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TX18: Cognitive Workload and Fatigue Study

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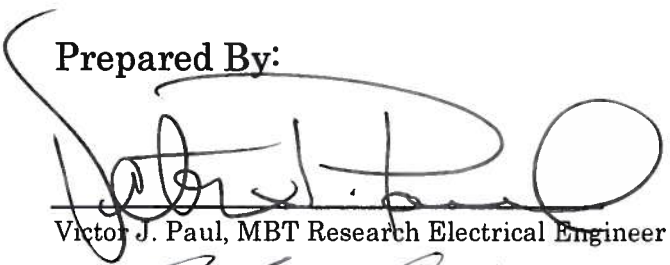
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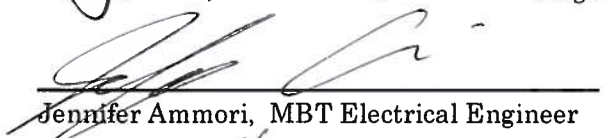
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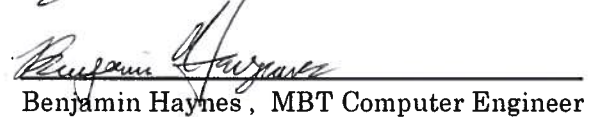
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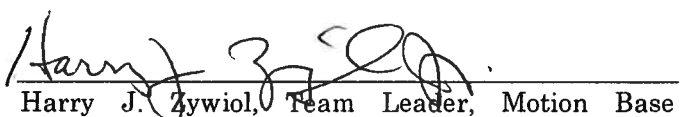
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Abstract

This project was conducted as a joint effort between the U.S. Army TARDEC's Ground Vehicle Simulation Laboratory (GVSL), The Army Research Laboratory-Human Research and Engineering Directorate (ARL-HRED), Joint Program Office – Mine Resistant, Ambush Protected Vehicles (JPO-MRAP), and DCS Corporation. The experiment was conducted on the TARDEC's Ride Motion Simulator in which 14 Marine Corps NCOs completed both cognitive workload and fatigue tasks. The objective of this study is to try to attempt to objectively measure and predict vehicle crew member cognitive load and fatigue using physiological measures such as electroencephalography (EEG) and eye-tracking. This report addresses the design, setup and execution of the study. Analysis of the cognitive loading and fatigue data is currently ongoing by JPO-MRAP and ARL-HRED and not presented here.

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INTRODUCTION

In the fall of 2011, JPO-MRAP Human Systems Integration and TARDEC simulation engineers held discussions to determine how experimental methods using motion base simulators can help quantify, in general, if cognitive load (measured via EEG) leads to performance decrements in critical crewmember tasks such as rollover avoidance or Improvised Explosive Device (IED) detection. A joint study (TARDEC, ARL-HRED, JPO-MRAP) was conducted by TARDEC's Motion Base Technologies (MBT) team, part of the Concepts, Analysis, System Simulation & Integration (CASSI) Hardware & Man-in-the-loop Simulation (HMS) group, using the Ride Motion Base Simulator (RMS), located in TARDEC's Ground Vehicle Simulation Laboratory (GVSL) in building 215. The study was conducted between 15 May and 14 June 2012. Fourteen Marines with combat experience in Afghanistan from Camp Lejeune, North Carolina, volunteered to support testing.

Initially, TARDEC was tasked to address the needs of the JPO-MRAP program. Concurrently, TARDEC engineers were beginning to prepare for a study with ARL-HRED to look at fatigue prediction using objective physiological measures such as EEG and eye-tracking. Because of the similarities in the types of physiological measures that were going to be recorded for both studies, TARDEC recommended to JPO-MRAP that they leverage the up-coming fatigue study and conduct both the cognitive loading and fatigue tests concurrently. JPO-MRAP concurred with TARDEC's recommendation and decided that because of their budget and time constraints, they would proceed with this study as a proof of concept to pave the way for future research. Because of this decision, JPO-MRAP further decided to focus on if researchers could indeed measure and detect cognitive loading experimentally during a simulated operational scenario while under motion. Because now the objectives of the study were not vehicle specific, TARDEC and JPO-MRAP researchers decided to utilize the planned RMS cab configuration and vehicle dynamics model.

EXPERIMENT SETUP

SIMULATOR DESCRIPTION

The RMS (Figure 1) is the smaller of the GVSL's 6-Degree-of-Freedom (6-DOF) simulators. It is a high-performance, single occupant motion base simulator designed to recreate the "ride" military ground vehicles. It is comprised of a platform mounted on a hexapod design that produces motions in the longitudinal, lateral, vertical, roll, pitch, and yaw directions.



Figure 1: TARDEC's Ride Motion Simulator (RMS)

The RMS has a much higher frequency bandwidth than most traditional driving simulators (40Hz) enabling it to recreate the high-frequency vibration often found in military vehicles traversing rough, cross-country terrains (1). The motion base provides a simulation capability in which soldiers can virtually operate their vehicles in relevant combat scenarios.

Translational Motion <i>(vert, lat, long)</i>	
Displacement	± 20 in
Velocity	± 50 in/s
Acceleration	± 2 g
<i>(Max independent transient)</i>	
Rotational Motion <i>(roll, pitch, yaw)</i>	
Displacement	± 20 deg
Velocity	± 70 deg/s
Acceleration	± 1150 deg/s ²
Max Payload	1600 lbs
Max. Frequency Bandwidth <i>(3 dB Frequency)</i>	40 Hz

Table 1: RMS Performance Specifications

For this study, the RMS was equipped with crew displays and driving controls for a manned simulation complete with computer-generated scenery, and audio/visual cueing. The simulator has the capability to collect performance data and is safety certified to permit use by soldiers and experimenters in accordance with the AR 70-25.

The study was conducted by simulating a notional 8x8 wheeled, combat vehicle operating in two vastly different terrains. For the cognitive loading portion of the experiment, the vehicle operated in varied terrain conditions ranging from a mild cross country, moderately rough mountainous climb, to a very rough mountainous climb. In the fatigue portion of the experiment, the vehicle operated in on-road conditions with no changes of elevation. In both operating conditions, the maximum accelerations did not exceed 2 g's (g = the acceleration due to gravity, 9.8 meters/second²) and simulator motion was contained within its normal operating envelope (± 20 inches in the translational directions and ± 20 degrees in the angular directions). The simulator's safety interlock system was set to ensure that the ride motion did not exceed these position or acceleration levels. The simulator receives its motion commands through a SCRAMNet+® reflective memory network. The hexapod receives position, velocity and acceleration commands from the real-time, distributed vehicle simulation system that was created using SimCreator® simulation software. A complete description of the vehicle simulation system and all of its components can be found beginning on page 10 in the section entitled "Simulation Environment".

CAB SETUP

The RMS cab was configured as a driver's station for a notional indirect vision, drive-by-wire, 8x8 wheeled combat vehicle. The driver's station consisted of a seat (Figure 2), two 17", 1920x1200 pixel displays, one for displaying the simulated environment (40° Horizontal Field of View) and one to display a tactical map (Figure 3), a yoke for vehicle steering and a pedal set for vehicle throttle and brake (Figure 4).



Figure 2: RMS Seat

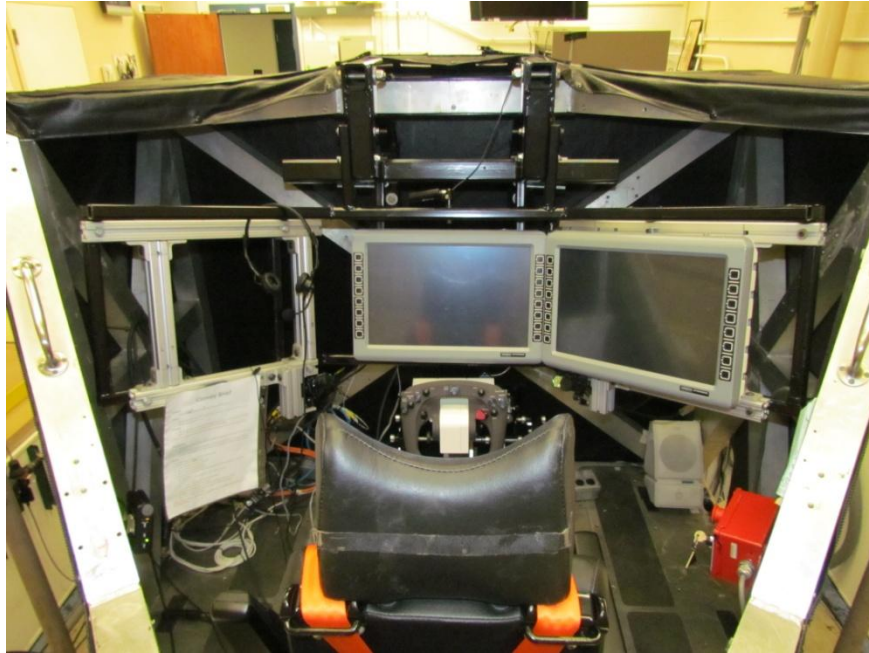


Figure 3: RMS Cab Set Up



Figure 4: Steering Yoke and driving pedals

The cab was equipped with a communication and audio cueing system. The communication system was comprised of a Telex® intercom that was used to simulate the vehicle radio for the occupant to communicate to his convoy and to respond to other radio communications. This intercom system allowed researchers to communicate with the occupant. The audio cueing system comprised of two stereo speakers and a subwoofer in order to present the participant with the engine sound of their vehicle and other external vehicle sounds. In addition, two cameras were mounted to the left and right of the center screen (Figure 5) to record eye tracking data. The cab is equipped with a Crew Interlock box which is tied into the simulator's safety interlock system (Figure 2). The box contains the "Motion Consent" key switch and an

“Emergency Stop”, plunger style button. Operational instructions of the safety devices are reviewed with each participant prior to running the experiment.

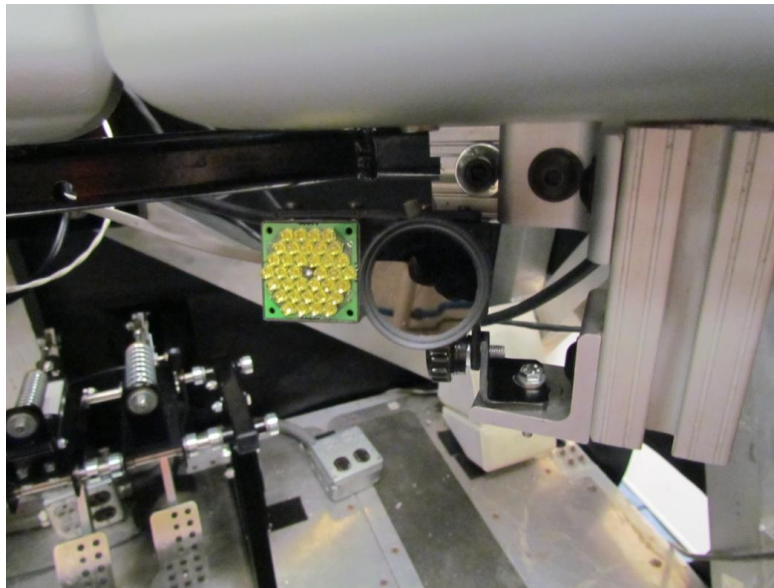


Figure 5: Eye Tracking Camera with Infrared Illumination Pod

SIMULATION ENVIRONMENT

The simulation environment consisted of multiple software packages integrated together to form a cohesive, seamless environment that consisted of vehicle dynamics, image generation, motion cueing, audio cueing, Semi-Automated Forces (SAF) generation and data collection. While a core part of the simulation was the same for each study task, there were differences that should be noted. This section will detail these simulation elements for each study task in addition to both simulated terrains.

Cognitive Loading Task

The cognitive loading task was created to produce an immersive environment in which the participants would perform a simulated convoy mission. As the mission progressed, participants were presented with increasingly difficult sections of cognitive tasks, which increased the cumulative cognitive workload as the scenario progressed. There were a variety of tasks which were considered in the comprehensive workload rating. These tasks included communications to and from the driver by headquarters, other vehicles in the convoy and other crew members in the driver's vehicle, IED threats scattered along the convoy route, with varying degrees of actual IED likelihood, Oncoming civilian traffic, maintain proper lead distance from other vehicles in the convoy, navigating the convoy route while referencing a Blue Force Tracking (BFT) device, identifying indicators of insurgency near or around native civilian populations, and reacting to IED events, and small arms ambush situations. A table containing the event types and EEG

codes related to them can be found below (Table 2: Cognitive Loading Task EEG Trigger Codes). A diagram depicting all of the simulation processes for the cognitive loading task can be found in Figure 6. Each of these processes is further detailed here.

