain, VR is used for flight training simulations, maintenance simulations, and safety training. Platforms such as RampVR (IATA, n.d.) and other flight simulators provide realistic flight simulations and real-time guidance and assistance to pilots, maintenance, and other aviation personnel. These applications and technologies provide unique capabilities tailored to each domain's specific needs and requirements.

(1) RampVR

RampVR is a VR training and simulation that provides training solutions for ground handling and ramp operations in the aviation industry. International Air Transport Association (IATA) implemented RampVR to promote VR technology in aviation training and develop new training solutions for ground handling and ramp operations personnel (IATA, n.d.).

Within the aviation maintenance domain, RampVR provides training programs that are intended to assist ground-handling personnel and ramp operators in acquiring the necessary skills and knowledge to carry out their responsibilities competently and safely. These training programs leverage virtual reality (VR) technology to develop realistic and engaging simulations of various scenarios and procedures, enabling trainees to train and learn in a secure and well-controlled environment.

Figure 7. RampVR Marshalling Training. Source: IATA (n.d.).

RampVR's VR training programs cover various topics, including aircraft turnaround procedures, baggage handling, marshaling, and pushback operations. The programs are customizable and can be tailored to meet the specific needs of different organizations (IATA, n.d.).

Figure 8. RampVR Proof of Concept. Source: IATA (n.d.).

RampVR's training programs have been well-received in the aviation industry, with customers reporting improved safety, efficiency, and overall performance. The company has also won several awards for its innovative use of VR technology in training and simulation (AN Aviation, n.d.).

2. Augmented Reality

AR is the "use of transparent glasses on which a computer displays data so the viewer can view the data superimposed on real-world scenes" (Stanney, 2002). According to Stanney' s definition, AR enhances a user's perception of the real world, where VR would replace it. The computer-generated content within AR is context-sensitive and based on real-world inputs, displaying real-time information to the user. The basic principles of operation for AR systems involve capturing signals from the real world, analyzing the signals, generating corresponding virtual content, aligning the virtual and real signals, and presenting the information to the user.

a. AR Use-cases and Technologies

AR is revolutionizing complex tasks in various fields, including maintenance. The increasing complexity of maintenance tasks necessitates thoroughly incorporating cognitive and fine motor skills underlying procedural actions during training (Ke et al., 2005). AR provides the ability to use smartphone and tablet devices to capture footage of proper demonstrations and insert labels, notes, and visual cues to create an “Adaptive Visual Aid,” an instructional imagery overlaid on a live image rendered through the camera (Webel et al., 2013). AR also allows users to access virtual information while interacting with real-world objects, removing the need for external instruction manuals requiring additional reading comprehension and translation. AR can also be used for quality assurance and review of the maintainer’s actions. AR systems improve precision and efficiency, which makes it a promising technology for maintenance tasks and training. AR can also reduce training requirements while enhancing the quality of performance. AR instructional techniques aim to reduce the necessity of information transference by projecting information on top of a real-world object using a phone or tablet device (Mcneely, 2022). AR is revolutionizing the maintenance industry and increasing the efficiency of complex tasks.

Figure 9. An Example of “Adaptive Visual Aid.” Source: Webel et al. (2013).

(1) Scope AR

Scope AR specializes in developing AR tools and technologies for use in industrial settings. They offer a range of AR solutions designed to help businesses improve productivity, reduce downtime, and enhance training and education programs. One of their keystone products is the WorkLink platform, which allows users to create and share AR content quickly and easily using various authoring tools (Scope AR, 2019).

Scope AR was one of the first companies to develop an AR authoring platform for HoloLens. The platform is designed to be easy to use and accessible to many users, allowing businesses to create and deploy AR content without requiring specialized programming skills or expertise (Matney, 2017).

Figure 10. Authoring Platform Example. Source: Scope AR (2018).

Scope AR also offers the ability to integrate with various other software tools and platforms that support a wide range of AR devices and technologies while maintaining a user-friendly design and functionality.

Scope AR has a strong track record of developing innovative and effective solutions. Their work on the HoloLens platform, in particular, has helped push the boundaries of what is possible with AR technology. It has opened up a range of new opportunities for businesses looking to leverage the power of AR in their operations.

Figure 11. Scope AR Ability to "Observe, Execute, and Record." Source: Scope AR (2018).

B. SUMMARY

This chapter delved into the capabilities of VR and AR technologies while highlighting their use cases in the maintenance and aviation domains. The affordability and potential of these technologies continue to pique the military's interest, particularly in light of the high costs and limited attempts allowed in live training. VR offers a safe and reproducible platform for training at a lower monetary and operational cost, while AR's most significant advantage is enabling users to interact with the real world. Although AR display technology has yet to mature, it could be valuable in training and daily operations such as aircraft towing evolutions.

IV. SIMULATION DEVELOPMENT

This chapter details the design and development of the NAWCAD AR interface for Major Fetterolf's (2020) ATEAR system. Major Fetterolf designed his system to allow the subjects to act as tow crew director within the virtual environment and give them an enhanced view of the aircraft and the surrounding environment utilizing an AR interface. The AR interfaces are designed to allow for faster and more accurate detection and response in potential collision scenarios. Major Fetterolf noted that the development of the AR interface involved several stages, including interface design, programming, and testing. As a result, the interface he designed was to be intuitive and user-friendly, focusing on providing the tow crew director with the most relevant information and views.

Major Fetterolf (2020) incorporated human performance metrics to evaluate the effectiveness of the AR interface. These human performance metrics were maintained and used as the primary performance measures in this study. The performance measures he incorporated were collision detection rate, mean stopping distance, and confidence levels. These measures were used to test the hypotheses annotated in Chapter I. Overall, developing the AR interface for the ATEAR system, Specifically the NAWCAD interface, represents a significant step forward in using AR technology operationally. The results of the Human Performance Metrics are discussed in Chapter VI, providing insight into the effectiveness of the AR interface and its potential for broader use in the aviation industry.

A. AR INTERFACE SYSTEM DESIGN AND DEVELOPMENT

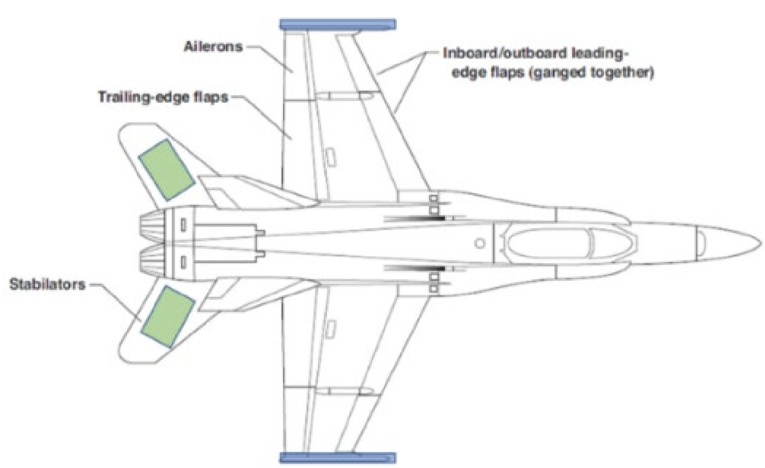
This section will explore the design and development of the experiment's two AR collision interfaces. This section provides a detailed account of the design of each interface and highlights the differences between them. The first interface was designed and developed by Major Fetterolf, while the second was designed by NAWCAD's RISE Lab for their Wing Walker Project and the interface was implemented into the ATEAR system for testing. By implementing these two different AR interfaces, we aimed to examine their effectiveness in improving towing operations. It should be noted that within ATEAR

Version 1, Major Fetterolf's collision detection interface is referred to as "AR." Within ATEAR Version 1.1, the NAWCAD RISE Lab interface is referred to as "Silhouette."

1. Collision Detection Interface for Version 1 (AR)

As previously mentioned, The AR collision detection interface that Major Fetterolf implemented within ATEAR Version 1 was to provide the TD with clear and concise information on the aircraft's position relative to its surroundings in a simple and accessible way. In addition, the FutureTech design team within the MOVES institute at NPS sought to design the AR interface so that it could be implemented by a DOD program for operational use.

In his thesis Major Fetterolf (2020) noted that the point of impact for most towing collisions is either the wing tips or the horizontal stabilators (refer to Figure 12). However, as all the scenarios he designed involve towing from the rear of the tow tractor, the FutureTech design team programmed the scenarios to ensure collisions occurred only on the wing tips, excluding the horizontal stabilators for experimental purposes. Therefore, the AR collision interface only locks onto the aircraft's wing tips and offers auditory and visual indicators to the tow crew director when executing the designed scenarios as seen in Figure 13 (Fetterolf, 2020).



Blue Boxes mark locations of wing tips and the green boxes mark horizontal stabilizers. Adapted from Brown and Schafer (2013)

Figure 12. F/A-18 Flight Control Surface. Source: Fetterolf (2020).

Figure 13. AR Collision Interface Wing Tip Indicators. Source: Fetterolf (2020).

The final design as annotated by Major Fetterolf is as follows: "when no objects are within three feet of the wing tip, the wing tip illuminates green and produces no auditory tones. If a wingtip sensor detects an object within three feet, the wingtip color changes to yellow, and an acoustic beeping tone starts playing out of the respective side of HMD headphones. If the sensor detects an object within six inches, the wing tip color changes to red, and the frequency of the auditory tone increases" (Fetterolf, 2020).

Major Fetterolf has introduced additional collision indicators in the AR interface that are accessible to the TD. These indicators include an overlay of the occluded wingtip, which is visible through the aircraft in situations where the TD is on one side of the aircraft, and the aircraft's fuselage obstructs the TD's view of the wingtip on the opposite side as seen in Figure 14. The AR collision interface is also designed to alert TDs of potential collisions when the aircraft is outside their field of vision, as depicted in Figure 15 (Fetterolf, 2020).

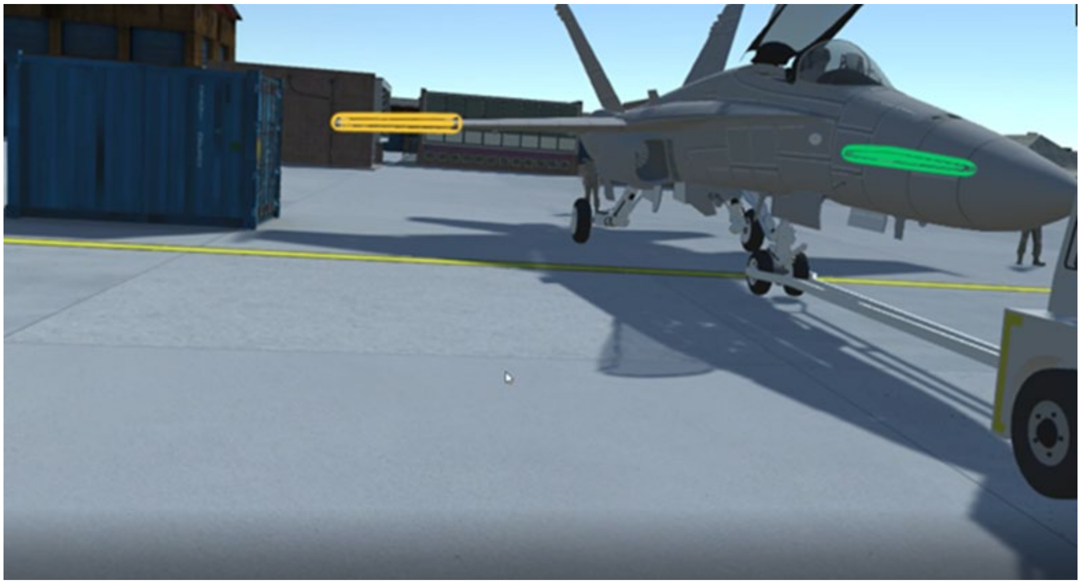


Figure 14. AR Collision Interface Interacting with Occluded Wingtip. Source: Fetterolf (2020).

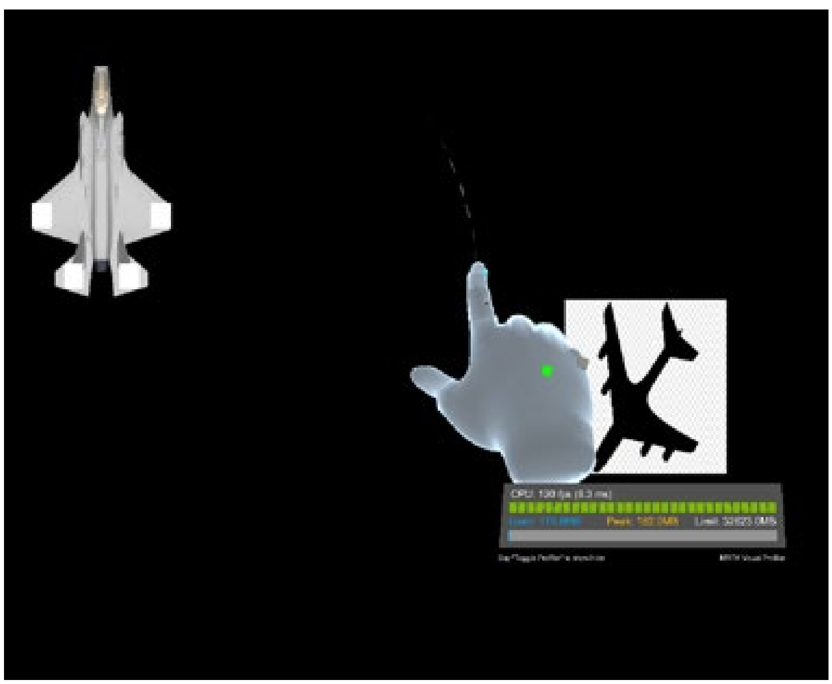
Figure 15. Potential Impact Warning When Aircraft Is Outside of FOV. Source: Fetterolf (2020).

2. Collision Detection Interface for Version 1.1 (Silhouette)

The following information was provided by Ezra Idy of NAWCAD's RISE Lab, His work and collaboration with the faculty and students of NJIT will be further discussed within this Section. Idy (2023) noted the numerous challenges and iterations that marked the journey of designing the Silhouette collision detection display. "The display aims to create a system that effectively conveys information to the tow crew members without causing distractions." In his process, the development of the display explored various design concepts and drew inspiration from unconventional sources, ultimately leading to a refined and practical solution. As previously mentioned, his design was made possible through a collaboration between Dr. Margarita Vinnikov of the NJIT iXR Lab and her students Charles Maher, Ryan Madsen, Jonathan Tan, John Campbell, and Christopher Miranda. The iXR Lab team took an iterative approach to finalize the design; the iterations are as follows:

1. Original Silhouette Model

The initial design featured a silhouette of the towed aircraft in the user's periphery, aiming to minimize distractions (refer to Figure 16). However, due to HoloLens 2's limitations, the interface obstructed the user's view, rendering the design impractical (Idy, 2023).

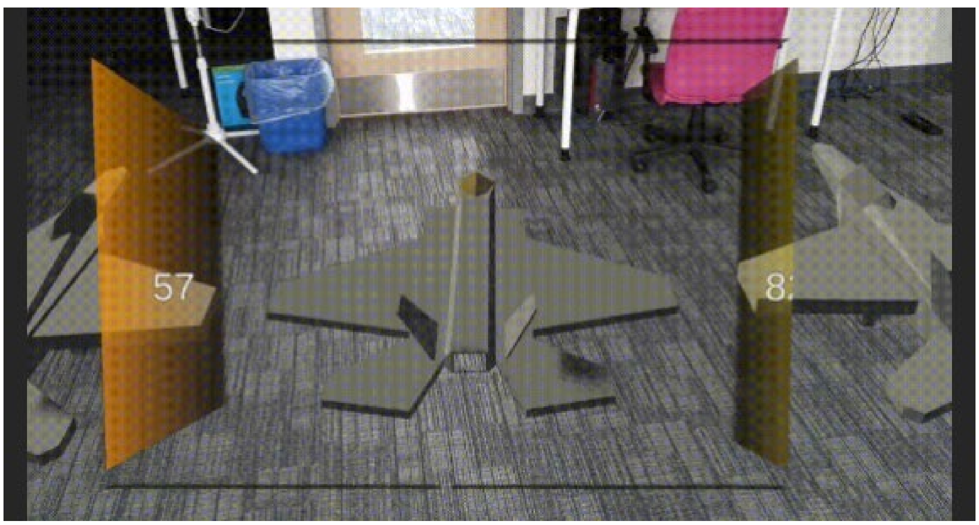


Data Source: image received from Ezra Idy from NAWCAD RISE Lab on March 15, 2023. The interface display in the top left of the image was ultimately discarded because the display would impede the user's vision when conducting towing operations.

Figure 16. Development of Original Silhouette Interface Display Design

2. Wedge Model

Idy, after the dismissal of the original design, noted that the NJIT iXR Lab team turned to first-person shooter video games for inspiration, observing how they conveyed direction and severity of damage using color gradients. The iXR Lab adapted this approach by creating a clear box divided into five sections corresponding to different aircraft sections, as seen in Figure 17. In addition, the system would display the distance between objects and use a color scheme (red, yellow, green) to indicate urgency. Unfortunately, the end-users found the wedge display too distracting, leading the team to rethink their approach (Idy, 2023).



Data Source: image received from Ezra Idy from NAWCAD RISE Lab on March 15, 2023. Similarly, the Wedge Model would impede the user's vision during towing operations leading to the development of the Outline Silhouette Model design.

Figure 17. Development and Testing of Wedge Model Design

3. Aircraft Outline Silhouette Model

Combining elements from the previous designs, the NJIT iXR Lab team developed a silhouette based on the aircraft's outline. The design allowed users to see through the display graphic, which avoided obstructing the user's view. In addition, the outline's color would change based on the proximity of objects, and the distance, in inches, is displayed near the silhouette outline.

For the final iteration, the iXR Lab team incorporated redundant information through multiple sensory channels to further enhance the interface. For example, haptic feedback, like vibrations, would alert wing and tail walkers to potential collisions. The design team also included sound warnings, but user feedback from initial testing suggested that this could interfere with radio communications during operations afloat. As a result, The user feedback led to removing the auditory channel from the design.

Ultimately, Idy noted, the Silhouette collision detection display's design and development process was a journey of continuous improvement, addressing challenges, and incorporating user feedback. The successful collaboration between Dr. Margarita Vinnikov, her students at the NJIT iXR Lab, and Ezra Idy of NAWCAD LKE RISE Lab resulted in an informative and minimally intrusive system, striking a balance between utility and user experience.

Again, this thesis directly supports NAWCAD's Wing Walker initiative, and the data collected supports the efforts to field this system and other similar AR technologies. Upon Ezra Idy's decision to implement the final silhouette design into the Wing Walker System, funding was requested and received to have the FutureTech design team implement the Silhouette interface display into ATEAR Version 1.1. See Figure 18 for an example of the Silhouette interface.

The image is taken from ATEAR Version 1.1. The image shows the Outline Silhouette Model from TD's perspective and will minimally impede the user's vision during towing operations.

Figure 18. Outline Silhouette Model Implemented within ATEAR Version 1.1

B. HUMAN PERFORMANCE METRICS

As mentioned in Chapter I, our hypotheses utilize three human performance metrics that were established by Major Fetterolf (2020). The identified measures of performance (MOPs) are collision detection rate, mean stopping distance, and confidence levels. Major Fetterolf (2020) defined and described the metrics as such:

1. Collision Detection Rate

"The collision detection rate is the rate at which the subject accurately predicts a collision. Therefore, if the scenario is a collision scenario, we expect subjects to blow the whistle. In contrast, for scenarios designated as caution or miss, we anticipated that subjects would refrain from blowing the whistle and allow the aircraft to move along its path" (Fetterolf, 2020).

2. Mean Stopping Distance

"The design team used simple time (i.e., simulation time) and the last known speed of the tow tractor to develop the "stopping distance" calculations. Ultimately, the goal is for the subjects to identify a collision faster using AR supplementation than without it" (Fetterolf, 2020). The stopping distance equation is:

$$Dist = LastKnownTractorSpeed(SchedCollisionSimTime - WhistleSimTime)$$

"The mean stopping distance for subjects using AR supplementation within a scenario set is compared against the mean stopping distance for subjects using the standard view in another scenario set "(Fetterolf, 2020).

3. Confidence Levels

The design team provided subjects with the ability to control the speed of the aircraft under tow in each scenario, to measure their confidence objectively and subjectively in predicting potential aircraft collisions. The experimental design outlined the methodology chapter specifies which scenario sets authorized speed control. Major Fetterolf (2020) designed speed modulation to be conducted by the subject through the use of the Rift's touch controller by pulling the trigger. He noted that pulling the trigger completely in (i.e., max speed) raises the tow tractor speed to 2 units per second (double the default speed). As mentioned in his thesis, higher confidence levels can be inferred from higher average tow tractor speeds, minimal variation in tow tractor speed, or both, for the purpose of data collection. The average speed rate and standard deviation of the rate for each scenario will measure each subject's speed values from the tow tractor (Fetterolf, 2020).

To measure each subject's subjective confidence, Major Fetterolf (2020) and the FutureTech design team implemented confidence questions at the end of each scenario. The team ended the scenarios in one of three ways:

1. The subject ends the scenario by blowing their whistle.
2. The aircraft collides with an object, whether the whistle is blown or not.
3. no collision occurs.

Given these three means to end a scenario, Major Fetterolf designed one of the following three confidence questions to be administered:

- Question A (trigger: whistle blown, regardless of programmed collision) - When you blew the whistle, how confident were you that a collision was going to happen?
- Question B (trigger: whistle NOT blown, programmed collision) - Before the scenario ended, how confident were you that the aircraft would finish its route collision-free?
- Question C (trigger: whistle NOT blown, no programmed collision) - What was your lowest degree of confidence that the aircraft would finish its route collision free?

When prompted, Major Fetterolf (2020) had the subjects place a marker on a linear analog scale to answer each question, as seen in Figure 19. "The slider bar corresponded to a 1–10 linear analog scale, low to high, respectively. The value captured is coded as a float, which yields a decimal (i.e., 7.3). To ensure data variability, Major Fetterolf and the design team intentionally did not incorporate a 'snap-to-grid' function on the slider bar or allow the subjects to view their selection's approximate value" (Fetterolf, 2020).

Figure 19. Confidence Question A with Slider Bar. Source: Fetterolf (2020).

C. SUMMARY

This chapter reviewed the simulation development of ATEAR Version 1 and the changes made in Version 1.1. This review included design and development of both the AR interfaces, to include NAWCAD's collaboration with the New Jersey Institute of Technology (NJIT) on designing and developing the Wing Walker System collision detection interface, and the captured performance measures of the subjects.

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V. METHODOLOGY

This chapter outlines the steps taken to collect and analyze data. In addition, this chapter will provide a detailed account of the participants, materials, procedures, and experiment design utilized in our study.

Firstly, we will discuss the participant selection process, including the criteria for identifying eligible participants, the number of individuals included in the study, and any demographic information collected. Next, we will detail the materials and equipment used in the study, including any specialized software or hardware required for data collection. This section will also provide information on how the materials were prepared and configured for use in the experiment.

Additionally, we will describe the experimental procedures employed, outlining the steps to ensure consistency across all participants and conditions. This section will also detail any ethical considerations taken to protect the rights and welfare of study participants. Finally, we will discuss the experiment design, including the conditions tested and any controls or counterbalancing employed. This section will also detail the statistical analyses used to analyze the data and the rationale behind these analyses.

A. PARTICIPANTS

The target audience for experimentation on the ATEAR Version 1.1 was USMC maintenance personnel who possess or had previously possessed a tow crew director qualification. The desired sample size to obtain statistically significant results from the experiment was 15–40 participants. These particular demographics were selected for the testing audience because the subjects have experience in the role in which the scenarios within ATEAR Version 1.1 were designed to replicate. As of November 2022, the III MAW Commanding General (CG), Major General Bradford J. Gering, approved the conduction of ATEAR Version 1.1 experimentation on the Maintainers of MAG-11. This approval is vital as the MAG-11 Maintainer performance and feedback on the AR collision detection interface would provide valuable insights into the potential use of AR to reduce towing-related AGMs.

B. MATERIALS

1. Physical Setup

Due to ATEAR being a stand-alone system, the physical setting for the experiment was conducted in VMFAT-101's AMO Conference Room. The conference room was a quiet space within a squadron's hangar utilized for debriefs, meetings, and training. During the experiment, the subject wore an Oculus Rift Head Mounted Display (HMD) and sat in a chair beside the proctor. The proctor utilized the laptop computer, identified in the Hardware section of this chapter, to administer the correct sequence of scenarios according to the Subject's ID. An example of the subject's physical experimental environment is seen in Figure 20.

Figure 20. ATEAR Version 1.1 Physical Set-up. Source: Fetterolf (2020).

2. Hardware

a. Display Solution

In his thesis, Major Fetterolf (2020) noted that using the Oculus Rift HMD (shown in Figure 21) as the immersive display for the experiment was a simple decision due to its "ease of use and seamless integration with the Unity game engine." The Oculus Rift, introduced to the market in 2016, is an affordable and effective immersive HMD typically used for gaming, but it also has other use cases, as discussed previously. Specifications of the Oculus Rift can be seen in Table 2 (Fetterolf, 2020).

Figure 21. Image of the Oculus Rift HMD and Controllers. Source: Pino (2019).

Table 2. Oculus Rift Specifications Adapted from Fetterolf (2020). Source: Alex (2018).

Display		Interfaces		Internal Tracking		Weight	Additional Features	
Resolution	1080x1200 per eye	Cable	10' detachable	Sensors	•Gyroscope •Accelerometer. •Magnetometer	470 grams	Controllers	Yes (2)
Refresh Rate	90Hz	HDMI	Yes	Tracking Area	5x5 ft		Audio	Organic Headphones
Field of View	110 degrees	USB Device	Yes				Power	Windows PC
		USB Host	USB 2.0 & 3.0					

b. Computer System

As previously noted, ATEAR Version 1.1 is a self-contained system that one person can operate on a single personal computer or laptop without network connectivity. ATEAR Version 1.1 runs on a Dell Precision 7760 laptop computer. Specifications on the laptop are in Table 3.

Table 3. Dell Precision 7760 specifications.

Processor	RAM	Operating System (OS)	Graphics Card
Intel Core i7	32 GB	Windows 10 Pro	NVIDIA RTX A3000
11850H			6016 MB VRAM
2.5GHz			

3. Software

a. Unity Game Engine

Unity Game Engine is a popular game development company that launched in 2005. Unity provides a powerful and user-friendly platform for game developers to create and publish games across multiple platforms, including PC, mobile, console, and VR. The game engine is highly versatile and supports a variety of programming languages. Additionally, Unity provides developers access to a wide range of tools, assets, and application plugins to enhance their game development process (Axon, 2016).

In recent years, Unity has expanded its focus beyond game development and into other areas, such as the automotive and industrial industries. The company has also invested in emerging technologies such as machine learning, augmented reality, and virtual reality, positioning itself as a leader in these areas (Unity, n.d.).

Overall, Unity Game Engine is a highly versatile and accessible game development engine and fosters a solid and supportive community of developers. Due to these aspects of the Unity Game Engine, Major Fetterolf (2020) made the decision to utilize this developing tool to model and simulate an AR interface system that could not only be implemented within the virtual environment of ATEAR but also with the modern technology of the real world, specifically within the NA.

C. PROCEDURE

1. Proctor Set-up

Like version 1 (Fetterolf 2020), ATEAR Version 1.1's home screen functions as the system's main menu, as seen in Figure 22. To assist the Proctor, the system will return to the home screen upon completion of each module. The Scenario Sets on the home screen meet the intent of the counterbalanced experimental design, allowing the home screen to be the point of moderation for the Proctor. The home screen is only visible to the Proctor on the laptop desktop. The home screen and its options remain hidden from the Subject upon dawning the HMD display. For all other aspects of ATEAR Version 1.1, the HMD display mirrors the desktop display (i.e., the execution of the tutorial and Scenario Sets). All home screen fields/selections help prepare the next set of scenarios for the Subject. While the home screen is active, the Subject will visually see "Please wait while we get you set up" in the HMD while the Proctor sets up the experiment with the system. The home screen, as designed by Major Fetterolf (2020), includes the following fields: subject ID, Is AR On, Is Silhouette On, Can Control Tractor Speed, Tutorial, Scenario Sets 1–4, and Exit. The only change made from version 1 to version 1.1 was the "Is Silhouette On" option. The following is a brief description of the selections fields available made available:

- Subject ID—The Proctor inputs the Subject's ID; a number used during the experiment to maintain anonymity and represent the Subject for data analysis. Please refer to Table 4 for the scenario set flow of Subject IDs.

- Is AR On—When selected, it activates the AR collision detection interface system.

- Is Silhouette On—When selected, it activates the Silhouette collision detection interface system.

- Can Control Tractor Speed—When selected, the Oculus Rift controller's trigger enables the Subject to adjust the tow tractor speed.
- Tutorial—Initiates the ATEAR Version 1.1 tutorial.
- Scenario Set 1–4—Chooses the desired scenarios for the Subject to experience based on experiment design. (refer to Table 4)
- Exit—Terminates the ATEAR Version 1.1 program.

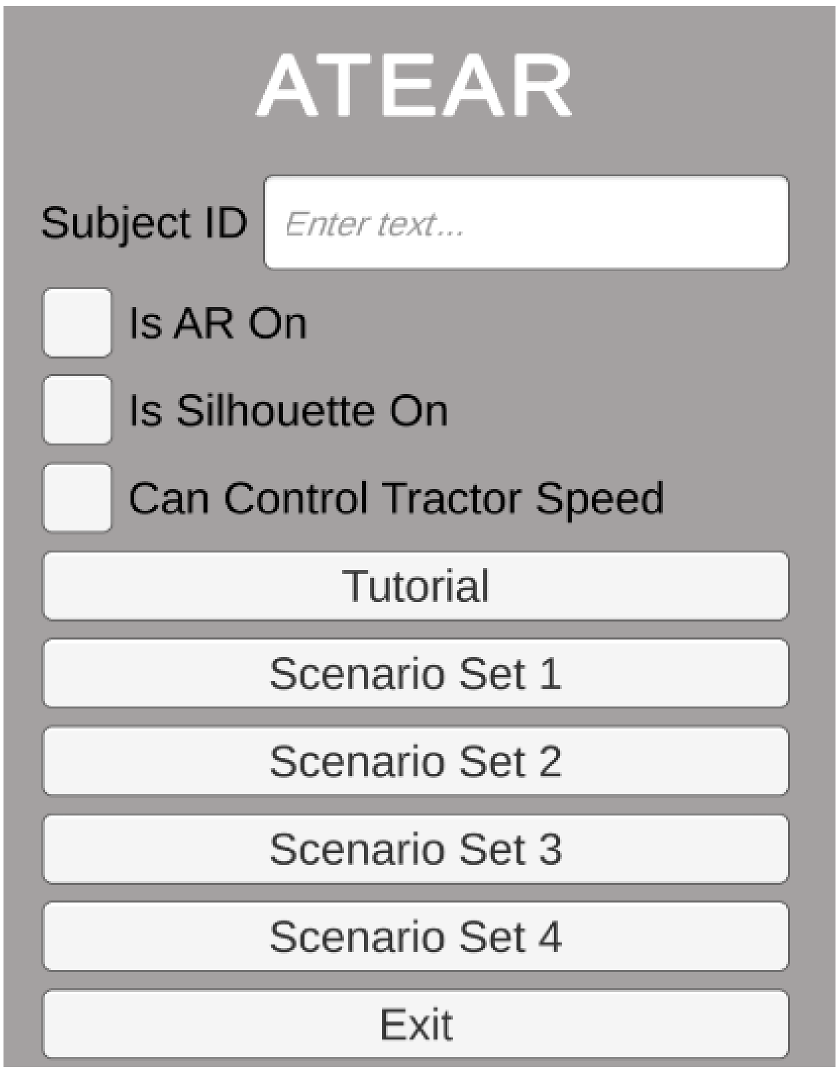


Figure 22. ATEAR Version 1.1 Home Screen

2. Tutorial Execution

When designing the ATEAR System, Major Fetterolf (2020) wanted to ensure the Subject's execution of the tutorial helps with the familiarization of the system before starting any scenarios. As seen in Figures 23 through 27, Major Fetterolf ensured the tutorial encompassed three modules - introduction to controls, the AR system, and tow tractor speed control. These tutorials ensure that Subjects understand the controls, environment, and how to interact with the environment. By design, each of the three modules presents instructions to the Subject, followed by the execution of those instructions in the basic environment The following are an in-depth description of the tutorial modules as described by Major Fetterolf:

- First Module: Controls—Upon selecting "Start," the Subject enters the tutorial environment to become familiar with a typical scenario. All equipment and personnel remain stationary during this module, and subjects can navigate around the aircraft and move their head. The module concludes upon pressing the "B" button (Fetterolf, 2020).

