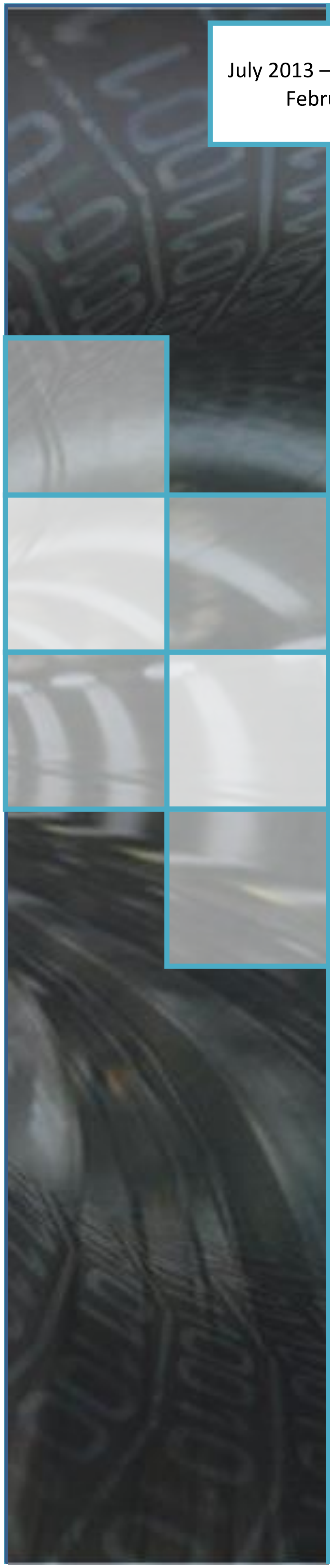

July 2013 –
February 2015

# Exploring the effect of simulated Motion Conditions on Task Performance

A Thesis submitted to the University of Sydney

In fulfilment of the requirements for the degree of

Master of Science (Psychology) by Research.

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This thesis is dedicated to my every day heroes: my family, my friends and my life mentors. The people who somehow always knew the perfect time to give me a call, go for a walk or, better yet, to grab a coffee.

## Abstract

This thesis explored the effects that four areas of motion conditioning presented in a motion simulator had on defence-force based task performance. It is a thesis produced in conjunction with the Defence Science and Technology Organisation, Land Operations Division, to expand their understanding of how researched motion conditions may affect their military personnel.

The four conditions explored in this thesis are Motion Sickness, Motion Fatigue, Motion Perception, and Mental Workload under motion conditions. All studies involved first year psychology students enrolled at the University of Sydney in accordance with the University's ethical guidelines (Project No: 2013/388). All participants were rewarded credit points for their participation.

In the study of Motion Sickness (Chapter Four), nausea was shown to have very little detrimental effect on task performance. In long term driving exposure there was a slight negative effect on the reaction time that was linked to motion sickness symptoms. In the scenario of short term driving exposure with constant a task load, in the form of the Defence force tasks, there were no detrimental effects seen on the performance of participants who suffered some form of motion/simulator sickness, compared to those that did not experience any nauseating effects.

Motion Fatigue (Chapter Five) had a two part focus. This study firstly explored two motion effects: boredom and constant motion. Using a study-based outcomes analysis to investigate how boredom and constant motion affected performance, it then explored what the best biomarker for fatigue would be in a defence context.

For the first focus, both motion effects are seen to elicit a fatigue response, with the boredom condition having slightly worse performance than that viewed from the motion condition response. The best indicators of the biomarkers used to measure fatigue were both the respiratory rate and the Root Mean Square of Successive Differences (RMSSD) between normal beats of the heart rate variability measure.

In Motion Perception (Chapter Six), six axes of motion at three intensities were tested using the set Defence force tasks to determine whether any one axis, or a certain intensity, negatively affected performance more than others. Higher errors occurred in the Roll direction with a trend of high intensity in the Z-axis having the greatest impact on time on task. From a comfort perspective, the Pitch direction was the least comfortable for participants.

In the final chapter of Mental Workload under motion (Chapter Seven), increased workload did not have a great impact on performance, although further studies are needed to confirm this. In an analysis of subjective scales of workload in simple tasks, participants were able to accurately determine their task performance; however this judgement was hindered in more difficult tasks which had no feedback. From a bio-measure perspective, pupil diameter and respiratory rate are found to be the most accurate in determining the changing levels of workload from this group of participants.

## Acknowledgements

There's a proverb that states that it takes a village to raise a child. In a similar way, it takes many people to bring a thesis together. I would like to deeply thank all the following who helped make this thesis happen:

- The Defence Science and Technology Organisation (DSTO) Land Operations Division, who supported the motion research presented here and provided valuable feedback throughout the process.
- My supervisors Professor Ian Curthoys and Dr Hamish MacDougall who shared their insight and support throughout this research. Thank you Dr McDougall for responding every time there was an issue with the simulator, for developing the appropriate technologies to further the research and most of all, for giving me the opportunity to work on such a wonderful project.
- Dr Ian Brown whose original work in Motion Sickness studies was a great diving board for me from which to explore the area and who provided assistance in the Matlab coding process.
- Samanthi Gootentike for her valuable direction in the writing process.
- Simon Jackson, who reviewed the statistical theory with me when I had found myself lost in a mathematical world not usually explored by engineers. Your patience helped me not only develop as a statistician but to also believe in myself.
- The wonderful people I've met in the laboratory: Dr Ann Burgess, Steve Rogers, Dr Ljiljana Ferguson and Tahmine Tohzmann. Your smiles, chats, resources, coffees and welcomes made the experience all the better.
- Anna Magdas, Dr Anna Dimitriou and Dr Graham Brooker who bravely assisted in the proof-reading process.
- My family, mentors, and friends who believed in me the whole time and were always ready to listen when I needed to talk. To the girls that helped me escape it all, the guys who put up with my rants, the ones who called, the ones who prayed, and the ones that kept checking up on me on Whatsapp - Thank you. You have all been my real-life heroes.
- God, for always giving me the strength to go on.