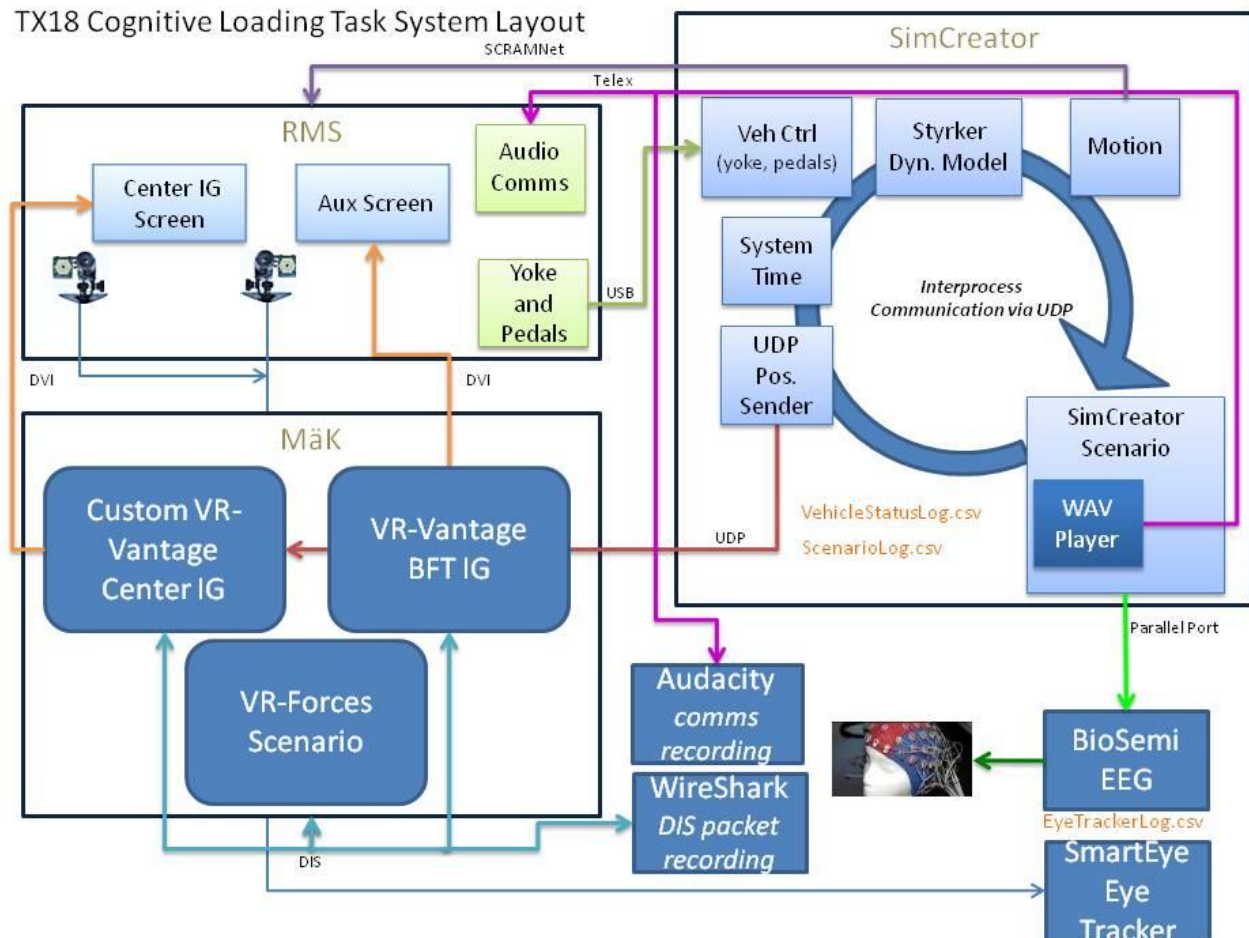


Figure 6: Process Communication Layout for Cognitive Loading Task

SimCreator®

SimCreator is a Commercial off-the-shelf (COTS) software package that was used to model several of the simulation processes. It is a graphical modeling environment that allows users to “wire-up” components to create models of systems and run them in real-time either locally or distributed across different machines located on a network. Users can choose from a number of predefined components or create their own components in order to create their model. For this study, the SimCreator simulation was broken up into several distributed blocks: Vehicle Dynamics, Scenario, Motion Cueing, Vehicle Controls, System Time and a User Datagram Protocol (UDP) Position Sender.

Vehicle Dynamics

The General Vehicle Dynamics System (GVDS) component of SimCreator® allows for easy creation of high fidelity, real-time vehicle dynamics models by providing a core dynamics engine.

This notional vehicle is based on the Stryker Infantry Carrier Vehicle (ICV). The real-time dynamics model is a somewhat generic 8x8 model with Stryker ICV characteristics. During model construction, some actual Stryker data were gathered and incorporated into the model. The model construction was completed for a previous program, and was a joint effort between Real-time Technologies Inc. (RTI) and TARDEC. JPO MRAP and TARDEC determined that this model would be effective and decided to leverage the previous development effort for the purposes of this study.



Figure 7: Stryker Infantry Carrier Vehicle

The ICV is modeled as nine separate rigid bodies and a power-train component. The rigid bodies consist of a primary “hull” body and eight wheel station bodies. The hull body represents the mass and inertia properties of the ICV while each wheel station models the suspension, tire and damping data. Steering is achieved by a look-up table for each steerable wheel station (front four) that were derived by exercising a high-resolution, non-real-time multi-body dynamics model of the same vehicle. The power train is built from several predefined power train components from within SimCreator®. It requires several inputs from the upper level of the model (individual wheel torques, acceleration pedal position, brake pedal force, and gear selection). With these inputs, the power train is able to return engine torque, engine speed, and wheel velocity back to its parent components (2).

The real-time vehicle dynamics model runs at a rate of 1 KHz on a custom Intel® Core™ 2 Q9450, 4GB DDR2 RAM workstation. The model receives acceleration, brake and steer

commands from the operator controls located on the RMS. The dynamics model in turn provides its position on the database (x, y and z), its orientation (heading, pitch and roll), its global body accelerations (all 6-DOF), vehicle speed, engine RPM and steer torque back to various processes within the simulation.

Scenario

There were two distinct scenario sub-systems that ran during the Cognitive Loading task; one within VT MäK's VR-Forces and one within SimCreator®. The latter is described here.

The SimCreator scenario was developed and executed with SimVista™, which is an add-on package to SimCreator®. SimVista™ is RTI's tile-based scene and scenario authoring system that allows users to drop in visual and control objects into a scene and control them via custom JavaScript files. In addition, it allows customization of visual and dynamics databases by defining roadways that can be used to calculate measures of driving performance (3).

The SimCreator scenario for the Cognitive Loading task was designed to accomplish three main functions; Measure driving performance of the participant vehicle; Mark, record and send codes to the EEG recording system to synchronize brain state data with simulation events; Send communication queries to the participant vehicle at pre-determined locations along the convoy route.

Motion Cueing

The motion cueing process handled all of the signals that were sent to the motion base. Vehicle state information (vehicle position, velocity and acceleration) was sent to motion cueing system which attempts, via RTI's OverTilt® component, to recreate the inertial feel of vehicle within the physical limitations of the motion base. These signals were communicated to the motion base via a SCRAMNet+® reflective memory network.

Vehicle Controls

The Vehicle Control process read the control devices (yoke, throttle and brake) via Universal Serial Bus (USB). This process then normalized the input (-1 to 1 for the yoke, 0 to 1 for the throttle and brake) and transmitted the inputs to the Stryker Dynamics and SimCreator Scenario processes. In addition, button pushes were transmitted from the yoke that represented the participant "keying" the radio while communicating.

System Time

The system time process took the current time on the system, formatted it and transmitted it to all of the other processes. This ensured that a synchronized time value was available to all processes. In addition, all computer clocks were synchronized using the Network Time Protocol.

UDP Position Sender

The UDP Position Sender process took vehicle state information and reformatted it into a UDP data packet and transmitted that information to the Custom VR-Vantage Center Image Generator (IG) process for visual rendering to the participant.

VRForces Scenario

The SAF engine for the cognitive loading scenario was VT MÄK's VRForces suite of software. The VRForces Scenario was linked to the Image Generators using the Distributed Interactive Simulation (DIS) protocol (IEEE Standard 1278), which advertised entity and vehicle locations to the Custom VR-Vantage Center Image Generator and the VR-Vantage Blue Force Tracker Image Generator. The DIS protocol used protocol data units (PDUs) to broadcast entity information, detonation and fire. VRForces provided Artificial Intelligence (AI) control of the various entities involved in the cognitive loading scenario.

Various events were introduced to the virtual simulation environment through scripting and live interaction with the VRForces SAF software. IED threats were predominately static, consisting of various representations of objects including trash bags, cardboard boxes, pallets, discarded tires and artillery shells. The individual configurations of IED threats varied, and ones which were deemed to be likely to contain IED's were marked at IED



Figure 8: Example of simulated IED threat

threats. Traffic was represented by 3D polygonal models of various civilian vehicles commonly found in the middle east; The vehicles included a 4 door sedan, a pickup truck, and a common mode of transport know as a "Jingle Truck", a bus that has been adorned with various colors and objects. These civilian vehicles traversed the road in the opposite direction of the participant vehicle, and either pulled off the road and stopped, or simply deviated from the road in order to allow the convoy to pass. The convoy was composed of the participant lead vehicle, followed by 4 computer controlled, researcher guided Stryker vehicles. The other members of the convoy were capable of communication over the Telex communication System. These vehicles were displayed on the participant BFT. This allowed the participant to monitor the status of the convoy, maintain adequate spacing and report back to the Forward Operating Base (FOB) on any issues that arose. Communications with the participant were based upon a script created by the Marine Subject Matter Expert (SME) before the experiment, but were read by investigators during the runs.

The Marine SME and TARDEC co-developed the cognitive loading scenario, drawing on previous military relevant operational experience. Utilizing this, events, force compositions, geographical locations and details of the scenarios were created and verified through collaboration between the SME and TARDEC. Using an iterative approach, the scenario contents were subjected to

multiple redesigns to ensure an appropriate level of fidelity was presented to the participants of the study.



Figure 9: Example of IED threat with artillery shell

The AI controlled entities were guided by a path algorithm called B-HAVE (Brains for Human Activities in Virtual Environments), developed and integrated in MAK's VRForces software. It was given an area around the village of Jalez to calculate polygon based path data. This allowed the AI-controlled entities freedom of movement while avoiding features, including buildings, vehicles, and vegetation. The computer controlled units followed a predefined route from the FOB through each checkpoint and ending in the village of Jalez. Each vehicles speed and status was controlled by researchers, to allow for variations by the participant. Events external to the convoy were controlled by scripts for each individual unit. Various groups of civilians populated the terrain, consisting primarily of nomadic shepherds with flocks of sheep, groups of walking pedestrians and wandering animals.

In addition to neutral forces occupying the virtual landscape, two ambushes occurred along the convoy route. These ambushes consisted of hostile insurgent forces utilizing small arms against the convoy vehicles. The ambush locations were determined by terrain features, and validated by the JPO SME. The first ambush occurred directly north of Check Point (CP) Spartan; during this ambush event 6 armed insurgents advanced from behind a small hill, and engaged the convoy when it came into range. The second ambush event happened a short time before the convoy reaches CP Fobbit; four armed insurgents opened with small arms fire from the top of a southern ridge. While the blue forces reacted to this attack a Vehicle based IED drove in front of the participant vehicle and detonated.

All of the events that had active or mobile components were triggered in the scenario by the proximity of the participant vehicle to an arbitrary trigger or phase line. These lines were set at a distance from the event which allowed the participant to view and react to the event before passing it and provided a consistent presentation of cognitive events for each individual run.



Figure 10: IED explosion along route

Custom VR-Vantage Center Image Generator

VRVantage was utilized as the IG for this experiment. The application was coded to receive direct input of the vehicle state, position and orientation from the vehicle model running on a separate machine, in order to use that information to set a proper eye point in the database for display on the RMS cab's center screen (see Figure 3: RMS Cab Set Up). This information was refreshed at a rate of 60Hz, and transmitted to the Custom VR-Vantage Center Image Generator through UDP packets from the SimCreator dynamics model. The Custom VR-Vantage Center Image Generator also used the vehicle position information to broadcast the position of the participant vehicle to the other simulation processes in the lab, over the DIS protocol. The visual database used is derived from the Jalez geotypical terrain. In addition to terrain elevation data, the visual database contains models for the various villages and towns required by the scenario. Trees and shrubbery were added in a random distribution, bounded by areas determined to be forested or containing vegetation. The vehicle and life form models were a combination of models provided with MAK's VR software suite and custom models from TARDEC.

VR-Vantage Blue Force Tracker Image Generator

A virtual BFT was displayed on the cab's right-hand screen (see Figure 3: RMS Cab Set Up) and was designed to provide the participants with navigation cues. The Plan View Display mode of VRVantage was used to simulate the BFT. This view displayed the blue force convoy vehicles, as well as information about each checkpoint and the designated route. This BFT was updated in real time, based on the actions and events within the scenario, using broadcast information received over the DIS protocol. It also displayed damage states of all friendly forces. Hostile

areas that the participant designated as areas of potential interest for route clearance teams were also marked on the map as they were called out.