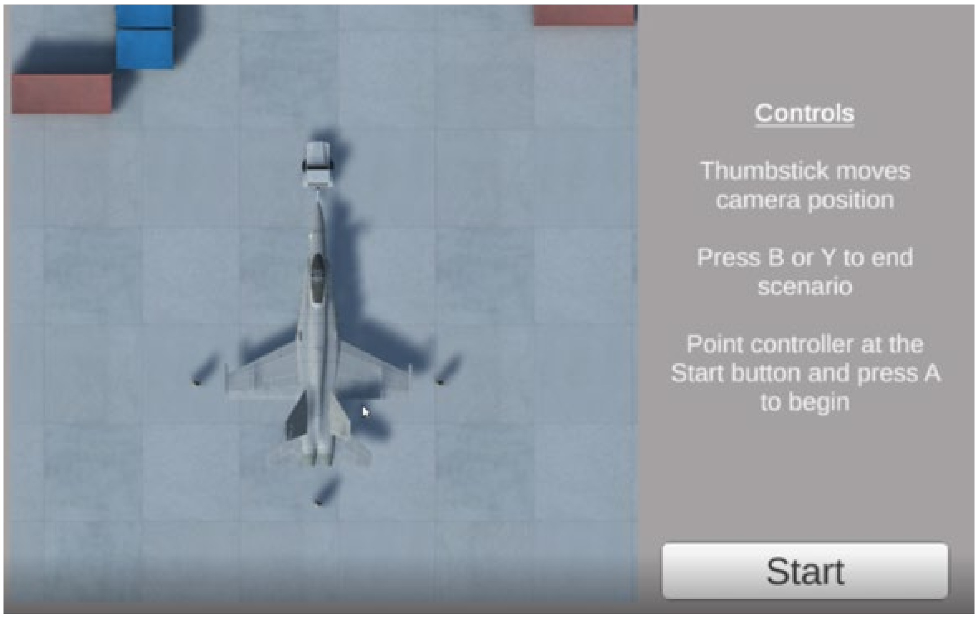


Figure 23. Tutorial: Controls. Source: Fetterolf (2020).

Figure 24. Controls Tutorial View in Environment 1. Source: Fetterolf (2020).

- Second Module: Alerts—Like the first module, equipment and personnel stay stationary within the scene. The Subject can navigate around the aircraft, with the right wing purposely placed close to a storage container to trigger the indicators of both the AR and Silhouette systems. The participant will be made aware that both collision detection interface displays will be visible during the module. The Subject must press the "B" button to end the scene (Fetterolf, 2020).

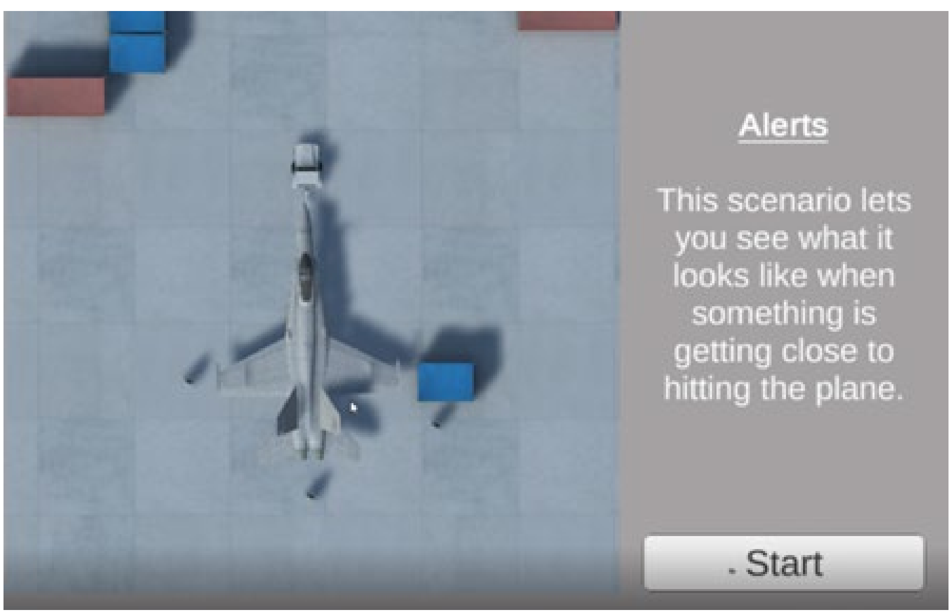


Figure 25. Tutorial: Alerts. Source: Fetterolf (2020).

Not shown in this tutorial image is the Silhouette Interface display. The proctors laptop only views the tail end of the aircraft of the Silhouette view. The Subject still can see and utilize the Silhouette Interface.

Figure 26. Alerts Tutorial View in Environment 1. Source: Fetterolf (2020)

- Third Module: Tractor Speed—This module teaches subjects how to modulate the speed of the tow tractor. Unlike the previous modules, the equipment and personnel are moving. The Subject can navigate around the aircraft, move their head, and change the tow tractor speed by modulating the trigger on the Oculus Rift controller. The module automatically concludes once the tow tractor has finished its predetermined path (Fetterolf, 2020).

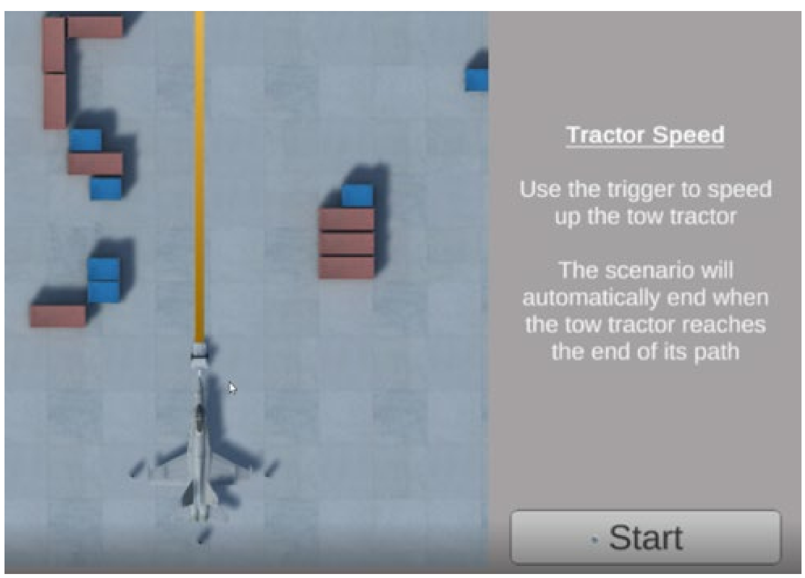


Figure 27. Tutorial: Tractor Speed. Source: Fetterolf (2020).

3. Scenario Sets Execution

The Subject will be able to see the objective and an overhead image of the environment before the start of each scenario; this image also includes the type of tow operations displayed before execution (refer to Figure 28). Since the tow tractor and aircraft follow a predetermined path, a yellow line shows the intended path to give subjects an idea of what to expect (Fetterolf, 2020).

Figure 28. Scenario Objective. Source: Fetterolf (2020).

By design of Major Fetterolf (2020), upon selecting "Start," the scenario begins. When the scene concludes (i.e., whistle blow, aircraft collision without whistle blow, or the scene ending on its own), he designed the system to "pose the respective confidence question to the Subject." While this question is displayed, the scenario will pause in the background. After pressing the "Proceed" button on the confidence level question, the "scenario complete" screen appears (refer to Figure 29). Additionally, Major Fetterolf (2020) designed this screen to provide feedback on the Subject's performance by showing a "top-down view of the completed scenario." He (2020) also designed the feedback for scenarios where the Subject blows the whistle in such a way that the scenario will resume until the aircraft reaches its scheduled stopping point (Fetterolf, 2020).

Figure 29. Scenario Complete. Source: Fetterolf (2020).

Additionally, in scenarios where the Subject blew the whistle, a black outline of the aircraft appears at its location at the time of the blown whistle or when ATEAR Version 1.1 stopped the scenario. Finally, for collision scenarios, the impact location is marked with a red "X" and the black outline of the aircraft, as seen in Figure 30 (Fetterolf, 2020).

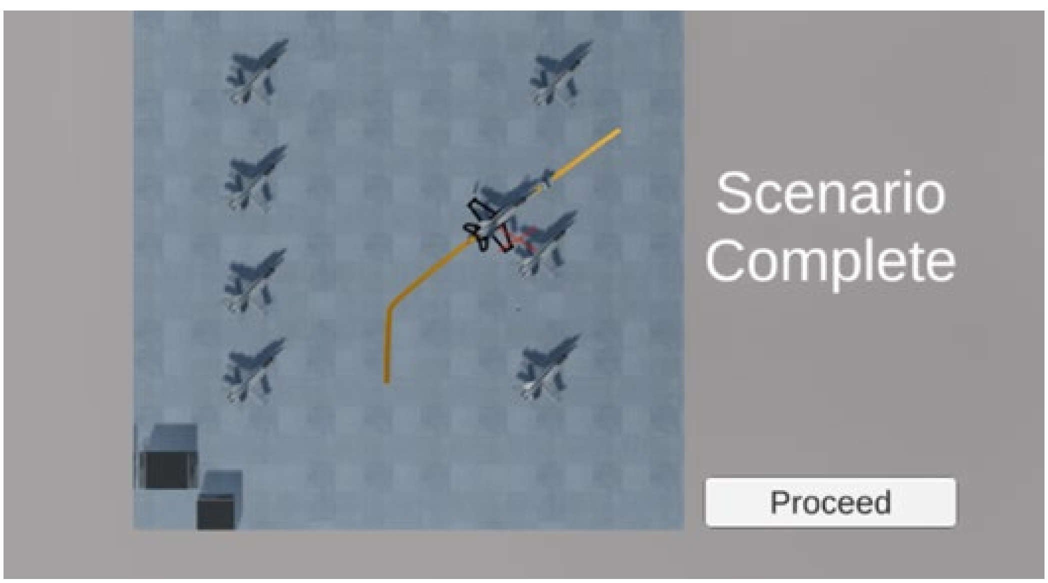


Figure 30. Example of Black Outline and Red "X." Source: Fetterolf (2020).

D. EXPERIMENTAL DESIGN

1. Design Conditions

The experiment is a within-subjects design where each subject completes 30 towing scenarios using the ATEAR Version 1.1 system. In addition, a counterbalanced, paired design is used for data analysis. Once assigned a Subject ID, each subject completes three VR sessions, with ten scenarios in each session, as outlined in Table 4.

Table 4. Subject-Within Counterbalanced Experimental Design

	Odd Subject ID (Ending in 1,5,9)	Even Subject ID (Ending in 2,6)	Odd Subject ID (Ending in 3,7)	Even Subject ID (Ending in 0,4,8)
Scenario Set 1	AR View	Standard View	Silhouette View	Standard View
Scenario Set 2	AR View w/ Spd Ctl	Standard View w/ Spd Ctl	Silhouette View w/ Spd Ctl	Standard View w/ Spd Ctl
Scenario Set 3	Standard View	AR View	Standard View	Silhouette View
Scenario Set 4	Standard View w/ Spd Ctl	AR View w/Spd Ctl	Standard View w/ Spd Ctl	Silhouette View w/ Spd Ctl
Scenaro Set 2/4	Silhouette View (Scn 2)	Silhouette View (Scn 4)	AR View (Scn 2)	AR View (Scn 4)
Scenario Set 1/3	Silhouette View w/Spd Ctl (Scn 1)	Silhouette View w/Spd Ctl (Scn 3)	AR View w/Spd Ctl (Scn 1)	AR View w/ Spd Ctl (Scn 3)

A counterbalanced, paired design was chosen to control the order effects in within-subject experiments. In this design, each participant experiences all experimental conditions in a different order, and the order of presentation is counterbalanced across participants. This design ensures that any effects of the order of presentation are balanced across the different conditions.

A within-subjects experiment is a research design in which each participant experiences all experimental conditions. In contrast, a between-subjects design assigns participants to different conditions, with each participant only experiencing one condition. Within-subjects experiments can have increased power and require fewer participants than between-subjects experiments. However, they also require careful counterbalancing to control the order effects.

2. ATEAR Version 1.1

The primary objective of this experiment involved immersing participants in a VE and evaluating their performance. The entire experiment, encompassing surveys and other assessments, is anticipated to last approximately 90 minutes. All pre- and post-experimental surveys are integrated into the QualtricsXM data collection platform, enabling participants to respond digitally (Qualtrics, n.d.). QualtricsXM also facilitated the export of responses into a CSV file for offline data analysis. An added advantage of QualtricsXM is the customization of surveys to direct participants to specific questions based on their recorded answers. The participants completed all QualtricsXM surveys on the proctor's computer, separate from the computer utilized for experimentation. The experiment's flow and the data gathered at each stage are outlined below, along with the rationale for each activity, where applicable (Fetterolf, 2020).

a. Pre-experiment

A direct reflection of Major Fetterolf's (2020)pilot testing, the pre-experiment for this thesis ensured each participant completed the approved NPS institutional review board (IRB) consent form (refer to Appendix B. Experiment Consent Form). Upon completion of the consent form, the participant was assigned a unique subject ID number. Following the assignment of the subject ID, participants were asked to complete the demographic survey (refer to Appendix C. ATEAR Demographic Survey) and the pre-experiment SSQ (refer to Appendix D. ATEAR SSQ) on the QualtricsXM platform on-line. The demographic survey documented relevant information, such as each participant's gender, age, eyesight, and aircraft towing experience. The SSQ, a digital adaptation of the standard paper and pencil SSQ (Kennedy et al., 1993; Walter et al., 2019), was a baseline measurement for each participant's simulation sickness level. This process was estimated to take about 10 minutes to complete (Fetterolf, 2020).

b. VE Familiarization and Training

Participants placed the HMD on their heads upon completion of the pre-experiment surveys. The proctor assisted the participants in adjusting the HMD to ensure proper fit. With the HMD correctly fitted, participants proceeded with the tutorial. This tutorial allowed participants to familiarize themselves with navigating and interacting within the VE using the same interaction methods required for the main study. The tutorial employed environment one, where participants practiced walking around the aircraft, learned how to control the aircraft's speed, and gained familiarity with the AR and Silhouette collision interface system functionality. During the tutorial, the proctor guided participants through ATEAR Version 1.1 and ensured that less apparent aspects of the system were highlighted. The proctor followed the experiment script to ensure consistent instruction between participants (refer to Appendix E. Experiment Script). The tutorial process was estimated to take approximately 10 minutes to complete (Fetterolf, 2020).

c. VE Scenario Sessions 1–3

Upon completion of the VE familiarization and training, participants were given the time to ask questions before starting the scenario sessions outlined in the experimental design conditions. The proctor addressed any questions before participants began scenario set one. Like Major Fetterolf's (2020) ATEAR Version 1, Version 1.1 generated data for each participant in CSV files corresponding to each scenario set. Major Fetterolf ensured that the primary performance variables recorded in each CSV included subject ID, AR status, speed control status, environment type, scenario type, start scenario time, tractor speed at 0.5-second intervals, stop tractor triggered, intended end time of scenario, confidence question type and response or aircraft collision triggered. In addition, participants answered one of two confidence questions based on their actions during each scenario (Fetterolf, 2020).

After completing scenario sets one, three, and five, participants proceeded to the next set of scenarios. In the following scenarios, participants could control the tow tractor's speed during the execution of these sets. The first two scenarios took approximately 15 minutes to complete. With six sets, the expected time within the VE was roughly 45 minutes. Upon the conclusion of scenario sets two and four, participants removed the HMD to take a break from the VE. During this break, participants completed the contrast sensitivity test during the first break and the cognitive processing speed tests during the second.

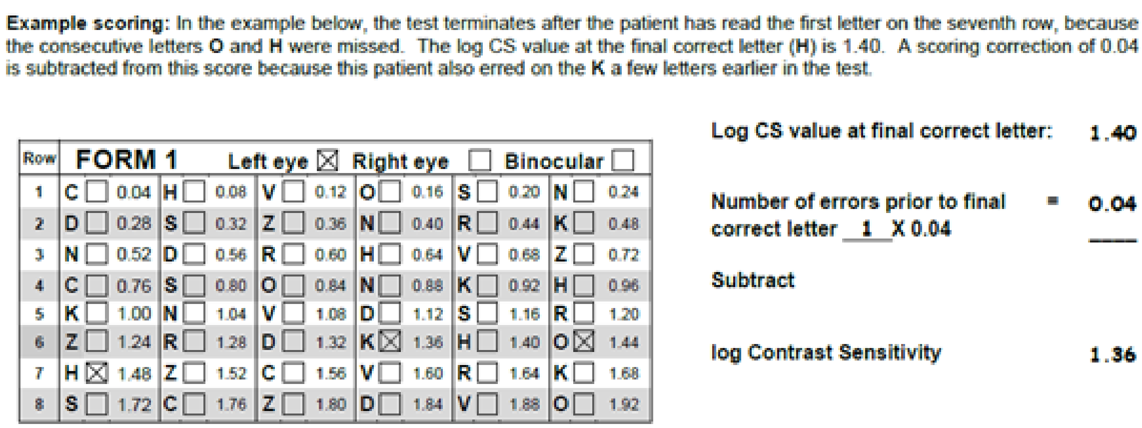
(1) Contrast Sensitivity Test

Contrast sensitivity refers to the ability to differentiate between varying shades of gray. The applicability of this test is directly correlated to our hypotheses as aircraft maintenance personnel encounter various gray shades while performing routine tasks. In the context of aircraft towing operations, the capacity to accurately distinguish between different gray contrasts can mean the difference between completing a towing evolution successfully or accidentally causing the aircraft to collide with nearby objects ending the evolution in a mishap. The participant's perception of the aircraft and other objects within the VE is essential for detecting potential collisions and verifying the accuracy of the aircraft towing process. "When the contrast between an object and the background is reduced, the quality of visual performance is diminished. This effect is more pronounced in individuals with poor vision, including those who wear corrective lenses" (Mohammed, 2017). Therefore, it would be possible to determine if poor performance within ATEAR Version 1.1 is due to inadequate contrast sensitivity rather than the VE's fidelity.

Major Fetterolf (2020) and his research team opted to utilize the MARS Contrast Senstivity test due to its "ease of use." As noted by Mars Perceptrix, (n.d.), this test is a standardized letter chart consisting of nine lines of specific letters. The top left letter is black, and as one moves from the top left to the bottom right, each subsequent letter becomes a lighter shade of gray, as seen in Figure 31 (Mars Perceptrix, n.d.).

Figure 31. Mars Contrast Sensitivity Chart. Source: Mars Perceptrix (n.d.).

The general procedure for conducting the MARS test resembles a standard eye test. First, participants covered their right eye and read letters from left to right on each line of the chart. Once their performance of the right eye was recorded, participants covered their left eye and repeated the test. However, unlike a standard eye exam, which typically takes place with the chart approximately 10 feet away, the contrast sensitivity test is conducted with the chart only 15.75 inches from the participant (Mars Perceptrix, n.d.). Scoring for each participant follows the Mars Letter Contrast Sensitivity Test Score Sheet guidelines, as seen in Figure 32. The participant's performance on the sensitivity test was evaluated using the scoring threshold chart (see Figure 33). The proctor's computer was the source of data collection for the contrast sensitivity test.



Example scoring: In the example below, the test terminates after the patient has read the first letter on the seventh row, because the consecutive letters **O** and **H** were missed. The log CS value at the final correct letter (**H**) is 1.40. A scoring correction of 0.04 is subtracted from this score because this patient also erred on the **K** a few letters earlier in the test.

Row	FORM 1		Left eye ☒		Right eye ☐	Binocular ☐
1	C ☐ 0.04	H ☐ 0.08	V ☐ 0.12	O ☐ 0.16	S ☐ 0.20	N ☐ 0.24
2	D ☐ 0.28	S ☐ 0.32	Z ☐ 0.36	N ☐ 0.40	R ☐ 0.44	K ☐ 0.48
3	N ☐ 0.52	D ☐ 0.56	R ☐ 0.60	H ☐ 0.64	V ☐ 0.68	Z ☐ 0.72
4	C ☐ 0.76	S ☐ 0.80	O ☐ 0.84	N ☐ 0.88	K ☐ 0.92	H ☐ 0.96
5	K ☐ 1.00	N ☐ 1.04	V ☐ 1.08	D ☐ 1.12	S ☐ 1.16	R ☐ 1.20
6	Z ☐ 1.24	R ☐ 1.28	D ☐ 1.32	K ☒ 1.36	H ☐ 1.40	O ☒ 1.44
7	H ☒ 1.48	Z ☐ 1.52	C ☐ 1.56	V ☐ 1.60	R ☐ 1.64	K ☐ 1.68
8	S ☐ 1.72	C ☐ 1.76	Z ☐ 1.80	D ☐ 1.84	V ☐ 1.88	O ☐ 1.92

Log CS value at final correct letter:	1.40
Number of errors prior to final correct letter __1__ X 0.04 =	0.04
Subtract	
log Contrast Sensitivity	1.36

Figure 32. Mars Contrast Sensitivity Scoring Example. Source: Mars Perceptrix (2013).

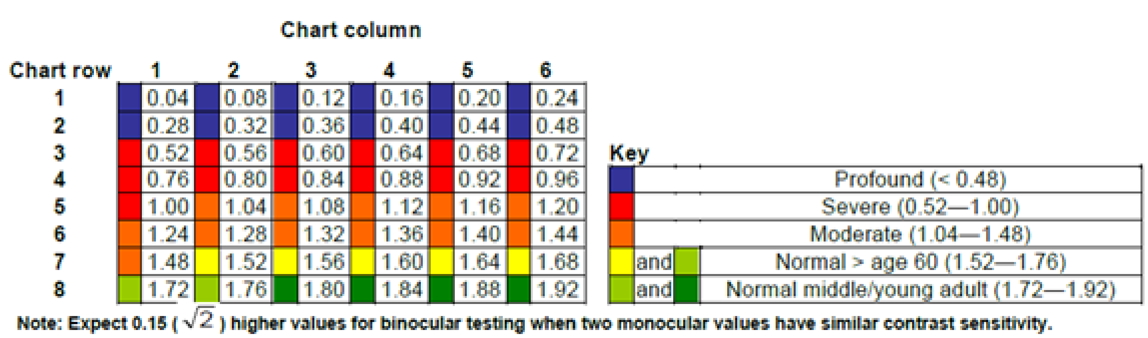


Chart column

Chart row	1	2	3	4	5	6
1	0.04	0.08	0.12	0.16	0.20	0.24
2	0.28	0.32	0.36	0.40	0.44	0.48
3	0.52	0.56	0.60	0.64	0.68	0.72
4	0.76	0.80	0.84	0.88	0.92	0.96
5	1.00	1.04	1.08	1.12	1.16	1.20
6	1.24	1.28	1.32	1.36	1.40	1.44
7	1.48	1.52	1.56	1.60	1.64	1.68
8	1.72	1.76	1.80	1.84	1.88	1.92

Note: Expect 0.15 ($\sqrt{2}$) higher values for binocular testing when two monocular values have similar contrast sensitivity.

Figure 33. Mars Contrast Sensitivity Scoring Thresholds. Source: Mars Perceptrix (2013).

(2) Cognitive Processing Speed Test

Like contrast sensitivity, Major Fetterolf (2020) annotated another factor that may influence a tow director’s ability to detect potential collisions to be cognitive processing speed, or the rate at which their brain processes information. He annotated that a participant’s subpar performance on the cognitive processing speed test may be directly correlated to poor performance in ATEAR Version 1.1. Therefore, upon completing the fourth scenario set, participants undertook a cognitive processing speed test called the Trail Making Test (TMT) (Bowie & Harvey, 2006).

Major Fetterolf (2020) had the FutureTech design team create a Unity-based TMT version. By design, each participant completes this version of an executable file on a Microsoft Surface tablet using the touch screen and their preferred index finger. The test consisted of four modules: Trail A tutorial, Trail A test, Trail B tutorial, and Trail B test. Figure 34 depicts the home screen for the TMT (Fetterolf, 2020).

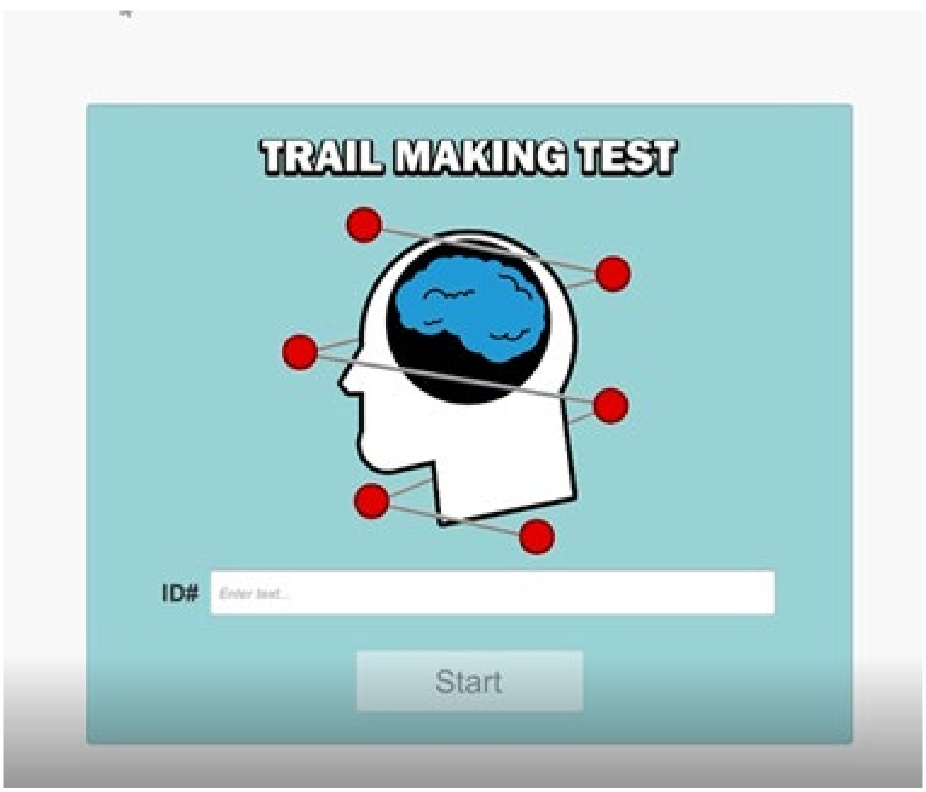


Figure 34. TMT Home Screen. Source: Fetterolf (2020).

- Trail A Tutorial—In this tutorial, the program demonstrated the task by drawing a black line connecting circles (1) and (2) and circles (2) and (3), as seen in Figure 35. The participant then started from where the line left off (circle 3) and connected the circles sequentially using their finger (Fetterolf, 2020).

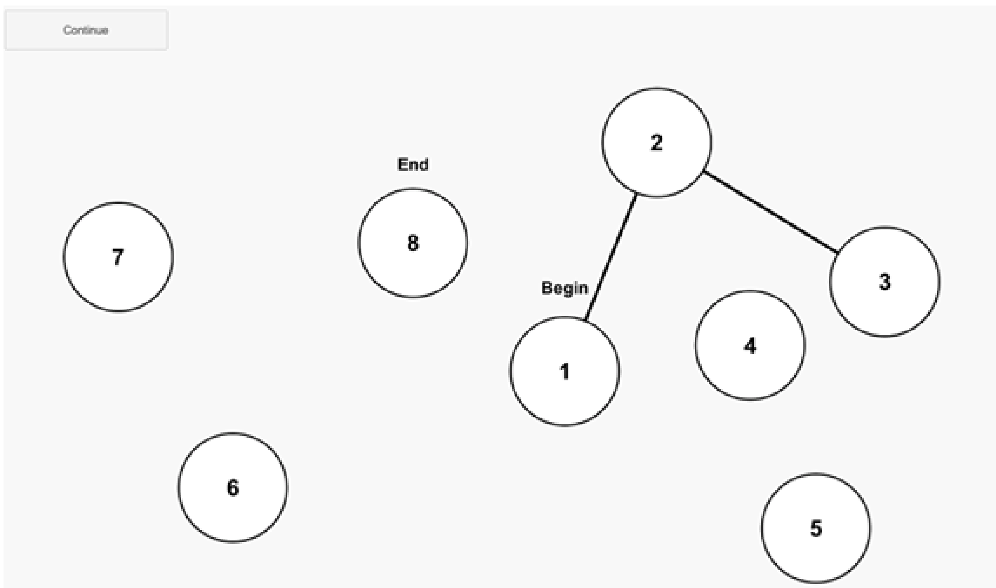


Figure 35. TMT Trail A Tutorial. Source: Fetterolf (2020).

- Trail A Test—Participants clicked "Start Test" after completing the tutorial to begin the official Trail A test. Unlike the tutorial, which featured only eight numbers, the test included numbers up to 25, as seen in Figure 36 (Fetterolf, 2020).

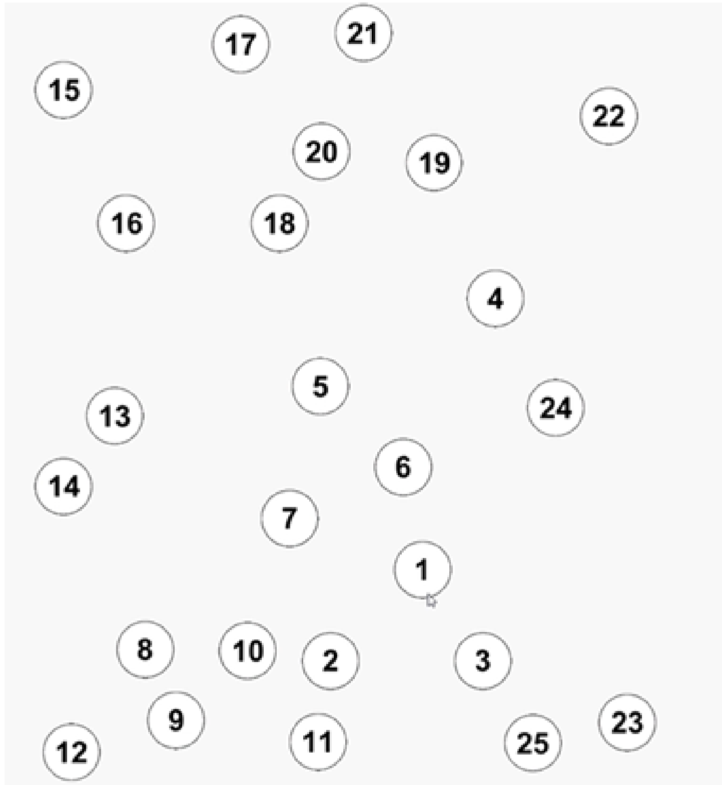


Figure 36. TMT Trail A Test. Source: Fetterolf (2020).

- Trail B Tutorial—This tutorial is similar to the Trail A tutorial. Similarly, it required participants to connect numbers and corresponding letters from the alphabet in sequential order (e.g., circles 1, A, 2, B, 3, D, and so on) (Fetterolf, 2020).
- Trail B Test—Like the Trail A test, the Trail B test contained more numbers and letters than its tutorial.

In each module, participants used their finger to connect the circles in sequential order. The screen's background flashed red if the participants selected the wrong circle (see Figure 37). The red background reverted to the standard white background within a second, and the most recent correct circle flashed green (see Figure 38). These visual cues served as a reminder of the last correct circle selected and as the location to resume the test (Fetterolf, 2020).