## Statement of Contribution

I hereby declare that a substantial portion of this thesis is my own work and any part that is not my own work has been clearly indicated by acknowledgement of sources. I have read and understood the University of Sydney student plagiarism coursework policy and procedure.

My contributions are as follows:

- I developed the experimentation used in this thesis with the aid of my supervisor when not identified, within the specifications set out by the Defence Science and Technology Organisation contract work.
- I carried out an extensive literature review citing all relevant sources.
- I undertook all investigations into the motion conditions listed in this thesis.
- The choice of tasks was chosen based on my own conclusions following advice on work from my supervisors, the early work in Motion Sickness Dr Iain Brown, The task sets designed by the Mount Sinai School of Medicine and the cognitive tasks developed by Mr Simon Jackson. Their contributions have been listed appropriately throughout this thesis.
- All layouts and diagrams have been created by me unless otherwise referenced.
- All conclusions are my own, influenced by discussions with my supervisor.
- This document is a product of my own thoughts and writings with references clearly indicated.

Elisabeth Stephany Magdas

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## Acronyms and Abbreviations

| | |
|---|---|
| **6-DOF** | Six Degrees of Freedom |
| **7-pNS** | Golding-Kerguelen 7-point Nausea Scale |
| **Acc** | Running Letters Task: Accuracy (percentage) |
| **AN** | Adapted Nausea |
| **ANOVA** | Analysis of Variance |
| **BMSe** | Emulated Battle Management System simulator |
| **BR** | Breathing Rate. Also referred to as Respiratory rate. |
| **BTB** | Bob's Track Builder |
| **CL** | Create Line: a task in the BMSe |
| **CT** | Create Text: a task in the BMSe |
| **CU** | Create Unit: a task in the BMSe |
| **difIC** | Stroop Task: Difference between Incongruent & Congruent trials (milliseconds) |
| **difIN** | Stroop Task: Difference between Incongruent & Neutral trials (milliseconds) |
| **difNC** | Stroop Task: Difference between Neutral & Congruent trials (milliseconds) |
| **difSR** | Number Switch Task: Difference between Switch & Repeat trials (milliseconds) |
| **DSTO** | Defence Science and Technology Organisation |
| **errC** | Stroop Task: Error frequency, Congruent trials |
| **errI** | Stroop Task: Error frequency, Incongruent trials |
| **errN** | Stroop Task: Error frequency, Neutral trials |
| **errR** | Number Switch Task: Error frequency, Repeat trials |
| **errS** | Number Switch Task: Error frequency, Switch trials |
| **HR** | Heart Rate |
| **HRV** | Heart Rate Variability |
| **IBM** | International Business Machines Corporation |
| **lapseC** | Stroop Task: Lapse frequency, Congruent trials |
| **lapseI** | Stroop Task: Lapse frequency, Incongruent trials |
| **lapseN** | Stroop Task: Lapse frequency, Neutral trials |
| **lapseR** | Number Switch Task Lapse frequency, Repeat trials |
| **lapseS** | Number Switch Task Lapse frequency, Switch trials |
| **LCD** | Liquid-Crystal Display |
| **LSD** | Least Significant Difference |
| ***M*** | Mean (average) |
| **meanC** | Stroop Task: Mean response time, Congruent trials (milliseconds) |
| **meanI** | Stroop Task: Mean response time, Incongruent trials (milliseconds) |
| **meanN** | Stroop Task: Mean response time, Neutral trials (milliseconds) |
| **meanR** | Number Switch Task: Mean response time, Repeat trials (milliseconds) |
| **meanS** | Number Switch Task: Mean response time, Switch trials (milliseconds) |
| **MF** | Motion Fatigue |
| **MP** | Motion Perception |
| **MS** | Motion Sickness |
| **MSSQ** | Motion Sickness Susceptibility Questionnaire |

| | |
|---|---|
| **MW** | Mental Workload |
| **NASA** | National Aeronautics and Space Administration |
| **NN** | Normal heart beats |
| **NN20** | Number of successive NN intervals that differ by 20 milliseconds |
| **NN50** | Number of successive NN intervals that differ by 50 milliseconds |
| **NoN** | No Nausea |
| **PN** | Progressive Nausea |
| **pNN20** | Proportion of NN20 divided by total NN |
| **pNN50** | Proportion of NN50 divided by total NN |
| **PZ** | Pan-Zoom : a task in the BMSe |
| **RMSSD** | Root Mean Square of Successive Differences |
| **RR** | Respiratory Rate |
| **RT** | Read Text: a task in the BMSe |
| **RU** | Read Unit: a task in the BMSe |
| **SD** | Standard Deviation |
| **SPSSS** | Statistical Package for the Social Sciences |
| **SSQ** | Simulator Sickness Questionnaire |
| **TBAS** | Test of Basic Aviation Skills |
| **TC** | Time to Complete : Timing measure used in the Pan-Zoom task in the BMSe |
| **TI** | Time to Initiate: Timing measure defined by the time taken to engage in a BMSe task |
| **TT** | Total Time: Timing measure used in the CU, CL, CT, RT and RU task in the BMSe |
| **USA** | United States of America |
| **USYD** | University of Sydney |

# 1. Introduction

This project was designed, in conjunction with the Defence Science and Technology Organisation (DSTO), Land Operations Division, to explore the effect that various motion conditions have on task performance in a civilian environment. Following a pilot study by the University of Sydney into Motion Sickness effects, meetings were held with the DSTO to outline further areas of motion that would be of interest to a defence land operations context. From the initial project outlines it was designed that four motion conditions were explored in the work of this thesis: Motion Sickness, Motion Fatigue, Motion Perception, and Mental Workload under changing Motion stressors. The data gathered from the civilian context is to later be compared with military personnel to evaluate the limits of expected human performance given a set motion scenario and to discover if any reliable biomarkers could be used to monitor and help model performance expectations during field work.