Terrain Database

The database consisted of a mountainous region that is geotypical of Jalez, Afghanistan (Latitude: 34° 28' 23.16" (34.4731), Longitude: 68° 38' 35.88" (68.6433), UTM 42S). Within this area, the customer defined Regions Of Interest (ROIs). These ROIs included roads through mountains, with four different town areas for engagements, while one of those towns bordered a mountain area.

The Jalez database was generated from elevation data acquired from the NASA Endeavor Shuttle Radar Topography Mission. The data was collected at a 90 meter resolution. A database developer/artist created the first cut of the Jalez Database for the MBT using Autodesk® Maya® software (*.obj), and converted the database to OpenFlight for delivery to the MBT team. Global textures were provided by the government. High resolution insets were used in all ROIs.



Figure 11: Full Extents of Jalez, Afghanistan Database OpenFlight Rendering

The final database required the roads to be corrected, not only in size and shape, but also in slope. There were many areas that the dynamics model was unable to climb and/or the motion base system was exceeding limits. For that reason, areas had to be adjusted to accommodate the mission requirements. The dynamics model was also modified to increase lateral grip on the tires to allow for more realistic motion on side sloping roads.

After the initial terrain database was generated and verified by the subject matter expert, the database was branched into two distinct versions: visual and terrain dynamics. The visual database was used to provide the out-the-window views to the participants of the experiment, while the dynamics database provided the terrain heights and features to the physics based vehicle modeling software. Vegetation and shrubbery was added to the visual version of the database based on global satellite and areal imagery. High resolution detail textures were laid over roads and dirt areas to improve on visual quality from an on-the-ground perspective. In addition to these small details, a small village was added along the planned convoy's route. This village was built from a combination of other polygonal models already contained within the database. The town was labeled as "Merz".



Figure 12: View of Merz town

Data Collection

Electroencephalography (EEG)

Continuous EEG data, which reflects the summed electrical activity of groups of neurons primarily in the cortex, was acquired using a 24-bit, 72-channel ActiveTwo amplifier and ActiView software (BioSemi, Amsterdam, Netherlands). All EEG recording sites were prepared in accordance with the standardized international 10-20 electrode placement system (4). EEG was recorded using an electrode cap (BioSemi Active Headcap™) with pre-amplified surface electrodes, as in several previous ARL-conducted studies (5) (6). A water-soluble electrode gel (Signa Gel; Parker Laboratories, Inc.; Fairfield, NJ) was inserted into each of the electrode casings to facilitate conductivity between the scalp and electrode surfaces. Event synchronization was accomplished by sending a code, in the form of an integer, from the Scenario

computer's parallel port to the ActiveTwo amplifier via its external trigger lines. Because the parallel port is limited to sending only 8 bits at one time, the EEG code was limited to an integer number between 0 and 255. All events were given a distinct code and all codes were summed together before they were sent through the parallel port to the EEG amplifier. Each code that was assigned to an event type was designed to allow recognition of multiple simultaneous event types. Table 2: Cognitive Loading Task EEG Trigger Codes represents the Cognitive Loading task scenario events and their corresponding EEG trigger codes.

Event	EEG Code
Ones: Communications	
Participant holding comm. Tx button	2
Triggered prerecorded comm. playing	5
Both events	7
Tens: People, IEDs and Vehicles	
Insurgent small arms ambush	10
People threat, not armed	20
People, no threat	30
IED threat of trash/debris, IED/artillery shell present	40
IED threat of trash/debris, no actual IED	50
IED threat-Dead animal, IED/artillery shell present	60
IED threat-Dead animal, no actual IED	70
AI controlled vehicle, VBIED present	80
AI controlled vehicle, civilian	90
Hundreds: Checkpoints	
Checkpoint Reached	100
Mission start	255

Table 2: Cognitive Loading Task EEG Trigger Codes

Eye Tracking

Eye and head movement behavior was measured and recorded using a Smart Eye Pro system (Smart Eye AB, Göteborg, Sweden). Smart Eye is a camera-based tracking system that allows completely non-contact operation, allowing for observation of the natural participant eye and head movement behavior at adequate spatial resolution ($\sim 0.5^\circ$). Eye and head movements, along with measurement reliability data, was logged in real time and synchronized with the other data measures. No video record was captured by this data collection system.

Simulation Data

Several simulation data were recorded during the task to record the state data of the simulated vehicle and the driving performance of the participant. Table 3 and Table 4 depict those data. In addition to the simulation based data that was recorded, all of the scenario's DIS PDU traffic that represented fire events was recorded using a COTS network monitoring program. Because each PDU was time-stamped, this data provided data analysts with the precise time that IED detonations or small arms fire events occurred.

Dynamics Log		
<i>Collection Channel</i>	<i>Units</i>	<i>Description</i>
SystemTimeHours	Hr	Value of Hours field from the designated system time
SystemTimeMinutes	Min	Value of Minutes field from the designated system time
SystemTimeSeconds	Sec	Value of Seconds field from the designated system time
SystemTimeMilliseconds	mSec	Value of Miliseconds field from the designated system time
Odometer	Km	Distance traveled
Speed	m/s	Vehicle speed
Acceleration	m/s ²	Vehicle acceleration
VehXPos	m	Vehicle X Position (VRForces Coord)
VehYPos	m	Vehicle Y Position (VRForces Coord)
VehZPos	m	Vehicle Z Position (VRForces Coord)
Roll	Deg	Vehicle Roll angle
Pitch	Deg	Vehicle Pitch angle
Heading	Deg	Vehicle heading (0° = due North)
Throttle	0 to 1	Normalized throttle input
Steer	-1 to 1	Normalized Steer input (-1 =full steer to left, +1=full steer to right)
Brake	0 to 1	Normalized Brake input.
SystemSimTime	ND	Simulation time elapsed
PertMagOut	ND	Perturbation Magnitude
LaneIntegrityStatus	ND	1= Vehicle in lane for 8 sec or more, 0=Vehicle out of lane
TTCROut	ND	Time to Contact Right
TTCLOut	ND	Time to Contact Left
LaneDeviationValue	ND	Offset distance from lane center
HeadingError	ND	Difference in heading between lane center and vehicle
RFTireTerrain	ND	Right Front Tire Terrain Type (0=Offroad, 10=Onroad, 50=FOB/Town)
MissionStartID	ND	Mission Start trigger
RRTireTerrain	ND	Right Rear Tire Terrain Type (0=Offroad, 10=Onroad, 50=FOB/Town)
LFTireTerrain	ND	Left Front Tire Terrain Type (0=Offroad, 10=Onroad, 50=FOB/Town)
LRTireTerrain	ND	Left Rear Tire Terrain Type (0=Offroad, 10=Onroad, 50=FOB/Town)

Table 3: Simulation Data - Dynamics Log

Scenario Log		
<i>Collection Channel</i>	<i>Units</i>	<i>Description</i>
SystemTimeHours	Hr	Value of Hours field from the designated system time
SystemTimeMinutes	Min	Value of Minutes field from the designated system time
SystemTimeSeconds	Sec	Value of Seconds field from the designated system time
SystemTimeMilliseconds	mSec	Value of Miliseconds field from the designated system time
Speed	m/s	Vehicle speed
Acceleration	m/s ²	Vehicle acceleration
VehXPos	m	Vehicle X Position (VRForces Coordinates)
VehYPos	m	Vehicle Y Position (VRForces Coordinates)
Heading	Deg	Vehicle heading (0° = due North)
PertCountOut	ND	Number of valid perturbations
PertMagOut	ND	Perturbation Magnitude
SystemSimTime	ND	Simulation time elapsed
MissionStartID	ND	Input Signal
EEGCodeOut	ND	Code that is sent to the EEG
YokeButtonOut	ND	Yoke Button Push Out (1=Pressed)
PertTypeOut	ND	Perturbation Type (0=None, 1=Lateral, 2=Longitudinal)
PertDirOut	ND	Perturbation Direction, Pos: Left/Slow, Neg: Right/Speed
LeadVehDistOut	m	Distance between lead vehicle and subject vehicle
LnOffsetOut	m	Lane Offset
HeadErrOut	rad	Heading Error Out

Table 4: Simulation Data - Scenario Log

Fatigue Task

The fatigue task built upon previous fatigue studies and, in stark contrast to the Cognitive Loading task, was developed to produce very little stimulus in order to mentally and physically fatigue the participant in order to look to see if subjective physiological measures, such as brain state or eye tracking data, can predict reductions in task effectiveness. The general notion behind the fatigue scenario was that the participants were tasked to participate in a convoy of two vehicles on a long, isolated two lane highway. During the trial, which lasted for 45 minutes, there was a primary task and a secondary task that occurred on the cab's center and right screens respectively (see Figure 3: RMS Cab Set Up). The primary task was a driving task. For this task, the participant's vehicle was the second vehicle in a two vehicle convoy and they were instructed to keep their vehicle in their lane, drive at a constant speed of 25mph and maintain a headway distance of 50 meters from the lead vehicle. The roadway was a two-lane, 8km oval with no traffic, buildings or other entities of any kind. The course was divided into 14 segments with each segment containing a proximity sensor that would send the number of the segment to the data collection system when the subject's vehicle crossed the sensor. During the trial, two types of perturbation stimulus were applied to the scenario. The first and most prevalent perturbation stimulus was a lateral force that would gently push the participant's vehicle out of his lane. This force would continue and grow until the participant recognized it and began to correct their vehicle. Once the participant re-positioned their vehicle within their lane for 8 seconds or more, then another lateral force was applied within a 0-2 second period of time. The

direction of these forces (left or right side of the vehicle) was randomized throughout the scenario. The second type of perturbation stimulus was a longitudinal perturbation. During this type of perturbation, the lead vehicle changed speed (faster or slower) causing the headway distance to change. This would continue until the participant recognized the changing headway distance and responded by either speeding up or slowing down. The participant's secondary task was a target identification task that was displayed on the right screen. In this task, two different types of visual stimulus (Figure 13), a target image and distractor image were presented to the participants every 9 to 11 seconds with presentation duration of one second. Participants were asked to respond to the target image by pressing either trigger on the steering yoke (See Figure 4: Steering Yoke and driving pedals). The distractor image was presented 85% of the time and the target image 15% of time. Each of the images was flashed at a rate of 20Hz during presentation in order to see if that display frequency showed up in the EEG data.

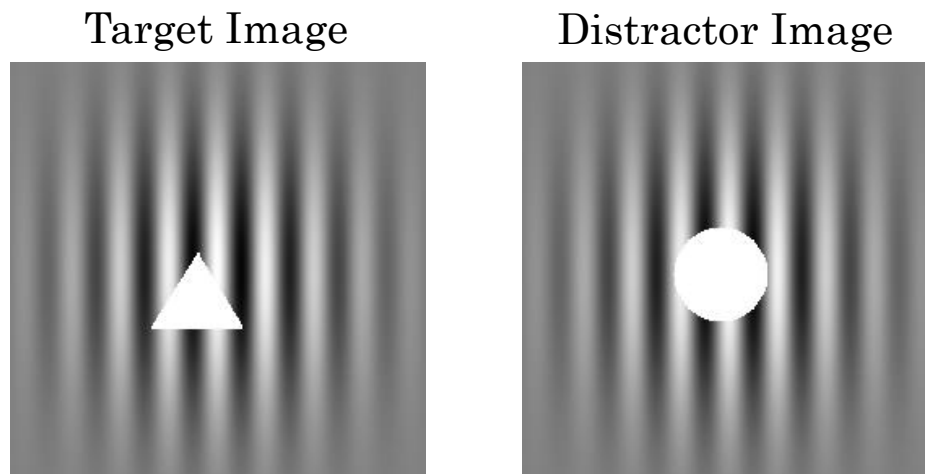


Figure 13: Fatigue Secondary Task Images

A diagram depicting all of the simulation processes for the fatigue task can be found in Figure 14. Each of these processes is further detailed here.

SimCreator®

For this study, the SimCreator® simulation was broken up into several distributed blocks: Vehicle Dynamics, Scenario and Stimulus Presentation, Motion Cueing, Center Visuals, Vehicle Controls, System Time and Stealth Visuals.

Vehicle Dynamics

The fatigue task used a vehicle dynamics process that was identical to the process of the same name in the cognitive loading task. It is detailed on page 12.