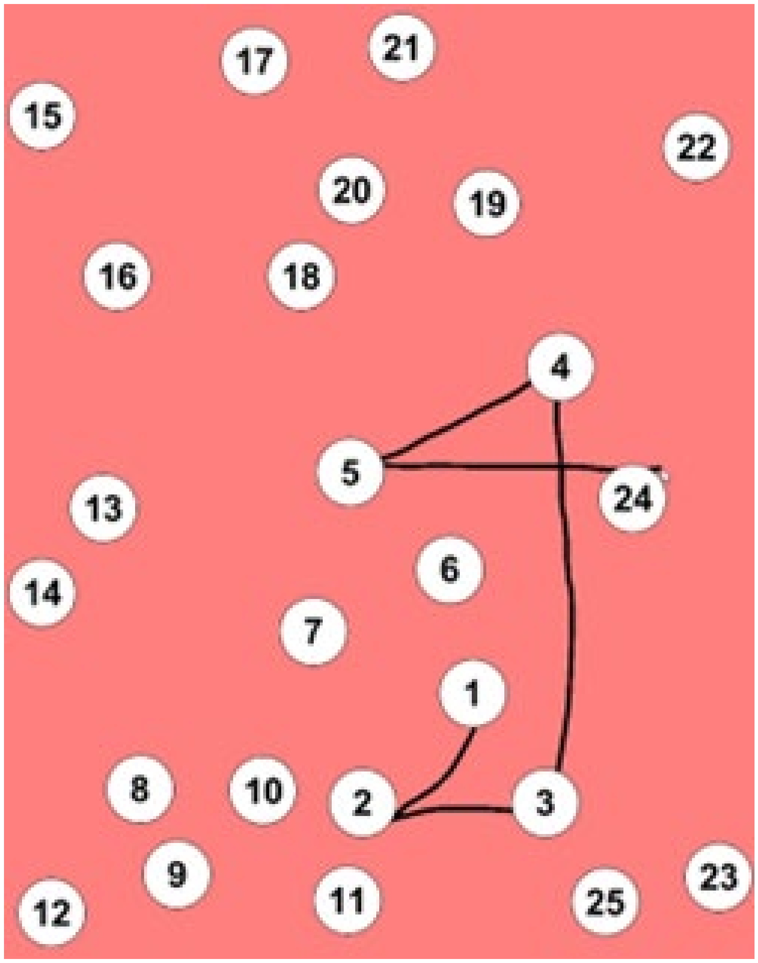


Figure 37. TMT Incorrect Trace Warning. Source: Fetterolf (2020).

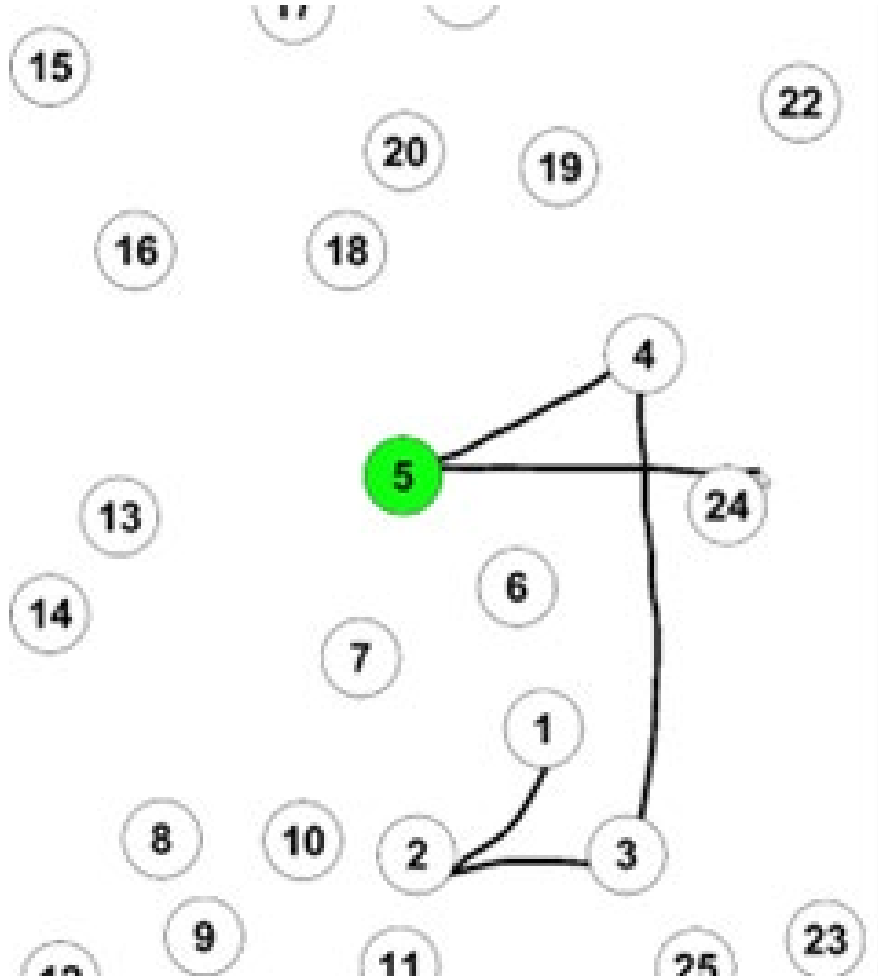


Figure 38. TMT Correct Circle Shown Post Error. Source: Fetterolf (2020)

Major Fetterolf (2020) ensured the TMT recorded the following information for each participant in a single CSV file: subject ID, start time, simulation time when each circle was correctly traced, simulation time when each tracing error occurred, end of test time, and test duration (see Figure 39). The primary variable of interest for Trails A and B tests was the total completion time (Bowie & Harvey, 2006). The proctor conducted record management of participant scores on their computer (Fetterolf, 2020).

155.5142	test-A-sta	2/28/2020 12:16
158.5104	circle-trac	1
158.5114	input-start	
158.9287	circle-trac	2
161.5315	circle-trac	3
162.2142	circle-trac	4
162.5972	circle-trac	5
163.2984	circle-trac	6
163.7153	circle-trac	7
164.482	circle-trac	8
164.7163	circle-trac	9
165.0495	circle-trac	10
165.5481	circle-trac	11
166.0335	circle-trac	12
166.5351	circle-trac	13
166.8164	circle-trac	14
167.7873	circle-trac	15
169.6029	circle-trac	16
170.6717	circle-trac	17
171.672	circle-trac	18
172.6707	circle-trac	19
173.1736	circle-trac	20
173.4409	circle-trac	21
173.7221	circle-trac	22
175.191	circle-trac	23
175.6421	circle-trac	24
176.008	circle-trac	25
176.014	test-A-en	2/28/2020 12:16
176.014	test-A-du	20.4997371

Figure 39. TMT CSV Output Example. Source: Fetterolf (2020).

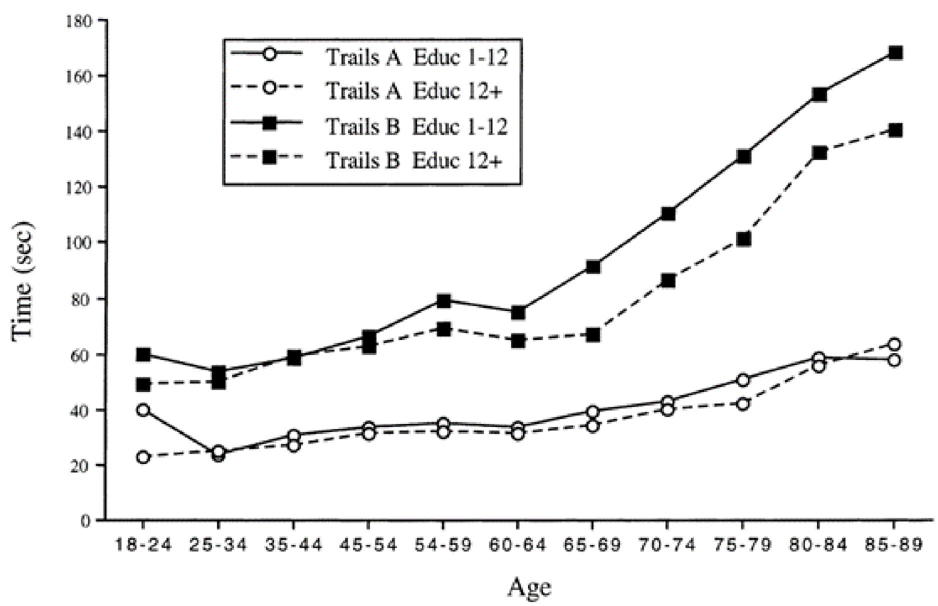


Figure 40. Typical Scoring for TMT Trail A and B Test. Source: Tombaugh (2004).

d. Post-experiment

Upon finishing the remaining scenario sets, participants completed the post-experiment SSQ on the QualtricsXM platform (refer to Appendix D. ATEAR SSQ). Comparative analysis was done on the post- and pre-experiment SSQ to ensure no significant cybersickness effects (Fetterolf, 2020).

Following the post-experiment SSQ, participants completed the post-experiment questionnaire (see Appendix F. Post-experiment Questionnaire). Key variables from this survey encompassed the following: participants' visual clarity in experiencing the towing scenarios within the virtual environment, whether they chose to wear corrective eyewear during the experiment, the towing model's accuracy, the adequacy of decision-making time within the virtual environment, "the usability and influence of the AR system," and "their expert perspective on the potential widespread adoption of a similar AR system" (Fetterolf, 2020). By design, the post-experiment questionnaires and surveys were estimated to take approximately 10 minutes (Fetterolf, 2020). The conclusion of the post-experiment questionnaire and a debriefing signified the end of the experiment.

e. Data Output and Record Management

For data output, Major Fetterolf (2020) had the FutureTech design team ensure that the ATEAR Version 1 system output a CSV file containing the following data: subject ID, AR status, speed control status, environment type, scenario type, start scenario time, tractor speed every 0.5 seconds, stop tractor triggered, intended end time of scenario, confidence question type and response, and/or aircraft collision triggered. Major Fetterolf noted and it was found to be true, "since tractor speed is logged every 0.5 seconds, each scenario set resulted in a CSV file with hundreds of lines" (Fetterolf, 2020).

To assist with data analysis, Major Fetterolf (2020) created a python program to extract the relevant information (refer to Appendix G. Data Analysis Python Code). In order for the python program to work, the proctor must manage and organize all CSV files inputted into the Python program. Then, once each subject's scenario set CSV files were in a single folder, the Python program is able to parse through each file and arranged specific data chronologically for each scenario (Fetterolf, 2020).

The parsed product produced by Major Fetterolf's (2020) code simplified the data output. This output included subject ID, AR status, ability to control tractor speed, environment type, scenario type, distance (if "Hit" scenario), collision prediction (correct/incorrect), mean tow tractor speed (if speed control enabled), tow tractor speed standard deviation (if tractor speed enabled), tow tractor's last known speed (if tractor speed enabled), confidence question type, and subject's confidence question response. Refer to Appendix H. Data Analysis Code Output for a sample output from ATEAR Version 1.1 comprising data from a single subject's execution of all scenarios (Fetterolf, 2020).

E. SUMMARY

This chapter covered various aspects of the methodology, such as the participants, materials, simulation development, experimental design, and experiment execution. The study involved the participation of active-duty USMC aircraft maintainers and prior service contractors from VMFAT-101. Each Subject consented to participate in a paired counterbalanced experiment design, including pre- and post-experiment questionnaires and surveys. The chapter also outlined how data will be collected from each Subject and utilized to answer the research questions posed. Overall, the chapter provided a comprehensive understanding of experiment execution and how it contributed to the field of study.

VI. EXPERIMENT RESULTS AND ANALYSIS

In this chapter, the findings from the experiment conducted are presented per the methodology outlined in Chapter V. Along with the findings and results of the collected data and the valuable insights gained from executing the experiment. For this experiment, software tools such as Qualtrics and Microsoft Excel were utilized for the statistical analysis of surveys and experiment data. Additionally, through the multiple iterations of experimenting, several areas in the experimental design were found to lack sufficiency. Therefore, this chapter will also discuss recommendations on the experimental design if further testing is required or warranted.

A. RESULTS

1. Demographic Survey Data

The study was conducted at VMFAT-101, and 21 subjects participated in the experiment. The sample included six Navy, fourteen Marine Corps, and one Army maintainers. Only one subject was female, and the rest were male. Of the 21 subjects, seven were Active-Duty Marines, while the others were prior service contractors. The rank of the subjects varied from E-2 to E-5, with nine subjects being E-4 and seven being E-5, indicating that most were senior NCOs.

The total years of being TD qualified by the subjects ranged from one to five years, totaling 54 years. The mean years qualified between subjects was 2.57 years, with a standard deviation of 1.5 and a variance of 2.24. In terms of experience with towing mishaps, only six of the subjects had witnessed a towing mishap in their career, and only two of the six were a member of the tow crew when the mishap occurred. Additionally, none of the subjects that were a member of the mishap tow crew were the TD during the evolution.

Regarding the subjects' habits and experience with gaming consoles, the minimum times per week spent playing was 1 hour and the maximum was 7 hours. In addition, the subjects' mean time playing per week is 2.33 hours, with a standard deviation of 1.78 hours and a variance of 3.17. Finally, only 11 of the subjects had utilized a Virtual Reality HMD before, indicating that the majority of the sample had little to no experience with this VR or AR technology. Furthermore, based on the lack of familiarity with HMDs, one subject experienced a more severe case of simulator sickness when conducting the tutorials and opted out of participating in the rest of the experiment. Additional information regarding the Demographic survey results can be seen in Appendix I (Demographic Survey Results).

2. Hypotheses

As noted in the Demographics Survey Data section, a total of 20 individuals were included in our data population. The size of this sample enabled our research team to use descriptive statistics and ANOVA F-statistic testing to gain valuable insights into the participants' performance and if the difference in the mean collision detection rate, stopping distance, and confidence levels are significantly different between the AR interfaces. The data was divided by environment and type, as each environment had variations in "Hit," "Danger," and "Caution" scenarios. For a breakdown of each participant's performance in each environment, please see Appendix L through N (Hit Scenario Analytics, Caution / Danger Analytics, and Performance Data Blocked by Environment Number and Type). Tables 5 through 10 are descriptive statistics for each hypothesis (please note that for all descriptive statistic tables "0","1",and "2," are No AR supplementation, AR interface, and Silhouette interface, respectively) :

Table 5. Collision Detection Rate Descriptive Statistics

Dependent Variable: Correct

Is_AR_On	Mean	Std. Deviation	N
0	.83	.372	200
1	.82	.385	200
2	.85	.363	200
Total	.83	.373	600

Table 6. Stopping Distance Descriptive Statistics

Dependent Variable: Stop_Distance

Is_AR_On	Mean	Std. Deviation	N
0	8.12	5.901	120
1	8.05	6.292	120
2	8.13	6.063	120
Total	8.10	6.071	360

Table 7. Hit Scenario Confidence Level—Question A

Dependent Variable: QuestionA

Is_AR_On	Mean	Std. Deviation	N
0	7.71	2.471	99
1	7.81	2.365	104
2	8.15	1.747	105
Total	7.89	2.213	308

Table 8. Hit Scenario Confidence Level—Question B

Dependent Variable: QuestionB

Is_AR_On	Mean	Std. Deviation	N
0	5.38	3.369	21
1	5.75	3.109	16
2	3.73	3.150	15
Total	5.02	3.275	52

Table 9. Danger/Caution Scenario Confidence Level—Question C

Dependent Variable: QuestionC

Is_AR_On	Mean	Std. Deviation	N
0	7.15	3.097	68
1	7.52	3.011	60
2	7.78	2.870	64
Total	7.47	2.992	192

Table 10. Danger/Caution Scenarios Confidence Level—Question A

Dependent Variable: QuestionA

Is_AR_On	Mean	Std. Deviation	N
0	7.71	2.471	99
1	7.81	2.365	104
2	8.15	1.747	105
Total	7.89	2.213	308

a. Hypothesis 1—Collision Detection Rate

According to the descriptive statistics, the Silhouette interface demonstrated a slightly better performance in identifying potential collisions in "Hit" scenarios. The overlay AR interface correctly identified 82% of collisions, while the Silhouette interface identified 85% of collisions. In comparison, standard towing operations had a collision identification rate of 83% in accordance with Table 5.

Table 11. Collision Detection Rate ANOVA F-Statistic Testing

Dependent Variable: Correct

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Contrast	.063	2	.032	.227	.797	.001	.454	.086
Error	83.270	597	.139					

The F tests the effect of Is_AR_On. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Computed using alpha = .05

$F(2, 597) = .23, p = .80, \eta_p^2 = .001$

Despite these positive results, the calculated significance (p) is greater than 0.05 showing no difference between the interfaces; thus, we fail to reject the null hypothesis concluding that there is no difference in collision detection rate between the standard view and the AR views.

Table 12. Collision Detection Rate Pairwise Comparisons

Pairwise Comparisons

Dependent Variable: Correct

(I) Is_AR_On	(J) Is_AR_On	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
0	1	.015	.037	.688	-.058	.088
	2	-.010	.037	.789	-.083	.063
1	0	-.015	.037	.688	-.088	.058
	2	-.025	.037	.504	-.098	.048
2	0	.010	.037	.789	-.063	.083
	1	.025	.037	.504	-.048	.098

Based on estimated marginal means

b. Hypothesis 2—Mean Stopping Distance

Once again the descriptive statistics show that the Silhouette interface demonstrated a slightly better performance in mean stopping difference within "Hit" scenarios. The overlay AR interface had a mean stopping distance before a pre-scheduled collision of 8.05

units, while the Silhouette interface and no AR supplementation scenarios produced means of 8.13 and 8.12 units, respectively (as seen in Table 6).

Table 13. Stopping Distance ANOVA F-Statistic Testing

Dependent Variable: Stop_Distance

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Contrast	.477	2	.239	.006	.994	.000	.013	.051
Error	13230.145	357	37.059					

The F tests the effect of Is_AR_On. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Computed using alpha = .05

$$F(2, 357) = .24, p = .99, \eta_p^2 = .000$$

Again, the calculated significance (p) is greater than 0.05 showing no difference between the interfaces; thus, we fail to reject the null hypothesis concluding that there is no difference in mean stopping difference between the standard view and the AR views.

Table 14. Mean Stopping Distance Pairwise Comparisons

Pairwise Comparisons

Dependent Variable: Stop_Distance

(I) Is_AR_On	(J) Is_AR_On	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
0	1	.074	.786	.925	-1.472	1.619
	2	-.007	.786	.993	-1.552	1.539
1	0	-.074	.786	.925	-1.619	1.472
	2	-.080	.786	.919	-1.626	1.465
2	0	.007	.786	.993	-1.539	1.552
	1	.080	.786	.919	-1.465	1.626

Based on estimated marginal means

c. *Hypothesis 3—Confidence Levels*

For this section, please reference Chapter IV.B.3 for more information about the confidence question.

(1) Confidence Question A

As seen in Table 7, for the scenarios labeled as "Hit," the descriptive statistics showed that using either AR interface resulted in a higher average confidence score in response to question A compared to the standard view.

Table 15. Confidence Question A ANOVA F-Statistic Testing

Dependent Variable: QuestionA

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Contrast	11.243	2	5.622	1.149	.318	.007	2.298	.252
Error	1492.221	305	4.893					

The F tests the effect of Is_AR_On. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Computed using alpha = .05

$$F(2, 305) = 1.149,\ p = .318,\ \eta_p^2 = .007$$

Despite the difference in the descriptive statistics, ANOVA testing in Table 15 shows no significance (p) between the interfaces. Once again, we fail to reject the null hypothesis concluding there is no difference in confidence levels between the different interfaces for "Hit" scenarios.

Table 16. Confidence Level Question A Pairwise Comparisons

Pairwise Comparisons

Dependent Variable: QuestionA

(I) Is_AR_On	(J) Is_AR_On	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
0	1	-.101	.311	.746	-.712	.511
	2	-.445	.310	.152	-1.055	.164
1	0	.101	.311	.746	-.511	.712
	2	-.345	.306	.261	-.947	.257
2	0	.445	.310	.152	-.164	1.055
	1	.345	.306	.261	-.257	.947

Based on estimated marginal means

(2) Confidence Question B

As seen in Table 8, The Silhouette interface resulted in lower confidence scores for "Hit" scenarios than the standard view and AR interface. Despite Question B annotating subjects' failure to prevent the collision, a lower confidence score here shows the subject was much closer to deciding to blow the whistle than those with higher scores.

Table 17. Confidence Level Question B ANOVA F-Statistic Testing

Dependent Variable: QuestionB

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Contrast	36.095	2	18.048	1.731	.188	.066	3.462	.346
Error	510.886	49	10.426					

The F tests the effect of Is_AR_On. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Computed using alpha = .05

$$F(2, 49) = 1.731, p = .188, \eta_p^2 = .066$$

ANOVA testing in Table 17 shows no significance (p) between the interfaces. Once again, we fail to reject the null hypothesis concluding there is no difference in confidence levels between the different interfaces for "Hit" scenarios.

Table 18. Confidence Level Question B Pairwise Comparisons

Pairwise Comparisons

Dependent Variable: QuestionB

(I) Is_AR_On	(J) Is_AR_On	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
0	1	-.369	1.072	.732	-2.522	1.784
	2	1.648	1.092	.138	-.546	3.841
1	0	.369	1.072	.732	-1.784	2.522
	2	2.017	1.160	.089	-.315	4.349
2	0	-1.648	1.092	.138	-3.841	.546
	1	-2.017	1.160	.089	-4.349	.315

Based on estimated marginal means

(3) Confidence Question C

Question C is specific to the "Danger" and Caution" scenarios. This question asked the subject their lowest degree of confidence during the scenario. With that being said, a relatively high score shows that the subjects were confident in their execution throughout the duration of the operation. Alternatively, a low score annotates that a subject, at any point of the scenario, may have experienced some doubt that the operation would end without collision.

Table 19. Confidence Level Question C ANOVA F-Statistic Testing

Dependent Variable: QuestionC

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Contrast	13.420	2	6.710	.748	.475	.008	1.495	.176
Error	1696.450	189	8.976					

The F tests the effect of Is_AR_On. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Computed using alpha = .05

$$F(2, 189) = 0.748, p = .475, \eta_p^2 = .008$$

Table 9 shows that both AR interfaces had a higher mean confidence score within the "Danger" and "Caution" scenarios. Despite the descriptive statistics showing higher mean confidence scores, ANOVA testing shows there is no significance (p) between interfaces.

Table 20. Confidence Question C Pairwise Comparisons

Pairwise Comparisons

Dependent Variable: QuestionC

(I) Is_AR_On	(J) Is_AR_On	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
0	1	-.370	.531	.487	-1.416	.677
	2	-.634	.522	.226	-1.663	.395
1	0	.370	.531	.487	-.677	1.416
	2	-.265	.538	.624	-1.327	.797
2	0	.634	.522	.226	-.395	1.663
	1	.265	.538	.624	-.797	1.327

Based on estimated marginal means

(4) Speed Modulation

This experiment's results indicated no significant difference in speed modulation between the AR interfaces and standard views for both "Hit" and "Danger / Caution" scenarios. The average speed for both scenarios between the interface was between 1.01 and 1.1 units per second. However, it should be noted that some subjects reported not using the speed modulation button, as they were trained to move the aircraft at a normal walking speed.

(5) Post-Experiment Questionnaire

The results of the post-experiment survey are presented in Appendix P. The data indicated that although subjects using the AR interfaces exhibited higher confidence based on the confidence questions for "Hit" scenarios, the subjects still agreed, on the questionnaire, that they maintained a higher level of confidence utilizing the AR interfaces with an average confidence level annotated at 7.4. On a scale of one to ten, the subjects also rated the difficulty of using the AR interfaces at 1.67, with a rating of 10 being difficult. Finally, a majority of subjects found believed a similar AR system should be implemented across the entire fleet, that it would reduce the number of AGMs in the fleet, and that the AR interfaces had a positive impact on their ability to understand the location of the aircraft's flight surfaces in relation to other objects on the flight line. When asked why they thought this, some responses included:

- "It serves as another set of eyes and helps gauge distance between A/C and object."
- "AR will help cut back on Mishaps."
- "The number of towing incidents would drop."
- "AR would help the director when the rest of the crew isn't the best."
- "It gives the director a heads up on incoming collisions to include on the other side of the A/C."

- “AR would help visualize flight surfaces at night.”

3. Contrast Sensitivity Test Results

The MARS Contrast Sensitivity Test was performed once on all the subjects between sessions one and two to determine if there was any association between contrast sensitivity and performance in the ATEAR system or within real-world towing operations. The data obtained from the test revealed that the average score for the left eye was 1.732, 1.72 for the right eye, and the binocular average was 1.784. The standard deviations for all tests were 0.0663, 0.069, and 0.048, respectively.

Statistical analysis of the results showed no causation of their performance within the ATEAR system. Therefore, these results suggest that contrast sensitivity does not significantly affect aircraft towing mishaps. However, it is important to note that the test was only performed once on a small population of maintainers. Therefore, further research is recommended to determine if there is any causal relationship between contrast sensitivity and aircraft towing mishap occurrences. The results, descriptive statistics, and score interpretation from the contrast sensitivity testing can been seen in Appendix K (Contrast Sensitivity Results).

4. Cognitive Processing Speed Test Results

Appendix O shows the results of the TMT Cognitive Processing Speed Test. The expected means and standard deviations for Trails A and B were based on normative data from Dr. Tombaugh’s study on the Trail Making Test (Tombaugh, 2004). Of the age groups, only the 18–24 group significantly underperformed the expected normative data for both Test A and B. The 25–34 approximately performed as expected for Test A but was over 9 secs above the expected time for Test B. Finally, the 35–44 age group underperformed Test A expectations by roughly 2 seconds and outperformed the expected for the test by an average of 2 seconds. Although this test raises concern, I recommend further testing since there was such a low population in each age group. In an adequately sized experiment, processing speed could affect how quickly people react to potential collisions. Therefore, most subjects in our study performed within the expected norms in terms of the duration of each test. It is highly recommended that cognitive processing speed be further tested for its potential causation of aviation ground operation mishaps.

5. SSQ Data

The participants completed two SSQ assessments- one before and one immediately after the experiment. The scores of each participant on different parameters, including nausea (N), oculomotor (O), disorientation (D), and total score (TS), are presented in Appendix J (SSQ Results). Upon analyzing the data for each category, no significant changes were observed between the scores obtained before and after VR exposure. It should be noted that Subject ID 12 voluntarily removed themself from the experiment based on their perceived VR-related sickness.

Additionally, the Data Analysis compared the total scores obtained before and after the experiment, which revealed a mean difference of 34.936267 with a standard deviation of 216.84854 and a 95% CI of -3.812 on the lower end and 193.80454 on the higher end. A negative total score indicates that the participant reported higher SSQ scores before the VR exposure. Since the confidence interval for the TS SSQ contained 0.00, it can be concluded that the experiment did not lead to any VR-related sickness among the participants.

B. SUMMARY

Based on results from the experiment and data analysis, it is inconclusive that AR technology would increase a maintainer's situational awareness during towing operations, at least within the virtual environment. Those who used the AR interfaces, based on descriptive statistics, showed that there is potential that fielding similar AR systems could be beneficial but further testing is still required. The experiment participants also recognized and noted the potential impact of such a system on a tow crew director's ability to effectively control towing evolutions safely and efficiently. Nevertheless, all participants gave positive feedback about the simulated AR system, and they believed that developing a similar AR device for fleet implementation would be worthwhile. A few minor changes could be made to ATEAR Version 1.1 before further testing is conducted. These updates include additional scenarios such as shipboard and night operations, removing the ATEAR

Version 1 overlay AR interface and speed modulation, and updating the CSV output file to make it easier for data cleaning. Finally, I recommend a much larger sample size of the same demographic. As it took four working days to collect 20 subjects, I recommend including more researchers to administer the experiment to save time and resources for both the researchers and the supporting units.

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VII. FUTURE WORK AND CONCLUSION

This chapter summarizes the study's findings and recommendations for future research. We will emphasize the significance of our research and its potential impact on the NAE. By providing recommendations for future research, we encourage other researchers to build upon this work and further advance the understanding of this area within the naval aviation domain. Ultimately, we aim to contribute to the body of knowledge in this field and to inform future research, practice, and policy.

A. RESEARCH OBJECTIVES

The data in the previous chapter and the ongoing relationship with the members of the NAWCAD RISE Lab prove that the research objectives of this thesis were successfully met. The Principle Investigators of this thesis collaborated with NAWCAD LKE MO&I to implement an AR collision detection overlay that provided a tow crew director with information about an aircraft's proximity to other objects within a simulated environment. The team integrated the NAWCAD AR "Silhouette" overlay into the ATEAR system. The investigation team conducted the designed experiment on MAG-11, III MAW maintainers, to gather objective and subjective data on the research questions.

The experiment assessed maintainers' ability to react and identify potential aircraft collisions with and without AR supplementation within the virtual environment of ATEAR. The experiment also clarified the potential of AR in this specific domain. Additionally, the experiment assisted NAWCAD RISE Lab in their continued efforts of developing and fielding AR support equipment, specifically the Wing Walker project.

This thesis was able to measure, subjectively and objectively, the effects of the AR system using VR technology. The VE for the VR system was built around the perspective of the tow crew director, and an HMD was used as the VR experience method to provide the user with the most immersion and increased sense of presence. Ultimately, the project successfully achieved its research objectives, and the findings, although deemed insignificant, provided insights into the potential of AR technology, particularly in the DOD aviation ground operation domain. Furthermore, this thesis and any potential future work can and will contribute to the ongoing efforts to improve the safety and efficiency of aviation ground operations within the NAE.

B. NAWCAD RISE LAB'S "WING WALKER" PROJECT

As previously discussed, this thesis directly supports the Wing Walker Project, a NAVAIR initiative. The data from this study provides a platform for the researchers in the NAWCAD RISE Lab to drive the Wing Walker Project toward full-scale production and fielding. Although the study modeled shore-based operations, the Wing Walker project is in response to the fleet's requests for assistance in reducing AGMs for shipboard operations. The Wing Walker project is one of several initiatives undertaken by the RISE Lab to improve flight deck procedures and safety utilizing existing worldwide cutting-edge technology and algorithms.

Discovered during continued correspondence with Ezra Idy (2023) of NAWCAD's RISE Lab, the initial design challenges of the Wing Walker project included determining LiDAR sensor placement, crew notification methods, removability and storage of the system, as well as addressing Emission Control (EmCon) conditions aboard ships. The challenges continue to be reviewed and addressed as more data and feedback becomes available through development and testing:

- Sensor placement: The primary concern was positioning sensors around the aircraft to detect the target aircraft and its neighbors. Early designs considered retractable booms with attached sensors, aerial drones, and ground rovers. Eventually, these designs were dismissed due to instability and Foreign Object Detection (FOD) issues. Currently, the solution involves attaching sensors to the tow crew and tow tractor, enabling full aircraft coverage without directly binding to the aircraft (Idy, 2023).

- Crew notification: Given the noisy flight deck environment and existing communication methods through the cranial, the Wing Walker project opted for a combination of AR and haptic feedback. The towing leader wears AR glasses to view sensor data, while the crew members receive haptic feedback during potential collisions (Idy, 2023).

- System removability and storage: The Wing Walker Project is designed for easy removal and compact storage. Maintenance requirements are reduced by using the tow tractor's power source, and future integration with tow tractor designs is simplified (Idy, 2023).

- EmCon conditions: Since the Wing Walker project utilizes LiDAR sensors, the system is not compatible for use when in EmCon conditions. Therefore, the Wing Walker project can only enhance towing evolutions when the ship conducts standard operations (Idy, 2023).

The Wing Walker project is funded by the Naval Innovative Science & Engineering (NISE) Basic and Applied Research (BAR) program for FY21-FY24. The project focuses on LiDAR and computer vision algorithms for aircraft detection and plans to conduct a demonstration by July 2023, testing the system while towing a F/A-18.