In general, studies in the area of motion effects focus on how these conditions affect a person's driving ability. For example, most literature on motion fatigue focuses solely on the driver, specifically, on changes to their driving behaviour and not on how prolonged exposure to motion affects performance ability outside of driving conditions. This is understandable since, outside a military context, tasks are seldom performed during long driving exposure times.

In research on Motion Sickness, there is an emphasis on theories of causation, symptoms, and potential treatments, as this is what civilian and medical interests focus on. Aspects of task performance under motion nauseated conditions are not especially concerning to the general public and therefore its investigation would not attract funding. Motion Perception does have some research focus on task performance; however, as is discussed in the Motion Perception Chapter, these studies are often limited to 3-axes of motion, which does not accurately simulate real-world conditions. Mental Workload under changing motion conditions is even less researched, with no previous bases of performance measure conducted and documented in known accredited literature at the time of the writing of my findings. This thesis shifts from previous research by moving away from driving performance and focusing instead on task performance, in particular, performance relating to military-based tasks under the influence of

Motion Sickness and under Motion Fatigue conditions. Beyond this it seeks to fill in the gaps of knowledge in the Motion Perception and Mental Workload conditions.

The work presented in this thesis is designed to start addressing another gap in available scientific literature; how motion affects the ability to perform Australian military-based tasks in a quantifiable manner. Knowledge of such a measure would mean that the DSTO can apply validated data into modelling software to predict performance of personnel given a specific motion-effect profile. The output of such software modelling will affect decisions on team-profiles, as well as size and task breakdown for personnel involved in field operations. The aim of this thesis is to build on the knowledge of how a person is affected by motion in a way that can be used by the military, to model expected behaviour.

This thesis is formatted for easy readability of the four areas of motion effects investigated so that, should only one area of motion effect be of interest, that chapter can stand alone as a resource with minimal references to other parts of the document. Following this introduction is the general literature review. This general review covers the research of areas encompassed by all four studies, that is, simulations, task measures, and biomeasure recordings. For each motion effect in particular, the relevant review is found in the 'Introduction' section of the relevant motion chapter. This is in keeping with each chapter's ability to perform as a stand-alone document. In a similar format, the chapter following the Literature Review is the Materials listing where all devices: simulators, biomeasure recording devices, software packages, and questionnaires used throughout the studies are described in full, in order to minimise repetition throughout this work.

The subsequent four chapters each present one of the four areas of motion effects investigated in this thesis. Each of these chapters introduces the motion effect of interest with its associated literature background, where available. The chapter then describes the methods used for the study, the results and ends with a short discussion and appropriate conclusion.

This thesis concludes with a final discussion that includes the findings from all four studies. This chapter also includes what was successful from the study, the limitations involved, and recommendations for future research work.

# 2. Literature Review

In reference to literature involved regarding the specific motion conditions investigated, please refer to the appropriate Introduction chapter associated to that motion study. This review is focused on literature that is applicable to all studies in this thesis.

## 2.1. Simulations in Research

A simulation, as it is applied in this context, is an imitation or re-enactment of a real-world system in real-time. There is a range of simulation types, from physical, interaction, and synthetic (computer-based) simulations. The very first modelling 'simulation' took place in 1777 with Claudio Rocchini Buffon's needle problem – a simple mathematical probabilistic modelling problem used to estimate π (Larson and Odoni, 1981). It is quite likely that the first physical-based training simulation did not take place until 1909 when the original flight training rig was developed to train pilots to fly the Antoinette monoplane (Greenyer, 2008). These simulators were not popular until the advent of World War 1, when air travel became an important means of spying on and attacking the enemy (Greenyer, 2008) rather than a civilian past-time activity. Pilots needed to be trained but planes were not cheap nor were they the safest place to learn. This heralded a shift in viewing simulators as a cost-effective training solution. Whilst this physical simulation took place in the early 1900s, computational simulations had to await further development in technology, coming into effect in the mid- 1940s (Goldsman et al., 2009). This era also saw the development of the first computers designed to solve specific problems, such as the implementation of the Monte Carlo method to solve issues relating to neutron diffusion (Hira and Gupta, 1998). By 1961, IBM began developing the General Purpose Simulation System (Gordon, 1978). In 1963 the earliest book on simulation: *The Art of Simulation* by Keith Douglas Tocher (Tocher, 1963), the developer of the General Simulation Program (Hollocks, 2008), was published. These computer advances brought simulations to the forefront of research and development.

Computer simulation opened the doors for the domestic market to have access to simulator technology. Today, simulations are used in many areas; in recreation, research, and training. The technology is readily available in gaming scenarios with a whole game genre dedicated to this style of game-play. There has been a recent surge of its popularity in medical practices with evidence of benefits in both training (Okuda et al., 2009) and therapeutic (Strickland, 2011) contexts. As for the military context, there has been continued use of this technology from the time of the World War 1 flight trainer, with this format of teaching being used quite extensively in military training protocols (Kennedy, 1999).