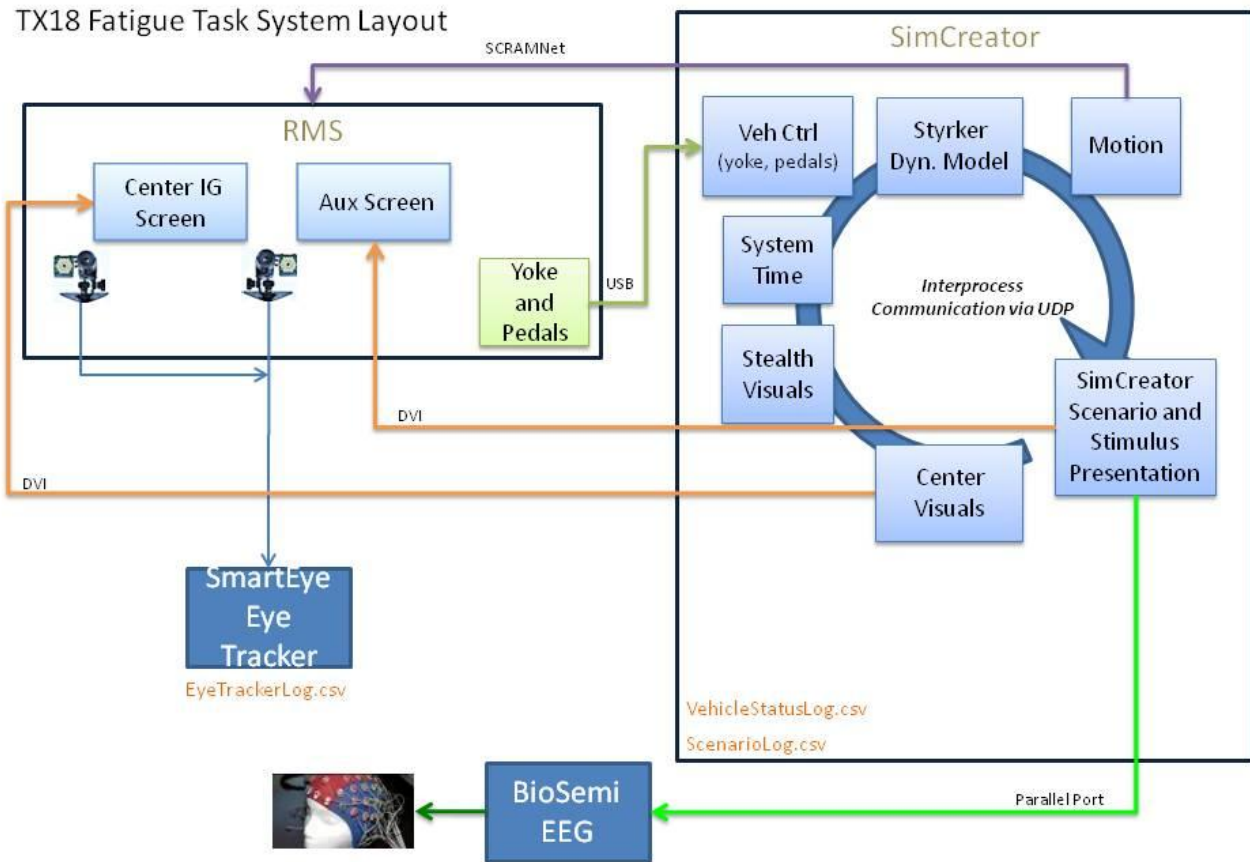


Figure 14: Process Communication Layout for Fatigue Task

Scenario and Stimulus Presentation

Unlike the Cognitive Loading task, the Fatigue task used only one scenario control process. This process was developed under SimVista™ and executed within the main simulation framework. The SimCreator® scenario controlled all aspects of the task such as lead vehicle behavior (speeding up/slowing down), lateral and longitudinal perturbations, (based on vehicle position) and presentation of the secondary task stimulus (presented on right screen of the cab. See Figure 3: RMS Cab Set Up). In addition, this process sent information on perturbation onset, button pushes and secondary task image presentation to the EEG trigger input.

Motion Cueing

The fatigue task used a motion cueing process that was identical to the process of the same name in the cognitive loading task. It is detailed on page 13.

Vehicle Controls

The fatigue task used a vehicle controls process that was almost identical to the process of the same name in the cognitive loading task. All vehicle control functions were identical to the cognitive loading task and only which yoke buttons (yoke triggers) were read for processing were changed for this task.

System Time

The fatigue task used a system time process that was identical to the process of the same name in the cognitive loading task. It is detailed on page 13.

Center Visuals

The center visuals process visually presented the participant with the simulated environment at an eye point position as if there was a camera mounted to the outside of the vehicle. It was presented on the center screen (See Figure 3: RMS Cab Set Up) and was updated with state information from the vehicle dynamics model at a 60Hz update rate.

Stealth Visuals

The stealth visuals process visually presented the experimenters with a third person view of the simulated environment. It was presented on an alternate screen that only the experimenters could see and was updated with state information from the vehicle dynamics model. This view was used to monitor the participants driving performance and the status of both lateral and longitudinal perturbations.

Terrain Database

The terrain database for the fatigue task was constructed within RTI's SimVista™ tile-based scene and scenario authoring system. The course consisted of a two lane highway configured in a 12.6km oval (Figure 13). There was a tree-line placed in the middle of the oval to give both the participants and experimenters orientation within the database. The course was divided into 14 segments with a proximity sensor placed at the beginning of each segment.

Data Collection

EEG, Eye Tracking and Simulation data for the Fatigue task was identical to that of the Cognitive loading task (Table 3 and Table 4) with the exception of the codes that were sent to the EEG collection system. Table 5 represents the Scenario events and

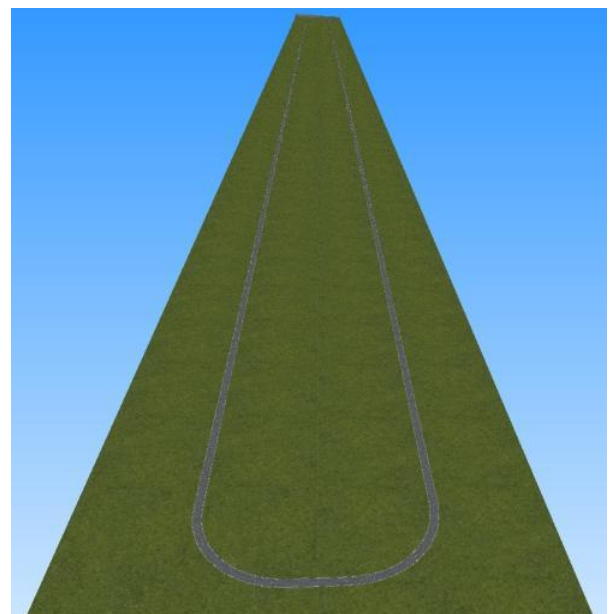


Figure 15: Fatigue Course

their corresponding EEG trigger codes for the Fatigue task.

Event	EEG Trigger
Vehicle Enters Zone	1-14
Yoke Trigger Pull	20
Distractor Image Appearance	100
Target Image Appearance	200

Table 5: EEG Trigger Codes for Fatigue Task

EXPERIMENT OPERATION

There were 14 total volunteers who participated in the experiment. The group consisted of enlisted Marines from the II Marine Expeditionary Force, located at Marine Corps Base Camp Lejeune, NC. Participant ranks ranged from Lance Corporal (E3) through Staff Sergeant (E6) each with at least 2 combat deployments to Afghanistan/Iraq (OEF/OIF). Recruitment for this study was conducted jointly by TARDEC and JPO-MRAP at Camp Lejeune in May 2012. Twenty (20) potential candidates were briefed on the purpose of the study and any questions were answered. Soldier Recruitment Lottery Ballots were then filled out stating their interest in participating in the study. Of the twenty (20) candidates, fourteen (14) were randomly selected from those willing to participate in the experiment.

Data collection was conducted from 15 May to 14 June 2012. A typical study week consisted of 3 days of data collection (1 day/participant, Tue-Thur) except for in the case of the last week of data collection (only 2 participants) or a holiday week (Memorial Day). All participants were asked to refrain from drinking caffeinated beverages on the day of data collection. All researchers who had direct contact with the subjects on the day of data collection had completed their Human Protections training which enables them to collect data on human subjects.

The daily schedule was executed as follows: All participants were provided an Experiment Introduction which explained the background of the experiment. A volunteer affidavit was handed out and briefed which the participants signed. The questionnaires listed in Table 6 were administered. Following this a safety brief was given on the RMS and initial SmartEye calibration was also done at this time. The participant then completed the training brief provided by an experimenter. The BioSemi headset was fitted onto the participant followed by SmartEye profile generation. The participant completed the following 4 forms before and after each mission 1) Simulator Sickness Questionnaire 2) Task-Induced Fatigue Scale 3) Visual-Analogue Scale for Fatigue (VAS-F) 4) Karolinska Sleepiness Scale. These questionnaires were asked before and after each mission so the simulator operator could gauge whether occupants were feeling any motion sickness. All questionnaires can be found in Appendix A: Questionnaire. The participant then received driver training on the RMS. The participant then completed the Cognitive Loading Mission. During the Cognitive Loading Mission, the Modified Cooper-Harper

Rating Scale (MCH) was completed 4 times. Lunch was provided following the completion of the Cognitive Loading Mission. Finally, the participant completed the Fatigue Mission.

Participant Questionnaire
Cognitive Failures Questionnaire
12-Item Grit Scale
LIFESPAN-F04:BFFI
LIFESPAN-F05: PANAS-X:GEN
LIFESPAN-F07:VVQ
Card Rotation Test

Table 6: Questionnaires Completed by Study Participants

During the first week of data collection, scripted audio was used during the Cognitive mission. After completing week 1, it was determined that live audio would provide a more realistic mission and was used starting week 2 and throughout the remainder of the data collection effort.

SIMULATION RESULTS

This simulation is the result of significant research efforts into this field of study, both at TARDEC and around the world. The scenarios, models and procedures used in this study were based on successful simulations, and the verification of SME's. Using previous studies as baselines, the study was crafted to look expressly at the cognitive effects of both loading and fatigue in operational environments. In order to produce operationally relevant data, the study facilitated the use of TARDEC's 6-DOF RMS platform and both a suite of simulation software and experience. The addition of a motion component introduces additional factors to the analysis of EEG data. These artifacts are detrimental to the clarity to the data, but are only a fraction of the noise which will be present in an operational vehicle or battlefield scenario. As it is, the increase in realism provides an environment in which the participant's cognitive state is closer to that in a true battlefield environment than in the traditional laboratory setting in which these types of cognitive experiments are traditionally executed. In order to fully utilize the high-fidelity simulation environment, participants with an active knowledge of operational scenarios, and multiple past deployments, with familiarity driving MRAP type vehicles in operational terrain. Subjected to the combat scenarios in this study, they provided a genuine Warfighter response.

Thirteen (13) of Fourteen (14) participants completed both study tasks. One (1) subject was removed from the experiment by the researchers due to motion sickness. Furthermore, the cognitive loading section of this study was dependant on the progressive increase of cognitive loading throughout the scenario. When queried about the state of their cognitive loading throughout the duration of the scenario, 89% of the participants who reported on the modified Cooper-Harper scale exhibited an increasing level of. In the fatigue portion of the study, 83% of participants who reported on the VAS-F and Karolinska Sleepiness Scale demonstrated

increased levels of fatigue upon completion of the fatigue task. These subjective measurements of loading and fatigue, when combined with the analysis of the EEG data can provide insight on the detection and mitigation of cognitive fatigue and loading dangers to task performance.

Further analysis of the cognitive loading and fatigue data is currently ongoing by JPO-MRAP, ARL-HRED and TARDEC and not presented here.

Given the positive results of this collaboration between JPO-MRAP, ARL-HRED and TARDEC, there exist many possibilities for future research into both neurophysiological technologies and Warfighter driven simulation.

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APPENDIX A: QUESTIONNAIRES

Date ____/____/____

Participant ID ____

Participant Questionnaire

Please note that all of the information requested here is strictly voluntary. This information is confidential, and it will be stored in a locked location separate from all other study data.

Gender: ☐ Female ☐ Male

How old are you? ____

What is your date of birth? ____/____/____

What is your height? ____ ft. ____ in.

What is your weight? ____ lbs.

What is your dominant hand? ☐ Right ☐ Left ☐ AmbidextrousWhat is your native language? ☐ English ☐ Other: ____

If other, how old were you when you started to speak English? ____

How many years of education have you completed?