As the Wing Walker Project continues to be tested and developed, future recommended work is the continued support of RISE Lab research. This research includes algorithm improvements for operations in degraded environments, such as haze or darkness, and additional modifications for emergency braking systems and procedures. Following FY24, the project aims to transition to a program of record for testing and deployment in actual fleet towing operations.

C. SUMMARY

In conclusion, this study aimed to evaluate the effectiveness of using augmented reality (AR) technology for aviation ground operations. The research objectives were met through the experiment, and the data collected provided insight into AR technology's potential benefits and limitations in this context. Although the hypotheses were deemed inconclusive, the results indicate a need for further testing and evaluation of AR technology in aviation ground operations.

The study was conducted in collaboration with NAWCAD's RISE Lab, and future work with the lab is recommended to further explore the use of AR technology for aviation ground operations. In addition, future research should focus on refining AR technology, optimizing algorithms and usability, and determining the impact of AR technology on safety, efficiency, and overall performance.

APPENDIX A. TOW CREW DIRECTOR AND AIRCRAFT TOWING QUALIFICATION SYLLABI

Description	Signer Authority	Auto Signable	Status	Due Date	Progress
AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC) (front/back matter)		No	ASSIGNED on 06-Mar-2023		0 of 46 (0.0%)
MD1. TECHNICAL READING		No			
A. READ NAVAIR 00-80T-113	TRAINEE	No	ACTIVE		
B. READ NAVAIR 17-1-537	TRAINEE	No	ACTIVE		
C. READ NAVAIR 00-80T-96 WP 00 005	TRAINEE	No	ACTIVE		
D. READ NAVAIR 00-80T-105	TRAINEE	No	ACTIVE		
E. READ NAVAIR 00-80T-106	TRAINEE	No	ACTIVE		
F. READ NAVAIR 00-80T-103	TRAINEE	No	ACTIVE		
G. READ IETMS 09 (SERIES)	TRAINEE	No	ACTIVE		
H. READ Local Command Procedures	TRAINEE	No	ACTIVE		
MD2. DISCUSS		No			
A. REQUIREMENT TO VERIFY TOW OPERATOR QUALIFICATION AND BRAKE RIDER QUALIFICATION PRIOR TO A/C MOVE	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
B. PRE-TOW BRIEF PROCEDURES	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
C. A/C MOVEMENT SAFETY REQUIREMENTS	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
D. PROCEDURES TO PREPARE A/C FOR TOWING	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
E. SITUATIONS WHICH PREVENT TOWING OF A/C	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
F. PROPER TOW BAR INSTALLATION	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
G. PROCEDURES FOR SECURING A/C	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
MD3. FLIGHTLINE OJT		No			
A. VERIFY TOW OPERATOR QUALIFICATION AND BRAKE RIDER QUALIFICATION PRIOR TO A/C MOVE	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
A. VERIFY TOW OPERATOR QUALIFICATION AND BRAKE RIDER QUALIFICATION PRIOR TO A/C MOVE (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
A. VERIFY TOW OPERATOR QUALIFICATION AND BRAKE RIDER QUALIFICATION PRIOR TO A/C MOVE (Rep: 3)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
B. PRE-TOW BRIEF WITH EMPHASIS ON SAFETY	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
B. PRE-TOW BRIEF WITH EMPHASIS ON SAFETY (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
B. PRE-TOW BRIEF WITH EMPHASIS ON SAFETY (Rep: 3)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
C. ENSURE A/C IS PREPARED FOR A TOW EVOLUTION	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
C. ENSURE A/C IS PREPARED FOR A TOW EVOLUTION (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
C. ENSURE A/C IS PREPARED FOR A TOW EVOLUTION (Rep: 3)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
D. ENSURE TOW BAR IS PROPERLY INSTALLED ON A/C	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
D. ENSURE TOW BAR IS PROPERLY INSTALLED ON A/C (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
D. ENSURE TOW BAR IS PROPERLY INSTALLED ON A/C (Rep: 3)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
E. SUCCESSFULLY DIRECT AN ENTIRE TOW EVOLUTION ON THE LINE (DAY)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
E. SUCCESSFULLY DIRECT AN ENTIRE TOW EVOLUTION ON THE LINE (DAY) (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
F. SUCCESSFULLY DIRECT AN ENTIRE TOW EVOLUTION ON THE LINE (NIGHT)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
G. ENSURE A/C IS PROPERLY SECURED	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
MD4. HANGER/CONFINED SPACE OJT		No			
A. VERIFY TOW OPERATOR QUALIFICATION AND BRAKE RIDER QUALIFICATION PRIOR TO A/C MOVE	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
A. VERIFY TOW OPERATOR QUALIFICATION AND BRAKE RIDER QUALIFICATION PRIOR TO A/C MOVE (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
B. PRE-TOW BRIEF WITH EMPHASIS ON SAFETY	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
B. PRE-TOW BRIEF WITH EMPHASIS ON SAFETY (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
C. ENSURE A/C IS PREPARED FOR A TOW EVOLUTION	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
C. ENSURE A/C IS PREPARED FOR A TOW EVOLUTION (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
D. ENSURE TOW BAR IS PROPERLY INSTALLED ON A/C	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
D. ENSURE TOW BAR IS PROPERLY INSTALLED ON A/C (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
E. SUCCESSFULLY DIRECT AN ENTIRE TOW EVOLUTION INTO THE HANGER OR CONFINED SPACE (DAY)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
F. SUCCESSFULLY DIRECT AN ENTIRE TOW EVOLUTION INTO THE HANGER OR CONFINED SPACE (NIGHT)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
G. ENSURE A/C IS PROPERLY SECURED	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	ACTIVE		
G. ENSURE A/C IS PROPERLY SECURED (Rep: 2)	AIRCRAFT TOW DIRECTOR QUALIFICATION (H-53K) (MC)	No	WAITING		
MD5. Practical Examination		No			
NOTE. SIGNATURE SHALL BE SIGNED BY A "A/C TOW DIRECTOR QUALIFIED" QUALITY ASSURANCE REPRESENTATIVE		No			
A. ACT AS A TOW DIRECTOR	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	ACTIVE		
MD6. WRITTEN EXAM		No			
TEST: A/C TOW DIRECTOR QUALIFICATION EXAM (H-53K) (MC)	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	ACTIVE		
MD7. ACKNOWLEDGMENT		No			
A. UNDERSTAND AND ACCEPT Responsibilities imposed upon me by virtue of this certification, I will conduct all operation authorized in accordance with all applicable directives and policies	TRAINEE	No	ACTIVE		

Description	Signer Authority	Auto Signable	Status	Due Date	Progress
AIRCRAFT TOW QUAL (H-53K) (MC) (front/back matter)		No	ASSIGNED on 06-Mar-2023		0 of 37 (0.0%)
AT1. Required Reading		No			
a. READ NA-80T-96	TRAINEE	No	ACTIVE		
b. READ IETMS 09-10-00-01A (Rep 1)	TRAINEE	No	ACTIVE		
c. READ NAVAIR 17-1-537	TRAINEE	No	ACTIVE		
d. READ NA 00-80T-113	TRAINEE	No	ACTIVE		
AT2. SE Operators licensing		No			
a. VERIFY Phase II License complete	SUPERVISOR (MC)	No	ACTIVE		
AT3. OJT		No			
a. PERFORM Connect tow tractor to tow-bar	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
a. PERFORM Connect tow tractor to tow-bar (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
b. PERFORM Connect tow-bar to aircraft	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
b. PERFORM Connect tow-bar to aircraft (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
c. ENSURE Aircraft properly prepared for towing	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
c. ENSURE Aircraft properly prepared for towing (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
d. PERFORM Tow A/C in hangar	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
d. PERFORM Tow A/C in hangar (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
e. PERFORM Tow A/C during night time evolution	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
e. PERFORM Tow A/C during night time evolution (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
f. PERFORM Tow A/C on flight line	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
f. PERFORM Tow A/C on flight line (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
g. PERFORM Director brief for towing of A/C	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
g. PERFORM Director brief for towing of A/C (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
h. PERFORM Direct towing of A/C in hangar	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
h. PERFORM Direct towing of A/C in hangar (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
i. PERFORM Direct towing of A/C on flight line	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
i. PERFORM Direct towing of A/C on flight line (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
j. PERFORM Direct towing of A/C at night	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
j. PERFORM Direct towing of A/C at night (Rep: 2)	AIRCRAFT TOW QUAL (H-53K) (MC)	No	ACTIVE		
AT4. Practical Examination		No			
a. PERFORM Connect tow tractor to tow-bar	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
b. PERFORM Connect tow-bar to aircraft	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
c. ENSURE Aircraft properly prepared for towing	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
d. PERFORM Tow A/C in hangar	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
e. PERFORM Tow A/C during night time evolution	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
f. PERFORM Tow A/C on flight line	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
g. PERFORM Director brief for towing of A/C	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	ACTIVE		
h. PERFORM Direct towing of A/C in hangar	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
i. PERFORM Direct towing of A/C on flight line	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	ACTIVE		
j. PERFORM Direct towing of A/C at night	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	ACTIVE		
MC TEST. Examinations		No			
1. TEST: AIRCRAFT TOW QUAL (H-53K-MC)	QUALITY ASSURANCE REPRESENTATIVE (MC)	No	WAITING		
AT5. ACKNOWLEDGMENT		No			
a. UNDERSTAND AND ACCEPT Responsibilities imposed upon me by virtue of the certification, I will conduct all operations authorized in accordance with all applicable directives and policies	TRAINEE	No	WAITING		

APPENDIX B. EXPERIMENT CONSENT FORM

Naval Postgraduate School
Consent to Participate in Research

You are invited to participate in a research study entitled "Leveraging Augmented Reality (AR) in Support of Aircraft Towing Evolutions." The purpose of the research is to explore the impact AR may have on a tow crew director's ability to identify potential aircraft collisions during the towing process. Participants in this study will observe a towing process of an F/A-18 from the perspective of a tow crew director using an Oculus Rift virtual reality head mounted display. Each participant will be asked to complete three towing sessions using standard view (no AR) and AR interface views. Participants will also complete questions regarding their background information, questions about your susceptibility to motion sickness, and cybersickness, a contrast sensitive test where you read letters of an eye chart, and trail marking test where you connect nodes in sequential order on a tablet.

Key Information:

1. Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which you would otherwise be entitled, and you may discontinue participation at any time without penalty or loss of benefits to which you otherwise would be entitled.
2. The potential risks of participating in this study are as follows: minor nausea and/or experiencing cybersickness (sensations of nausea, temporary loss of ability to coordinate the eyes to move with accuracy and control, and disorientation). After onset, the discomfort could last for a duration of up to one hour. You may, at any time, communicate discomfort to the researcher, and if desired, terminate the experiment. In the event you show or exert symptoms of cybersickness related to the VR system, you will ne removed from the study and your chain of command will be notified, as will medical personnel. You will be asked to sit in the experiment location until the discomfort subsides or as Medical personnel deems necessary.
3. You will not directly benefit from participating in this study but if this simulated AR system proves to be an effective means of mitigating risk during towing evolutions, the Navy could use this system to better sustain material readiness of aircraft and fleet.
4. There is no cost to participate in this research study. You will not be compensated for your participation.
5. Up to 40 individuals will participate in this study. Participation is expected to last 95 minutes. The alternative to participating in this study is to not participate.

Study Procedures:

During this experiment, you will experience several aircraft towing scenarios from the perspective of a tow crew director using an Oculus Rift virtual reality (VR) interface. If you wear glasses, it is possible to wear them underneath the Oculus Rift. However, this may alter your perception of the VE or become uncomfortable. Wearing glasses during the experiment is your choice. Each subject will complete all sessions in one sitting, which is expected to take approximately 95 minutes.

a. The experiment will be divided into six sessions:
    i. Pre-experiment questionnaires (10 min):
        1. Demographic questionnaire.
        2. Simulator sickness questionnaire (SSQ).
    ii. Introduction/system familiarity (10 min):
        1. Utilized to orient you with what type of scenarios you will encounter in the experiment, as well as gain an understanding of the user interface.
    iii. Towing collision identification Session A (15 min):
        1. Complete 10 scenes in which you will be asked to identify any potential towing collisions.
        2. 5 scenes without the ability to control aircraft movement speed and 5 scenes with the ability to control aircraft movement speed.
    iv. VE break period (10 min):
        1. Contrast sensitivity test
    v. Towing collision identification Session B (15 min):
        1. Complete 10 scenes in which you will be asked to identify any potential towing collisions.
        2. 5 scenes without the ability to control aircraft movement speed and 5 scenes with the ability to control aircraft movement speed.
    vi. VE break period (10 min):
        1. Cognitive processing speed test.
    vii. Towing collision identification Session C (15 min):
        1. Complete 10 scenes in which you will be asked to identify any potential towing collisions.
        2. 5 scenes without the ability to control aircraft movement speed and 5 scenes with the ability to control aircraft movement speed.
    viii. Post-experiment questionnaires (10 min):
        1. Post-experiment SSQ.
        2. Survey questions regarding perceived performance in the experiment, potential utilization of AR technology during towing evolutions, and overall usability of the system.

The procedures for the experiment are designed specifically for this research and will serve no purpose other than research. You will not be recorded from an audio or video perspective. No confidential information will be retained by any member of the research team.

Confidentiality & Privacy Act. Any information that is obtained during this study will be kept confidential to the full extent permitted by law. All efforts, within reason, will be made to keep your personal information in your research record confidential but total confidentiality cannot be guaranteed. In the event you exert symptoms of severe sickness related to the VR system, your chain of command will be notified, as will medical personnel. All paper records will be maintained by the student researcher during collection and then stored in a locked office at NPS. All electronic records will be stored on the NPS secure server. The information collected as part of the research, even if identifiers are removed, will not be used, or distributed for future research studies.

Points of Contact. If you have any questions or comments about the research, or you experience an injury or have questions about any discomforts that you experience while taking part in this study please contact the Principal Investigator, Dr. Mollie McGuire, (831) 656-2995, mrmcguir@nps.edu. Questions about your rights as a research subject or any other concerns may be addressed to the Navy Postgraduate School IRB Vice Chair, Mr. Bryan Hudgens, 831-656-2039, bryan.hudgens@nps.edu.

Statement of Consent. I have read the information provided above. I have been given the opportunity to ask questions and all the questions have been answered to my satisfaction. I have been provided with a copy of this form for my records and I agree to participate in this study. I understand that by agreeing to participate in this research and signing this form, I do not waive any of my legal rights.

☐I consent to participate in the research study.

☐I do not consent to participate in the research study.

______________________________ ______________________________

Signature of Participant Date

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APPENDIX C. ATEAR DEMOGRAPHICS SURVEY

ATEAR Demographics

Start of Block: Default Question Block

Q1 Please enter your Subject ID (ex. 3):

____

Q2 Please enter today's date (ex. 2/5/2023):

____

Q3 Please enter your age (ex. 23):

____

Q4 Select your gender:

- ○ Male (1)
- ○ Female (2)
- ○ Prefer not to say (3)

Q5 What is your preferred writing hand?

- ○ Left (1)
- ○ Right (2)
- ○ Ambidextrous (3)

Q6 Do you wear corrective lenses for your eyes?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Do you wear corrective lenses for your eyes? = Yes (1)

Q6A What is your uncorrected vision (ex. 20/400)? If you do not know your uncorrected vision, please type 0000 in the box below.

____

Display This Question:

If Do you wear corrective lenses for your eyes? = Yes (1)

Q6B Will you be wearing glasses or contacts for this experiment?

- ◯ Yes (1)
- ◯ No (2)

Q7 Please select your branch of military service:

- ◯ Marine Corps (1)
- ◯ Navy (2)

Q8 Please enter your current squadron (ex. VMFA-323 or VFA-122):

Q9 How many years have you served in the military (ex. 3.5)?

____

Display This Question:
If Please select your branch of military service: = Marine Corps (1)

10A Please select your rank:

- ◯ Pvt (1)
- ◯ Pfc (2)
- ◯ LCpl (3)
- ◯ Cpl (4)
- ◯ Sgt (5)
- ◯ SSgt (6)
- ◯ GySgt (7)
- ◯ MSgt (8)
- ◯ MGySgt (9)

Display This Question:
If Please select your branch of military service: = Navy (2)

Q10B Please select your rank:

- ◯ SR (1)
- ◯ SA (2)
- ◯ SN (3)
- ◯ PO3 (4)
- ◯ PO2 (5)
- ◯ PO1 (6)
- ◯ CPO (7)
- ◯ SCPO (8)
- ◯ MCPO (9)

Q11 Please enter your MOS (USMC) or NEC(USN):

____

Q12 How many total years have you served at the organizational/squadron level?

- less than 1 (1)
- 1-2 (2)
- 3-4 (3)
- 5-6 (4)
- 7-8 (5)
- 9-10 (6)
- 11+ (7)

Q13 Is your tow crew director qualification currently active?

- Yes (1)
- No (2)

Q14 How many total years have you been tow crew director qualified?

- Less than 1 (1)
- 1-2 (2)
- 3-4 (3)
- 5-6 (4)
- 7-8 (5)
- 9-10 (6)
- 11+ (7)

Q15 Have you ever directly witnessed a towing mishap with an F/A-18?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Have you ever directly witnessed a towing mishap with an F/A-18? = Yes (1)

Q15A Were you a member of the tow crew during the mishap?

- ◯ Yes (1)
- ◯ No (2)

Display This Question:

If Were you a member of the tow crew during the mishap? = Yes (1)

Q15B Were you serving as the tow crew director during the mishap?

- ◯ Yes (1)
- ◯ No (2)

Q16 Have you ever utilized virtual reality (VR) displays?

- ◯ Yes (1)
- ◯ No (2)

Q17 How many hours a week do you play desktop computer games?

- 0 (1)
- 1-2 (2)
- 3-4 (3)
- 5-6 (4)
- 7-8 (5)
- 9-10 (6)
- 11+ (7)

Q18 Are you susceptible to motion sickness?

- Yes (1)
- Maybe (2)
- No (3)

End of Block: Default Question Block

APPENDIX D. ATEAR SSQ

Q1 Please enter your Subject ID (ex. 3):

____

Q2 Please enter today's date (ex. 2/5/2023):

____

Q1 For the following questions, please select the degree to which each symptom is affecting you right now.

Q2 General Discomfort

- ○ None (1)
- ○ Slight (2)
- ○ Moderate (3)
- ○ Severe (4)

Q3 Fatigue

- ○ None (1)
- ○ Slight (2)
- ○ Moderate (3)
- ○ Severe (4)

Q4 Headache

- ○ None (1)
- ○ Slight (2)
- ○ Moderate (3)
- ○ Severe (4)

Q5 Eye Strain

- ○ None (1)
- ○ Slight (2)
- ○ Moderate (3)
- ○ Severe (4)

Q6 Difficulty Focusing

- ○ None (1)
- ○ Slight (2)
- ○ Moderate (3)
- ○ Severe (4)

Q7 Salivation Increasing

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q8 Sweating

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q9 Nausea

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q10 Difficulty Concentrating

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q11 Fullness of Head (your head feels heavy)

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q12 Blurred Vision

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q14 Dizziness With Eyes Open

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q13 Dizziness With Eyes Closed

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q15 Vertigo (loss of orientation with respect to vertical upright)

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q16 Stomach Awareness (upset stomach, just short of nausea)

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

Q17 Burping

- None (1)
- Slight (2)
- Moderate (3)
- Severe (4)

End of Block: Default Question Block

*same for both pre and post-experiment

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APPENDIX E. EXPERIMENT SCRIPT

ATEAR: Experiment Script
<u>*PLEASE STAY SEATED AT ALL TIMES***</u>**

☐**<u>Pre-Experiment</u>**

1. Pre-SSQ
2. ATEAR Demographics Survey

☐**<u>Tutorial</u>**

"Prior to starting the experiment, we are going to walk through a tutorial."

☐ Fit headset to user, talk about interpupillary distance (IPD)*

1. **First Screen:**
   The actions for each button are on the screen. Notice that you will press the "B" button to end the scenario. When I say "end scenario," I mean blow the whistle as if an aircraft were to collide with another object on the flight line and you needed to stop the tow crew. If you are very confident that the aircraft will NOT collide with something else, DO NOT press the "B" button to end the scene early. If you do so, it will skew the data collected from the experiment.

   Without pressing anything, please slide the headset up so you can physically see each controller button. Go ahead and place the headset back on your head. Once it is in a comfortable position, go ahead and continue.

   What you see here is a standard scene with the aircraft on the flight line. Use the thumbstick to navigate around the front end of the plane. Your freedom of movement remains fixed in a U shape around the front of the plane. For programming reasons, the U shape is tied to the orientation of the wings, NOT the tug. For some scenes you may experience that you will not have the ideal movement pattern and may "walk through" the tug. Just note that this is a limitation of the software. When you are satisfied, press the "B" button to end the scene.

   After each scene, you will get a 2D, top down illustration of the aircraft. The black outline of the aircraft indicates the location you decided to blow the whistle. In this case, the aircraft did not move so the outline remains on the aircraft itself. For other scenes, you may blow the whistle before an aircraft hits an object. During the scene playback, you will see an outline of the aircraft position in which you blew the whistle. Additionally, the scene will continue to play through what was pre-programmed. For scenes that an aircraft was programmed to collide with another object, the aircraft impact zone will be marked with a red X.

"Fold your ear phones away from your ears. Select 'Proceed'."

2. **Second Screen:**
   This scene will show you how the simulated AR systems works. Select "Start" when you are ready. Notice how the wing tip indicator on your right is green. Wing tips will remain green until the wing tip comes in close proximity with another object on the flight line. If you look at the wing tip on your left side, you see that it is yellow. This yellow indicator tells you that the wing tip on that side is close to an object. As the aircraft gets even closer to an object, the wingtip indicator will turn red. Additionally, you'll notice auditory tones through the

headphones. These auditory tones are directly correlated with the colors of the wing tip. As the wing tip turns to red, the frequency of the auditory tones increases. Now look to your right so the aircraft is out of your field of view. Notice the yellow indicator on the left side of your eye. This is telling you that there is an issue to the left and you need to orient your head towards that direction.

Additionally, you will notice an outline of an F/A-18 in the top right corner of the display. This outline or "Silhouette" will be utilized as your AR system in a set of scenarios. Similar to the other system just described, the Silhouette system aircraft outline will change colors depending on the region of the aircraft that is close to colliding. The colors scale from green to red, with red being danger close. Additionally the distance will be displayed between the objects near the aircraft outline.

When you are satisfied, press the "B" button to complete this screen. Click "Proceed". One thing I want to mention about the AR systems. Some scenes are programmed as collisions, near-misses, misses, etc. If the wingtip indicator is red, DO NOT assume the aircraft will collide with the object.

3. **Third Screen:**
   For some scenes, you will have the ability to control the speed of the tow tractor. We intend to utilize this data to see the level of confidence you have in your ability to foresee an aircraft collision. When ready, click "start".

   Pull and release the trigger. You'll notice your speed increases and decreases accordingly. When you're finished, press the "B" button to end the scene.

"Go ahead and select 'Proceed.' The tutorial is now complete."

☐**EXPERIMENT**

"You will be executing 3 sets of 10 scenarios. For the first 5 scenarios of each set, you will not be able to control aircraft speed. For the last 5, you will be able to control aircraft movement speed. At the end of each scene, you will be asked to enter your confidence in your ability to identify a potential collision. Pay attention to the wording of each question because they do vary slightly. To enter your answer for each question, simply slide the selection bar to your desired location and select 'Proceed'."

"Do you have any questions? If not, you may begin the experiment."

☐**VE Break 1**

1. Contrast Sensitivity Test

☐**VE Break 2**

1. Cognitive Speed Processing Test

☐**Post Experiment**

1. Post-SSQ
2. Post-experiment Survey

APPENDIX F. POST-EXPERIMENT QUESTIONNAIRE

Q1 Please enter your Subject ID (ex. 03):

____

Q2 Please enter today's date (ex. 2/5/2023):

____

Q3 Could you see the towing scenarios clearly in the Oculus Rift?

○ Yes (1)

○ No (2)

Display This Question:
If Could you see the towing scenarios clearly in the Oculus Rift? = No

Q4 Were you wearing corrective lenses?

○ Yes (1)

○ No (2)

Display This Question:
If Could you see the towing scenarios clearly in the Oculus Rift? = Yes

Q5 Were you wearing glasses?

○ Yes (1)

○ No (2)

Display This Question:
If Were you wearing glasses? = No

Q6 Were you wearing contact lenses?

○ Yes (1)

○ No (2)

Display This Question:
If Could you see the towing scenarios clearly in the Oculus Rift? = No

Q7 Why do you feel that you could not see the towing scenarios clearly?

____

Q8 Did the towing scenes accurately represent towing an F/A-18? (We understand the entire process is not captured. Replicating the entire tow process is out of the scope of this project)

○ Yes (1)

○ No (2)

Q9 Did you have enough time to gain an understanding of your situation and identify potential collision areas for aircraft in each scene?

○ Yes (1)

○ No (2)

Display This Question:

If Did you have enough time to gain an understanding of your situation and identify potential collis... = No

Q10 Which scene(s) did you feel like you did not have enough time allotted to make decisions? (select all that apply)

- ☐ Outdoor towing around storage containers (1)
- ☐ Outdoor towing around aircraft (2)
- ☐ Indoor Towing inside the Hangar (3)

Q11 On a scale of 1 to 10 (10 being the most difficult), rate the difficulty utilizing the AR system:

	0	1	2	3	4	5	6	7	8	9	10
Difficulty ()											

Q12 What impact did the AR display have on your ability to understand the location of the aircraft in reference to other objects (i.e., aircraft, boxes, support equipment) on the flight line?

- ○ Helped Understanding (1)
- ○ No Effect (2)
- ○ Reduced Understanding (3)

Q13 On a scale of 1 to 10 (10 being the most confident), rate your confidence in towing with the AR system?

	0	1	2	3	4	5	6	7	8	9	10
Confidence ()											

Q14 If an AR system was fielded to the fleet and utilized for towing aircraft, do you think the number of towing-related incidents would decrease?

- ○ Yes (1)
- ○ No (2)

Q15 Do you think a similar AR system should be incorporated into the towing process across the fleet?

- ○ Yes (1)
- ○ No (2)

Display This Question:

If Do you think a similar AR system should be incorporated into the towing process across the fleet? = Yes

Q16 Why do you think a similar AR system should be incorporated into the towing process?

____

Display This Question:

If Do you think a similar AR system should be incorporated into the towing process across the fleet? = No

Q17 Why do you think a similar AR system should NOT be incorporated into the towing process?

APPENDIX G. DATA ANALYSIS PYTHON CODE

```python
import csv
import glob
import errno
import statistics
import math
# put your path here
path = 'C://Users/Admin/Desktop/Results/1000/*.csv'

files = glob.glob(path)
# print(len(files))
# used for calculating distance
recentSpeed = 0.00
triggerTimeforSpeed = 0.00
collisionTimeforSpeed = 0.00

for name in files:
    # reads each file
    with open(name, newline='') as f:
        f_reader = csv.reader(f, delimiter=',')

        speedControl = False
        recordSpeed = False
        speedArray = []
        reactionTime = 0.00
        objectCollided = False
        tractorStopped = False

        for line in f_reader:

            simTime = line[0]
            task = line[1]
            speed = line[2]

            # print QuestionResponse
            if task == ('Question A'):
                print(task + ',' + speed)
            if task == ('Question B'):
                print(task + ',' + speed)
            # print subjectID
            if task == ('Subject ID'):
                print(task + ',' + speed)
            # print AR status
            if task == ('Is AR On'):
                print(task + ',' + speed)
            # print Speed Control
            if task == ('Can Control Tractor Speed'):
                print(task + ',' + speed)
                speedControl = True
            # print EnvironmentType
```

```python
            if task == ('Running Scenario'):
                print(speed)
            # print StartScenario
            if task == ('Start Scenario Triggered'):
                # print(task + ',' + simTime)
                recordSpeed = True
            # print ObjectCollisionTrigger
            if task == ('Object Collision Triggered'):
                # print(task + ',' + simTime)
                objectCollided = True
            collisionTimeforSpeed = float(simTime)

            # print StopTowTractor
            if task == ('Stop Tractor Triggered'):
                print(task + ',' + simTime)
                tractorStopped = True
                if speedControl == True:
                    # print("i am in the speed control")
                    print('Mean is,', statistics.mean(speedArray))
                    print('Stdev is,', statistics.stdev(speedArray))
                    print('Most recent speed is,',
                          speedArray[len(speedArray)-1])
                    recordSpeed = False
                    triggerTimeforSpeed = float(simTime)
                    recentSpeed = float(speedArray[len(speedArray)-1])
                    speedArray = []

            # print FinishScenario
            if task == ('Finish Scenario Triggered'):
                if len(speedArray) > 0:
                    if speedControl == True:
                        print('Mean is,', statistics.mean(speedArray))
                        print('Stdev is,', statistics.stdev(speedArray))
                        print('Most recent speed is,',
                              speedArray[len(speedArray)-1])
                        recordSpeed = False

            if recordSpeed == True:
                if speed != '':
                    if task == 'Tractor Speed':
                        speedArray.append(float(speed))

        print('Distance is', (collisionTimeforSpeed -
                              triggerTimeforSpeed)*recentSpeed)


# print(collisionTimeforSpeed-triggerTimeforSpeed*recentSpeed)

        collisionTimeforSpeed = 0.00
        triggerTimeforSpeed = 0.00
        recentSpeed = 0.00

        if objectCollided == tractorStopped:
            print('Collison Prediction' + ',' + 'Correct')
            objectCollided = False
            tractorStopped = False

        if objectCollided != tractorStopped:
            print('Collison Prediction' + ',' + 'Incorrect')
            objectCollided = False
            tractorStopped = False
        print('*** next file ***')
```

APPENDIX H. DATA ANALYSIS CODE OUTPUT

```
Subject ID,1000
Is AR On,No
Can Control Tractor Speed,No
Environment 1 - Caution
Mean is, 0.9909929623529412
Stdev is, 0.09157641145707746
Most recent speed is, 1.009061
Environment 2 - Hit 2
Mean is, 0.9898911265306123
Stdev is, 0.09865178666842121
Most recent speed is, 1.006562
Mean is, 0.9898911265306123
Stdev is, 0.09865178666842121
Most recent speed is, 1.006562
Question B,7.660465
Environment 3 - Danger
Mean is, 0.9891591638190955
Stdev is, 0.10418380345388033
Most recent speed is, 1.006591
Environment 4 - Hit 3
Stop Tractor Triggered,336.6314314
Mean is, 0.986984859009009
Stdev is, 0.11427679211463292
Most recent speed is, 1.008125
Question A,7.624131
Scenario 4 - Return to Hangar
Stop Tractor Triggered,393.4055989
Mean is, 0.9806051789473684
Stdev is, 0.149092384942013
Most recent speed is, 1.004504
Question A,8.470711
Distance is 12.509626525243256
Collison Prediction,Correct
*** next file ***
Subject ID,1000
Is AR On,No
Can Control Tractor Speed,Yes
Environment 1 - Hit 2
Stop Tractor Triggered,76.2354589
Mean is, 1.696695028125
Stdev is, 0.5159823079085062
Most recent speed is, 0.9345491
Question A,7.179736
Environment 2 - Hit 1
Stop Tractor Triggered,145.7261207
Mean is, 1.6833558323529412
Stdev is, 0.5529713251834656
Most recent speed is, 1.156627
Question A,8.126157
Environment 3 - Caution
Mean is, 1.9413731192307693
Stdev is, 0.37025905515859786
Most recent speed is, 2.000775
```

```
Environment 4 - Danger
Mean is, 1.779760807017544
Stdev is, 0.4935675004554493
Most recent speed is, 2.000765
Scenario 4 - Return to Hangar
Stop Tractor Triggered,282.2386988
Mean is, 1.8167188294871794
Stdev is, 0.474778722107451
Most recent speed is, 1.999223
Question A,8.936414
Distance is 21.008320495422065
Collison Prediction,Correct
*** next file ***
Subject ID,1000
Is AR On,No
Can Control Tractor Speed,No
Environment 1 - Danger
Stop Tractor Triggered,39.8488751
Mean is, 0.9410101909090909
Stdev is, 0.26165201305750524
Most recent speed is, 1.009839
Question A,1
Environment 2 - Caution
Mean is, 0.99100016875
Stdev is, 0.09706044161237634
Most recent speed is, 1.000646
Environment 3 - Hit 2
Stop Tractor Triggered,237.2654043
Mean is, 0.9862349647058823
Stdev is, 0.1197407994390893
Most recent speed is, 1.009395
Question A,10
Environment 4 - Hit 1
Stop Tractor Triggered,265.9773382
Mean is, 0.9532921384615385
Stdev is, 0.24107844249591093
Most recent speed is, 0.9954326
Question A,10
Scenario 4 - Return to Hangar
Stop Tractor Triggered,316.9432736
Mean is, 0.9804688243902439
Stdev is, 0.1404503417765186
Most recent speed is, 0.9959778
Question A,10
Distance is 8.017431855022432
Collison Prediction,Correct
*** next file ***
Subject ID,1000
Is AR On,No
Can Control Tractor Speed,Yes
Environment 1 - Hit 1
Stop Tractor Triggered,52.0032723
Mean is, 1.9007321642857142
```

APPENDIX I. DEMOGRAPHIC SURVEY RESULTS

Q3 - Please enter your age (ex. 23):

21 Responses

Female (2)

Please enter your age (ex. 23):
31

Male (1)

Please enter your age (ex. 23):
23
25
26
22
28
22
26
33
22
23
28
36
27
23
26
21
20
24
28

Q9 - How many years have you served in the military (ex. 3.5)?