From a research perspective, simulators are a desirable delivery mechanism as they provide a controlled environment in which to test real-world scenarios. They are generally also cheaper to run than the real-world alternative would be, allowing for multiplicity of tests that would otherwise be unachievable from a cost perspective. The disadvantage of these systems is that to date no simulator has become the 'perfect' immersive replica of a real world environment. The technology available still has yet to reach the level of seamless replication. The brain can register these small discrepancies within a limit to what is acceptable whilst still perceiving whether it is real. It will depend on the individual on how as a participant they will respond to the simulation, and whether their brain is tricked into believing it to be 'real' or not. As such, whilst simulators are very useful for training, real-world comparison tests are still needed to validate findings. Despite this limitation, the ease and degree of control of simulation environments does make it the best option for test purposes.

The simulator in this study is both a physical and a computational simulation. The pros of the simulator used in this study are that it is an enclosed 6-degrees-of-freedom simulator with motion profiles along the 6-axes closely matched to visual racing scenarios. By using this simulator we can test a range of terrains through this environment to analyse driving/motion effects as would be experienced by military units.

## 2.2. Task selection and Measures

### 2.2.1. Military Tasks – the Battle Management System

The Motion Sickness (Chapter 4), Motion fatigue (Chapter 5), and Motion perception (Chapter 6) studies in this thesis involve the use of the emulated Battle Management System (BMSe) provided by the DSTO and described in Chapter 3.1.2: Emulated Battle Management System simulator (BMSe). The original Battle Management System (BMS) used in Australia was developed by Elbit Systems (Elbit Systems Ltd., Haifa, Israel). This relatively new software aims to improve safety and communication for army personnel by relaying information on operations, fire engagements, manoeuvrability, intelligence information, and logistics (2014). Any personnel other than the driver of the military vehicle can be expected to be in control of the operation of the device during field operations.

The operation of such a system is handled by a Toshiba Toughbook to ensure durability in the field. Inputs are made using a touchpad or touch screen and the utilisation of the keyboard. The emulated simulator version of the BMS lacks the complexity of options available on a standard field BMS system. However, it does maintain the main functions of the delivery process and style of inputs a soldier could be expected to complete.

### 2.2.2. Cognitive Tasks

To validate that the defence based tasks could also affect other tasks on a wider scale, cognitive based tasks were used to measure performance degradation on a more general cognitive level.

#### 2.2.2.1. Stroop

The Stroop test was first introduced by J.R. Stroop in 1935. Today it is a well-established test for cognitive flexibility and stress. Whilst there are many versions of this test, the core of all Stroop tasks involves the presentation of stimuli to which, in either congruent or incongruent conditions (neutral condition optional), the participant must respond.

Two types of Stroop tests have been used in this thesis. In the Motion Fatigue test (5.2.4 Performance Measures), a Colour-naming Stroop test was implemented. In the Mental Workload under motion conditions (7.2.4 Task Measures), a spatial Stroop test was used instead.

The Colour-Word Stroop test is based on the original interference test developed by J.R. Stroop. A review of Stroop tests by MacLeod (MacLeod, 1991) showed that this version of the Stroop test remains the most common format administered. It involves seeing the name of a colour typed out in a font colour that is either congruent or incongruent with the name presented. Participants read the word out loud while the mean time to respond is measured. From a research perspective, the most common time measure is that taken to respond to the incongruent conditions (Uttl and Graf, 1997, MacLeod, 1991). For the colour-word Stroop test used in this thesis, there is a small variation on the original test where participants make a response as to whether the stimuli are congruent or incongruent with computer input. This categorical method was first practiced in 1964 showing again that sorting decisions of incongruent trials takes longer than sorting congruent ones (Tecce and Happ, 1964).

The Spatial Stroop test is a further modification to the original test. This version, as used in this thesis, removes the word and colour components, adding spatial reasoning to the inhibitory control. Instead of words, the participant is now presented with an arrow pointing left or right that can appear at the left, centre (neutral), or right of the screen. Time is measured for incongruent (unmatched side of screen to direction of arrow), congruent (matched side of screen to direction of arrow) and neutral trials (arrow appears in centre)., The defining elements of the Stroop test, that a participant has to view a stimulus, remains core in the design of this test, even though the delivery style is different.

#### 2.2.2.2. Memory

The memory-match test as used in the study of Motion Sickness (4.2.4.2 Match Test) in this thesis, is an analysis of short-term working memory. One of the first examples of such a memory test is documented by Skinner in 1950. This test used pigeons exposed to green or red stimuli that disappeared. The pigeon is trained to respond by selecting one of two options: a red or a green light, depending on which one matched the original stimulus (Skinner, 1950). The test has since grown in complexity for use in human trials.

The version used is based on the common psychological testing Match-to-sample task as can be found in the test-battery of the Psychology Experiment Building Language (PEBL) open source program released in 2009 (Mueller, 2009). The origins of such a test date back to 1998 where it formed part of the Performance Assessment Battery used by the Unified Tri-service Cognitive Performance Assessment of the United States of America military department (Perez et al., 1987). In this format, a 4x4 grid pattern is presented to the viewer with a pattern made up in the 16 square grids of two colours. Participants are presented this initial stimulus for a specific time period before it disappears and a pair of matrices appears, one of which is a match to the original. Error rate and time to respond are both measures used to analyse results from this task.

#### 2.2.2.3. Reaction Time

Reaction time based tests have long been an element of studying cognitive processes in a psychology setting. In the late 1800s, the work of Donders, Buccula and Wundt pioneered mental chronometry research (Brozek, 1970). However, Wundt found that the variability of reaction times between participants was too great, leading him to abandon the research (Hergenhahn and Henley, 2013). It wasn’t until 1960 that reaction time was rediscovered and came into the popular usage we see today (Hergenhahn and Henley, 2013).