(typically, High School = 12, College = 16, etc.) ____

A. Occupation: ☐ Civilian ☐ Military

If Military:

What is your rank? ____

How many years in service? ____

What is your MOS? ____

How many months/years of combat service? ____

B. Do you drink caffeinated beverages (e.g., coffee, tea, cola, etc.)? Yes No

On average, how many caffeinated beverages do you consume in a DAY? ____

On average, how many caffeinated beverages do you consume in a WEEK? ____

In the PAST 24 HOURS, how many caffeinated beverages have you consumed? ____

Is this: ☐ More than usual ☐ Usual ☐ Less than usual

C. Do you smoke cigarettes (or other tobacco products)? Yes No

On average, how many cigarettes do you smoke in a DAY? ____

Subject ID: _____ 2 of 3

On average, how many days do you smoke in a MONTH? _____

In the PAST 24 HOURS, how many cigarettes have you smoked? _____

Is this: ☐ More than usual ☐ Usual ☐ Less than usual

D. How long ago was your last meal? _____

At this point in the day, have you eaten: ☐ More than usual ☐ Usual ☐ Less than usual

E. Did you exercise today? Yes No

If so, what was the activity and how long ago? _____

On average, how many times do you exercise in a WEEK? _____

F. How many hours of sleep did you get last night? _____

Is this: ☐ More than usual ☐ Usual ☐ Less than usual

On average, how many hours of sleep do you get each night? _____

G. Do you drink alcoholic beverages? Yes No

On average, how many alcoholic beverages do you consume in a WEEK? _____

On average, how many days do you consume alcoholic beverages in a MONTH? _____

In the PAST 24 HOURS, how many alcoholic beverages have you consumed? _____

Is this: ☐ More than usual ☐ Usual ☐ Less than usual

H. Are you currently experiencing the effects of any recent illness (cold, flu, etc.) or injury? (Circle one) Yes No

If yes, please list _____

I. Are you currently taking any prescription, cold or flu, or anti-motion sickness medications? (Circle one) Yes No

If yes, please list _____

J. Are you currently experiencing any significant stressors in your life (e.g., family or relationship problems, work-related issues, illness or death in the family, etc.)? Yes No

If so, please explain: _____

K. Please comment on which of these things, if any, are particularly different today and if you think they may affect your performance (for better or worse).

Date ____/____/____ Mission #____ Participant ID____

Simulator Sickness Questionnaire (SSQ)

Please note that all of the information requested here is strictly voluntary. This information is confidential, and it will be stored in a locked location separate from all other study data.

Please rate the following measures of motion sickness for the trial performed (or right now) by circling the word that best describes your feelings:

General Discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eyestrain	None	Slight	Moderate	Severe
Difficulty Focusing	None	Slight	Moderate	Severe
Increased Salivation	None	Slight	Moderate	Severe
Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty Concentrating	None	Slight	Moderate	Severe
Fullness of Head	None	Slight	Moderate	Severe
Blurred Vision	None	Slight	Moderate	Severe
Dizzy (eyes open)	None	Slight	Moderate	Severe
Dizzy (eyes closed)	None	Slight	Moderate	Severe
Vertigo *	None	Slight	Moderate	Severe
Stomach Awareness **	None	Slight	Moderate	Severe
Burping	None	Slight	Moderate	Severe

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

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

The Cognitive Failures Questionnaire
(Broadbent, Cooper, FitzGerald & Parkes, 1982)

The following questions are about minor mistakes which everyone makes from time to time, but some of which happen more often than others. We want to know how often these things have happened to you in the past 6 months. Please circle the appropriate number.

		Very often	Quite often	Occasio n- ally	Very rarely	Never
1.	Do you read something and find you haven't been thinking about it and must read it again?	4	3	2	1	0
2.	Do you find you forget why you went from one part of the house to the other?	4	3	2	1	0
3.	Do you fail to notice signposts on the road?	4	3	2	1	0
4.	Do you find you confuse right and left when giving directions?	4	3	2	1	0
5.	Do you bump into people?	4	3	2	1	0
6.	Do you find you forget whether you've turned off a light or a fire or locked the door?	4	3	2	1	0
7.	Do you fail to listen to people's names when you are meeting them?	4	3	2	1	0
8.	Do you say something and realize afterwards that it might be taken as insulting?	4	3	2	1	0
9.	Do you fail to hear people speaking to you when you are doing something else?	4	3	2	1	0
10.	Do you lose your temper and regret it?	4	3	2	1	0
11.	Do you leave important letters unanswered for days?	4	3	2	1	0
12.	Do you find you forget which way to turn on a	4	3	2	1	0

	road you know well but rarely use?					
13	Do you fail to see what you want in a supermarket (although it's there)?	4	3	2	1	0
14	Do you find yourself suddenly wondering whether you've used a word correctly?	4	3	2	1	0
		Very often	Quite often	Occasionally	Very rarely	Never
15	Do you have trouble making up your mind?	4	3	2	1	0
16	Do you find you forget appointments?	4	3	2	1	0
17	Do you forget where you put something like a newspaper or a book?	4	3	2	1	0
18	Do you find you accidentally throw away the thing you want and keep what you meant to throw away – as in the example of throwing away the matchbox and putting the used match in your pocket?	4	3	2	1	0
19	Do you daydream when you ought to be listening to something?	4	3	2	1	0
20	Do you find you forget people's names?	4	3	2	1	0
21	Do you start doing one thing at home and get distracted into doing something else (unintentionally)?	4	3	2	1	0
22	Do you find you can't quite remember something although it's "on the tip of your tongue"?	4	3	2	1	0

23	Do you find you forget what you came to the shops to buy?	4	3	2	1	0
24	Do you drop things?	4	3	2	1	0
25	Do you find you can't think of anything to say?	4	3	2	1	0

Broadbent, D.E., Cooper, P.F., FitzGerald, P., & Parkes, K.R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, 21, 1-16.

12- Item Grit Scale

Directions for taking the Grit Scale: Please respond to the following 12 items. Be honest – there are no right or wrong answers!

1. I have overcome setbacks to conquer an important challenge.

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

2. New ideas and projects sometimes distract me from previous ones.*

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

3. My interests change from year to year.*

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

4. Setbacks don't discourage me.

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

5. I have been obsessed with a certain idea or project for a short time but later lost interest.*

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

6. I am a hard worker.

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

7. I often set a goal but later choose to pursue a different one.*

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

8. I have difficulty maintaining my focus on projects that take more than a few months to complete.*

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

9. I finish whatever I begin.

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

10. I have achieved a goal that took years of work.

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

11. I become interested in new pursuits every few months.*

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

12. I am diligent.

- ☐ Very much like me
- ☐ Mostly like me
- ☐ Somewhat like me
- ☐ Not much like me
- ☐ Not like me at all

Scoring:

1. For questions 1, 4, 6, 9, 10 and 12 assign the following points:

5 = Very much like me

4 = Mostly like me

3 = Somewhat like me

2 = Not much like me

1 = Not like me at all

2. For questions 2, 3, 5, 7, 8 and 11 assign the following points:

1 = Very much like me

2 = Mostly like me

3 = Somewhat like me

4 = Not much like me

5 = Not like me at all

Add up all the points and divide by 12. The maximum score on this scale is 5 (extremely gritty), and the lowest scale on this scale is 1 (not at all gritty).

Duckworth, A.L., Peterson, C., Matthews, M.D., & Kelly, D.R. (2007). Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology*, 9, 1087-1101.

Big Five Inventory (BFFI)

LIFESPAN-F04: BFFI

Subject ID: _____

1 of 1

Here are a number of characteristics that may or may not apply to you. For example, do you agree that you are someone who likes to spend time with others? Please write a number next to each statement to indicate the extent to which you agree or disagree with that statement.

Disagree strongly 1	Disagree a little 2	Neither agree nor disagree 3	Agree a little 4	Agree strongly 5
---------------------------	---------------------------	------------------------------------	------------------------	------------------------

I see myself as someone who...

- | | |
|---|---|
| <p>___ 1. Is talkative</p> <p>___ 2. Tends to find fault with others</p> <p>___ 3. Does a thorough job</p> <p>___ 4. Is depressed, blue</p> <p>___ 5. Is original, comes up with new ideas</p> <p>___ 6. Is reserved</p> <p>___ 7. Is helpful and unselfish with others</p> <p>___ 8. Can be somewhat careless</p> <p>___ 9. Is relaxed, handles stress well</p> <p>___ 10. Is curious about many different things</p> <p>___ 11. Is full of energy</p> <p>___ 12. Starts quarrels with others</p> <p>___ 13. Is a reliable worker</p> <p>___ 14. Can be tense</p> <p>___ 15. Is ingenious, a deep thinker</p> <p>___ 16. Generates a lot of enthusiasm</p> <p>___ 17. Has a forgiving nature</p> <p>___ 18. Tends to be disorganized</p> <p>___ 19. Worries a lot</p> <p>___ 20. Has an active imagination</p> <p>___ 21. Tends to be quiet</p> <p>___ 22. Is generally trusting</p> | <p>___ 23. Tends to be lazy</p> <p>___ 24. Is emotionally stable, not easily upset</p> <p>___ 25. Is inventive</p> <p>___ 26. Has an assertive personality</p> <p>___ 27. Can be cold and aloof</p> <p>___ 28. Perseveres until the task is finished</p> <p>___ 29. Can be moody</p> <p>___ 30. Values artistic, aesthetic experiences</p> <p>___ 31. Is sometimes shy, inhibited</p> <p>___ 32. Is considerate and kind to almost everyone</p> <p>___ 33. Does things efficiently</p> <p>___ 34. Remains calm in tense situations</p> <p>___ 35. Prefers work that is routine</p> <p>___ 36. Is outgoing, sociable</p> <p>___ 37. Is sometimes rude to others</p> <p>___ 38. Makes plans and follows through with them</p> <p>___ 39. Gets nervous easily</p> <p>___ 40. Likes to reflect, play with ideas</p> <p>___ 41. Has few artistic interests</p> <p>___ 42. Likes to cooperate with others</p> <p>___ 43. Is easily distracted</p> <p>___ 44. Is sophisticated in art, music, literature</p> |
|---|---|

Positive Affect/Negative Affect Schedule (PANAS)

LIFESPAN-F05: PANAS-X: Gen

Subject ID: _____

1 of 1

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you feel this way **in general**.

Use the following scale to record your answers:

1 very slightly or not at all	2 a little	3 moderately	4 quite a bit	5 extremely
_____ cheerful	_____ sad	_____ active	_____ angry at self	
_____ disgusted	_____ calm	_____ guilty	_____ enthusiastic	
_____ attentive	_____ afraid	_____ joyful	_____ downhearted	
_____ bashful	_____ tired	_____ nervous	_____ sheepish	
_____ sluggish	_____ amazed	_____ lonely	_____ distressed	
_____ daring	_____ shaky	_____ sleepy	_____ blameworthy	
_____ surprised	_____ happy	_____ excited	_____ determined	
_____ strong	_____ timid	_____ hostile	_____ frightened	
_____ scornful	_____ alone	_____ proud	_____ astonished	
_____ relaxed	_____ alert	_____ jittery	_____ interested	
_____ irritable	_____ upset	_____ lively	_____ loathing	
_____ delighted	_____ angry	_____ ashamed	_____ confident	
_____ inspired	_____ bold	_____ at ease	_____ energetic	
_____ fearless	_____ blue	_____ scared	_____ concentrating	
_____ disgusted with self	_____ shy	_____ drowsy	_____ dissatisfied with self	
_____ distracted	_____ motivated			

Visualizer/Verbalizer Questionnaire (VVQ)

LIFESPAN-F07: VVQ

Subject ID: _____

1 of 3

1. I enjoy doing work that requires the use of words.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

2. My daydreams are sometimes so vivid I feel as though I actually experience the scene.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

3. I enjoy learning new words.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

4. I can easily think of synonyms for words.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

5. My powers of imagination are higher than average.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

6. I seldom dream.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

7. I read rather slowly.

☐ ☐ ☐ ☐ ☐ ☐ ☐

Strongly agree Moderately agree Slightly agree Neither agree or disagree Slightly disagree Moderately disagree Strongly disagree

LIFESPAN-F07: VVQ

Subject ID: _____

2 of 3

8. I cannot generate a mental picture of a friend's face when I close my eyes.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

9. I don't believe that anyone can think in terms of mental pictures.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

10. I prefer to read instructions about how to do something rather than have someone show me.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

11. My dreams are extremely vivid.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

12. I have better than average fluency in using words.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

13. My daydreams are rather indistinct and hazy.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

14. I spend very little time attempting to increase my vocabulary.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

LIFESPAN-F07: VVQ

Subject ID: _____

3 of 3

15. My thinking often consists of mental pictures or images.

☐	☐	☐	☐	☐	☐	☐
Strongly agree	Moderately agree	Slightly agree	Neither agree or disagree	Slightly disagree	Moderately disagree	Strongly disagree

LIFESPAN-F19: CRT

Subject ID: _____

1 of 2

CARD ROTATION TEST

This is a test of your ability to see differences in figures. Look at the 5 triangle-shaped cards drawn below.



All of these drawings are of the same card, which has been slid around into different positions on the page.

Now look at the 2 cards below:



These two cards are different. The first cannot be made to look like the second by sliding it around on the page. It would have to be flipped over or made differently.

Each problem in this test consists of one card on the left of a vertical line and eight cards on the right. You are to decide whether each of the eight cards on the right is the same as or different from the card at the left. Mark the box beside the S if it is the same as the one at the beginning of the row. Mark the box beside the D if it is different from the one at the beginning of the row.