21 Responses

Navy (2)

How many years have you served in the military (ex. 3.5)?
8
1.5
5
3.5
3

Marine Corps (1)

How many years have you served in the military (ex. 3.5)?
3.8
5
3
3.5
4.5
4
5
12
3
5
5
3
5
9

undefined

How many years have you served in the military (ex. 3.5)?
4

Q11 - Please enter your MOS (USMC) or NEC(USN):

21 Responses

Navy (2)

Please enter your MOS (USMC) or NEC(USN):
AM
AME
AT
AO
AME

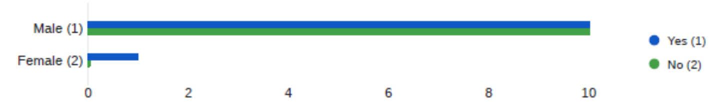
Marine Corps (1)

Please enter your MOS (USMC) or NEC(USN):
6217/AD
6323
6092
6287
6217
6317
6217
6467
6317
6336
6257
6317
6217
6217

undefined

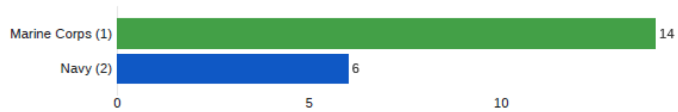
Please enter your MOS (USMC) or NEC(USN):
15D

Q6 - Do you wear corrective lenses for your eyes?

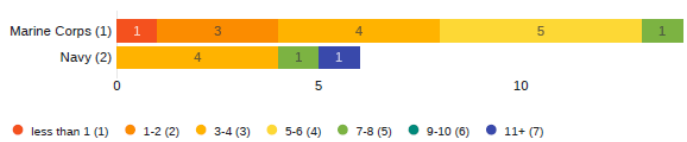


Q6B - Will you be wearing glasses or contacts for this experiment?

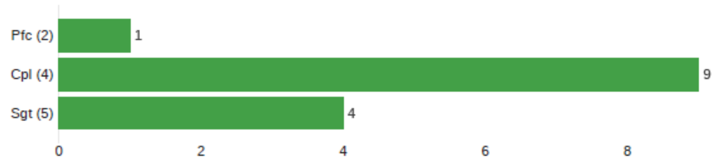
Q7 - Please select your branch of military service:



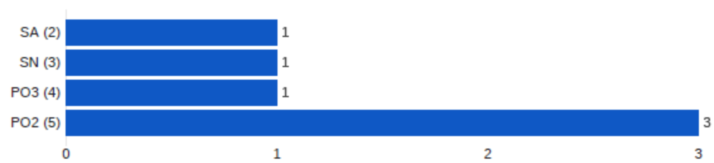
Q12 - How many total years have you served at the organizational/squadron level?



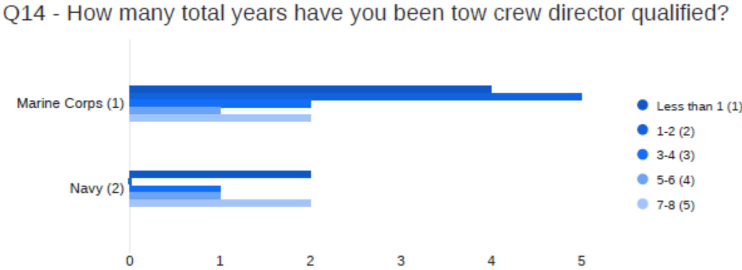
10A - Please select your rank:



Q10B - Please select your rank:



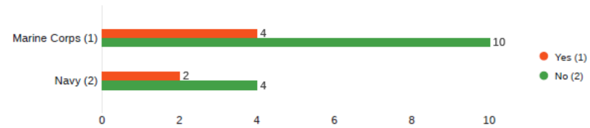
Q14 - How many total years have you been tow crew director qualified?



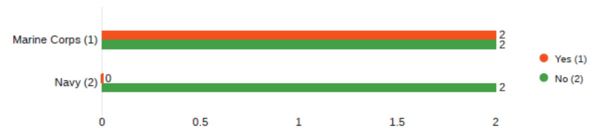
Q14 - How many total years have you been tow crew director qualified?

Field	Min	Max	Mean	Standard Deviation	Variance	Responses	Sum
How many total years have you been tow crew director qualified?	1.00	5.00	2.57	1.50	2.24	21	54.00

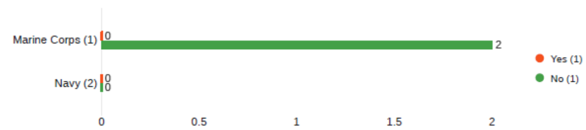
Q15 - Have you ever directly witnessed a towing mishap with an F/A-18?



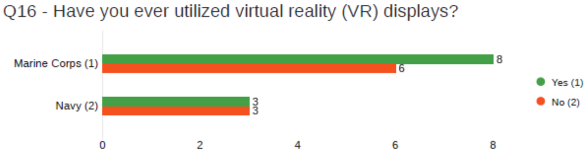
Q15A - Were you a member of the tow crew during the mishap?



Q15B - Were you serving as the tow crew director during the mishap?



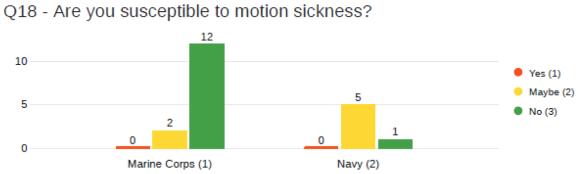
Q16 - Have you ever utilized virtual reality (VR) displays?



Q17 - How many hours a week do you play desktop computer games?

Field	Min	Max	Mean	Standard Deviation	Variance	Responses	Sum
How many hours a week do you play desktop computer games?	1.00	7.00	2.33	1.78	3.17	21	49.00

Q18 - Are you susceptible to motion sickness?



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APPENDIX J. SSQ RESULTS

Pre-SSQ

Subject ID	0				1				2				3				4				5				6				7				8				9				10				11			
	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D
General Discomfort			0			0	0			0	0			0	0				0				0			0	0				0				0				0		1	1	1				0	
Fatigue			0				0				0				0				0				0				0				0		1		1				0				0				0	
Headache			0				0				0				0		1		1				0				0				0				0				0		1		1				0	
Eye Strain			0				0				0				0				0				0				0				0				0				0		1		1				0	
Difficulty Focusing			0	0			0	0			0	0			0	0			0				0				0				0				0				0		1		1	1			0	
Salvation Increase						0				0				0												0																0						
Sweating						0				0				0												0																0						
Nausea				0		0		0		0		0		0		0										0															1	1		1				
Difficulty Concentrating			0			0	0			0	0			0	0				0				0			0	0				0				0				0			0	0				0	
Fullness of Head				0				0				0				0																												0				
Blurred Vision			0	0			0	0			0	0			0	0			0				0				0				0				0				0				0	0			0	
Dizziness w/ Eyes Open				0				0				0				0																												0				
Dizziness w/ Eyes Closed				0				0				0				0																												0				
Vertigo				0				0				0				0																												0				
Stomach Awareness						0				0				0												0																0						
Burping						0			1	1				0											1	1																0						
Totals			0	0		0	0	0	1	9.5	0	0		0	0	0	1		7.6				0		1	9.5	0				0		1		7.6				0			19.1	30.3	27.8			0	
Total Score (TS)	0				0				35.6796				0				28.3492				0				35.6796				0				28.3492				0				288.8776				0			

Subject ID	12				13				14				15				16				17				18				19				20				MAX SCORE POSSIBLE			
	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D
General Discomfort		0	0				0				0				0			0	0				0			0	0				0				0		3	3	3	
Fatigue			0				0				0				0				0				0				0		1		1				0		3		3	
Headache	1		1				0				0				0				0				0				0				0				0		3		3	
Eye Strain			0				0				0				0				0				0				0				0		1		1		3		3	
Difficulty Focusing			0	0			0				0				0		1		1	1			0				0	0			0		1		1	1	3		3	3
Salvation Increase	1	1																0							1	1											3	3		
Sweating		0															1	1							1	1											3	3		
Nausea		0		0														0		0						0		0								0	3	3		3
Difficulty Concentrating		0	0				0				0				0		1	1	1				0			0	0				0				0		3	3	3	
Fullness of Head	1			1																0					1			1								0	3			3
Blurred Vision			0	0			0				0				0				0	0			0				0	0			0				0	0	3		3	3
Dizziness w/ Eyes Open				0																0								0								0	3			3
Dizziness w/ Eyes Closed				0																0								0								0	3			3
Vertigo				0																0								0								0	3			3
Stomach Awareness		0																0								0											3	3		
Burping		0																0							1	1											3	3		
Totals		9.5	7.6	13.9			0				0				0			19.1	15.2	13.9			0			28.6	0	13.9	1		7.6				15.2	13.9	48	200.34	159.18	292.32
Total Score (TS)	116.0896				0				0				0				180.1184				0				159.0996				28.3492				108.7592				2437.8816			

Post-SSQ

Subject ID	0				1				2				3				4				5				6				7				8				9				10				11			
	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D
General Discomfort	1	1	1			0	0		1	1	1			0	0				0				0				0		1	1	1		1	1	1				0		1	1	1				0	
Fatigue	1		1				0				0				0				0				0				0		1		1		0		0				0				0				0	
Headache	1		1				0		1		1				0		1		1				0				0		1		1		0		0				0		1		1				0	
Eye Strain	1		1		1		1		1		1				0				1				0				0				2		1		1				0		1		1				0	
Difficulty Focusing	0		0	0			0	0			0	0	1		1	1			0				0				0				2	2	0		0	0			0		1		1	1			0	
Salvation Increase	2	2				0				0				0																0			1	1								0						
Sweating	0	0			1	1				0				0																0			2	2								0						
Nausea	1	1		1		0		0		2		2		0		0														0		0	1	1		1					1	1		1				
Difficulty Concentrating	0	0	0			0	0			0	0			0	0				0				0				0			0	0		0	0	0				0			0	0				0	
Fullness of Head	1			1				0				0				0													1			1	1			1								0				
Blurred Vision	0		0	0			0	0			0	0			0	0			0				0				0		1		1	1	0		0	0			0				0	0			0	
Dizziness w/ Eyes Open	1			1				0	1			1				0																0	0			0								0				
Dizziness w/ Eyes Closed	1			1				0				0				0																0	1			1								0				
Vertigo	1			1				0				0				0																0	0			0								0				
Stomach Awareness	1	1				0				2				0																0			2	2								0						
Burping	0	0				0				0				0																0			0	0								0						
Totals	12	48	30.3	70		9.5	8	0		48	22.7	41.8	1	0	8	13.9	1		15				0				0			9.5	60.6	55.7	10	66.8	15	41.8			0			19.1	30.3	27.8			0	
Total Score (TS)	552.0988				64.0288				419.628				80.41				56.6984				0				0				470.7164				462.638				0				288.8776				0			

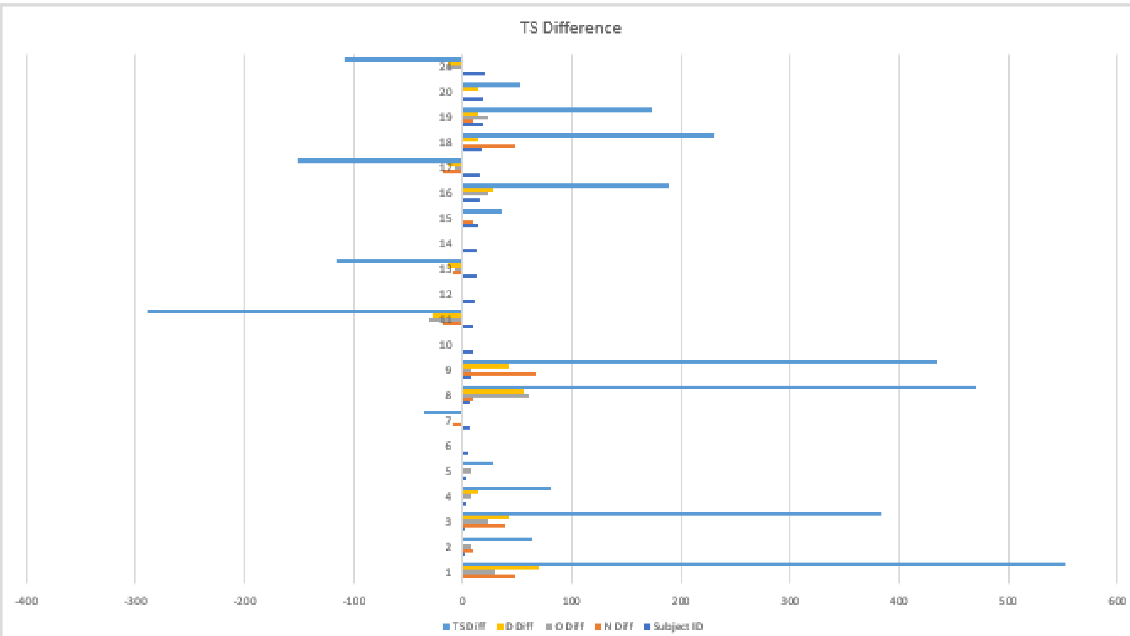
Subject ID	12				13				14				15				16				17				18				19				20				MAX SCORE POSSIBLE			
	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D	I	N	O	D
General Discomfort	X	X	X				0			0	0				0				0			0	0		1	1	1				0				0		3	3	3	
Fatigue	X		X				0				0		1		1				0				0				0		1		1				0		3		3	
Headache	X		X				0				0				0				0				0				0				0				0		3		3	
Eye Strain	X		X				0				0				0		1		1				0		1		1				0				0		3		3	
Difficulty Focusing	X		X	X			0				0		1		1	1			0				0	0			0	0			0	0			0		3		3	3
Salvation Increase	X	X								0											1	1			1	1											3	3		
Sweating	X	X							1	1												2			1	1											3	3		
Nausea	X	X		X						0						0					1	1		1		0		0				0					3	3		3
Difficulty Concentrating	X	X	X				0			0	0				0				0			0	0			0	0				0				0		3	3	3	
Fullness of Head	X			X												0								0	1			1	1			1					3			3
Blurred Vision	X		X	X			0				0		1		1	1			0				0	0	1		1	1			0	0			0		3		3	3
Dizziness w/ Eyes Open	X			X												0								0				0				0					3			3
Dizziness w/ Eyes Closed	X			X												0								0				0				0					3			3
Vertigo	X			X												0								0				0				0					3			3
Stomach Awareness	X	X								0											1	1				0											3	3		
Burping	X	X								0												0			1	1											3	3		
Totals			0				0		1	9.5	0				22.7	27.8	1		7.6			48	0	13.9		38.2	22.7	27.8			7.6	13.9			0		48	200.34	159.18	292.32
Total Score (TS)	0				0				35.6796				189.1692				28.3492				230.4588				331.8876				80.41				0				2437.8816			

Subject ID	N Before	N After	N Diff	O Before	O After	O Diff	D Before	D After	D Diff	TS Before	TS After	TS Diff
0	0	47.7	47.7	0	30.32	30.32	0	69.6	69.6	0	552.1	552.1
1	0	9.54	9.54	0	8	8	0	0	0	0	64.029	64.029
2	9.54	47.7	38.16	0	22.74	22.74	0	41.76	41.76	35.68	419.63	383.95
3	0	0	0	0	8	8	0	13.92	13.92	0	80.41	80.41
4	0	0	0	7.58	15.2	7.62	0	0	0	28.349	56.698	28.349
5	0	0	0	0	0	0	0	0	0	0	0	0
6	9.54	0	-9.54	0	0	0	0	0	0	35.68	0	-35.68
7	0	9.54	9.54	0	60.64	60.64	0	55.68	55.68	0	470.72	470.72
8	0	66.78	66.78	7.58	15.2	7.62	0	41.76	41.76	28.349	462.64	434.29
9	0	0	0	0	0	0	0	0	0	0	0	0
10	19.08	0	-19.08	30.32	0	-30.32	27.84	0	-27.84	288.88	0	-288.88
11	0	0	0	0	0	0	0	0	0	0	0	0
12	9.54	0	-9.54	7.58	0	-7.58	13.92	0	-13.92	116.09	0	-116.09
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	9.54	9.54	0	0	0	0	0	0	0	35.68	35.68
15	0	0	0	0	22.74	22.74	0	27.84	27.84	0	189.17	189.17
16	19.08	0	-19.08	15.16	7.58	-7.58	13.92	0	-13.92	180.12	28.349	-151.77
17	0	47.7	47.7	0	0	0	0	13.92	13.92	0	230.46	230.46
18	28.62	38.16	9.54	0	22.74	22.74	13.92	27.84	13.92	159.1	331.89	172.79
19	0	0	0	7.58	7.58	0	0	13.92	13.92	28.349	80.41	52.061
20	0	0	0	15.16	0	-15.16	13.92	0	-13.92	108.76	0	-108.76

TS Diff	
Mean	94.896267
Standard Error	47.320231
Median	35.6796
Mode	0
Standard Deviation	216.84854
Sample Variance	47023.29
Kurtosis	-0.023617
Skewness	0.6507304
Range	840.9764
Minimum	-288.8776
Maximum	552.0988
Sum	1992.8216
Count	21
Confidence Level(95.0%)	98.708273
Mean + CI	193.60454
Mean - CI	-3.8120061

Diff =Xafter - Xbefore

*note that 0 is contained in the C.I. meaning that the experiment did not lead to VR-related sickness



APPENDIX K. CONTRAST SENSITIVITY RESULTS

Subject ID	Correct Value	# Errors	Left log CS	Correct Value	# Errors	Right log CS	Correct Value	# Errors	Bino log CS
0	1.6	2	1.52	1.68	0	1.68	1.8	1	1.76
1	1.8	0	1.8	1.8	1	1.76	1.84	0	1.84
2	1.8	0	1.8	1.8	0	1.8	1.84	0	1.84
3	1.68	0	1.68	1.68	0	1.68	1.8	1	1.76
4	1.8	1	1.76	1.76	0	1.76	1.8	1	1.76
5	1.8	0	1.8	1.84	0	1.84	1.88	1	1.84
6	1.68	0	1.68	1.68	1	1.64	1.68	0	1.68
7	1.76	0	1.76	1.76	1	1.72	1.8	0	1.8
8	1.76	1	1.72	1.76	0	1.76	1.8	0	1.8
9	1.8	2	1.72	1.76	1	1.72	1.8	0	1.8
10	1.76	1	1.72	1.76	0	1.76	1.84	1	1.8
11	1.8	0	1.8	1.76	0	1.76	1.8	1	1.76
13	1.8	1	1.76	1.68	0	1.68	1.84	0	1.84
14	1.8	2	1.72	1.68	0	1.68	1.8	1	1.76
15	1.8	1	1.76	1.8	0	1.8	1.8	0	1.8
16	1.8	0	1.8	1.76	0	1.76	1.8	0	1.8
17	1.68	0	1.68	1.44	0	1.44	1.76	1	1.72
18	1.68	0	1.68	1.68	0	1.68	1.8	0	1.8
19	1.8	1	1.76	1.76	1	1.72	1.8	1	1.76
20	1.72	0	1.72	1.76	0	1.76	1.8	1	1.76

Correct Value = final correct letter identified value
Errors = number of errors prior to final correct value
log CS = Correct Value - (# Errors * 0.04)

Score Interpretation	
Severity	log CS score range
Profound Loss	log CS < 0.48
Severe Loss	0.52 <= log CS <=1.00
Moderate Loss	1.04 <= log CS <= 1.48
Mild Loss	1.52 <= log CS <= 1.76
No Loss	1.72 <= log CS <= 1.92

Left log CS	
Mean	1.732
Standard Error	0.014825298
Median	1.74
Mode	1.8
Standard Deviation	0.06630075
Sample Variance	0.004395789
Kurtosis	4.53336062
Skewness	-1.688963782
Range	0.28
Minimum	1.52
Maximum	1.8
Sum	34.64
Count	20
Confidence Level(95.0%)	0.031029706

Right log CS	
Mean	1.72
Standard Error	0.018581258
Median	1.74
Mode	1.76
Standard Deviation	0.083097913
Sample Variance	0.006905263
Kurtosis	6.319703491
Skewness	-1.995882356
Range	0.4
Minimum	1.44
Maximum	1.84
Sum	34.4
Count	20
Confidence Level(95.0%)	0.03889102

Bino log CS	
Mean	1.784
Standard Error	0.009358362
Median	1.8
Mode	1.76
Standard Deviation	0.041851869
Sample Variance	0.001751579
Kurtosis	0.602085509
Skewness	-0.600408194
Range	0.16
Minimum	1.68
Maximum	1.84
Sum	35.68
Count	20
Confidence Level(95.0%)	0.019587278

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APPENDIX L. HIT SCENARIO ANALYTICS

	AR View						
Environment	Identification	Distance	Confidence A	Confidence B	Avg Speed	Avg Speed Std Dev	Last Known Speed
Hit	Correct	27.65	10		1.7051071	0.728954194	1.990224
Hit	Correct	14.25766418	6.505061		1.811305	0.428186045	1.972714
Hit	Incorrect	0		7.172195	1.4190737	0.493704667	1.931575
Hit	Incorrect	0		1	1.7891113	0.669101311	1.822449
Hit	Correct	11.08739078	7.500555		1.6550589	0.545272287	1.715783
Hit	Correct	40.68395407	9.405859		1.2520406	0.373020495	1.296515
Hit	Correct	6.484510348	6.375114		1.2422843	0.475916893	1.291561
Hit	Correct	6.070693515	10		1.5416296	0.549001011	1.084214
Hit	Correct	11.87117798	10		1.5489065	0.482811318	1.074595
Hit	Correct	9.564888226	10		1.5727818	0.545276923	1.066202
Hit	Correct	10.13216256	5.465519		1.7441382	0.504911098	1.038064
Hit	Correct	6.323930181	4.938453		1.0924246	0.476306745	1.015553
Hit	Correct	7.013167761	6.622871		0.9816547	0.141492906	1.014765
Hit	Correct	6.78523971	8.839211		1.196998	0.462990377	1.012799
Hit	Correct	4.46602903	10		0.9789075	0.146785923	1.01265
Hit	Incorrect	0		3.235096	0.9697133	0.177880713	1.012542
Hit	Correct	8.106125858	7.660067		1.3818321	0.494663608	1.011126
Hit	Correct	11.69977561	8.040861		0.9860408	0.127078788	1.010967
Hit	Correct	9.526036922	9.827435		1.4072764	0.527566852	1.010399
Hit	Correct	5.057806153	8.461394		0.9732157	0.160360799	1.010197
Hit	Incorrect	0		5.079738	1.0599328	0.210910551	1.009891
Hit	Correct	6.059914422	10		0.9814174	0.146372346	1.008224
Hit	Correct	16.15742404	1.671304		0.9899274	0.100756772	1.008115
Hit	Incorrect	0		9.088261	0.9905279	0.098111628	1.008052
Hit	Incorrect	0		9.528307	1.0886338	0.226333346	1.007661
Hit	Correct	7.260501807	8.322533		0.9464119	0.253003408	1.007643
Hit	Correct	12.13414398	6.321077		1.3234459	0.575901292	1.007531
Hit	Correct	5.825780418	8.48327		0.9444208	0.249971932	1.007398
Hit	Incorrect	0		7.809415	1.2503495	0.500793671	1.007299
Hit	Incorrect	0		6.306495	0.9806579	0.141179872	1.00596
Hit	Correct	15.63142888	6.946365		0.9872714	0.114299903	1.005432
Hit	Correct	9.634611055	9.726033		0.9659826	0.193299159	1.005012
Hit	Correct	17.80004433	8.538831		0.9900778	0.10094334	1.004864
Hit	Incorrect	0		5.824921	0.9877592	0.114334374	1.004605
Hit	Correct	8.666477982	8.216873		0.9861834	0.120531751	1.004275
Hit	Correct	7.659734155	7.22993		0.9436128	0.261292098	1.004239
Hit	Correct	5.461142404	7.642715		0.9440989	0.251470207	1.004073
Hit	Correct	7.139236706	8.100777		0.9816236	0.145812147	1.004032
Hit	Correct	9.148334346	4.207916		1.1292306	0.350427765	1.003757
Hit	Correct	7.270033626	7.245316		0.9815118	0.136539012	1.003662
Hit	Correct	7.886061737	5.949014		1.0966111	0.344665602	1.003532
Hit	Correct	8.773899592	8.658315		0.9785465	0.152474573	1.003415
Hit	Correct	7.906621195	10		0.9869493	0.118783016	1.003377
Hit	Correct	15.54285492	10		0.9843825	0.123737779	1.00334
Hit	Correct	8.911621457	8.387004		0.9858953	0.122636538	1.003141
Hit	Correct	5.80169533	10		1.0156169	0.239094466	1.003057
Hit	Incorrect	0		10	0.9907449	0.098247731	1.00303
Hit	Correct	5.271675433	8.011938		1.007318	0.1980382	1.002578
Hit	Correct	10.66690711	1.491166		0.986668	0.119141661	1.002111
Hit	Correct	7.673054851	10		0.9892368	0.112103629	1.002023
Hit	Correct	9.96256595	10		0.9874226	0.107424274	1.001521
Hit	Correct	7.25837464	9.643737		1.0401618	0.222546994	1.001516
Hit	Correct	8.746214409	8.128531		1.3892738	0.502186166	1.001166
Hit	Correct	6.945657636	9.090377		1.2025027	0.418268072	1.00096
Hit	Correct	11.07868123	8.776837		0.9861982	0.11847254	1.000934
Hit	Correct	6.953952449	6.520472		0.9874273	0.112512198	1.000932
Hit	Incorrect	0		10	0.9852377	0.123323993	1.000751
Hit	Correct	7.194313487	10		0.988004	0.105482914	1.00049
Hit	Correct	9.596919998	10		0.9844608	0.126467411	1.000154
Hit	Correct	14.42210061	9.875938		0.9813743	0.140808133	1.000033
Hit	Correct	12.43228195	6.528487		1.1009787	0.294231406	0.9996538
Hit	Correct	7.323131272	8.983769		0.9887469	0.108766106	0.9992005
Hit	Correct	7.161036515	6.43912		0.9868753	0.1095169	0.9990178
Hit	Correct	7.342485924	5.518102		0.9804782	0.146872391	0.9982992
Hit	Correct	11.66065515	10		1.0091446	0.14914472	0.9982722
Hit	Correct	8.49795158	6.45185		0.9893359	0.107508797	0.9981425
Hit	Correct	10.94845261	8.861696		0.9847424	0.124456841	0.9977596
Hit	Correct	6.157957801	4.638536		0.9667986	0.184824463	0.9976676
Hit	Correct	6.533437586	9.805249		0.9749758	0.16649938	0.997406
Hit	Correct	9.827002068	6.729662		0.9767907	0.155729586	0.9970282
Hit	Incorrect	0		4.014963	1.0282369	0.176778238	0.9968544
Hit	Incorrect	0		5.563044	0.9807924	0.136865489	0.9967678
Hit	Correct	7.268421158	9.557775		0.9858589	0.124687613	0.9964915
Hit	Correct	10.67488163	9.908849		0.9854276	0.12021682	0.9964252
Hit	Correct	7.529711854	9.969888		0.9872621	0.110559658	0.9962977
Hit	Correct	7.057599686	1.84278		0.9801072	0.140284949	0.9957526
Hit	Correct	7.616345722	8.307043		0.9750025	0.167034735	0.9956008
Hit	Correct	9.150344643	10		0.9881128	0.11121887	0.9954087
Hit	Correct	13.4156751	1.164573		0.9889978	0.106443562	0.9952296
Hit	Correct	8.066646244	9.799369		1.2789883	0.414843017	0.995191
Hit	Correct	7.31079576	10		0.9903827	0.102906587	0.9951315
Hit	Correct	6.622314501	9.12363		1.1770608	0.456486724	0.9950855

Hit	Correct	6.204634169	4.767311		1.0839658	0.232468342	0.9950035
Hit	Correct	8.194067366	5.997971		0.9866158	0.121837294	0.9949678
Hit	Incorrect	0		3.991986	0.9802828	0.138630305	0.9945475
Hit	Correct	5.561110898	8.666572		0.9890772	0.106793462	0.9945364
Hit	Correct	4.87981363	1		0.9849892	0.12424291	0.9939549
Hit	Correct	4.390026826	9.348321		1.0526813	0.273191113	0.99382
Hit	Correct	6.448835588	6.559028		0.9851254	0.117417546	0.9934752
Hit	Correct	8.005125252	7.478934		1.1018529	0.230794567	0.9933857
Hit	Correct	9.50526545	7.458086		1.0424516	0.207250888	0.9929857
Hit	Correct	9.279961666	8.504526		0.9672529	0.180942804	0.99244
Hit	Correct	2.804577744	1		0.9774497	0.23089217	0.9917144
Hit	Correct	8.357823341	8.884645		0.9852514	0.124322378	0.9916911
Hit	Correct	11.44745307	7.100241		1.5812721	0.56184417	0.9916127
Hit	Correct	9.238344271	9.458027		0.9740741	0.159694291	0.9915181
Hit	Correct	9.495200011	5.509315		1.0827163	0.326708623	0.9913791
Hit	Correct	8.021430682	9.577797		0.9738175	0.158817954	0.9910328
Hit	Incorrect	0		1.135935	0.9906824	0.099958407	0.9909477
Hit	Correct	19.51528729	7.110319		0.9892342	0.102610324	0.9909279
Hit	Correct	7.689773828	7.130591		1.4210637	0.504984168	0.9896463
Hit	Correct	7.804995144	1		0.9901047	0.114522988	0.9890899
Hit	Correct	7.203418077	10		0.9724583	0.169725094	0.9889572
Hit	Correct	6.469881856	7.586728		0.9864786	0.16978214	0.9886693
Hit	Correct	8.229973014	7.886137		0.987016	0.11702111	0.9886119
Hit	Correct	8.872469564	7.738487		0.9799319	0.138780038	0.9882939
Hit	Correct	3.697758343	10		0.9743227	0.159797736	0.987594
Hit	Correct	6.082753613	10		0.9840337	0.123818662	0.9849029
Hit	Correct	9.040578822	6.802666		1.5921042	0.55743431	0.9820317
Hit	Correct	4.839342862	10		0.950251	0.234550494	0.9778431
Hit	Correct	6.563088039	10		0.9798921	0.142461188	0.9769413
Hit	Correct	9.78334573	6.171758		1.141999	0.257156924	0.9769014
Hit	Correct	6.769960662	8.457814		1.4116509	0.589914954	0.9708803
Hit	Correct	3.593243563	8.353676		0.9500115	0.232553598	0.969837
Hit	Incorrect	0		2.443448	1.1403828	0.579546535	0.9659221
Hit	Correct	5.274852819	8.812734		1.3252576	0.486640854	0.9427809
Hit	Correct	5.467774299	10		1.3176113	0.538567689	0.9392754
Hit	Correct	8.768817264	5.811256		1.3865982	0.748020704	0.9236441
Hit	Correct	7.680213947	10		1.6374628	0.507971186	0.906902
Hit	Correct	44.47192638	5.46619		0.9605436	0.189699047	0.8691687
Overall Averages	0.866666667	8.05	7.79	5.76	1.10	0.25	1.04