There are four types of reaction type tests in research: the simple test, where the participant responds to a single visual or auditory cue, the choice reaction test, the recognition reaction test, where a participant only responds to a selected stimuli ignoring the distractors, and the modification of the choice test which is a serial reaction time test (Kosinski, 2013). There is equivalence in the motor reaction speed for each task, such that the speed in a simple task can be explained by this task having the shortest processing time (Miller and Low, 2001). The hypothesis is that this decrease in processing time will limit the natural variability in response between participants of the same age and educational group. For this reason, the simple test has been used in this thesis where reaction times are concerned, in particular, for the study of Motion Sickness effects (4.2.4 Task sets) and Motion Fatigue (5.2.4 Performance Measures). Further information can be found in these corresponding chapters.

#### 2.2.2.4. TBAS Dot

The TBAS Dot is part of a series of cognitive tasks used in conjunction with the NASA research team at the University of Mount Sinai. It stands for the Test of Basic Aviation Skills (TBAS) Direct Orientation Test (DOT) which is one of nine sub-tests from the TBAS examination tool used in the selection of Air Force pilot candidates in the USA (2012).

The test was first implemented in 2007 (Rumsey, 2012). It is a psychomotor test battery that measures the ability to process spatial orientation based on the visual directional information of a plane relative to a target. Participants must respond in a fixed time using keyboard directional controls. In this way this test measures both spatial understanding and mental flexibility.

This measure has been used as a performance measure in both the study of Motion Sickness (4.2.4 Task sets) and Motion Fatigue (5.2.4 Performance Measures). A further description of the task procedures involved can be found in Chapter 4.2.4.1 TBAS Dot Task.

# 3. Materials

## 3.1. Simulators

### 3.1.1. Motion Simulator

In all studies, a CKAS (V7,CKAS Mechatronics, Victoria, Australia) 6 Degrees-of-Freedom (6DOF) motion platform is utilised to supply the simulated motion. This platform is an ideal choice for motion testing as it allows freedom to test along all axes of motion as highlighted in Figure 1. The seating cabin attached to the motion base is a modified polyethylene moulded circular rainwater tank which occludes outside light appropriately for simulations. The safety of this enclosure has been tested and approved by the National Aeronautics and Space Administration (NASA) standards (Protocol approval: Pro 0242).

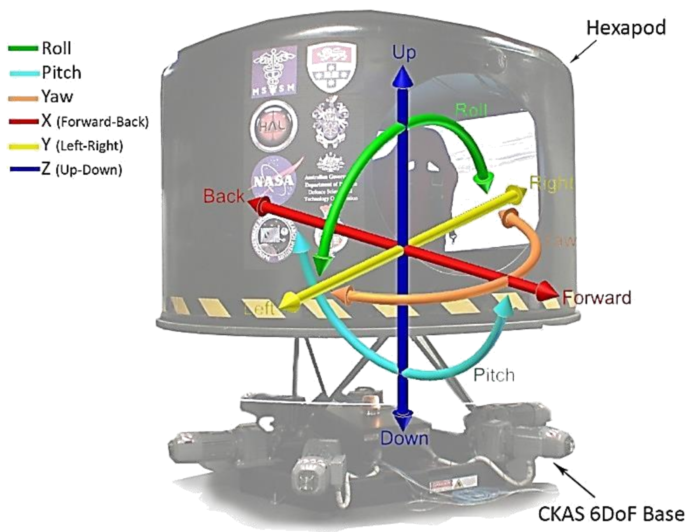


Figure 1 Motion Simulator used for testing with 6 degrees of motion highlighted

Visual input is provided by three BenQ (BenQ Corporation, Taipei, Taiwan) High Definition projectors to project a landscape with aspect ratio 3840:1024. These three projectors project onto three corresponding visual boards (1.15m x 0.9m) offset by 120$^{o}$ as shown in Figure 2. The position of this placement creates a full-surround visual interface by exceeding the peripheral visual range when a participant's vision is fixated on the centre screen.

Participants are seated in a racing-car style adjustable cushioned seat bolted in the centre of the enclosure and attached to the seat by a four-point safety harness seatbelt. The racing seat is adjustable over a range of 0.2m forward-back on the centre plate. In front of the participant is a ball-bearing steering wheel and a three pedal system is placed at the feet as the control system for all driving simulation scenarios presented in this Master's document.

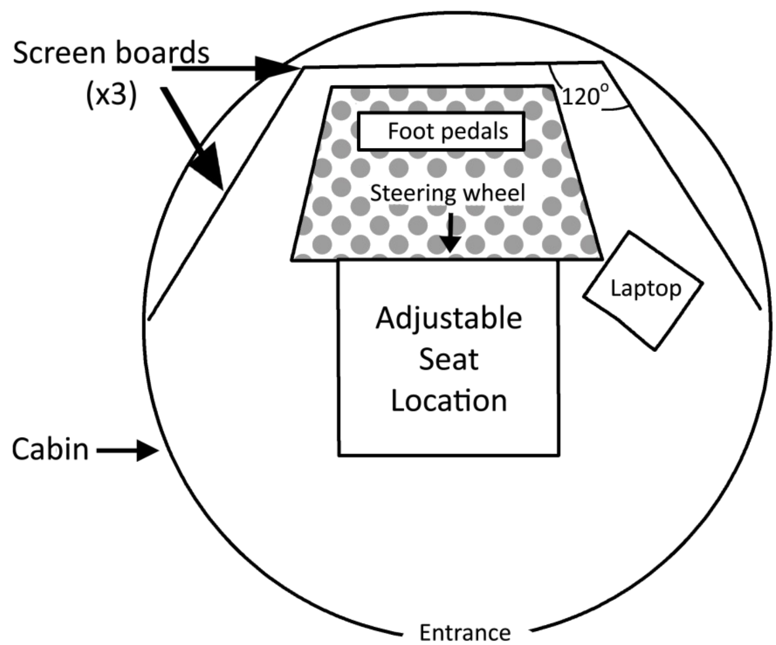


Figure 2 Cabin setup of Motion Simulator

Offset from the control system and to the right is the delivery method for the performance tasks. In the Motion Sickness study, this delivery method is a Toshiba Toughbook, with base section fitted at seated arm height. In all subsequent studies, the visual delivery of tasks is via a 19 inch display monitor fixed at the same location. Manual responses to the tasks in these studies are made using a moveable keyboard and a fixed orbit trackball mouse that is fitted at the base of the monitor.