Practice on the following rows. The first row has been correctly marked for you.

B										
		S ☒ D ☐	S ☐ D ☒	S ☒ D ☐	S ☒ D ☐	S ☐ D ☒	S ☐ D ☒	S ☐ D ☒	S ☐ D ☒	S ☐ D ☒
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐

Your score on this test will be the number of items answered correctly minus the number answered incorrectly. Therefore, it will not be to your advantage to guess, unless you have some idea whether the card is the same or different. Work as quickly as you can without sacrificing accuracy.

You will have 3 minutes to complete the test on the following page.

LIFESPAN-F19: CRT

Subject ID: _____

2 of 2

CARD ROTATION TEST

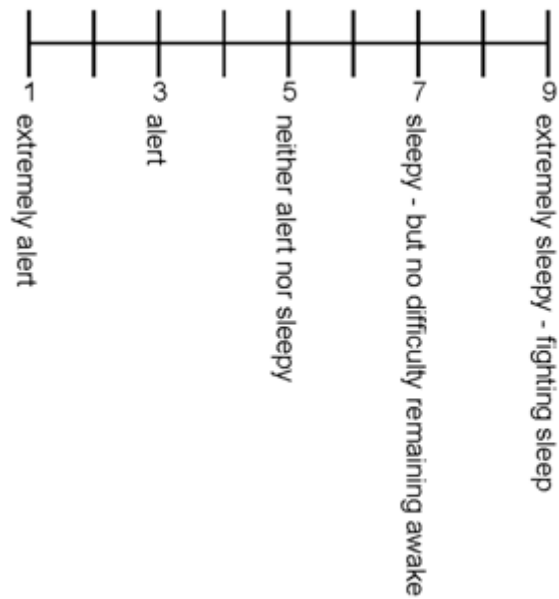
(3 minutes)

1.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
2.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
3.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
4.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
5.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
6.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
7.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
8.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
9.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐
10.									
		S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐	S ☐ D ☐

Visual-Analogue Scale for Fatigue (VAS-F)



Karolinska Sleepiness Scale

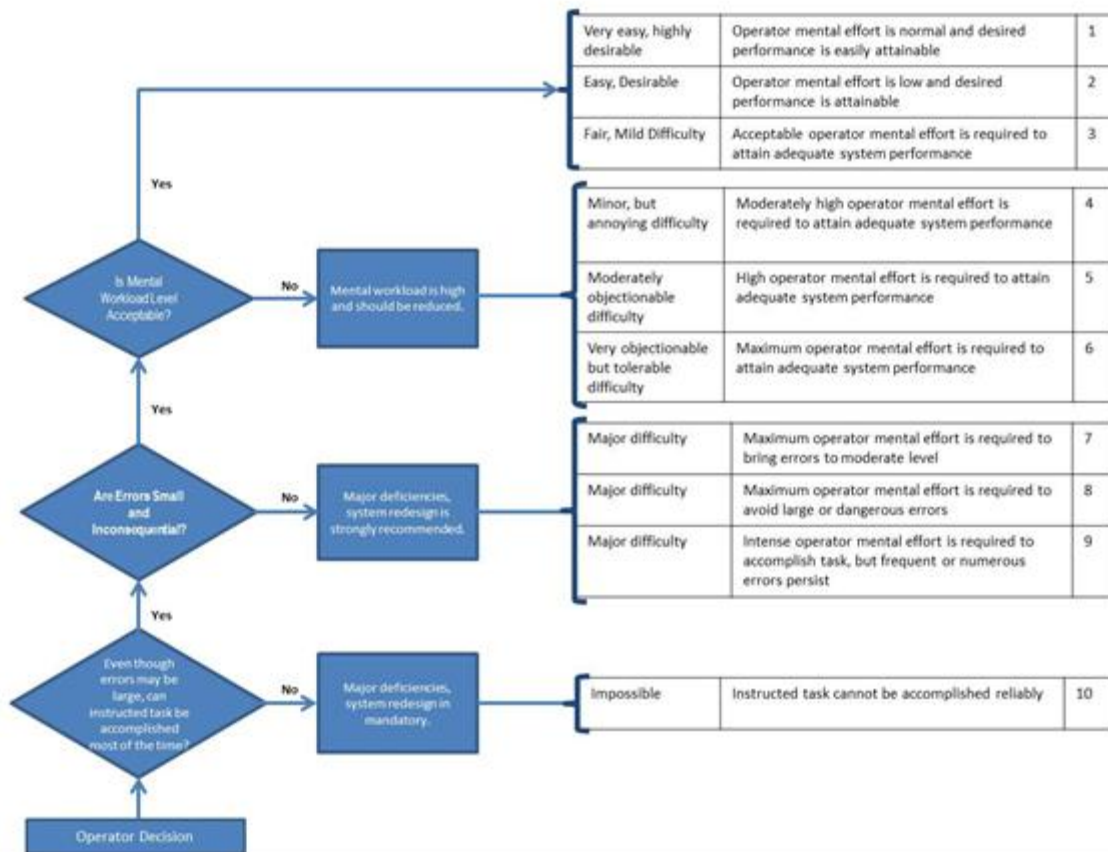


Task-Induced Fatigue Scale

Here are some words and phrases which might describe how you feel RIGHT NOW. Please rate your agreement with each phrase on a scale from 0 (Not at all) to 5 (Very much so), by circling your preferred response. Numbers between 0 and 5 represent intermediate degrees of agreement.

1. Have a headache	0	1	2	3	4	5
2. Flickering in eyes	0	1	2	3	4	5
3. Hearing ability reduced	0	1	2	3	4	5
4. Feel tired in the whole body	0	1	2	3	4	5
5. Having tremors in the limbs	0	1	2	3	4	5
6. Bored	0	1	2	3	4	5
7. Would rather be doing something else	0	1	2	3	4	5
8. Feeling of heaviness in the eyes	0	1	2	3	4	5
9. Humming in ears	0	1	2	3	4	5
10. Fed up with the task	0	1	2	3	4	5
11. Feel stiff in the legs and arms	0	1	2	3	4	5
12. Apathetic	0	1	2	3	4	5
13. Unable to straighten up in posture	0	1	2	3	4	5
14. Don't want to do the task ever again	0	1	2	3	4	5
15. Eyes feel strained	0	1	2	3	4	5
16. Feel sick or nauseous	0	1	2	3	4	5
17. Don't care what happens next	0	1	2	3	4	5
18. Feel stomach pains	0	1	2	3	4	5
19. Vision is blurred	0	1	2	3	4	5
20. Vision appears to 'swim'	0	1	2	3	4	5
21. Find the task monotonous	0	1	2	3	4	5
22. Feel ill	0	1	2	3	4	5
23. Don't want to think about the task	0	1	2	3	4	5

Modified Cooper-Harper Rating Scale (MCH)



APPENDIX B: IRB PROTOCOL

HUMAN SUBJECT RESEARCH PROTOCOL

U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

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Abstract

The purpose of this project is to investigate the reliability and generalizability of a neural fatigue-based driver performance prediction methodology and a neural workload-based driver performance prediction methodology on Army-relevant simulated driving tasks. The protocol aims to compare the ability of existing algorithms to dynamically classify a participant's fatigue state during the simulated mission. The protocol also aims to compare the ability of existing algorithms to dynamically classify a participant's mental state at varying levels of task difficulty for the participants throughout the simulated mission. For each experimental session, one Soldier participant will be recruited to perform two driving scenarios, one low-activity for evaluation with the fatigue-based monitor, and one high-activity for evaluation with the workload-based monitor. The majority of the participants will be active duty Soldiers recruited by TARDEC and Joint Program Office (JPO) Mine Resistant Ambush Protected (MRAP). The Soldiers will fly to Warren, MI to be tested in the Ground Vehicle Simulation Laboratory (GVSL) located at TARDEC at the Detroit Arsenal. Availability of particular units has not been determined. In addition to the Soldiers, civilian participants will be recruited by ARL to be tested at the Mission Impact through Neurotechnology Design (MIND) lab located at ARL on Aberdeen Proving Ground.

Location of Research:

Participants will be tested in the Ground Vehicle Simulation Laboratory (GVSL) located at US Army Tank-Automotive Research, Development and Engineering Center (TARDEC) at the Detroit Arsenal in Warren, MI and in the Mission Impact through Neurotechnology Design (MIND) lab located at ARL on Aberdeen Proving Ground, MD.

Data Collection Dates:

The data collection will occur between March and August 2012 in the indoor, climate-controlled Ground Vehicle Simulation Laboratory (GVSL) in Warren, MI and in the Mission Impact through Neurotechnology Design (MIND) lab located at ARL on Aberdeen Proving Ground, MD.

Study Sponsor

ARL/HRED, TARDEC, JPO MRAP

Background

Commanders of military vehicles are responsible for allocating the tasks of a mission plan to the crew members who are operating the vehicle. Within the US Army, the classic approach

has been to define a role for each crew member and to predefine the types of tasks that should be assigned to each role. This approach has made it possible to design a different task-specific crewstation and to train crew members for each role. During a mission, each task maps to exactly one crew member, so there is no confusion about who should perform each task.

The US Army is currently developing a System of Systems (SoS) containing manned vehicles, unmanned vehicles, ground sensors, and Soldiers all working together through an integrated network. One of the objectives is to increase Soldier survivability in ground vehicle operations. This objective is expected to be accomplished through increased mobility and self-contained operations as well as increased reliance on complex information networks, while, at the same time, minimizing crew size. The combination of an increased number of tasks for each member and fewer crew members means that it is essential to manage the task allocation process intelligently.

Several new technologies are currently being developed to help maximize Soldier performance in vehicles. TARDEC is developing a Warfighter Machine Interface (WMI) that allows each crew member to perform almost any mission task. The U.S. Army Human Research and Engineering Directorate (HRED) is developing a suite of sensors to measure the physiological and cognitive states of Soldiers in operational environments.

This experiment incorporates two of the underlying computational components that are needed to fuel the technical development of the HRED sensor suite. The first includes modifications in the simulation design algorithms to increase the realism of the task and provide more interaction with and control of the simulated task environment to the participants. The second investigates the feasibility of existing algorithms to successfully classify the participant's mental state, and in particular, to discriminate times of high and low fatigue and times of high task difficulty compared to times of low task difficulty. Together, these components will enable the development of metrics to assess physiological and cognitive states of Soldiers to maximize Soldier performance in operational environments. .

The experiment consists of two mission scenarios that are each 45 minutes in duration where the number of tasks, as well as the difficulty of the tasks, are varied to dynamically manipulate the difficulty of the mission scenario. Before each mission, the participants are given an operation board that states the goals of the mission. Throughout the scenario, the number and difficulty of the tasks facing the participants are manipulated to create blocks of time where the difficulty is easy (few tasks, easy tasks), blocks of time where the difficulty is medium (several tasks, none very taxing), and blocks of time where the difficulty is high (many tasks and/or tasks that require lots of cognitive processing). Each of these blocks can last from a minute to several minutes and provides a measure of the physiological processing during the three levels of difficulty (easy, medium, and hard). These blocks of data will then be used to compare the performance of many different classification algorithms to see what ones are able to discriminate among the three cognitive states. This research builds on work done by the Air Force in flight simulators (Prinzel, Freeman, Scerbo, Mikulka, & Pope, 2003; Wilson & Russell 2003) as well as research investigating the combination of multiple physiological measures (Noel, Bauer, & Lanning, 2004). In addition, it extends several comparative studies of cognitive state classification to Army-relevant contexts (Luo & Sajda, 2006; Sato et al, 2009).

Through the dynamic manipulation of task difficulty, this experiment aims to provide the underlying research needed to develop a suite of sensor technologies that will feed a dynamic task allocation system.

Research Objective

By increasing the realism of the simulated, operational scenarios, the research objective is to obtain neurophysiological data during a driving scenario in order to evaluate whether algorithms can successfully identify dynamic changes in fatigue and workload based on a set of neurophysiological measurements, such as neural data from electroencephalography (EEG), eye movement patterns, respiration patterns, and galvanic skin responses.

Instrumentation and Facilities

Equipment or Apparatus

The following apparatuses may be used in this series of experiments:

Ride Motion (RMS) and Crew Station/Turret Motion Based Simulators (CS/TMBS): Both the RMS and CS/TMBS are 6 degree-of freedom (DOF) motion based simulators capable of reproducing the dynamics of military ground vehicles over a vast array of terrains (Figures 1 and 2) seen by current force vehicles. Both are comprised of a platform mounted on a hexapod design that produces motions in the longitudinal, lateral, vertical, roll, pitch, and yaw directions.



Figure 1 - Ride Motion Simulator (RMS)



Figure 2 – Crew Station/Turret Motion Base Simulator (CS/TMBS)

Both simulators support a re-configurable cab that is large enough to allow simulation of a crew station. The system has the capability to collect performance data and has been safety certified to permit use by Soldiers and experimenters.