	Standard View						
Environment	Identification	Distance	Confidence A	Confidence B	Avg Speed	Avg Speed Std Dev	Last Known Speed
Hit	Incorrect	0		10	1.5007751	0.537451536	1.842497
Hit	Correct	20.59411466	10		1.4060217	0.534177856	1.712743
Hit	Correct	40.83226766	8.291795		1.0469634	0.429327285	1.117867
Hit	Correct	7.316118069	10		1.3366051	0.481894531	1.026536
Hit	Correct	3.240946392	8.623384		1.1333444	0.348976069	1.017197
Hit	Correct	5.513681198	3.416378		1.1656066	0.422362528	1.016497
Hit	Correct	8.170888205	10		1.3410223	0.406931609	1.013999
Hit	Correct	3.038790121	1		0.9965855	0.178032225	1.013605
Hit	Correct	4.526661099	6.514592		1.198959	0.349045129	1.012449
Hit	Correct	7.844463529	10		0.9332123	0.278514177	1.01232
Hit	Correct	9.373230704	9.189322		1.1523642	0.40300034	1.010541
Hit	Correct	8.566969983	7.873979		0.9865163	0.114136377	1.009908
Hit	Correct	16.80044312	8.40395		0.9890771	0.108592325	1.009681
Hit	Incorrect	0		5.029572	0.9819259	0.141095369	1.009606
Hit	Correct	10.55834845	8.864274		0.9887358	0.108076081	1.009356
Hit	Incorrect	0		9.175234	0.9898202	0.099919408	1.008835
Hit	Correct	17.88144229	8.928101		0.946753	0.246611503	1.008707
Hit	Correct	8.27031697	9.845846		1.2382743	0.32046198	1.00837
Hit	Correct	11.66730375	5.244644		0.9860601	0.121006861	1.00833
Hit	Incorrect	0		10	0.9907586	0.100275206	1.00833
Hit	Correct	6.271905193	8.777102		0.979792	0.144523186	1.008218
Hit	Correct	8.957357907	9.22435		1.4289155	0.475839547	1.007236
Hit	Correct	8.773850005	5.931588		1.1313971	0.377206079	1.006913
Hit	Correct	9.004010014	5.350551		1.1878762	0.327109451	1.006499
Hit	Correct	8.888059965	7.046656		0.9813721	0.144350225	1.006451
Hit	Correct	11.39485511	7.963069		0.9631378	0.200394722	1.00585
Hit	Correct	9.995858801	9.649956		0.9816961	0.138480553	1.005727
Hit	Correct	10.18463987	9.07558		0.9854917	0.126053266	1.005692
Hit	Correct	11.80373348	7.519544		0.9689423	0.175746629	1.00556
Hit	Correct	13.83512308	8.048934		0.9791689	0.144261438	1.005452
Hit	Correct	20.9674422	6.71702		0.989268	0.102370487	1.005292
Hit	Correct	9.859959544	9.461432		0.9780267	0.146723216	1.005049
Hit	Correct	9.208616625	8.12189		0.9879152	0.127660807	1.004835
Hit	Incorrect	0		8.556768	0.9910208	0.09883064	1.00431
Hit	Correct	7.872322576	2.702396		0.9687154	0.178870577	1.004267
Hit	Correct	5.017056655	9.665064		0.9811847	0.141867375	1.003809
Hit	Correct	8.764753437	8.728676		0.9839728	0.124604017	1.003739
Hit	Incorrect	0		6.925143	0.9898963	0.09892042	1.003577
Hit	Correct	6.231154502	10		0.9788387	0.145246245	1.003569
Hit	Correct	8.235962774	6.774065		0.9785494	0.147625201	1.003544
Hit	Correct	7.371156081	8.540233		1.1236715	0.374582892	1.003152

Hit	Correct	17.13943728	3.494281		1.0130156	0.151753126	1.002896
Hit	Correct	5.689011871	7.77523		0.9731244	0.16772134	1.002823
Hit	Correct	8.854901111	5.016295		0.9804343	0.143535388	1.002608
Hit	Correct	6.966448538	9.739617		0.93858	0.263291932	1.002585
Hit	Correct	7.63526447	10		0.984965	0.124395762	1.00253
Hit	Correct	15.52873242	7.849802		0.9896154	0.099813654	1.002498
Hit	Correct	7.397246088	10		0.9888985	0.107562734	1.001993
Hit	Correct	16.29977962	1		1.2168452	0.465583172	1.001981
Hit	Correct	10.06540169	7.904311		1.1157282	0.349478374	1.001896
Hit	Correct	8.695545774	8.722899		1.0185721	0.19705901	1.001808
Hit	Correct	9.353469629	5.818264		0.9866685	0.114400757	1.001638
Hit	Incorrect	0		3.692678	0.990072	0.099564736	1.001107
Hit	Incorrect	0		7.246737	0.9918754	0.193267418	1.001071
Hit	Correct	7.843902365	1.989658		0.9465831	0.239851332	1.00088
Hit	Correct	14.31307053	1		0.9890524	0.113779924	1.000729
Hit	Correct	12.56531571	10		0.9853292	0.11712455	1.000703
Hit	Correct	15.71273147	10		1.1817934	0.422707688	1.000671
Hit	Correct	7.597749816	9.197058		1.099036	0.336284039	1.000626
Hit	Correct	8.750190535	8.471594		1.0380546	0.260695461	1.000479
Hit	Correct	19.65404324	9.656563		1.2593006	0.360515901	0.9996284
Hit	Correct	8.756146158	10		0.926027	0.287744393	0.9995606
Hit	Correct	13.50055957	5.070994		0.9853938	0.123686346	0.9993121
Hit	Correct	8.247523195	6.615281		0.9851411	0.125784413	0.9991525
Hit	Correct	6.220877142	9.549886		0.9733869	0.163047639	0.999093
Hit	Correct	8.686443609	10		0.974652	0.159606174	0.9990157
Hit	Correct	6.653709835	10		0.9855566	0.125073695	0.9989055
Hit	Correct	8.316571296	8.819551		0.9790823	0.142078948	0.9987024
Hit	Correct	5.092116067	7.904691		0.9717994	0.166793193	0.9986719
Hit	Incorrect	0		4.74121	1.0394987	0.171585524	0.9986559
Hit	Correct	13.91604128	9.963869		0.9884481	0.111045318	0.998389
Hit	Incorrect	0		2.877606	0.9874005	0.107523108	0.9980924
Hit	Correct	11.39130655	1		0.980397	0.141440516	0.9973959
Hit	Incorrect	0		7.297587	0.9873099	0.11450317	0.9971567
Hit	Correct	5.865365555	9.204901		0.9730719	0.162063703	0.9969495
Hit	Correct	7.712892244	9.806523		1.2678105	0.486792583	0.996141
Hit	Correct	5.968930485	5.561453		1.6578523	0.60015411	0.9959083
Hit	Incorrect	0		1	0.9900663	0.100933412	0.9958757
Hit	Correct	5.076551642	8.593586		0.9809191	0.141953687	0.9957932
Hit	Correct	6.899891833	7.175375		0.9807974	0.143988905	0.9953607
Hit	Correct	8.818447796	5.806146		1.0668689	0.303817355	0.9951979
Hit	Correct	10.51642739	6.291671		0.9860771	0.110721219	0.9951646
Hit	Correct	7.403070835	7.044874		1.4353855	0.524934395	0.9947375
Hit	Correct	13.11129088	8.661856		0.9444572	0.249752164	0.9945951
Hit	Correct	13.0587899	5.371587		0.9859795	0.120340226	0.9944255
Hit	Correct	17.85545111	8.999393		1.1931426	0.30424122	0.9943558
Hit	Incorrect	0		4.871511	0.9869516	0.117522686	0.9943451
Hit	Correct	8.31752407	5.20201		0.9867632	0.118358349	0.9940734
Hit	Correct	11.74242803	7.61308		0.9880674	0.108700109	0.994014
Hit	Correct	8.44800303	6.335292		1.0286193	0.163577021	0.9937113
Hit	Correct	14.58651621	2.396362		0.9893363	0.110150371	0.9936234
Hit	Correct	19.8605669	9.460577		0.9876175	0.114596483	0.9934017
Hit	Correct	13.58893972	9.17145		0.9893559	0.101373289	0.9933861
Hit	Correct	11.39995696	7.475856		0.988397	0.109271921	0.9927305
Hit	Correct	7.688511017	10		0.9798052	0.144339259	0.9917189
Hit	Correct	6.657020948	8.159368		0.988252	0.107884328	0.9912177
Hit	Incorrect	0		1.489677	0.9889017	0.107948313	0.990969
Hit	Correct	6.718208971	9.698124		0.9867503	0.116579665	0.9909511
Hit	Incorrect	0		6.442919	0.9809556	0.141264562	0.9908136
Hit	Correct	6.277893876	10			0.146439762	0.9902453
Hit	Correct	6.172437349	10		0.9717578	0.168645845	0.9887556
Hit	Incorrect	0		10	0.980966	0.142612599	0.9886425
Hit	Incorrect	0		8.745132	1.1222942	0.317819279	0.9878742
Hit	Incorrect	0		1.170859	1.2438378	0.36624735	0.9875526
Hit	Correct	7.16519151	9.194606		1.1144976	0.321453604	0.9873499
Hit	Correct	7.276288917	7.215874		0.9695258	0.178030254	0.9841828
Hit	Correct	6.721349107	8.955822		1.2602276	0.434968746	0.9834577
Hit	Correct	11.53789766	9.525497		0.9774874	0.150478908	0.9825767
Hit	Correct	8.828177992	9.219974		0.9884246	0.108985164	0.9814646
Hit	Correct	7.158641355	10		1.353142	0.471765731	0.9760739
Hit	Correct	7.002804069	10		1.2490479	0.356389312	0.9723361
Hit	Correct	6.459918633	4.078573		0.9828229	0.134612373	0.9618699
Hit	Incorrect	0		1	0.9520509	0.223063183	0.9428938
Hit	Incorrect	0		1.406639	0.9500441	0.225522852	0.9424241
Hit	Correct	6.352856352	10		1.2602899	0.472347221	0.9397414
Hit	Incorrect	0		1.606872	0.9861549	0.119580592	0.9355585
Hit	Correct	5.867143887	5.044031		1.6591457	0.556990888	0.9338127
Hit	Correct	7.792593289	6.871068		1.468175	0.540335212	0.9237013
Hit	Correct	4.512852083	4.232991		1.0897766	0.344583127	0.7678824
Hit	Correct	6.217766663	6.81245		1.2966312	0.49118948	0.7591539
Overall Averages	0.825	8.12	7.69	5.39	1.06	0.23	1.01

	Silhouette View						
Environment	Identification	Distance	Confidence A	Confidence B	Avg Speed	Avg Speed Std Dev	Last Known Speed
Hit	Correct	10.3249	10		1.895508887	0.490639983	1.983268
Hit	Correct	13.9717	5.332794		1.659343571	0.504756677	1.958178
Hit	Correct	19.4216	3.596833		1.252384119	0.472705865	1.863078
Hit	Correct	18.7692	10		1.18791023	0.452552502	1.473788
Hit	Incorrect	0		2.030344	1.163435309	0.403835915	1.385779
Hit	Correct	15.7187	6.46186		1.071155003	0.348494612	1.282776
Hit	Correct	7.86271	7.656082		1.659064814	0.749171885	1.167108
Hit	Correct	11.2693	8.163965		1.329344729	0.393988199	1.144517
Hit	Correct	9.92476	7.781897		1.727007017	0.522002337	1.087407
Hit	Correct	35.6643	7.189491		1.25403892	0.482677473	1.051976
Hit	Correct	4.57426	10		1.584196859	0.607954685	1.033176
Hit	Correct	5.85239	9.834882		1.316952786	0.457051422	1.027006
Hit	Incorrect	0		1	1.042758581	0.291305775	1.016673
Hit	Correct	10.1629	4.83821		0.988563487	0.109426032	1.016092
Hit	Correct	6.33395	9.331105		0.979021798	0.141705987	1.012644
Hit	Correct	8.89838	8.565285		1.049898762	0.23429255	1.010549
Hit	Correct	6.44607	8.521916		0.98701096	0.120023972	1.010505
Hit	Correct	3.68949	9.109964		0.979583292	0.145572434	1.009989
Hit	Correct	12.1517	10		0.969850463	0.173365088	1.009907
Hit	Correct	12.051	9.734098		0.988909651	0.11071201	1.009654
Hit	Incorrect	0		5.331594	1.168809944	0.297055192	1.008918
Hit	Correct	8.24449	8.368701		1.105064875	0.237790665	1.008888
Hit	Correct	6.09978	5.590546		0.989397338	0.106958379	1.008861
Hit	Correct	7.10512	8.100477		0.985851125	0.125222088	1.008796
Hit	Correct	11.1784	9.935798		0.969647291	0.178585501	1.008566
Hit	Incorrect	0		1	0.980580318	0.138345241	1.008415
Hit	Correct	8.82756	10		0.991293523	0.102489627	1.007999
Hit	Correct	10.2396	6.298554		1.544994412	0.56683286	1.007186
Hit	Correct	10.6442	10		1.046847896	0.199273024	1.007098
Hit	Correct	8.81687	6.471199		0.98725124	0.119567864	1.006377
Hit	Correct	13.3625	7.957943		0.988625461	0.107642685	1.006239
Hit	Correct	13.3081	7.419549		0.9528993	0.215464637	1.005984
Hit	Correct	4.78061	5.026761		0.97896098	0.143900353	1.00569
Hit	Correct	10.6714	9.207456		1.29225032	0.434608439	1.005519
Hit	Correct	7.29542	10		1.313119118	0.492661296	1.005205
Hit	Correct	10.5218	5.177874		0.987730068	0.114565044	1.005105
Hit	Correct	4.76223	10		0.97760696	0.154316829	1.004902
Hit	Incorrect	0		8.68972	0.98236592	0.142482208	1.004691
Hit	Correct	6.41945	10		0.988985378	0.107279594	1.004566
Hit	Correct	13.533	9.621425		0.98643616	0.121667407	1.004532
Hit	Correct	4.90411	7.446753		0.967799092	0.178113336	1.004323
Hit	Correct	7.38516	5.484685		0.984863935	0.123796769	1.004238
Hit	Correct	14.8423	8.418894		0.989170513	0.102023799	1.004197
Hit	Correct	4.3673	8.090361		1.588899536	0.550302261	1.003978
Hit	Correct	6.408	10		0.974550825	0.161737271	1.003916
Hit	Correct	9.05921	10		0.987476459	0.111892281	1.003907
Hit	Correct	20.7152	7.617884		0.98944943	0.109303088	1.003366
Hit	Correct	4.75928	10		0.979610087	0.144105572	1.003228
Hit	Correct	7.44539	9.071767		1.373883592	0.52029478	1.002905
Hit	Correct	5.30683	9.323028		0.9725313	0.166238853	1.002546
Hit	Correct	4.03053	9.413063		0.982500155	0.143664702	1.002427
Hit	Correct	6.81159	8.284336		0.979845897	0.144736516	1.001991
Hit	Correct	15.8943	4.620738		0.980560005	0.141645439	1.001818
Hit	Incorrect	0		4.093511	1.078467654	0.278525165	1.00158
Hit	Correct	6.97117	9.729644		0.943805125	0.251491751	1.001462
Hit	Correct	5.11602	9.460508		0.98169488	0.142302279	1.001405
Hit	Correct	6.93242	7.113659		0.98828501	0.107868167	1.00124
Hit	Correct	40.8706	7.877984		0.989663056	0.10220266	1.001117
Hit	Incorrect	0		1	0.980597288	0.141437519	1.000689
Hit	Correct	5.66399	8.161978		0.945912008	0.247527907	1.000529
Hit	Correct	10.2993	7.236413		1.269063179	0.470661667	1.000507
Hit	Correct	6.37752	7.517935		1.178078635	0.40112416	1.000083
Hit	Correct	6.56886	10		0.972628019	0.165175767	0.9995366
Hit	Correct	7.02627	8.97902		0.979490008	0.14266094	0.9991785
Hit	Correct	10.4181	9.566986		0.98865416	0.108921617	0.9991511
Hit	Correct	6.40235	9.279132		0.984694492	0.124986835	0.9989554
Hit	Correct	5.98336	10		0.988123022	0.110477204	0.9987542
Hit	Correct	7.77635	10		0.985103999	0.123920332	0.9985093
Hit	Correct	12.6597	8.813304		1.223257463	0.319226972	0.9984216
Hit	Correct	8.62967	5.551573		1.106921098	0.226404743	0.9980412
Hit	Correct	9.1028	5.823337		0.984279041	0.120914638	0.9976272
Hit	Correct	9.62275	9.163407		0.989292488	0.100634204	0.9975376
Hit	Incorrect	0		1	1.31385983	0.453746534	0.9974902
Hit	Correct	10.0877	9.329867		0.989912384	0.1026683	0.997455
Hit	Correct	7.56345	10		0.986494959	0.123743046	0.9974221
Hit	Correct	4.43688	8.571268		0.973661975	0.160787136	0.997053
Hit	Correct	6.74132	9.215031		1.005733996	0.222521312	0.997021
Hit	Correct	7.62739	6.875498		0.984665837	0.123987004	0.9964764
Hit	Correct	9.73008	6.500609		1.042749784	0.243426192	0.9962976
Hit	Correct	24.8932	5.498715		0.988364329	0.114790083	0.9956598
Hit	Incorrect	0		1.165415	0.971590233	0.17425265	0.9954855
Hit	Correct	7.6986	7.726669		1.121761178	0.381792653	0.9949093

Hit	Correct	9.91575	9.638627		0.987648172	0.112239527	0.9947356
Hit	Correct	9.79982	8.387479		0.987003062	0.107756991	0.9941502
Hit	Correct	6.99555	9.579749		1.088767405	0.291343874	0.9941097
Hit	Correct	6.73949	9.437151		1.08761432	0.322653461	0.9935856
Hit	Correct	5.18276	8.34086		1.186979346	0.377226478	0.9935065
Hit	Correct	6.53708	7.009131		1.409780131	0.459873454	0.9933454
Hit	Correct	10.5765	8.77718		0.988599518	0.109787218	0.9931065
Hit	Incorrect	0		5.53546	1.598199334	0.597981385	0.9929306
Hit	Correct	10.17	10		0.987839328	0.112026169	0.992532
Hit	Correct	5.47714	9.363479		0.971782518	0.165629578	0.9921504
Hit	Correct	9.49467	7.203014		0.980202799	0.140240157	0.9920089
Hit	Correct	6.71177	7.108406		0.979573608	0.140450456	0.9920031
Hit	Incorrect	0		6.924353	0.988478093	0.107374622	0.9918657
Hit	Incorrect	0		1	0.981972736	0.140056325	0.9910969
Hit	Correct	9.02383	8.364878		1.204534095	0.382573292	0.9902124
Hit	Correct	15.1247	7.287282		0.990922974	0.101702781	0.9898342
Hit	Correct	5.41457	8.322506		0.985758688	0.124675215	0.9894434
Hit	Correct	7.7952	8.973943		1.326641712	0.453046898	0.9892754
Hit	Correct	7.78936	7.730579		0.976448625	0.157336621	0.9889987
Hit	Correct	7.15521	8.452114		0.985849019	0.11900758	0.9888717
Hit	Correct	6.00377	8.719091		0.965973905	0.182294138	0.9886017
Hit	Correct	5.0131	8.08647		0.9854435	0.123869637	0.988583
Hit	Correct	9.06349	1		0.986365566	0.119253501	0.9880621
Hit	Correct	7.92346	10		1.613040684	0.558232743	0.987101
Hit	Correct	15.8949	7.137587		0.979684177	0.142483238	0.9852594
Hit	Correct	10.1059	10		1.076333994	0.237933816	0.9851891
Hit	Correct	4.19838	5.812601		0.95297295	0.230102152	0.9827684
Hit	Correct	4.90269	6.557088		0.979180756	0.142893833	0.9807347
Hit	Correct	4.34201	5.602616		1.51442917	0.607454529	0.9797248
Hit	Correct	3.51974	8.162204		0.953313971	0.233313753	0.9796092
Hit	Correct	6.50494	10		1.289193586	0.567730389	0.9781849
Hit	Correct	6.30428	9.306999		0.986250669	0.119350997	0.9777102
Hit	Correct	9.08393	9.785527		0.988427144	0.109389178	0.9750821
Hit	Correct	11.8201	5.390153		0.953148707	0.227403233	0.9675866
Hit	Incorrect	0		1	0.974804757	0.257379694	0.9569749
Hit	Incorrect	0		8.612967	0.94800994	0.224876225	0.9420696
Hit	Incorrect	0		6.616683	0.95228994	0.220739783	0.9328704
Hit	Correct	4.5152	8.382814		1.612812939	0.522869115	0.9042278
Overall Averages	0.875	8.13	8.18	3.67	1.09	0.24	1.03

- •Confidence Question A – When you blew the whistle, how confident were you that a collision was going to happen? (trigger: whistle blown, regardless of programmed collision)
- •Confidence Question B - Before the scenario ended, how confident were you that the aircraft would finish its route collision free? (trigger: whistle NOT blown, programmed collision)
- •Confidence Question C – What was your lowest degree of confidence that the aircraft would finish its route collision free? (trigger: whistle NOT blown, no programmed collision)
- •Distance = ((ObjectCollisionTriggered - StopTractorTriggered) * MostRecentTractorSpeed) i.e. units between the scheduled object collision location and the aircraft location at the point in which the subject blew the whistle .
- • Avg Speed - the mean speed of the towing operation for the duration of the scenario. Speed can only vary between 1-2 unit/sec depending on the subjects confidence and training.
- •Last Known Speed - the speed either at the time in which the subject blew the whistle in order to stop the evolution or the at the time the aircraft reached its final destination.

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APPENDIX M. DANGER/CAUTION SCENARIO ANALYTICS

	AR View						
Environment	Identification	Distance	Confidence A	Confidence C	Avg Speed	Avg Speed Std Dev	Last Known Speed
Danger / Caution	Correct			8.824228	1.3317977	0.509055107	2.295701
Danger / Caution	Correct			10	1.3080914	0.438820798	2.0303
Danger / Caution	Correct			6.116218	1.1105711	0.351494955	2.007037
Danger / Caution	Correct			8.855793	1.2955715	0.524951996	2.005918
Danger / Caution	Correct			1	1.5705276	0.515689991	2.000718
Danger / Caution	Correct			10	1.6392614	0.513422064	1.999943
Danger / Caution	Correct			10	1.3067856	0.523855822	1.996821
Danger / Caution	Correct			10	1.9174976	0.357578364	1.992052
Danger / Caution	Correct			6.728109	1.4210206	0.517367672	1.988694
Danger / Caution	Correct			9.987425	1.4087708	0.474881515	1.987492
Danger / Caution	Correct			10	1.6946669	0.512604063	1.987098
Danger / Caution	Correct			5.396077	1.1275143	0.372298224	1.979421
Danger / Caution	Correct			6.664611	1.8168517	0.406229568	1.973078
Danger / Caution	Correct			10	1.338543	0.486712674	1.970178
Danger / Caution	Correct			10	1.5778586	0.463361725	1.95071
Danger / Caution	Correct			8.106256	1.1799407	0.417631314	1.946753
Danger / Caution	Correct			10	1.5063728	0.495298405	1.941508
Danger / Caution	Correct			10	1.3673427	0.474587002	1.941103
Danger / Caution	Correct			9.761619	1.4849388	0.529616727	1.936809
Danger / Caution	Correct			5.34213	1.728767	0.460232716	1.908459
Danger / Caution	Correct			8.740783	1.365443	0.487987692	1.892358
Danger / Caution	Correct			1.906525	1.2578197	0.431528184	1.886511
Danger / Caution	Correct			10	1.3351695	0.420215548	1.801977
Danger / Caution	Correct			6.648523	1.0807398	0.219064866	1.51055
Danger / Caution	Correct			6.641663	1.0582256	0.210236114	1.421123
Danger / Caution	Incorrect		2.05189		0.9876283	0.113585198	1.015326
Danger / Caution	Correct			10	0.9868451	0.11701067	1.011789
Danger / Caution	Incorrect		7.972714		0.9779869	0.148232217	1.011246
Danger / Caution	Correct			10	0.9907095	0.094890629	1.011204
Danger / Caution	Correct			3.866843	1.0792509	0.215587439	1.010759
Danger / Caution	Incorrect		5.611999		1.0124936	0.15703181	1.010557
Danger / Caution	Correct			10	0.9873682	0.118911822	1.010224
Danger / Caution	Incorrect		3.593945		1.3643664	0.537182055	1.010016
Danger / Caution	Correct			10	0.9865554	0.117299882	1.009402
Danger / Caution	Correct			3.412025	0.9852341	0.117786791	1.007947
Danger / Caution	Correct			5.674816	0.9916356	0.093326083	1.007813
Danger / Caution	Correct			10	0.9916024	0.093373149	1.007507
Danger / Caution	Correct			10	0.9925832	0.090988119	1.00727
Danger / Caution	Correct			10	0.9904292	0.096408277	1.006658
Danger / Caution	Correct			9.287775	0.9872503	0.11723717	1.005944
Danger / Caution	Correct			10	0.9858219	0.118581023	1.005715
Danger / Caution	Correct			10	0.9855122	0.118224979	1.005587
Danger / Caution	Correct			2.28406	0.9922277	0.096326302	1.003629
Danger / Caution	Incorrect		4.020627		0.9574511	0.223093673	1.00345
Danger / Caution	Correct			10	0.9866247	0.120283256	1.003386
Danger / Caution	Correct			5.722784	0.9863255	0.118683026	1.001912
Danger / Caution	Correct			1	0.9857023	0.119939749	1.001742
Danger / Caution	Correct			8.932724	0.9900182	0.098063705	1.001099
Danger / Caution	Incorrect		1		1.0659197	0.183012307	1.001081
Danger / Caution	Incorrect		1.00		0.989404	0.106488811	1.000877
Danger / Caution	Incorrect		8.74		0.9876339	0.109790183	1.000798
Danger / Caution	Correct			2.05	0.9913483	0.094516475	0.9996421
Danger / Caution	Correct			5.681691	0.9899297	0.105260571	0.9995104
Danger / Caution	Correct			9.988716	0.9917182	0.096344821	0.9991946
Danger / Caution	Correct			1	1.0522306	0.20693881	0.9990914
Danger / Caution	Correct			2.268719	0.9908676	0.093115028	0.9989545
Danger / Caution	Correct			5.513554	0.9915606	0.094629237	0.9988908
Danger / Caution	Correct			8.565312	0.9850826	0.118118632	0.9980471
Danger / Caution	Incorrect		7.671512		0.981303	0.140313496	0.997709
Danger / Caution	Incorrect		5.514179		0.9874308	0.114507794	0.997394
Danger / Caution	Correct			5.237179	0.9908885	0.093732206	0.9965769
Danger / Caution	Incorrect		5.340033		0.982362	0.136825851	0.9962955
Danger / Caution	Correct			10	0.9903841	0.096562424	0.9944683
Danger / Caution	Correct			10	0.9915716	0.091968872	0.9942143
Danger / Caution	Incorrect		8.229259		0.9819805	0.13741215	0.9930938
Danger / Caution	Incorrect		10		0.9782699	0.146813939	0.9911555
Danger / Caution	Incorrect		6.347332		0.9821439	0.142574338	0.9908839
Danger / Caution	Correct			4.854556	0.9912271	0.09341103	0.9905117
Danger / Caution	Correct			8.628169	0.9920942	0.093202017	0.9898428
Danger / Caution	Incorrect		7.015867		0.9880297	0.105285818	0.9889926
Danger / Caution	Correct			9.254753	0.9860626	0.118776228	0.98884
Danger / Caution	Incorrect		1		0.97923	0.149702054	0.9873998
Danger / Caution	Correct			1.614026	0.9861091	0.117865462	0.9872997
Danger / Caution	Correct			10	0.9915941	0.094813464	0.9871864
Danger / Caution	Correct			4.58961	0.9859696	0.118918574	0.9867181
Danger / Caution	Incorrect		8.861206		0.9782084	0.15000589	0.9864078
Danger / Caution	Incorrect		10		1.3310798	0.675486681	0.9742299
Danger / Caution	Incorrect		1		1.3126702	0.474647039	0.9046191
Danger / Caution	Correct			7.676809	1.344468	0.489928523	0.8244752
Danger / Caution	Incorrect		4.001055		1.2507353	0.557271764	0.7700711
Overall Averages	0.75	N/A	5.45	6.29	1.03	0.17	0.98