### 3.1.2. Emulated Battle Management System simulator (BMSe)

The Battle Management System emulator is a simulation program that emulates tasks that are similar to those which a soldier of the Australian Army can be expected to complete when on deployment. It is designed for use in training and study conditions. These tasks have been developed for, and supplied by, the Defence Science and Technology Organisation (DSTO) Land Operations division so that the studies conducted in this thesis could show direct relevance to the military context.

The base simulation consists of six tasks which are repeated once. All tasks are completed on a 'map image' as shown in Figure 3. The task instruction is presented in the top bar situated above this map image. Once each task is completed, the participant is instructed to select the 'next task' button on the top right of the display in order to progress through to the next task of the task set. The tasks are explained in brief in Table 1 and their scoring of these tasks is laid out in Table 2.

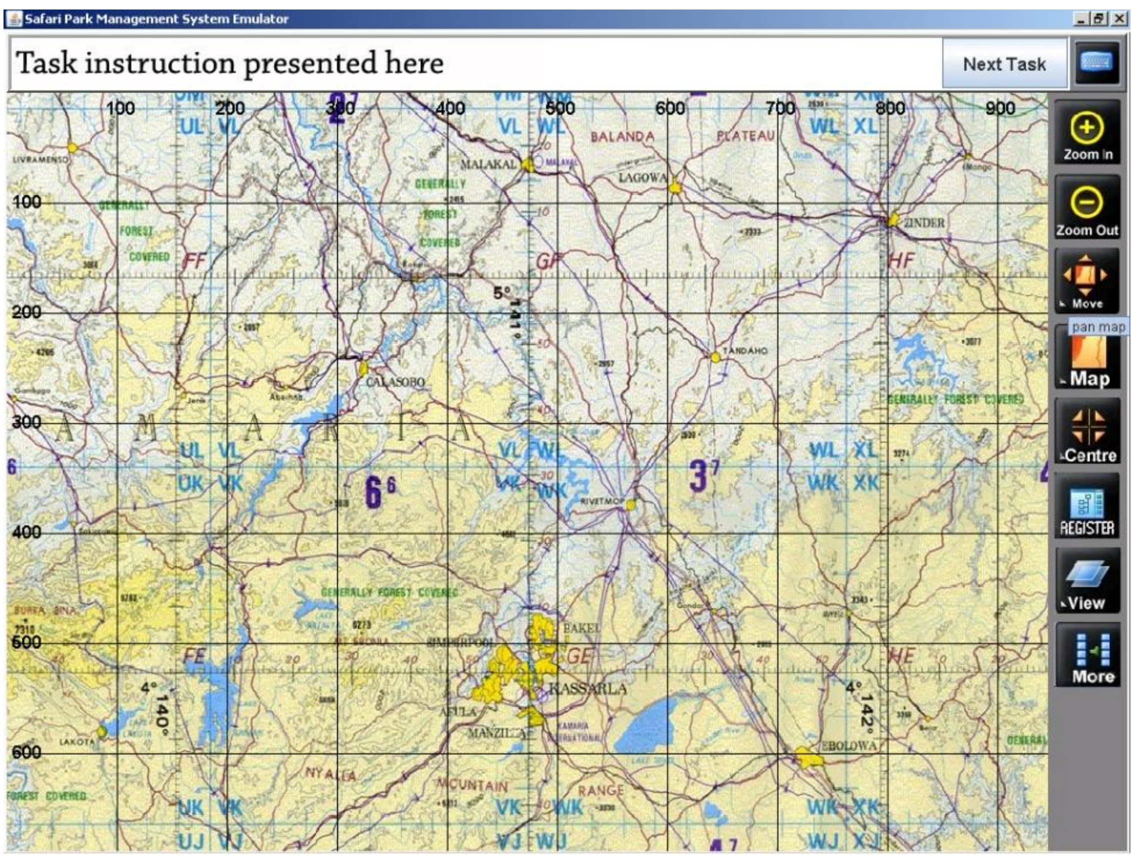


Figure 3 BMSe Task display as viewed by participant

Table 1 Task Descriptions for each task presented in the BMSe

| Name | Code | Task Description |
|---|---|---|
| Pan-Zoom | PZ | Move the map in a fixed direction and zoom in or out according to the given instruction. |
| Create Unit | CU | Select and place a specified unit from a drop down menu at the specific coordinate. |
| Create Line | CL | Starting at a given coordinate, a path was drawn following the given instructions. |
| Create Text | CT | Type out text from the Instruction box into the Message window (operator noted mistakes) |
| Read Text | RT | Recite the words that appeared in the Message window |
| Read Unit | RU | Identify three measures of a unit's position on the map: type, size and location. |

Table 2 Error Descriptions for each task presented in the BMSe

| Code | Error measurement |
|---|---|
| PZ | Incorrect pan direction was scored as an error of 0.5. Incorrect zoom selection was scored as an error of 0.5. Maximum error was 1. |
| CU | Incorrect animal selection or incorrect placement was scored as an error of 1. |
| CL | Incorrect coordinate at any point resulted in an error of 1 for that point. |
| CT | Errors accumulated for every incorrect letter typed for each word. |
| RT | Incorrect words, repetition of words and missed words results in an error of 1. |
| RU | Each incorrect measure was scored as an error of 1 for a total possible error of 3. |

All participants in this study were civilians. In an initial investigation in Motion Sickness effects using the BMSe by Dr Iain Brown, it was decided to replace the military context with a more socially acceptable 'safari theme' context for these participants. With this theme, military objects, such as artillery units, have been replaced with animals, such as an elephant. These modifications are not expected to affect the outcome in any way as the core test parameters remain unmodified. Further changes developed by me to this task was in the creation of randomised words used in the reading and typing tasks of this experiment and the creation of the 18 series of test profiles used in the Motion Perception study.