Crewstation: The simulation environment shall be constructed to present participants with visual, motion and audio cuing to recreate a realistic driving experience. The simulator cab will be configured with a Surrogate Common Crew Station or similar human-machine interface, which includes a vehicle seat, a seat belt, a yoke, and flat panel displays. The temperature will typically be normal room temperature. Audio cuing shall be limited to presenting the participant with the commander's voice and the vehicle's sounds (engine noise correlated to engine RPM). MIL-STD-1474D, 12 February 1997, "Department of Defense Design Criteria Standard – Noise Limits", will be used as a guideline regarding noise exposure and hearing protection requirements.

Eye-tracking and Monitoring System: SmartEye™ (SmartEye, Goteborg, Sweden) and RED 250 (SensoMotoric Instruments, Teltow, Germany) are a camera-based tracking systems that allow completely non-contact operation, allowing for observation of the natural participant eye and head movement behavior at adequate spatial resolution ($\sim 0.5^\circ$). Eye and head movements, along with measurement reliability data, may be logged in real time and synchronized with the other data measures. No video record is captured by this data collection system.

BioSemi EEG System: An EEG system using an ActiveTwo amplifier and electrode cap (resembling a swim cap) with pre-amplified surface electrodes (BioSemi, Amsterdam, Netherlands), sampling at a rate of 500 Hz. EEG recording sites will be prepared in accord with the standardized international 10-20 electrode placement system (Nuwer et al., 1994) and performed with strict adherence to the safety guidelines established by the Society for Psychophysiological Research (Putnam, Johnson, & Roth, 1992). A water-soluble, salinated (salty) electrode gel will be inserted into each of the electrode casings to facilitate conductivity between the scalp and electrode surfaces. Vertical (VEOG) and horizontal (HEOG) eye

movements will be monitored using bipolar electrode montages attached superior and inferior to the right eye (VEOG) and both orbital fossa (HEOG).

BioSemi Respiration Belt: The belt measures changes in thoracic or abdominal circumference during respiration through inductive plethysmography in order to derive breathing rate. The belt connects directly to the same power supply and amplifiers used for the EEG components of the BioSemi system.

BioSemi Galvanic Skin Response (GSR): The GSR consists of 2 passive electrodes to induce an oscillator signal synchronized with the sample rate, and uses “Lock-in detection” that enables the stimulus-current to be as low as 1 μ A. The low-current and synchronization of the GSR oscillator ensure that the biopotential measurements collected by the EEG components of the BioSemi system are not corrupted by the GSR. These electrodes connect directly to the ActiveTwo amplifier of the EEG system.

Video/Audio Recording System: Video data will be captured using 1 to 2 video cameras mounted on the inside cabin of the crewstation. All video data will only be used for data analysis. Audio data will be recorded in order to capture the digital threat reporting and dialogue between the participant and investigators.

Standard PC: A standard computer may be used to present auditory and visual stimuli to participants, where the timing and spatial location of the stimuli are controlled by experimental presentation software, such as MATLAB or E-Prime. Participant responses may be collected using a touch screen, keyboard, keypad, mouse, joystick, or microphone (verbal responses), or a combination of these modalities.

Materials, Tests, Tasks, and Stimuli

Tasks and Stimuli

Driving Simulation: The simulation environment shall be constructed to present participants with visual, motion, and audio cuing to recreate a realistic driving experience. Volunteers will be seated at a crew station, and will be able to control the direction and speed of the vehicle as it navigates through a simulated environment. The experiment will simulate a combat or tactical vehicle traversing cross-country terrain with maximum accelerations not exceeding 2 g's (g = The acceleration due to gravity, 9.8 meters/ second²). The motions experienced by the test volunteers will not exceed ranges beyond ± 20 inches in the translational directions and ± 20 degrees in the angular directions. The simulator's safety interlock system will be set to ensure that the ride motion does not exceed these position or acceleration levels. The Driver will be equipped with a headset that allows audio communication to be presented to them in order to simulate the dynamic communications among members of the battalion. Experimenters will also be able to communicate through the audio communication system, as well as maintaining sight of the participants via camera views and direct vision, at all times throughout the experiment.

Fatigue Scenario:

Participants will perform a primary task, driving; and may consist of a secondary task, a visual oddball. The driving task will consist of driving on a flat, straight road. The vehicle will receive horizontal perturbations, pushing it off course, which the driver will have to react to. The driver will control vehicle speed, and may be part of a convoy with the additional task to maintain following distance from the leading vehicle in the convoy.

The visual oddball would consist of a one of two images being shown on a secondary monitor. One image will be a target; the other will be a distracter. The subject would respond to the target image by pressing a button on the steering wheel.

Workload Scenario:

Participants will perform a primary task, driving; and secondary tasks, communication and IED detection. These tasks are all consistent with M-ATV Driver tasks where vehicle operation is the primary task and the Driver acts as back-up for the Vehicle Commander by performing secondary tasks of monitoring communications, making return calls, as well as monitoring and avoiding known, suspected, and unknown IED emplacements.

The experimental design is 2 x 2 within-subjects design. The within-subjects approach is dictated by the limited number of experienced operators available to support the research. Independent variables will be communication activity and IED detection with high and low levels for each.

Comm s	IED		
		High (h)	Low(l)
	High(H)	Hh	Hl
	Low(L)	Lh	Ll

The scenario will have 8 segments (4 outbound and 4 inbound). The order of experimental condition will be randomly distributed across segments to assure that training and order effects are counterbalanced across participants. The four combinations of independent variables (IED and Comms) can be presented in 24 different orders (permutations). Participants will experience an easy driving condition (specified by instructions to the participant) on the outbound leg and the more difficult driving condition on the inbound leg. This approach, together with a random order assignment, will effectively counterbalance training and experience on the simulated course. The more difficult driving condition on the inbound (return) leg will serve to increase cognitive demands, and is expected to counteract the effects of learning that may have occurred on the outbound leg.

Participants will sit before the driver crew station monitors. They will be able to communicate with the experimenters via headsets connected to the Audio Recording System. The participant will complete several missions through the simulated environment. Rest periods will occur between each of the tasks as the experimenter loads the appropriate scripts. Additional break

time requested by the participants will also be given. Experimental testing is expected to take no more than 3 hours to complete.

Secondary Task Levels of Difficulty

Communication activities and IED detection and avoidance are the secondary tasks. Their levels of difficulty will be manipulated to form the 2x2 matrix. The levels of manipulation are presented below.

	IED		
		High (h)	Low(l)
	High(H)	• Higher number of higher priority comm calls to/from driver • 0 – 6 IEDs present with greater threat “Distractors” and ambush present (situation that looks like possible IED)	• Higher number of higher priority comm calls to/from driver • 0 – 4 IEDs present with few “Distractors” present (situation that looks like possible IED)
Comms	Low(L)	• Lower number of higher priority comm calls to/from driver • 0 – 6 IEDs present with greater threat “Distractors” and ambush present (situation that looks like possible IED)	• Lower number of higher priority comm calls to/from driver • 0 – 4 IEDs present with few “Distractors” present (situation that looks like possible IED)

Participants

All experiments will include no more than 100 civilian or military volunteer participants. All volunteers will be 18-45 years old, US citizens, report normal or correct to normal vision, report normal hearing, and report experience driving a vehicle. The Soldier participants will be military volunteers from II MEF Motor Transport at Camp Lejeune, NC by TARDEC and the MRAP JPO Engineering Human Systems Integration Lead. There will also be approximately 20 civilian volunteers recruited by ARL through a local temp agency. The time required to complete the study session will not exceed 4 hours of simulator time in one session .

The Soldier recruitment process will be as follows:

1. Experiment Team members will travel to Camp LeJeune, NC to meet with a pool of personnel who have volunteered to be briefed on the study and the need for participants. We anticipate 20 or more volunteers will attend the initial briefing.
2. After the participant briefing (see IRB Package), potential participants will also be given an explanation of:
 - a. Informed Consent, potential risks, and benefits of participation
 - b. Explanation of the travel requirements
 - c. Reiteration that they are under no obligation to participate
 - d. Question/answer period
3. Once the initial briefing and above topics have been covered, each volunteer will be given a ballot (Appendix M) and invited to place their names along with their interest level in a drawing box. Names will be drawn from the box until 14 subjects who agree to undergo the experiment are found.
4. The 14 participants who are selected will arrive at TARDEC, where they will be presented with an Informed Consent form. As with any experiment, they will be under no obligation to participate if they do not wish to do so.

We cannot completely control local social pressure, command pressure, or compulsion of participants, but anticipate that the lottery process will allow for volunteers to opt out without penalty.

Civilian participants will be recruited from a local temp agency in Aberdeen that specializes in providing experimental subjects. Soldier participants will not be paid, but civilian participants will.

Procedure & Experimental Design

TARDEC Procedure:

This experiment investigates driving performance in a crewstation, predicting performance based on neurophysiological measurements. The target population will be military personnel who have combat experience and are recruited through TARDEC and the MRAP JPO Engineering Human Systems Integration Lead. Based on discussions with the Deputy, the recruitment plan for the active military personnel is to fly Soldiers in for a three day session.

On Day 1, the Soldier will travel to TARDEC. On Day 2, the Soldiers will report for an experimental session that is expected to last 8 hours. The Soldier will then be given the opportunity to read the consent form, and if they agree to participate, they will sign a consent agreement. Upon giving consent, the Soldier will be briefed about the experimental procedures and receive a safety briefing on the Ride Motion Simulator. Then, the participant questionnaire will be administered to ensure compliance with the experiment selection criteria (Appendix A). This questionnaire may be followed by the Cognitive Failures Questionnaire (CFQ, Appendix C), the 12-item Grit Scale (Appendix D), the Big Five Inventory (BFFI, Appendix E), the Positive

Affect/Negative Affect Schedule (PANAS, Appendix F), the Visual/Verbalizer Questionnaire (VVQ, Appendix G), or the Card Rotation Test (CRT, Appendix H). This paperwork is expected to last 15-20 minutes.

The Soldier will then complete a practice run on the Ride Motion Simulator that will take no longer than 20 minutes to complete. The Soldier will then be fitted with the EEG electrode cap. The participant(s) will be encouraged to ask any questions or alert the experimenter if any discomfort occurs and needs to be corrected. The participant may then be fitted with the Galvanic Skin Response sensors and the Respiration Belt. The configuration script for the eye-tracking system will also be completed. The total setup time is expected to take 35-50 minutes.

The participant will sit comfortably in front of the driver crew station monitors. The participant will be able to communicate with the experimenters, using headsets that are connected to the Audio Recording System. The participant will complete several missions through the simulated environment. The participant will have rest periods between each of the tasks as the experimenter loads the appropriate scripts, as well as any additional break time requested by the volunteers. In addition, the participants on the simulator may be asked to fill out the Simulator Sickness questionnaire after each mission (Appendix B), as well as the Visual-Analog Scale for Fatigue (VAS-F, Appendix I), the Karolinska Sleepiness Scale (Appendix J), and the Task-Induced Fatigue Scale (TISF, Appendix K) and the Modified Cooper-Harper Scale (Appendix L). The experimental testing is expected to take no more than 3 hours to complete.

At the end of the testing, the experimenter will remove the EEG system(s) and any other physiological sensors, and participants will be encouraged to ask any questions about the experiment as well as provide any feedback about the experimental session. Each participant will be asked to complete an exit questionnaire (Appendices C & D). This is likely to take 15-30 minutes, depending on the total number of questions that the participants ask.

On Day 3, the Soldiers will travel back to their home location. No experimental tasks will be completed on Day 3.

In summary, the participants will complete experimental tasks on Day 2. The total duration of the experimental testing time will not exceed 8 hours on Day 2.

APG Procedure:

This experiment investigates driving performance in a crewstation, predicting performance based on neurophysiological measurements. The target population will be civilians recruited from temp agencies in Aberdeen specializing in providing experimental subjects. The subjects will spend a half day at APG for the experiment.

The subject will then be given the opportunity to read the consent form, and if they agree to participate, they will sign a consent agreement. Upon giving consent, the participant questionnaire will be administered to ensure compliance with the experiment selection criteria

(Appendix A). This questionnaire may be followed by the Cognitive Failures Questionnaire (CFQ, Appendix C), the 12-item Grit Scale (Appendix D), the Big Five Inventory (BFFI, Appendix E), the Positive Affect/Negative Affect Schedule (PANAS, Appendix F), the Visual/Verbalizer Questionnaire (VVQ, Appendix G), or the Card Rotation Test (CRT, Appendix H). This paperwork is expected to last 15-20 minutes.