	Standard View						
Environment	Identification	Distance	Confidence A	Confidence C	Avg Speed	Avg Speed Std Dev	Last Known Speed
Danger / Caution	Correct			10	1.4249668	0.502528344	2.079302
Danger / Caution	Correct			4.673635	1.1041458	0.357571213	2.00784
Danger / Caution	Correct			10	1.7352077	0.492200515	1.997193
Danger / Caution	Correct			10	1.2382805	0.466361626	1.994782
Danger / Caution	Correct			10	1.4543461	0.555596808	1.993276
Danger / Caution	Correct			1	1.5595928	0.520714264	1.988132
Danger / Caution	Correct			8.853676	1.4297319	0.565614494	1.969266
Danger / Caution	Correct			10	1.1602812	0.39230021	1.967488
Danger / Caution	Correct			4.411424	1.3531779	0.514775034	1.966831
Danger / Caution	Correct			6.098079	1.4790982	0.527066912	1.961224
Danger / Caution	Correct			1.465323	1.2047055	0.382312481	1.947021
Danger / Caution	Correct			4.366212	1.359437	0.508136115	1.945727
Danger / Caution	Correct			7.318905	1.2364388	0.459239351	1.940416
Danger / Caution	Correct			9.32119	1.116137	0.368518422	1.937568
Danger / Caution	Correct			1	1.3536304	0.448287042	1.931816
Danger / Caution	Correct			10	1.5713856	0.437811015	1.91111
Danger / Caution	Correct			1.387821	1.2071191	0.394494625	1.859513
Danger / Caution	Correct			7.034451	1.3268671	0.348638204	1.817048
Danger / Caution	Correct			7.941335	1.237902	0.341289513	1.718034
Danger / Caution	Correct			6.35614	1.0663285	0.205888012	1.546136
Danger / Caution	Correct			9.395616	1.2879924	0.36240268	1.165793
Danger / Caution	Correct			1	1.0633204	0.18472655	1.088201
Danger / Caution	Incorrect		5.770912		1.0380566	0.196316362	1.075343
Danger / Caution	Incorrect		5.073906		0.9830408	0.136458156	1.06349
Danger / Caution	Correct			1	0.991568	0.094556598	1.013166
Danger / Caution	Correct			8.190829	0.9915184	0.093295366	1.011394
Danger / Caution	Correct			8.65541	0.9912975	0.09426682	1.011382
Danger / Caution	Correct			10	0.9910392	0.096074001	1.009706
Danger / Caution	Correct			7.359671	0.99169	0.094722807	1.008467
Danger / Caution	Correct			5.685015	0.9869681	0.118209587	1.008171
Danger / Caution	Correct			10	0.9913542	0.093597039	1.007761
Danger / Caution	Correct			10	0.9918125	0.094538845	1.00604
Danger / Caution	Correct			10	0.9868821	0.119810909	1.005876
Danger / Caution	Correct			8.731566	0.9877506	0.115525896	1.005471
Danger / Caution	Correct			5.78335	0.9895099	0.105219801	1.004636
Danger / Caution	Correct			10	0.9946268	0.127739175	1.004386
Danger / Caution	Incorrect		4.400701		0.9956957	0.183394438	1.003642
Danger / Caution	Incorrect		5.844408		0.9813985	0.141703189	1.003464
Danger / Caution	Correct			8.228354	1.0861382	0.311102429	1.003198
Danger / Caution	Correct			10	0.9915221	0.09282647	1.003145
Danger / Caution	Correct			8.11794	0.9915329	0.095306133	1.002986
Danger / Caution	Correct			9.083481	0.987071	0.119663263	1.002424
Danger / Caution	Correct			3.201429	0.9912941	0.091785851	1.002127
Danger / Caution	Correct			8.645558	0.9887083	0.104851226	1.002087
Danger / Caution	Correct			1	0.9915225	0.094961235	1.002074
Danger / Caution	Correct			1	0.991221	0.09423148	1.001637
Danger / Caution	Correct			7.538816	0.9854349	0.117787765	1.001365
Danger / Caution	Correct			10	0.9909422	0.095254986	1.001247
Danger / Caution	Incorrect		10		0.9917645	0.093773018	1.000751
Danger / Caution	Correct			6.22963	0.9910886	0.09559641	1.000475
Danger / Caution	Correct			5.626722	0.9851587	0.11877858	1.00032
Danger / Caution	Correct			10	0.9871697	0.118207141	0.9999208
Danger / Caution	Correct			3.326125	0.988661	0.104572007	0.9988937
Danger / Caution	Correct			8.901803	0.990954	0.092527635	0.9984123
Danger / Caution	Incorrect		3.130552		0.9867968	0.117591945	0.9976743
Danger / Caution	Correct			8.73369	0.9918492	0.091288701	0.9974303
Danger / Caution	Correct			9.926054	0.9900294	0.094695621	0.9971523
Danger / Caution	Correct			9.562426	0.9909774	0.095618603	0.9968242
Danger / Caution	Correct			10	0.9913817	0.093503458	0.9955189
Danger / Caution	Correct			5.895391	0.9861789	0.118899195	0.9953383
Danger / Caution	Correct			1	0.9910245	0.093351029	0.9949106
Danger / Caution	Correct			7.350127	0.9905089	0.094143723	0.9945018
Danger / Caution	Correct			10	0.9909365	0.094581313	0.9939988
Danger / Caution	Incorrect		6.543025		0.988608	0.108537865	0.9938146
Danger / Caution	Incorrect		7.397747		1.1550405	0.414868528	0.9934211
Danger / Caution	Correct			10	0.9855419	0.118946474	0.992207
Danger / Caution	Correct			6.191855	0.9905088	0.094757611	0.9920978
Danger / Caution	Correct			5.667188	0.9910738	0.093533095	0.9920394
Danger / Caution	Correct			10	0.9909312	0.097102228	0.9908336
Danger / Caution	Correct			8.028309	0.9910075	0.093979703	0.9903117
Danger / Caution	Incorrect		9.046197		0.9868212	0.114390142	0.9901657
Danger / Caution	Correct			10	0.9904548	0.122897166	0.9900235
Danger / Caution	Correct			4.645864	0.9896523	0.093988643	0.98967
Danger / Caution	Correct			6.877792	0.9899073	0.103697016	0.9894223
Danger / Caution	Correct			5.424673	0.9925183	0.093184146	0.9882228
Danger / Caution	Correct			10	0.9914074	0.093765686	0.9857238
Danger / Caution	Correct			10	0.9881888	0.120765263	0.9830458
Danger / Caution	Incorrect		2.302312		0.9827705	0.131087725	0.9821873
Danger / Caution	Incorrect		4.9595		0.9669112	0.186794427	0.9729434
Danger / Caution	Incorrect		8.995998		1.3949983	0.572894225	0.9695729
Overall Averages	0.85	N/A	6.12	7.64	1.01	0.13	0.99

	Silhouette View						
Environment	Identification	Distance	Confidence A	Confidence C	Avg Speed	Avg Speed Std Dev	Last Known Speed
Danger / Caution	Correct			8.001295	1.131433378	0.377209317	2.23578
Danger / Caution	Correct			7.131728	1.16538301	0.436841895	2.161074
Danger / Caution	Correct			8.339369	1.374584668	0.454065221	2.089428
Danger / Caution	Correct			1	1.175533968	0.312328384	2.03668
Danger / Caution	Correct			9.271232	1.475115409	0.535189922	2.000555
Danger / Caution	Correct			10	1.833892144	0.438627925	1.999384
Danger / Caution	Correct			10	1.615662541	0.535097287	1.999266
Danger / Caution	Correct			7.832744	1.76056112	0.486650798	1.995756
Danger / Caution	Correct			9.219218	1.786557807	0.532430232	1.994117
Danger / Caution	Correct			10	1.523912062	0.52616711	1.975035
Danger / Caution	Correct			10	1.351837889	0.4911284	1.95805
Danger / Caution	Correct			9.983221	1.412731914	0.406146589	1.953951
Danger / Caution	Correct			10	1.198677523	0.428036765	1.942196
Danger / Caution	Correct			7.619135	1.343547273	0.482919818	1.926294
Danger / Caution	Correct			1.710129	1.223518279	0.389161525	1.924923
Danger / Caution	Correct			3.501721	1.209177463	0.400456816	1.923571
Danger / Caution	Correct			10	1.263716878	0.448186702	1.916597
Danger / Caution	Correct			5.077932	1.280489419	0.451902223	1.899639
Danger / Caution	Correct			4.109866	1.734880061	0.464740764	1.895753
Danger / Caution	Correct			7.047256	1.134465672	0.306191085	1.460295
Danger / Caution	Correct			9.658329	1.330683143	0.425500401	1.447844
Danger / Caution	Correct			9.427098	1.115428289	0.29572989	1.165843
Danger / Caution	Incorrect		5.524165		1.549650022	0.634347759	1.078993
Danger / Caution	Correct			1	0.99213508	0.096471528	1.013988
Danger / Caution	Incorrect		4.323797		1.580427046	0.638246556	1.013374
Danger / Caution	Correct			9.595842	0.986430209	0.118488936	1.011791
Danger / Caution	Correct			1	1.08993559	0.204299032	1.011582
Danger / Caution	Correct			6.83832	1.067883108	0.230681528	1.011489
Danger / Caution	Correct			9.291082	0.986618754	0.117923484	1.010672
Danger / Caution	Correct			9.812314	0.991487304	0.09383159	1.009096
Danger / Caution	Correct			10	0.991938023	0.094702753	1.009095
Danger / Caution	Incorrect		5.611604		0.961221475	0.213284752	1.008338
Danger / Caution	Incorrect		7.950172		0.963596121	0.198601573	1.007744
Danger / Caution	Correct			7.401731	0.993060039	0.094268124	1.007104
Danger / Caution	Correct			2.998246	0.991502269	0.095574886	1.006991
Danger / Caution	Incorrect		7.915257		0.963682253	0.198344941	1.006619
Danger / Caution	Correct			10	0.987774392	0.119239115	1.006533
Danger / Caution	Correct			10	0.986867721	0.117466987	1.006113
Danger / Caution	Correct			10	0.990261069	0.092964916	1.006022
Danger / Caution	Correct			10	0.986666573	0.118901498	1.005929
Danger / Caution	Correct			9.538813	0.987836876	0.118487424	1.004869
Danger / Caution	Incorrect		3.155167		0.986949767	0.110943728	1.004703
Danger / Caution	Incorrect		7.301476		0.979911002	0.153340196	1.002955
Danger / Caution	Incorrect		9.629375		0.988437034	0.109189769	1.002849
Danger / Caution	Correct			9.695077	0.991362217	0.09352854	1.002744
Danger / Caution	Correct			7.959674	0.990784932	0.093824815	1.002697
Danger / Caution	Incorrect		9.548559		0.951740107	0.229469612	1.002239
Danger / Caution	Correct			10	0.990028027	0.092724152	1.001323
Danger / Caution	Correct			8.537299	0.99144209	0.096095607	1.000792
Danger / Caution	Correct			10	0.99092269	0.094285751	1.000678
Danger / Caution	Correct			9.988102	0.986846944	0.1190163	1.000281
Danger / Caution	Correct			10	0.991423539	0.095381491	0.9998285
Danger / Caution	Correct			9.248134	0.991266176	0.094308256	0.9997672
Danger / Caution	Correct			9.809074	0.988001027	0.122079168	0.9997491
Danger / Caution	Incorrect		5.80139		0.986554127	0.114094132	0.9997458
Danger / Caution	Correct			9.311236	0.986750588	0.115742035	0.9990688
Danger / Caution	Correct			7.124379	0.991887974	0.096083627	0.9987844
Danger / Caution	Correct			10	0.985483015	0.118683468	0.9985912
Danger / Caution	Incorrect		1		0.981777557	0.139001875	0.9983184
Danger / Caution	Correct			7.007249	0.986458829	0.117741138	0.9977897
Danger / Caution	Correct			1	0.992031904	0.093794389	0.9961346
Danger / Caution	Correct			4.738713	0.985505147	0.119062768	0.9953594
Danger / Caution	Correct			5.395054	0.991648379	0.094876067	0.9951622
Danger / Caution	Correct			8.864615	0.98548745	0.120610091	0.9940037
Danger / Caution	Correct			10	0.986994032	0.11661176	0.9938779
Danger / Caution	Correct			5.361437	0.993715282	0.094395686	0.9936101
Danger / Caution	Correct			3.229707	0.987136962	0.118185408	0.9926258
Danger / Caution	Correct			10	0.991184721	0.095395552	0.9923814
Danger / Caution	Correct			1.911575	0.99120636	0.095401924	0.991543
Danger / Caution	Incorrect		6.553473		0.981010102	0.140106846	0.9908302
Danger / Caution	Correct			10	0.986175821	0.116731105	0.9904619
Danger / Caution	Correct			10	0.990194925	0.094384404	0.9896995
Danger / Caution	Correct			4.593042	0.98561384	0.118216085	0.989509
Danger / Caution	Incorrect		5.158319		0.979422086	0.147976153	0.9892697
Danger / Caution	Correct			9.429564	0.985259744	0.11951675	0.9870816
Danger / Caution	Incorrect		7.259427		1.066971961	0.252393289	0.9842417
Danger / Caution	Incorrect		8.319923		1.123080898	0.310641189	0.9759848
Danger / Caution	Correct			9.503438	1.118174375	0.23694856	0.9649207
Danger / Caution	Correct			8.470577	1.11464632	0.332538005	0.9572681
Danger / Caution	Correct		9.589486		1.118280277	0.397219512	0.6549492
Overall Averages	0.8125	N/A	6.54	7.71	1.01	0.14	0.98

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APPENDIX N. DANGER/CAUTION SCENARIO ANALYTICS

Environment 1 - Hit 1

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**0**	**1**	**0**	**2**	**3**	**2**	**4**	**5**	**4**	**6**	**7**	**6**	**8**	**9**	**8**	**10**	**11**	**10**	**14**	**13**	**14**	**16**	**15**	**16**	**18**	**17**	**18**	**20**	**19**	**20**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	100.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct	8.90	8.12	12.02
Standard Distance		12.5653			8.3175			6.7213			8.1709			8.7502			9.0040			6.7182			8.2703			7.1586			5.5137		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	10.6749			7.6898			8.1941			8.0051			11.0787			6.4488			8.2300			5.2717			7.9066			15.5429			8.18	8.09	8.22
Silhouette Distance			10.6714			7.1552			8.6297			9.1028			9.0238			7.2954			7.4454			6.4461			35.6643			18.7692	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	9.9088	10.0000	9.2075	7.1306	5.2020	8.4521	5.9980	8.9558	5.5516	7.4789	10.0000	5.8233	8.7768	8.4716	8.3649	6.5590	5.3506	10.0000	7.8861	9.6981	9.0718	8.0119	9.8458	8.5219	10.0000	10.0000	7.1895	10.0000	3.4164	10.0000			
Confidence Level Question																															AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9854	0.9853	1.2923	1.4211	0.9868	0.9858	0.9866	1.2602	1.1069	1.1019	1.3410	0.9843	0.9862	1.0381	1.2045	0.9851	1.1879	1.3131	0.9870	0.9868	1.3739	1.0073	1.2383	0.9870	0.9869	1.3531	1.2540	0.9844	1.1656	1.1879	0.99667411	0.99911031	1.05
Speed Std Dev	0.1202	0.1171	0.4346	0.5050	0.1184	0.1190	0.1218	0.4350	0.2264	0.2308	0.4069	0.1209	0.1185	0.2607	0.3826	0.1174	0.3271	0.4927	0.1170	0.1166	0.5203	0.1980	0.3205	0.1200	0.1188	0.4718	0.4827	0.1237	0.4224	0.4526	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9964	1.0007	1.0055	0.9896	0.9941	0.9889	0.9950	0.9835	0.9980	0.9934	1.0140	0.9976	1.0009	1.0005	0.9902	0.9935	1.0065	1.0052	0.9886	0.9910	1.0029	1.0026	1.0084	1.0105	1.0034	0.9761	1.0520	1.0033	1.0165	1.4738	1.0432	1.1543	1.17
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.1771	0.2996	0.34

Environment 1 - Hit 2

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**1**	**0**	**1**	**3**	**2**	**3**	**5**	**4**	**5**	**7**	**6**	**7**	**9**	**8**	**9**	**11**	**10**	**11**	**13**	**14**	**13**	**15**	**16**	**15**	**17**	**18**	**17**	**19**	**20**	**19**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Incorrect			Incorrect			Correct			Correct			Incorrect			Correct			Incorrect		90.00%	60.00%	80.00%
AR Collision ID	Correct			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct			Incorrect			Correct	12.25	8.19	10.41
Standard Distance		17.8555			8.6955			17.1394			0.0000			0.0000			15.7127			6.2178			0.0000			16.2998			0.0000		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	13.4157			15.6314			9.1483			5.5611			0.0000			12.4323			9.9626			40.6840			7.1943			8.4980			7.04	6.50	7.34
Silhouette Distance			9.7998			0.0000			6.4194			12.6597			20.7152			10.1629			24.8932			13.3625			0.0000			6.0998	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	1.1646	8.9994	8.3875	6.9464	8.7229		4.2079	3.4943	10.0000	8.6666		8.8133			7.6179	6.5285	10.0000	4.8382	10.0000	6.8125	5.4987	9.4059		7.9579	10.0000	1.0000		6.4519		5.5905	4.0150	6.5910	3.68
Confidence Level Question						2.0303					4.7412		4.0150	2.8776									8.7451				5.3316		10.0000		AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.989	1.1931	0.9870	0.98727	1.0186	1.163435	1.12923	1.0130	0.988985	0.98907717	1.0395	1.223257	1.02824	0.9874	0.989449	1.10097875	1.1818	0.988563	0.98742261	1.2966	0.988364	1.25204065	1.1223	0.988625	0.98800403	1.2168	1.16880994	0.98934	1.5008	0.989397	1.02912579	1.0588	1.04
Speed Std Dev	0.10644	0.3042	0.1078	0.1143	0.1971	0.403836	0.35043	0.1518	0.10728	0.10679346	0.1716	0.319227	0.17678	0.1075	0.109303	0.29423141	0.4227	0.109426	0.10742427	0.4912	0.11479	0.3730205	0.3178	0.107643	0.10548291	0.4656	0.29705519	0.10751	0.5375	0.106958	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.99523	0.9944	0.9942	1.00543	1.0018	1.385779	1.00376	1.0029	1.004566	0.9945364	0.9987	0.998422	0.99685	0.9981	1.003366	0.9996538	1.0007	1.016092	1.001521	0.7592	0.99566	1.296515	0.9879	1.006239	1.00049	1.0020	1.008918	0.99814	1.8425	1.008861	1.0645	1.1570	1.05
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2040	0.3167	0.18

Environment 1 - Danger

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**0**	**1**	**0**	**2**	**3**	**2**	**4**	**5**	**4**	**6**	**7**	**6**	**8**	**9**	**8**	**10**	**11**	**10**	**14**	**13**	**14**	**16**	**15**	**16**	**18**	**17**	**18**	**20**	**19**	**20**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Incorrect		70.00%	80.00%	70.00%
AR Collision ID	Correct			Incorrect			Correct			Incorrect			Correct			Correct			Correct			Correct			Incorrect			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Incorrect			Incorrect			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																															6.45	4.42	6.20
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question				7.0159	6.5430				5.8014	8.7357															3.5939		3.1552		2.3023	9.6294	6.9081	5.7411	6.29
Confidence Level Question	10.0000	8.0283	10.0000			9.2712	3.8668	8.1908			1.0000	1.0000	8.8242	8.7337	9.2481	5.3421	6.1919	1.0000	8.7408	5.4247	10.0000	4.8546	1.0000	3.5017		7.3597		6.7281			AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	1.3081	0.9910	0.9914	0.9880	0.9886	1.4751	1.0793	0.9915	0.9866	0.9876	0.9916	1.0899	1.3318	0.9918	0.9913	1.7288	0.9905	0.9920	1.3654	0.9925	0.9903	0.9912	0.9910	1.2092	1.3644	0.9917	0.9869	1.4210	0.9828	0.9884	1.4076601	0.9972	1.19
Speed Std Dev	0.4388	0.0940	0.0954	0.1053	0.1085	0.5352	0.2156	0.0933	0.1141	0.1098	0.0946	0.2043	0.5091	0.0913	0.0943	0.4602	0.0948	0.0938	0.4880	0.0932	0.0930	0.0934	0.0934	0.4005	0.5372	0.0947	0.1109	0.5174	0.1311	0.1092	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	2.0303	0.9903	0.9998	0.9890	0.9938	2.0006	1.0108	1.0114	0.9997	1.0008	1.0132	1.0116	2.2957	0.9974	0.9998	1.9085	0.9921	0.9961	1.8924	0.9882	1.0060	0.9905	0.9949	1.9236	1.0100	1.0085	1.0047	1.9887	0.9822	1.0028	1.2249	0.9903	1.07
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.3130	0.0989	0.19

Environment 1 - Caution

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**1**	**0**	**1**	**3**	**2**	**3**	**5**	**4**	**5**	**7**	**6**	**7**	**9**	**8**	**9**	**11**	**10**	**11**	**13**	**14**	**13**	**15**	**16**	**15**	**17**	**18**	**17**	**19**	**20**	**19**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	90.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																																5.07	
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question											5.0739																				7.3085	7.5942	9.02
Confidence Level Question	8.6282	8.6554	10.0000	10.0000	7.3501	5.3614	10.0000	4.6459	10.0000	1.0000		7.4017	5.6748	10.0000	9.8123	5.5136	8.9018	9.6583	10.0000	9.9261	7.9597	2.2687	3.2014	9.9832	10.0000	5.6672	10.0000	10.0000	10.0000	10.0000	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9921	0.9913	0.9900	1.3385	0.9905	0.9937	0.9926	0.9897	1.3518	1.5705	0.9830	0.9931	0.9916	0.9915	0.9915	0.9916	0.9910	1.3307	0.9907	0.9900	0.9908	0.9909	0.9913	1.4127	1.5779	0.9911	0.9902	0.9916	0.9914	1.5239	1.29513346	1.0060	1.33
Speed Std Dev	0.0932	0.0943	0.0927	0.4867	0.0941	0.0944	0.0910	0.0940	0.4911	0.5157	0.1365	0.0943	0.0933	0.0928	0.0938	0.0946	0.0925	0.4255	0.0949	0.0947	0.0938	0.0931	0.0918	0.4061	0.4634	0.0935	0.0944	0.0920	0.0936	0.5262	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9898	1.0114	1.0013	1.9702	0.9945	0.9936	1.0073	0.9897	1.9581	2.0007	1.0635	1.0071	1.0078	1.0031	1.0091	0.9989	0.9984	1.4478	1.0112	0.9972	1.0027	0.9990	1.0021	1.9540	1.9507	0.9920	0.9897	0.9942	1.0078	1.9750	1.1427	0.9901	1.16
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2119	0.0978	0.24

Environment 2 - Hit 2

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**1**	**0**	**1**	**3**	**2**	**3**	**5**	**4**	**5**	**7**	**6**	**7**	**9**	**8**	**9**	**11**	**10**	**11**	**13**	**14**	**13**	**15**	**16**	**15**	**17**	**18**	**17**	**19**	**20**	**19**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Incorrect			Correct			Correct			Incorrect			Incorrect			Incorrect			Correct			Incorrect			Incorrect		70.00%	40.00%	100.00%
AR Collision ID	Incorrect			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct			Incorrect			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct	12.35	10.99	13.89
Standard Distance		13.5889			8.3175			20.9674			14.3131			8.7502			9.0040			6.7182			15.5287			7.1586			5.5137		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	10.6749			8.7462			8.1941			7.6802			17.8000			16.1574			7.3108			19.5153			11.8712			15.5429			7.92	6.18	8.16
Silhouette Distance			9.6228			15.1247			7.7952			8.8276			10.0877			6.5371			40.8706			11.2693			14.8423			13.9717	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question		9.1715	9.1634	8.1285		7.2873		6.7170	8.9739	10.0000	1.0000	10.0000	8.5388		9.3299	1.6713		7.0091	10.0000		7.8780	7.1103	7.8498	8.1640	10.0000		8.4189			5.3328			
Confidence Level Question	1.1359				3.6927		10.0000							8.5568			6.9251			9.1752						1.0000		9.0883	10.0000		AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9907	0.9894	0.9893	1.3893	0.9901	0.9909	0.9907	0.9893	1.3266	1.6375	0.9891	0.9913	0.9901	0.9910	0.9899	0.9899	0.9899	1.4098	0.9904	0.9898	0.9897	0.9892	0.9896	1.3293	1.5489	0.9901	0.9892	0.9905	0.9908	1.6593	0.99837311	1.00239398	1.11
Speed Std Dev	0.1000	0.1014	0.1006	0.5022	0.0996	0.1017	0.0982	0.1024	0.4530	0.5080	0.1138	0.1025	0.1009	0.0988	0.1027	0.1008	0.0989	0.4599	0.1029	0.0999	0.1022	0.1026	0.0998	0.3940	0.4828	0.1009	0.1020	0.0981	0.1003	0.5048	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9909	0.9934	0.9975	1.0012	1.0011	0.9898	1.0030	1.0053	0.9893	0.9069	1.0007	1.0080	1.0049	1.0043	0.9975	1.0081	1.0036	0.9933	0.9951	1.0088	1.0011	0.9909	1.0025	1.1445	1.0746	0.9959	1.0042	1.0081	1.0083	1.9582	1.1507	0.9899	1.17
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2197	0.1016	0.24

Environment 2 - Hit 1

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**1**	**0**	**1**	**3**	**2**	**3**	**5**	**4**	**5**	**7**	**6**	**7**	**9**	**8**	**9**	**11**	**10**	**11**	**13**	**14**	**13**	**15**	**16**	**15**	**17**	**18**	**17**	**19**	**20**	**19**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	100.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct	8.18	10.67	10.48
Standard Distance		7.0028			8.7739			10.5164			8.4480			11.7424			7.7926			10.0654			7.1652			14.5865			20.5941		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	7.8050			6.9540			7.1610			9.1503			11.6607			6.2046			7.5297			9.7833			7.6731			7.8861			6.95	7.25	8.57
Silhouette Distance			12.0510			19.4216			5.9834			10.6442			9.9157			6.9324			10.1700			9.0592			10.1059			10.5218	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	1.0000	10.0000	9.7341	6.5205	5.9316	3.5968	6.4391	6.2917	10.0000	8.6666	6.3353	10.0000	10.0000	7.6131	9.6386	4.7673	6.8711	7.1137	9.9699	7.9043	10.0000	6.1718	9.1946	10.0000	10.0000	2.3964	10.0000	5.9490	10.0000	5.5905			
Confidence Level Question																															AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9901	1.2490	0.9889	0.9874	1.1314	1.2524	0.9869	0.9861	0.9881	0.9881	1.0286	1.0468	1.0091	0.9881	0.9876	1.0840	1.4682	0.9883	0.9873	1.1157	0.9878	1.1420	1.1145	0.9875	0.9892	0.9893	1.0763	1.0966	1.4060	0.9877	0.99397244	1.0581	1.09
Speed Std Dev	0.1145	0.3564	0.1107	0.1125	0.3772	0.4727	0.1095	0.1107	0.1105	0.1112	0.1636	0.1993	0.1491	0.1087	0.1122	0.2325	0.5403	0.1079	0.1106	0.3495	0.1120	0.2572	0.3215	0.1119	0.1121	0.1102	0.2379	0.3447	0.5342	0.1146	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9891	0.9723	1.0097	1.0009	1.0069	1.8631	0.9990	0.9952	0.9988	0.9954	0.9937	1.0071	0.9983	0.9940	0.9947	0.9950	0.9237	1.0012	0.9963	1.0019	0.9925	0.9769	0.9873	1.0039	1.0020	0.9936	0.9852	1.0035	1.7127	1.0051	1.0520	1.1477	1.03
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.1896	0.2972	0.17

Environment 2 - Danger

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**0**	**1**	**0**	**2**	**3**	**2**	**4**	**5**	**4**	**6**	**7**	**6**	**8**	**9**	**8**	**10**	**11**	**10**	**14**	**13**	**14**	**16**	**15**	**16**	**18**	**17**	**18**	**20**	**19**	**20**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Incorrect			Correct			Correct			Incorrect			Correct			Incorrect			Correct		50.00%	70.00%	60.00%
AR Collision ID	Correct			Incorrect			Incorrect			Incorrect			Correct			Correct			Correct			Incorrect			Correct			Incorrect			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Incorrect			Incorrect			Correct			Incorrect			Incorrect			Correct			Correct			Correct			Correct			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																															5.12	5.71	7.76
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question			7.9502	4.0011		5.6116	5.5142			10.0000	4.9595	7.9153			9.5486					9.0462		4.0206				3.1306		2.0519			7.1988	6.5936	8.91
Confidence Level Question	5.6817	10.0000			8.6456			5.8954	10.0000				5.7228	6.8778		4.5896	3.3261	8.3394	10.0000		10.0000		5.6267	7.0473	10.0000		8.8646		5.7834	9.2192	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9899	0.9872	0.9636	1.2507	0.9887	0.9612	0.9874	0.9862	1.1987	1.3311	0.9669	0.9637	0.9863	0.9899	0.9517	0.9860	0.9887	1.3746	0.9866	0.9868	0.9855	0.9575	0.9852	1.1345	1.3673	0.9868	0.9855	0.9876	0.9895	1.7866	1.06995269	0.9951	1.35
Speed Std Dev	0.1053	0.1182	0.1986	0.5573	0.1049	0.2133	0.1145	0.1189	0.4280	0.6755	0.1868	0.1983	0.1187	0.1037	0.2295	0.1189	0.1046	0.4541	0.1173	0.1144	0.1187	0.2231	0.1188	0.3062	0.4746	0.1176	0.1206	0.1136	0.1052	0.5324	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9995	0.9999	1.0077	0.7701	1.0021	1.0083	0.9974	0.9953	1.9422	0.9742	0.9729	1.0066	1.0019	0.9894	1.0022	0.9867	0.9989	2.0894	1.0094	0.9902	0.9986	1.0035	1.0003	1.4603	1.9411	0.9977	0.9940	1.0153	1.0046	1.9941	1.0828	0.9856	1.13
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2632	0.1193	0.28

Environment 2 - Caution

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	**0**	**1**	**0**	**2**	**3**	**2**	**4**	**5**	**4**	**6**	**7**	**6**	**8**	**9**	**8**	**10**	**11**	**10**	**14**	**13**	**14**	**16**	**15**	**16**	**18**	**17**	**18**	**20**	**19**	**20**	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	100.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																																	
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question																															8.4301	7.5915	8.82
Confidence Level Question	10.0000	10.0000	10.0000	8.5653	10.0000	8.0013	8.1063	10.0000	9.9881	1.0000	1.0000	1.0000	10.0000	9.0835	9.8091	6.6417	4.3662	9.4296	10.0000	10.0000	10.0000	9.9874	1.4653	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9866	0.9946	0.9878	0.9851	1.4250	1.1314	1.1799	0.9869	0.9868	0.9857	1.0633	1.1755	0.9858	0.9871	0.9880	1.0582	1.3594	0.9853	0.9874	1.2383	0.9862	1.4088	1.2047	0.9867	0.9855	0.9882	1.2637	1.3068	1.4543	0.9869	1.33778901	1.5044	1.32
Speed Std Dev	0.1203	0.1277	0.1192	0.1181	0.5025	0.3772	0.4176	0.1198	0.1190	0.1199	0.1847	0.3123	0.1186	0.1197	0.1221	0.2102	0.5081	0.1195	0.1189	0.4664	0.1167	0.4749	0.3823	0.1189	0.1182	0.1208	0.4482	0.5239	0.5556	0.1175	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0034	1.0044	1.0065	0.9980	2.0793	2.2358	1.9468	1.0059	1.0003	1.0017	1.0882	2.0367	1.0057	1.0024	0.9997	1.4211	1.9457	0.9871	1.0102	1.9948	0.9905	1.9875	1.9470	1.0059	1.0056	0.9830	1.9166	1.9968	1.9933	1.0061	1.0878	1.1702	1.05
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2348	0.3088	0.20

Environment 3 - Hit 1

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	0	1	0	2	3	2	4	5	4	6	7	6	8	9	8	13	11	10	14	13	14	16	15	16	18	17	18	20	19	20	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Incorrect			Incorrect			Correct			Correct			Correct		100.00%	80.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct	8.22	7.58	7.33
Standard Distance		7.6353			8.8184			7.3712			7.3161			10.1846			0.0000			0.0000			19.6540			8.9574			5.8671		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	10.9485			9.0406			11.6998			2.8046			7.2684			6.6537			8.3578			6.9457			8.9116			9.5969			8.06	8.42	8.74
Silhouette Distance			6.9955			7.5634			8.8984			5.4146			6.7395			4.5152			10.2993			5.0131			9.9248			7.9235	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	8.8617	10.0000	9.5797	6.8027	5.8061	10.0000	8.0409	8.5402	8.5653	1.0000	10.0000	8.3225	9.5578	9.0756	9.4372	10.0000		8.3828	8.8846		7.2364	9.0904	9.6566	8.0865	8.3870	9.2244	7.7819	10.0000	5.0440	10.0000	#DIV/0!	5.5854	#DIV/0!
Confidence Level Question																	1.1709			10.0000											AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9847	0.9850	1.0888	1.5921	1.0669	0.9865	0.9860	1.1237	1.0499	0.9774	1.3366	0.9858	0.9859	0.9855	1.0876	0.9852	1.2438	1.6128	0.9853	0.9856	1.2691	1.2025	1.2593	0.9854	0.9859	1.4289	1.7270	0.9845	1.6591	1.6130	0.99756613	0.99602431	1.00
Speed Std Dev	0.1245	0.1244	0.2913	0.5574	0.3038	0.1237	0.1271	0.3746	0.2343	0.2309	0.4819	0.1247	0.1247	0.1261	0.3227	0.1233	0.3662	0.5229	0.1243	0.1251	0.4707	0.4183	0.3605	0.1239	0.1226	0.4758	0.5220	0.1265	0.5570	0.5582	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9978	1.0025	0.9941	0.9820	0.9952	0.9974	1.0110	1.0032	1.0105	0.9917	1.0265	0.9894	0.9965	1.0057	0.9936	1.0008	0.9876	0.9042	0.9917	0.9989	1.0005	1.0010	0.9996	0.9886	1.0031	1.0072	1.0874	1.0002	0.9338	0.9871	1.0670	1.2074	1.24
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2080	0.3295	0.33