## 3.2. Biomeasure Units

### 3.2.1. Bioharness

In all studies, where biometric analysis is appropriate, participants wore a Bioharness® 3 (Zephyr, Annapolis, Maryland, USA) unit. This device is a lightweight, non-intrusive chest Strap that is used to monitor a range of inputs such as body temperature, heart-rate, heart-rate variability, activity and posture (through the on-board 3-axis accelerometer,) and location (via Global Positioning Satellite), sampled at one second intervals. For this thesis, the measurements from the device used for analysis are Heart Rate (HR) (beats per minute), Respiratory Rate (RR) (breaths per minute) and R-R intervals measurements, which are processed by using the Kubios Heart Rate Variability Analysis Software (University of Western Finland, Finland) to provide measurements of Heart Rate Variability (HRV).

The Bioharness® is worn across the chest as shown in Figure 4. The chest strap is adjustable and available in both Small and Large sizing options to maintain firm fixation for all participants throughout the study. Sections (4) and (5) on the harness are slightly moistened with water to improve signal conduction. This signal connection is checked via a Bluetooth connection. The live feed from the Bluetooth assists in affirming that the participant is wearing the device correctly and that the device is transmitting data in reliable ranges prior to the start of any study. The Bluetooth measurements are not used for final analysis, as the transmission is interrupted once the participant enters the simulator. Instead, the computer device attached to the chest strap records data time-stamped at one second intervals for post-analysis. No flags can be sent to the device, so these automated timestamps are relied upon for accurate cross-examination of conditions.


**Figure 4 Bioharness® 3 details and wearing location as provided by the Zephyr Bioharness® 3 User Manual.**

### 3.2.2. Video Goggles

Video goggles were used in the Motion Fatigue and Mental Workload study to analyse blink rate, blink velocity, and pupil dilation. These goggles, and the post-processing software, have been developed by Dr Hamish MacDougall for the fatigue study. The goggles are constructed from a motorcycle sunglasses frame (Ugly Fish Eyewear, Fairy Meadow, New South Wales, Australia) designed to comfortably sit on the face as shown in Figure 5. The goggles sample at a rate of 300Hz through a high speed video camera (FireFly MV®, Point Grey, Richmond, British Columbia, Canada) mounted to the frame. A visible light filter is used to minimise external light influences with two infra-red light emitting diodes fitted to supply the appropriate illumination necessary to track pupil activity. A dichroic mirror reflects these infra-red images to the camera where they are captured by the camera for post-processing.

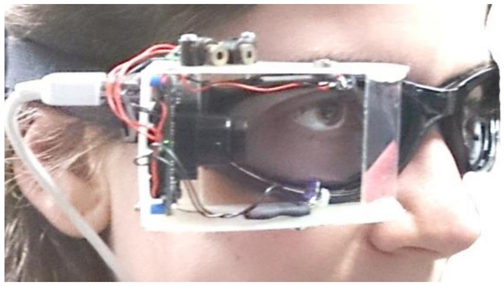

Figure 5 Image of Video goggles as worn by participants during studies

## 3.3. Software Packages

### 3.3.1. RFactor

RFactor (Image Space Inc., Michigan, USA) is a sports racing video game package released to the public market in November 2005. Unlike other racing simulations at the time, RFactor has an advanced 15 degrees of freedom physics engine to closely emulate motion under real-world conditions (wind factors, collision detection, wear in tire tread, vehicle handling choice and so forth). The package is customisable with the ability to create and import new race tracks and vehicles according to study requirements.

CKAS Mechatronics has paired the motion effects generated by the physics engine in RFactor to the CKAS base using LabView (National Instruments, Austin, Texas, USA). In this way, the motion generated in all matched motion scenarios is motion which coincides with the visual input generated by this gaming engine.

### 3.3.2. Kubios HRV package

Kubios Heart Rate Variability Analysis Software (University of Western Finland, Finland) is a mathematical modelling tool that reads R-R intervals and outputs HRV data using a graphical interface. Final reports for section selected data outputs are exported in Excel, Pdf, and Text File formats. In the studies conducted for this Masters, the data corresponding to the time-domain intervals are investigated. These measures are the mean and standard deviation of RR intervals, Root mean square of successive differences (RMSSD) data, the number of pairs of successive NN intervals that differ by more than 50 seconds (NN50) and the proportion of NN intervals that differ by 20 seconds (NN20) intervals divided by the total number of NN intervals (pNN20).

### 3.3.3. Matlab

Matlab (Mathworks®, Natick, Massachusetts, USA) is a technical computing software package used, in the context of this Masters, as a mathematical and signal processing tool. It has been used extensively in the processing of the BMSe data to Excel format output as well as analysing the means and variance measures from large groups of data.