The subject will then complete a practice run using the driving simulator that will take no longer than 20 minutes to complete. The subject will then be fitted with the EEG electrode cap. The participant(s) will be encouraged to ask any questions or alert the experimenter if any discomfort occurs and needs to be corrected. The subject may then be fitted with the Galvanic Skin Response sensors and the Respiration Belt. The configuration script for the eye-tracking system will also be completed. The total setup time is expected to take 35-50 minutes.

The subject will sit comfortably in front of the driver crew station monitor. The participant will be able to communicate with the experimenters through a microphone. The participant will complete the fatigue task using the simulated driving environment. In addition, the participants on the simulator may be asked to fill out the Simulator Sickness questionnaire after each mission (Appendix B), as well as the Visual-Analog Scale for Fatigue (VAS-F, Appendix I), the Karolinska Sleepiness Scale (Appendix J), and the Task-Induced Fatigue Scale (TISF, Appendix K) and the Modified Cooper-Harper Scale (Appendix L). The experimental testing is expected to take no more than 3 hours to complete.

At the end of the testing, the experimenter will remove the EEG system(s) and any other physiological sensors, and participants will be encouraged to ask any questions about the experiment as well as provide any feedback about the experimental session. Each participant will be asked to complete an exit questionnaire (Appendices C & D). This is likely to take 15-30 minutes, depending on the total number of questions that the participants ask.

In summary, the participants will complete in a half-day at APG. The total duration of the experimental testing time will not exceed 4 hours.

Data Analysis

The behavioral data will be analyzed to assess the behavioral performance at driving and target identification tasks during the missions. Performance will be evaluated using metrics based on reaction time to both driving and target identification tasks.

The physiological data (EEG, GSR, respiration, eye tracking) will be analyzed alone and/or in conjunction with one or more of the other physiological metrics. Different algorithms (pattern classifiers, neural networks, etc.) will be used to assess whether the participant's fatigue levels and workload can be determined as they dynamically change throughout the mission.

Discomforts, Risks, & Mitigation of Each Risk

There are no more than minimal risks involved in the study. The risks do not exceed those encountered in an individual's daily life.

Potential hazards associated with the Ride Motion Simulation hardware, their probability, severity and corrective mitigations are summarized in Section 5.5 of the RMS Safety Assessment Report. The most likely condition for injury is that of whole body vibration. To minimize that risk, MIL-STD-1472D, 14 March 1989, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities", Para 5.8.4.1, "Whole body vibration" will be used as a guideline in determining safe vibration levels. The intent is to replicate typical vehicle motion experienced by a combat or tactical vehicle traversing urban terrain. While this environment may be "rough," it is not considered injurious. Accelerations are all within the safety limits set by the ISO 2631-1, Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole-body Vibration. In the event of an unforeseen event, the simulator can be stopped at any time by the investigator or the occupant of the simulator. In the event of a catastrophic failure, there are police and fire emergency crews located right at the Detroit Arsenal in Warren, Michigan.

There are minimal risks associated with the head and eye-tracking apparatus used in this experiment. The infrared eye-tracking pods used in this experiment are well within the Maximum Permissible Exposure (MPE) limit, based on the International Electrotechnical Commission (IEC) Standard 60825-1 V1.2. Also, the pod's minimum operating distance is well beyond the distance that represents an ocular hazard (based on the IEC Standard 60825-1 V1.2.).

Risks associated with the non-invasive recording of EEG from the scalp are minimal. Electrode caps will be washed in hot soapy water and sterilized with a disinfectant solution immediately following each test session. Manufacturer specifications for the EEG system confirm that risk of electrical shock is minimal or non-existent under the described conditions.

For the EEG electrodes, preparation for the ear and eye area electrodes consists of carefully cleaning the area surrounding the ear and eye with alcohol on a cotton swab. Special care will be taken to assure alcohol does not enter the eye or ear of the participant. The electrode gel and adhesive tape used to secure electrodes in place may cause skin irritation to some participants and eye irritation could be a risk if the gel inadvertently comes into contact with the eyes. If contact occurs, the gel will be flushed out with water and first aid will be provided as needed.

The investigator will wear polypropylene or nitrile gloves during all contact with participants, and a sealed container will be kept in a locked cabinet for the disposal of alcohol pads, adhesive electrode collars, and other EEG-related trash. Responses on the demographic questionnaires regarding gel and alcohol allergies will be monitored closely to avoid allergic reactions.

There is a risk concerning motion and simulator sickness and after effects, which can occur in some people while driving in a simulated vehicle. Symptoms of sickness include but are not

limited to: nausea, cold sweating, pallor, and vomiting. Participants will be kept in both visual and verbal contact via video cameras and communication headsets located in the simulator cab during their simulation exposures. If the participant reports symptoms of sickness, the experiment can be terminated at any time. If the participant reports and/or exhibits severe motion sickness symptoms (e.g., emesis), the experimenter will stop the experiment. Emesis bags will be positioned near the participant's seat. Aftereffects are symptoms that persist or arise after the participant is removed from the provocative environment. Aftereffects for this experiment may include but are not limited to symptoms commonly associated with extended periods of computer operation (e.g., eye strain, neck strain, headache, etc.) and symptoms commonly associated with motion sickness. All participants will be told of the possibility of aftereffects. The ~5 minute breaks between driving trials are expected to abate any motion sickness and aftereffects given the relatively low level and range of whole-body motions expected in this experiment. However, if participants would like additional time to rest and recover between mission scenarios, they will be granted more time. Participants will be asked to remain at the test facilities until motion sickness symptoms have subsided.

Benefits

The only benefit to study participation is the knowledge that participation contributes to increasing our understanding of brain function that may one day advance the performance of Soldier-System interfaces and other Soldier technologies.

Confidentiality or Anonymity

Each participant will be assigned a unique, non-personally identifying ID number that will be used on all questionnaires, data files, and data logs. Only one sheet will contain the mapping between participant information and the participant ID, and this sheet will be kept confidential and stored behind a locked door. All participant consent forms will be stored locally by TARDEC's Human Protections Administrator.

References

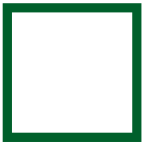
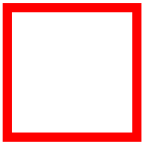
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Soldier Recruitment Lottery Ballot

Thank you for considering participation in the *Dynamic Classification of Warfighter State* research. We appreciate your time. If you have any remaining questions, please ask them **before** you complete this form.

Your name: _____

	Yes, I am interested in entering the lottery to be selected as a participant for this research study
	No, I am NOT interested in entering the lottery. I would not like to be considered as a participant in this research study

RDRL-HRS-E (70-25a)

25 April 2012

MEMORANDUM TO: Brent Lance, Translational Neuroscience, ARL-IRED, APG, MD**SUBJECT:** Notification of Approval for Amended Research Project Titled *Dynamic Classification of Soldier State*, Project No. ARL 10-051, after an Amendment Review by Expedited Procedures

The purpose of this memo is to notify you that the amendment of your project has received human-use approval after a review by expedited procedures, conducted on 12 April 2012.

Title 32, Code of Federal Regulations, Part 219.110(h)(2), permits the use of expedited review procedures of minor changes in previously approved research during the period for which approval is authorized. The original protocol was reviewed on 11 August 2010 by expedited procedures, and it received a continuing review on 20 September 2011. Approval for your project was extended for one year from the approval date, 20 September 2011, to 19 September 2012. The present amendment review was completed before the expiration date of 19 September 2012. The current expiration date for your study remains 19 September 2012.

As principal investigator, you are responsible for ensuring that the study is conducted in accordance with the final version of your protocol. You cannot delegate your supervisory responsibility to anyone else associated with the project. If you leave the project a new principal investigator should be designated for the research. Designation of a new principal investigator should be reported to the IRB.

In addition, you must report the following to the IRB chairperson:

- You must report changes in research personnel, including the principal investigator, involved in the study.
- You must report changes in the research procedures before they are initiated. You can report minor changes by completing the ARL-IRED amendment form.
- You may make changes in research procedures implemented to eliminate immediate hazards to the subjects, but they must be reported within 10 days of their implementation on the amendment form.
- You must report completion or discontinuation of your study by submitting a completion or discontinuation report to the IRB.
- You must report plans to continue your study beyond the expiration date before you attain that date, by submission of a continuing review form 30 days before the expiration date.
- You must promptly report any injury or unanticipated problem to the IRB. This report should describe the event, evaluate its probable relationship to the study, and summarize the resulting outcome. An unanticipated problem is an adverse event that is not expected, given

APPENDIX C: STRYKER MODEL VEHICLE DESCRIPTION DOCUMENT

Function: Stryker SimCreator® Model**Author:**

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Description:

Model name : Stryker_CV_VTI

1. Nine body model

2. A DADS model of the Stryker Engineer variant was used to find suspension locations wrt hull cg and to generate curves for modeling the following as functions of suspension vertical travel:

- a. Effective unsprung mass (turns out to be constant)
- b. Nonlinear effective vertical stiffness (including jounce and rebound stops)
- c. Wheel longitudinal and lateral positions
- d. Wheel camber, castor, and toein
- e. Ratio of shock stroke velocity to wheel vertical velocity

3. The DADS model was exercised to determine the SimCreator® AntiRollRate constants for the four rear wheels and the front wheel steer angles as nonlinear functions of pitman arm rotation. The DADS animation feature was used to determine the steer limit by estimating the point where a tire ran into the hull.

4. The DADS model provided tire damping, tire radius, tire width, curves for tire vertical stiffness at several tire pressures, and curves of shock force/velocity data. Some of this data is considered proprietary by GDLS, so the model can be distributed to only signers of GDLS' non-disclosure agreement.

5. A PST VIPER Report on the Stryker Command Vehicle was used to adjust the hull mass and cg location wrt the wheels. The moments of inertia of the eight unsprung masses, including use of the parallel axis theorem, were subtracted from the VIPER system moments to calculate the SimCreator® sprung mass moments.

6. Following is a comparison of VIPER data to SimCreator® model output data:

Measurement	VIPER	SimCreator®
Total weight (kg)	16456.50	16457.00k
Lateral cg (cm)	3.05	2.95
Longitudinal cg (cm)	176.38	176.08
Vertical cg (cm)	127.77	128.25

Ixx (kg-m-m)	16260.00 (System)	10233 (Hull/Sprung Mass)
Iyy (kg-m-m)	69622.61 (System)	61324 (Hull/Sprung Mass)
Izz (kg-m-m)	63554.92 (System)	53071 (Hull/Sprung Mass)
Ixz (kg-m-m)	1086.71	not modeled
Track (cm)	230.51	230.00 (rear) 230.23 (front)
Axle Long. Distance (cm)		
Axle1	0	0
Axle2	121.59	122.59
Axle3	263.19	262.33
Axle4	384.78	384.10
Wheel Loads (N)		
Axle1	21796 (L) 23665 (R)	22167 (L) 23238 (R)
Axle2	21351 (L) 23665 (R)	22303 (L) 23354 (R)
Axle3	17526 (L) 17793 (R)	17025 (L) 18060 (R)
Axle4	17882 (L) 17704 (R)	17131 (L) 18164 (R)
Axle Loads (N)		
Axle1	45461	45406
Axle2	45016	45657
Axle3	35319	35085
Axle4	35586	35295

Status:

Possible future enhancements:

1. Model the CTIS (Central Tire Inflation System) to allow the subject in a Motion Base experiment to adjust the tire pressure (and thereby the model tire vertical stiffness - affecting the ride) on the fly.

2. Create a SimCreator® six-dof-body component with non-zero cross products of inertia.

Validation effort initiated 4Q FY07.

APPENDIX D: LIST OF ACRONYMS

AI	Artificial Intelligence
AR	Army Regulation
ARL	Army Research Laboratory
BFT	Blue Force Tracker
B-HAVE	Brains for Human Activities in Virtual Environments
CASSI	Concepts, Analysis, System Simulation & Integration Organization
COA	Courses of Action
COTS	Commercial Off the Shelf
CP	Check Point
DIS	Distributed Interactive Simulation
DoA	Department of the Army
DOF	Degree of Freedom
EEG	Electroencephalography
FOB	Forward Operating Base
GVDS	General Vehicle Dynamics System
GVSL	Ground Vehicle Simulation Laboratory
HMS	Hardware & Man-in-the-Loop Simulation
HRED	Human Research and Engineering Directorate
ICV	Infantry Carrier Vehicle
IED	Improvised Explosive Device
IG	Image Generator
JPO	Joint Program Office
MBT	Motion Base Technologies
MCH	Modified Cooper-Harper
MRAP	Mine Resistant Ambush Protected
NCO	Non-Commissioned Officer
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
PDU	Protocol Data Unit
RMS	Ride Motion Simulator
ROI	Regions of Interest
RTI	Real-time Technologies Inc.
SAF	Semi-Automated Forces
SME	Subject Matter Expert
TARDEC	Tank Automotive Research, Development and Engineering Center
UDP	User Datagram Protocol
USB	Universal Serial Bus
VAS-F	Visual-Analogue Scale for Fatigue