Environment 3 - Hit 2

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	0	1	0	2	3	2	4	5	4	6	7	6	8	9	8	10	11	10	14	13	14	16	15	16	18	17	18	20	19	20	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Incorrect			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct		90.00%	80.00%	90.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct	8.67	8.72	7.93
Standard Distance		16.8004			0.0000			10.5583			13.9160			11.4000			0.0000			7.3972			8.8282			6.6570			11.6673		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	8.0666			8.6665			9.5053			9.6346			9.5260			14.2577			0.0000			7.3231			10.1322			9.5649			8.44	8.42	7.78
Silhouette Distance			9.0839			4.3673			8.8169			8.2445			10.4181			10.5765			0.0000			5.1828			9.0635			13.5330	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	9.7994	8.4040	9.7855	8.2169		8.0904	7.4581	8.8643	6.4712	9.7260	9.9639	8.3687	9.8274	7.4759	9.5670	6.5051		8.7772		10.0000		8.9838	9.2200	8.3409	5.4655	8.1594	1.0000	10.0000	5.2446	9.6214	7.1722	3.1806	6.92
Confidence Level Question					4.8715												1.4897		7.1722		6.9244										AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	1.2790	0.9891	0.9884	0.9862	0.9870	1.5889	1.0425	0.9887	0.9873	0.9660	0.9884	1.1051	1.4073	0.9884	0.9887	1.8113	0.9889	0.9886	1.4191	0.9889	0.9885	0.9887	0.9884	1.1870	1.7441	0.9883	0.9864	1.5728	0.9861	0.9864	1.20301082	0.9978	1.00
Speed Std Dev	0.4148	0.1086	0.1094	0.1205	0.1175	0.5503	0.2073	0.1081	0.1196	0.1933	0.1110	0.2378	0.5276	0.1093	0.1089	0.4282	0.1079	0.1098	0.4937	0.1076	0.1074	0.1088	0.1090	0.3772	0.5049	0.1079	0.1193	0.5453	0.1210	0.1217	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9952	1.0097	0.9751	1.0043	0.9943	1.0040	0.9930	1.0094	1.0064	1.0050	0.9984	1.0089	1.0104	0.9927	0.9992	1.9727	0.9910	0.9931	1.9316	1.0020	0.9919	0.9992	0.9815	0.9935	1.0381	0.9912	0.9881	1.0662	1.0083	1.0045	1.2927	0.9882	1.08
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.3238	0.1108	0.20

Environment 3 - Danger

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	1	0	1	3	2	3	5	4	5	7	6	7	9	8	9	11	10	11	13	14	13	15	16	15	17	18	17	19	20	19	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Incorrect			Correct			Correct			Incorrect			Correct			Incorrect			Correct		50.00%	70.00%	60.00%
AR Collision ID	Correct			Incorrect			Incorrect			Incorrect			Correct			Correct			Correct			Incorrect			Correct			Incorrect			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Incorrect			Incorrect			Correct			Incorrect			Incorrect			Correct			Correct			Correct			Correct			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																															5.12	5.71	7.76
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question			7.9502	4.0011		5.6116	5.5142			10.0000	4.9595	7.9153			9.5486					9.0462		4.0206				3.1306		2.0519			7.1988	6.5936	8.91
Confidence Level Question	5.6817	10.0000			8.6456			5.8954	10.0000				5.7228	6.8778		4.5896	3.3261	8.3394	10.0000		10.0000		5.6267	7.0473	10.0000		8.8646		5.7834	9.2192	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9899	0.9872	0.9636	1.2507	0.9887	0.9612	0.9874	0.9862	1.1987	1.3311	0.9669	0.9637	0.9863	0.9899	0.9517	0.9860	0.9887	1.3746	0.9866	0.9868	0.9855	0.9575	0.9852	1.1345	1.3673	0.9868	0.9855	0.9876	0.9895	1.7866	1.06995269	0.9951	1.35
Speed Std Dev	0.1053	0.1182	0.1986	0.5573	0.1049	0.2133	0.1145	0.1189	0.4280	0.6755	0.1868	0.1983	0.1187	0.1037	0.2295	0.1189	0.1046	0.4541	0.1173	0.1144	0.1187	0.2231	0.1188	0.3062	0.4746	0.1176	0.1206	0.1136	0.1052	0.5324	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9995	0.9999	1.0077	0.7701	1.0021	1.0083	0.9974	0.9953	1.9422	0.9742	0.9729	1.0066	1.0019	0.9894	1.0022	0.9867	0.9989	2.0894	1.0094	0.9902	0.9986	1.0035	1.0003	1.4603	1.9411	0.9977	0.9940	1.0153	1.0046	1.9941	1.0828	0.9856	1.13
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2632	0.1193	0.28

Environment 3 - Caution

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	1	0	1	3	2	3	5	4	5	7	6	7	9	8	9	11	10	11	13	14	13	15	16	15	17	18	17	19	20	19	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	100.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																																	
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question																															8.4301	7.5915	8.82
Confidence Level Question	10.0000	10.0000	10.0000	8.5653	10.0000	8.0013	8.1063	10.0000	9.9881	1.0000	1.0000	1.0000	10.0000	9.0835	9.8091	6.6417	4.3662	9.4296	10.0000	10.0000	10.0000	9.9874	1.4653	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	10.0000	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9866	0.9946	0.9878	0.9851	1.4250	1.1314	1.1799	0.9869	0.9868	0.9857	1.0633	1.1755	0.9858	0.9871	0.9880	1.0582	1.3594	0.9853	0.9874	1.2383	0.9862	1.4088	1.2047	0.9867	0.9855	0.9882	1.2637	1.3068	1.4543	0.9869	1.33778901	1.5044	1.32
Speed Std Dev	0.1203	0.1277	0.1192	0.1181	0.5025	0.3772	0.4176	0.1198	0.1190	0.1199	0.1847	0.3123	0.1186	0.1197	0.1221	0.2102	0.5081	0.1195	0.1189	0.4664	0.1167	0.4749	0.3823	0.1189	0.1182	0.1208	0.4482	0.5239	0.5556	0.1175	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0034	1.0044	1.0065	0.9980	2.0793	2.2358	1.9468	1.0059	1.0003	1.0017	1.0882	2.0367	1.0057	1.0024	0.9997	1.4211	1.9457	0.9871	1.0102	1.9948	0.9905	1.9875	1.9470	1.0059	1.0056	0.9830	1.9166	1.9968	1.9933	1.0061	1.0878	1.1702	1.05
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2348	0.3088	0.20

Environment 4 - Hit 1

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	0	1	0	2	3	2	4	5	4	6	7	6	8	9	8	10	11	10	14	13	14	16	15	16	18	17	18	20	19	20	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Incorrect			Correct			Correct			Incorrect			Correct			Correct			Incorrect			Correct		80.00%	70.00%	70.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Incorrect			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Incorrect			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Incorrect	5.15	6.89	4.63
Standard Distance		13.1113			6.4599			0.0000			8.7561			17.8814			0.0000			7.8445			6.9664			0.0000			7.8439		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	7.2605			4.8393			7.6597			5.4611			5.8258			0.0000			8.1061			3.5932			8.7688			0.0000			7.94	7.63	7.75
Silhouette Distance			0.0000			7.8627			5.6640			0.0000			6.9712			4.1984			6.3043			3.5197			11.8201			0.0000	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	8.3225	8.6619		10.0000	4.0786	7.6561	7.2299		8.1620	7.6427	10.0000		8.4833	8.9281	9.7296			5.8126	7.6601	10.0000	9.3070	8.3537	9.7396	8.1622	5.8113		5.3902		1.9897		1.7217	1.3378	5.41
Confidence Level Question			6.6167					1.0000				1.0000				1.0000	1.6069									1.4066		2.4434		8.6130	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9464	0.9445	0.9523	0.9503	0.9828	1.6591	0.9436	0.9521	0.9459	0.9441	0.9260	0.9748	0.9444	0.9468	0.9438	1.7891	0.9862	0.9530	1.3818	0.9332	0.9863	0.9500	0.9386	0.9533	1.3866	0.9500	0.9531	1.1404	0.9466	0.9480	1.06941743	0.9801394	0.99
Speed Std Dev	0.2530	0.2498	0.2207	0.2346	0.1346	0.7492	0.2613	0.2231	0.2475	0.2515	0.2877	0.2574	0.2500	0.2466	0.2515	0.6691	0.1196	0.2301	0.4947	0.2785	0.1194	0.2326	0.2633	0.2333	0.7480	0.2255	0.2274	0.5795	0.2399	0.2249	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0076	0.9946	0.9329	0.9778	0.9619	1.1671	1.0042	0.9429	1.0005	1.0041	0.9996	0.9570	1.0074	1.0087	1.0015	1.8224	0.9356	0.9828	1.0111	1.0123	0.9777	0.9698	1.0026	0.9796	0.9236	0.9424	0.9676	0.9659	1.0009	0.9421	1.1377	0.9507	1.03
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.3974	0.2269	0.28

Environment 4 - Hit 2

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	0	1	0	2	3	2	4	5	4	6	7	6	8	9	8	10	11	10	14	13	14	16	15	16	18	17	18	20	19	20	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	90.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct	6.43	6.27	6.68
Standard Distance		8.6864			0.0000			6.2209			6.3529			5.6890			4.5267			11.8037			5.8654			7.5977			5.9689		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	7.6163			6.7700			7.2034			5.8017			6.5334			3.6978			5.0578			4.3900			8.0214			9.2383			9.34	8.37	9.70
Silhouette Distance			6.4080			4.7622			11.1784			5.3068			6.5689			4.5743			6.7413			4.4369			10.3249			6.5049	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	8.3070	10.0000	10.0000	8.4578		10.0000	10.0000	9.5499	9.9358	10.0000	10.0000	9.3230	9.8052	7.7752	10.0000	10.0000	6.5146	10.0000	8.4614	7.5195	9.2150	9.3483	9.2049	8.5713	9.5778	9.1971	10.0000	9.4580	5.5615	10.0000	#DIV/0!	7.2467	#DIV/0!
Confidence Level Question					7.2467																										AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9750	0.9747	0.9746	1.4117	0.9919	0.9776	0.9725	0.9734	0.9696	1.0156	1.2603	0.9725	0.9750	0.9731	0.9726	0.9743	1.1990	1.5842	0.9732	0.9689	1.0057	1.0527	0.9731	0.9737	0.9738	1.0990	1.8955	0.9741	1.6579	1.2892	0.99334781	0.9953	1.10
Speed Std Dev	0.1670	0.1596	0.1617	0.5899	0.1933	0.1543	0.1697	0.1630	0.1786	0.2391	0.4723	0.1662	0.1665	0.1677	0.1652	0.1598	0.3490	0.6080	0.1604	0.1757	0.2225	0.2732	0.1621	0.1608	0.1588	0.3363	0.4906	0.1597	0.6002	0.5677	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9956	0.9990	1.0039	0.9709	1.0011	1.0049	0.9890	0.9991	1.0086	1.0031	0.9397	1.0025	0.9974	1.0028	0.9995	0.9876	1.0124	1.0332	1.0102	1.0056	0.9970	0.9938	0.9969	0.9971	0.9910	1.0006	1.9833	0.9915	0.9959	0.9782	1.0297	1.1071	1.16
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2237	0.2779	0.29

Environment 4 - Hit 3

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	1	0	1	3	2	3	5	4	5	7	6	7	9	8	9	11	10	11	13	14	13	15	16	15	17	18	17	19	20	19	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Incorrect		60.00%	90.00%	50.00%
AR Collision ID	Incorrect			Correct			Incorrect			Correct			Incorrect			Incorrect			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Incorrect			Correct			Correct			Correct			Correct			Incorrect			Incorrect			Incorrect			Correct			Incorrect	6.13	9.65	4.14
Standard Distance		9.9959			8.5670			13.8351			11.3949			19.8606			9.3535			7.2763			8.3166			7.8723			0.0000		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	0.0000			6.3239			0.0000			27.6547			0.0000			0.0000			6.5631			9.2800			5.2749			6.1580			7.82	7.51	7.70
Silhouette Distance			0.0000			13.3081			7.6986			6.0038			4.9041			0.0000			0.0000			0.0000			9.4947			0.0000	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question		9.6500		4.9385	7.8740	7.4195		8.0489	7.7267	10.0000	7.9631	8.7191		9.4606	7.4468		5.8183		10.0000	7.2159		8.5045	8.8196		8.8127	2.7024	7.2030	4.6385			4.6538	7.2976	2.56
Confidence Level Question	5.8249		1.1654				3.2351						5.5630			3.9920		1.0000			1.0000			4.0935					7.2976	5.5355	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9878	0.9817	0.9716	1.0924	0.9865	0.9529	0.9697	0.9792	1.1218	1.7051	0.9631	0.9660	0.9808	0.9876	0.9678	0.9803	0.9867	1.3139	0.9799	0.9695	0.9806	0.9673	0.9791	1.0785	1.3253	0.9687	0.9802	0.9668	0.9873	1.5982	1.09251911	1.0006	1.00
Speed Std Dev	0.1143	0.1385	0.1743	0.4763	0.1141	0.2155	0.1779	0.1443	0.3818	0.7290	0.2004	0.1823	0.1369	0.1146	0.1781	0.1386	0.1144	0.4537	0.1425	0.1780	0.1383	0.1809	0.1421	0.2785	0.4866	0.1789	0.1402	0.1848	0.1145	0.5980	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0046	1.0057	0.9955	1.0156	1.0099	1.0060	1.0125	1.0055	0.9949	1.9902	1.0059	0.9886	0.9968	0.9934	1.0043	0.9945	1.0016	0.9975	0.9769	0.9842	1.0084	0.9924	0.9987	1.0016	0.9428	1.0043	0.9920	0.9977	0.9972	0.9929	1.0949	0.9789	1.09
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2792	0.1440	0.27

Environment 4 - Danger

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	1	0	1	3	2	3	5	4	5	7	6	7	9	8	9	11	10	11	13	14	13	15	16	15	17	18	17	19	20	19	AR Correct	Standard Correct	SIlhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		100.00%	100.00%	100.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																																	
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question	1.0000			7.9727		9.5895				10.0000	5.7709	8.3199	8.8612		7.3015							1.0000		5.1583					8.9960		6.8625	5.8892	8.37
Confidence Level Question		10.0000	9.5388		4.4114		5.3961	5.6850	9.2911					7.5388		6.6485	6.0981	7.0072	10.0000	7.3189	10.0000		1.3878		3.4120	4.6736	5.0779	8.8558		9.3112	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9792	0.9905	0.9878	0.9780	1.3532	1.1183	1.1275	0.9870	0.9866	0.9783	1.0381	1.1231	0.9782	0.9854	0.9799	1.0807	1.4791	0.9865	0.9868	1.2364	0.9870	1.3127	1.2071	0.9794	0.9852	1.1041	1.2805	1.2956	1.3950	0.9868	1.23990769	1.4780	1.05
Speed Std Dev	0.1497	0.1229	0.1185	0.1482	0.5148	0.3972	0.3723	0.1182	0.1179	0.1468	0.1963	0.3106	0.1500	0.1178	0.1533	0.2191	0.5271	0.1177	0.1170	0.4592	0.1166	0.4746	0.3945	0.1480	0.1178	0.3576	0.4519	0.5250	0.5729	0.1157	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	0.9874	0.9900	1.0049	1.0112	1.9668	0.6549	1.9794	1.0082	1.0107	0.9912	1.0753	0.9760	0.9864	1.0014	1.0030	1.5106	1.9612	0.9978	1.0118	1.9404	0.9939	0.9046	1.8595	0.9893	1.0079	2.0078	1.8996	2.0059	0.9696	0.9991	1.0713	1.1776	1.04
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2394	0.3381	0.20

Environment 5 - Hit 3

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	1	0	1	3	2	3	5	4	5	7	6	7	9	8	9	11	10	11	13	14	13	15	16	15	17	18	17	19	20	19	AR Correct	Standard Correct	Silhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		70.00%	100.00%	90.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Incorrect			Correct			Incorrect			Correct			Incorrect			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct	5.52	10.23	6.98
Standard Distance		9.2086			7.7129			8.2475			3.0388			8.7648			7.4031			9.3732			3.2409			4.5129			40.8323		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	14.4221			7.0132			9.4952			6.0599			7.2700			0.0000			4.8798			0.0000			6.0828			0.0000			7.18	7.17	8.06
Silhouette Distance			7.1051			15.7187			6.4023			0.0000			5.1160			7.6274			7.7763			6.3340			6.3775			7.3852	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	9.8759	8.1219	8.1005	6.6229	9.8065	6.4619	5.5093	6.6153	9.2791	10.0000	1.0000		7.2453	8.7287	9.4605		7.0449	6.8755	1.0000	9.1893	10.0000		8.6234	9.3311	10.0000	4.2330	7.5179		8.2918	5.4847	7.4725	#DIV/0!	1.00
Confidence Level Question												1.0000				5.0797						9.5283						7.8094			AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9814	0.9879	0.9859	0.9817	1.2678	1.0712	1.0827	0.9851	0.9847	0.9814	0.9966	0.9820	0.9815	0.9840	0.9817	1.0599	1.4354	0.9847	0.9850	1.1524	0.9851	1.0886	1.1333	0.9790	0.9840	1.0898	1.1781	1.2503	1.0470	0.9849	1.00217719	0.99256974	1.03
Speed Std Dev	0.1408	0.1277	0.1252	0.1415	0.4868	0.3485	0.3267	0.1258	0.1250	0.1464	0.1780	0.1401	0.1365	0.1246	0.1423	0.2109	0.5249	0.1240	0.1242	0.4030	0.1239	0.2263	0.3490	0.1417	0.1238	0.3446	0.4011	0.5008	0.4293	0.1238	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0000	1.0048	1.0088	1.0148	0.9961	1.2828	0.9914	0.9992	0.9990	1.0082	1.0136	0.9911	1.0037	1.0037	1.0014	1.0099	0.9947	0.9965	0.9940	1.0105	0.9985	1.0077	1.0172	1.0126	0.9849	0.7679	1.0001	1.0073	1.1179	1.0042	1.0377	1.1079	1.01
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2078	0.3094	0.18

Environment 5 - Hit 2

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	0	1	0	2	3	2	4	5	4	6	7	6	8	9	8	10	11	10	14	13	14	16	15	16	18	17	18	20	19	20	AR Correct	Standard Correct	Silhouette Correct
Standard Collision ID		Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct		90.00%	100.00%	90.00%
AR Collision ID	Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Correct			Correct	7.77	7.47	7.13
Standard Distance		7.6885			8.2360			5.0921			6.2312			5.0766			13.5006			6.2779			5.0171			6.1724			11.3913		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	7.2584			7.1392			6.4699			0.0000			6.6223			11.0874			6.7852			8.7739			11.4475			12.1341			8.10	7.90	7.62
Silhouette Distance			5.4771			10.2396			4.9027			0.0000			6.8116			4.7806			7.0263			4.0305			15.8943			12.1517	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	9.6437	10.0000	9.3635	8.1008	6.7741	6.2986	7.5867	7.9047	6.5571		10.0000		9.1236	8.5936	8.2843	7.5006	5.0710	5.0268	8.8392	10.0000	8.9790	8.6583	9.6651	9.4131	7.1002	10.0000	4.6207	6.3211	1.0000	10.0000	6.3065	#DIV/0!	1.00
Confidence Level Question										6.3065		1.0000																			AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	1.0402	0.9798	0.9718	0.9816	0.9785	1.5450	0.9865	0.9718	0.9792	0.9807	0.9788	1.0428	1.1771	0.9809	0.9798	1.6551	0.9854	0.9790	1.1970	0.9803	0.9795	0.9785	0.9812	0.9825	1.5813	0.9718	0.9806	1.3234	0.9804	0.9699	1.07166064	0.9973	1.00
Speed Std Dev	0.2225	0.1443	0.1656	0.1458	0.1476	0.5668	0.1698	0.1668	0.1429	0.1412	0.1452	0.2913	0.4565	0.1420	0.1447	0.5453	0.1237	0.1439	0.4630	0.1464	0.1427	0.1525	0.1419	0.1437	0.5618	0.1686	0.1416	0.5759	0.1414	0.1734	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0015	0.9917	0.9922	1.0040	1.0035	1.0072	0.9887	0.9987	0.9807	1.0060	1.0036	1.0167	0.9951	0.9958	1.0020	1.7158	0.9993	1.0057	1.0128	0.9902	0.9992	1.0034	1.0038	1.0024	0.9916	0.9888	1.0018	1.0075	0.9974	1.0099	1.1841	0.9789	1.04
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.3356	0.1468	0.21

Environment 5 - Hit 1

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	1	0	1	3	2	3	5	4	5	7	6	7	9	8	9	11	10	11	13	14	13	15	16	15	17	18	17	19	20	19	AR Correct	Standard Correct	Silhouette Correct
Standard Collision ID		Correct			Correct			Correct			Incorrect			Correct			Correct			Incorrect			Correct			Incorrect			Correct		100.00%	70.00%	80.00%
AR Collision ID	Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Correct			Correct			Correct			Incorrect			Correct			Correct			Correct			Correct			Incorrect			Correct	11.07	6.54	5.88
Standard Distance		11.5379			6.8999			8.8881			0.0000			9.8600			8.8549			0.0000			6.2719			0.0000			13.0588		AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance	10.6669			6.4845			9.8270			6.0707			8.8725			7.0576			4.4660			44.4719			5.4678			7.3425			6.52	7.48	7.88
Silhouette Distance			7.7894			6.7118			4.7593			0.0000			3.6895			5.8524			15.8949			9.7301			0.0000			4.3420	AR Confidence Q-B	Standard Confidence Q-B	Silhouette Confidence Q-B
Confidence Level Question	1.4912	9.5255	7.7306	6.3751	7.1754	7.1084	6.7297	7.0467	10.0000	10.0000			7.7385	9.4614	9.1100	1.8428	5.0163	9.8349	10.0000		7.1376	5.4662	8.7771	6.5006	10.0000			5.5181	5.3716	5.6026	#DIV/0!	7.1575	4.84
Confidence Level Question											10.0000	1.0000								6.4429						5.0296	8.6897				AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9867	0.9775	0.9764	1.2423	0.9808	0.9796	0.9768	0.9814	0.9796	1.5416	0.9810	0.9806	0.9799	0.9780	0.9796	0.9801	0.9804	1.3170	0.9789	0.9810	0.9797	0.9605	0.9798	1.0427	1.3176	0.9819	0.9824	0.9805	0.9860	1.5144	1.01588197	0.9984	1.00
Speed Std Dev	0.1191	0.1505	0.1573	0.4759	0.1440	0.1405	0.1557	0.1444	0.1441	0.5490	0.1426	0.1414	0.1388	0.1467	0.1456	0.1403	0.1435	0.4571	0.1468	0.1413	0.1425	0.1897	0.1445	0.2434	0.5386	0.1411	0.1425	0.1469	0.1203	0.6075	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0021	0.9826	0.9890	1.2916	0.9954	0.9920	0.9970	1.0065	1.0032	1.0842	0.9886	1.0007	0.9883	1.0050	1.0100	0.9958	1.0026	1.0270	1.0127	0.9908	0.9853	0.8692	1.0082	0.9963	0.9393	1.0096	1.0047	0.9983	0.9944	0.9797	1.0936	0.9808	1.07
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.2632	0.1419	0.23

Environment 5 - Danger

	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR	Standard	Silhouette	AR Stats (Avg)	Standard Stats (Avg)	Silhouette Stats (Avg)
Subject	0	1	0	2	3	2	4	5	4	6	7	6	8	9	8	10	11	10	14	13	14	16	15	16	18	17	18	20	19	20	AR Correct	Standard Correct	Silhouette Correct
Standard Collision ID		Correct			Incorrect			Correct			Correct			Incorrect			Correct			Correct			Correct			Incorrect			Correct		50.00%	70.00%	50.00%
AR Collision ID	Correct			Correct			Incorrect			Incorrect			Incorrect			Correct			Incorrect			Correct			Incorrect			Correct			AR Distance	Standard Distance	Silhouette Distance
Silhouette Collision ID			Incorrect			Correct			Correct			Incorrect			Correct			Incorrect			Incorrect			Correct			Incorrect			Correct			
Standard Distance																															AR Confidence Q-A	Standard Confidence Q-A	Silhouette Confidence Q-A
AR Distance																																	
Silhouette Distance																															AR Confidence Q-C	Standard Confidence Q-C	Silhouette Confidence Q-C
Confidence Level Question			6.5535		4.4007		7.6715			5.6120		1.0000	8.2293	5.8444				4.3238	6.3473		7.2594				5.3400	7.39775	5.5242				6.7899	7.4577	5.86
Confidence Level Question	9.2878	8.7316		7.6768		3.2297		9.3212	4.7387		1.0000				9.5958	1.6140	7.9413			10.0000		6.1162	6.3561	4.5930				9.2548	8.8537	7.1317	AR Last Known Speed	Standard Last Known Speed	Silhouette Last Known Speed
Speed Avg	0.9873	0.9878	0.9810	1.3445	0.9957	0.9871	0.9813	1.1161	0.9855	1.0125	1.5596	0.9818	0.9820	0.9814	0.9864	0.9861	1.2379	1.5804	0.9821	0.9855	1.0670	1.1106	1.0663	0.9856	0.9824	1.1550	1.5497	0.9861	1.4297	1.1654	1.08016621	1.4157	1.12
Speed Std Dev	0.1172	0.1155	0.1401	0.4899	0.1834	0.1182	0.1403	0.3685	0.1191	0.1570	0.5207	0.1390	0.1374	0.1417	0.1185	0.1179	0.3413	0.6382	0.1426	0.1189	0.2524	0.3515	0.2059	0.1182	0.1368	0.4149	0.6343	0.1188	0.5656	0.4368	AR Speed	Standard Speed	Silhouette Speed
Last Known Speed	1.0059	1.0055	0.9908	0.8245	1.0036	0.9926	0.9977	1.9376	0.9954	1.0106	1.9881	0.9983	0.9931	1.0035	1.0118	0.9873	1.7180	1.0134	0.9909	0.9922	0.9842	2.0070	1.5461	0.9895	0.9963	0.9934	1.0790	0.9888	1.9693	2.1611	1.0355	1.1515	1.13
																															AR Speed Deviation	Standard Speed Deviation	Silhouette Speed Deviation
																															0.1908	0.2976	0.27

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APPENDIX O. COGNITIVE PROCESSING SPEED RESULTS

			Age Group 18-24			
Subject ID	**Gender**	**Age**	**Education Level**	**Test A Duration**		**Test B Duration**
3	M	20	1-12	44.630097		61.2097081
4	M	21	1-12	19.0098291		53.5801581
11	M	22	1-12	47.5801102		76.8799985
14	M	22	1-12	48.1398847		100.360088
16	M	22	1-12	20.0003827		68.9698374
6	M	23	1-12	40.6645806		53.8398875
10	M	23	1-12	25.6096188		56.2796189
19	M	23	1-12	27.8052017		63.4201259
2	M	24	1-12	30.7296368		40.5401495
			Mean Test A	33.79659351	**Mean Test B**	63.89773021
			Expected Mean Test A	22.93	**Expected Mean Test A**	48.97
			Std Dev Test A	11.62735335	**Std Dev Test B**	17.11157268
			Expected Std Dev Test A	6.87	**Expected Std Dev Test B**	12.69
			Age Group 25-34			
Subject ID	**Gender**	**Age**	**Education Level**	**Test A Duration**		**Test B Duration**
18	M	25	1-12	20.2996757		39.569379
5	M	26	1-12	27.1398515		37.844389
13	M	26	1-12	16.0947006		35.784652
17	M	26	1-12	22.2899812		57.7100066
7	M	27	1-12	29.9247481		52.4099834
1	M	28	1-12	23.9202041		41.1198552
9	M	28	1-12	38.5349199		63.1595264
15	M	28	1-12	24.5403145		176.826997
20	F	31	1-12	16.5396913		33.6797864
			Mean Test A	24.36489854	**Mean Test B**	59.78939722
			Expected Mean Test A	24.4	**Expected Mean Test A**	50.68
			Std Dev Test A	6.982940653	**Std Dev Test B**	45.08999479
			Expected Std Dev Test A	8.71	**Expected Std Dev Test B**	12.36
			Age Group 35-44			
Subject ID	**Gender**	**Age**	**Education Level**	**Test A Duration**		**Test B Duration**
8	M	36	1-12	23.359625		43.6600974
0	M	39	1-12	29.4198642		52.2800102
			Mean Test A	26.3897446	**Mean Test B**	47.9700538
			Expected Mean Test A	24.4	**Expected Mean Test A**	50.68
			Std Dev Test A	4.285236234	**Std Dev Test B**	6.095198794
			Expected Std Dev Test A	10.09	**Expected Std Dev Test B**	16.41

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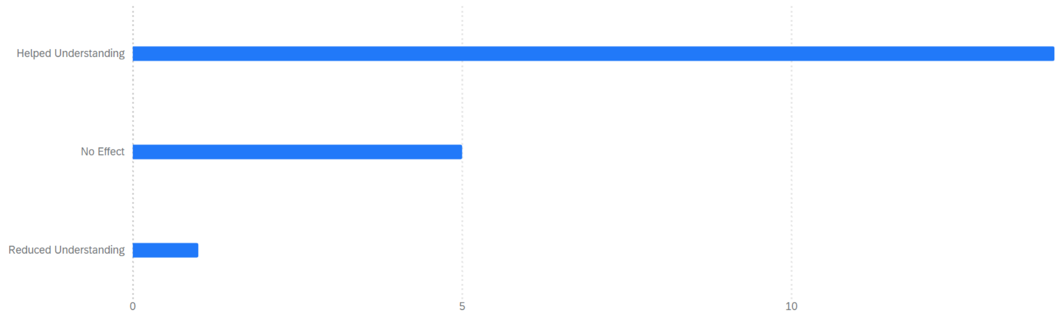
APPENDIX P. POST-EXPERIMENT QUESTIONNAIRE RESULTS

On a scale of 1 to 10 (10 being the most difficult), rate the difficulty utilizing the AR system: 18

On a scale of 1 to 10 (10 being the most difficult), rate the difficulty ut...	Average	Minimum	Maximum	Count
Difficulty	1.67	0.00	5.00	18

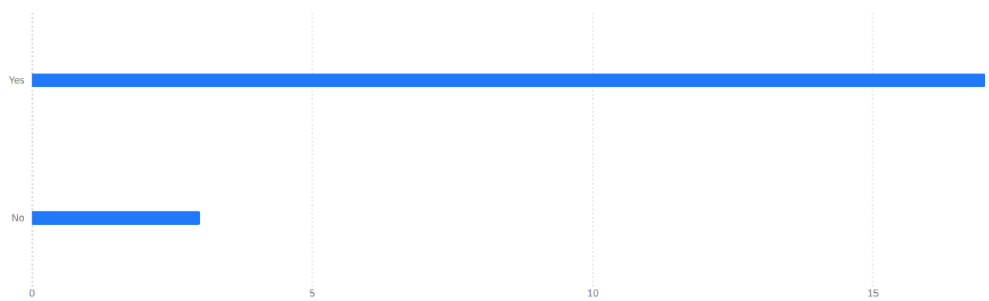
What impact did the AR display have on your ability to understand the location of the aircraft in reference to other objects (i.e., aircraft, boxes, sup... 20



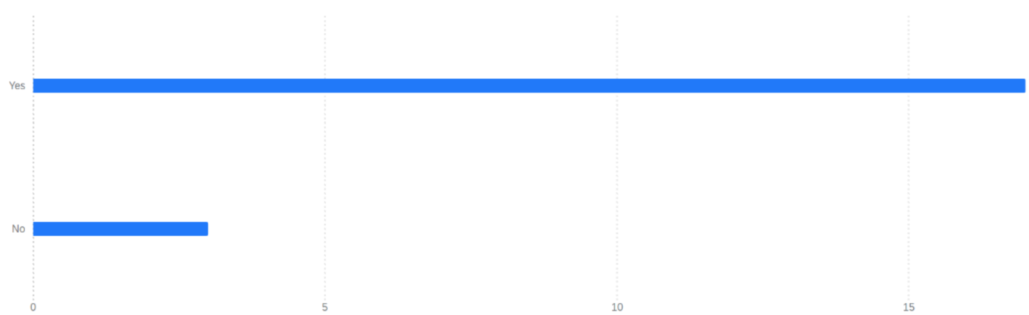
On a scale of 1 to 10 (10 being the most confident), rate your confidence in towing with the AR system? 20

On a scale of 1 to 10 (10 being the most confident), rate your confidence i...	Average	Minimum	Maximum	Count
Confidence	7.40	4.00	10.00	20

If an AR system was fielded to the fleet and utilized for towing aircraft, do you think the number of towing-related incidents would decrease? 20



Do you think a similar AR system should be incorperated into the towing process across the fleet? 20



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