The Matlab code used for the BMSe analysis was developed by Dr Iain Brown (Brown, 2011). It reads the output file and processes these results in a format that includes the timing factors for each task, which the raw output file does not give. In the studies presented in this file, this base code was used with permission, with changes made by myself as necessary. This base code can be seen in Appendix A: Matlab script for processing data from BMSE by Dr Iain Brown

All other Matlab codes used to process datasets have been developed solely by me.

### 3.3.4. SPSS

IBM SPSS Statistics (IBM Corporation, New York, USA) is a statistical package software designed for Social Sciences statistical analysis. This package has been used for all statistical analysis presented in this Master's thesis unless otherwise stated.

### 3.3.5. Bob's Track Builder Pro

Bob's Track Builder (BTB) Pro (Bobs Track Builder, Australia), initially released in 2009, was developed to create specialised tracks in formats supported by a number of racing simulation software packages, including rFactor. Through graphical interface, road maps can be designed or input from Google Earth. Modifications are possible to develop a personalised terrain model using polygon mesh modelling design, with the addition of numerous physical assets, as required to develop the ideal testing environment.

This program was used for the Motion Fatigue study to create a 'Boring' scenario track. The specifications in mind when designing this track, was to have long stretches of plain road with turns after long distances to act as test points to monitor the participant's alertness. The author developed this track with minimal assets to remove as many external stimulant factors as possible. The overlay of this track is seen in Figure 6. The terrain is raised alongside the road to encourage the participant to stay on track. This change in terrain height acts as a reference to fatigue conditions such as micro- sleep, since drifting to these areas of the track created an obvious motion effect in the simulation.

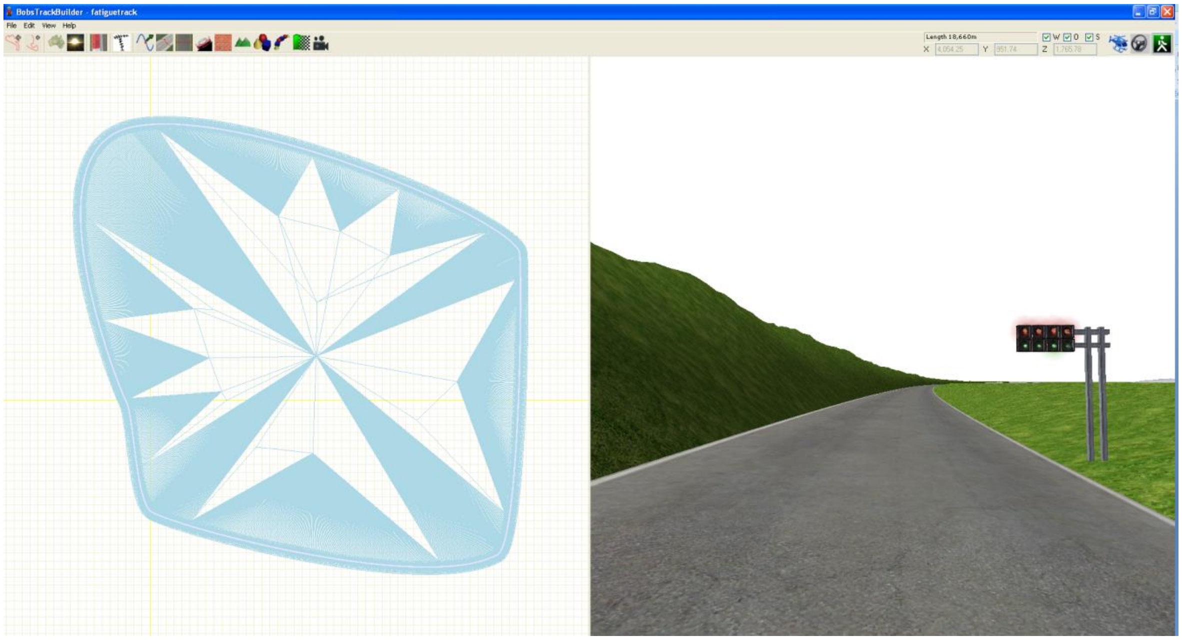

**Figure 6 View of Bob's Track Builder, Fatigue Course. On left is the top 2D polygonal view of the course. To the right is a 3D look from the start section of the road.**

## 3.4. Questionnaires

### 3.4.1. Simulator Sickness Questionnaire

The Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) was developed in 1993. It lists 14 symptoms that the participant responds to prior and post-simulated motion. Each factor can be ranked from: none, slight, moderate, and severe (see Appendix B: Simulator Sickness Questionnaire). The output is mathematically weighted and split into a numerical total score (change between pre- and post-inputs) and divided symptomatic scores in the categories of nausea, oculomotor, and disorientation.

### 3.4.2. Seven Point Nausea Scale

The Golding-Kerguelen 7-point Nausea Scale (7-pNS) was developed in 1992 (Golding and Kerguelen, 1992). This scale has 7 points, ranging from 0-6, by which a participant can quickly and effectively respond to their state of well-being during a study condition (see Appendix C: Golding-Kerguelen Seven

Point Nausea Scale). In this scale, a level ‘0’ corresponds to feeling no ill-effects whilst a level ‘6’ signifies a level whereby the participant is too ill to continue. Whilst originally developed with simulations involving vertical and horizontal oscillations, the scale translates well to motion simulation conditions. The scale does not have the same level of complexity as the SSQ. However, it is ideal in achieving a fast subjective response from the participant during time crucial activities when completing the SSQ is not feasible.

### 3.4.3. Stanford Sleepiness Scale

The Stanford sleepiness scale was developed in 1972 by the Department of Psychiatry and Behavioural Sciences at Stanford University School of Medicine. It is another 7 point Likert-type scale designed as a quick measure to assess alertness. The scale is rated from ‘1’ indicating the sensation of “feeling active, vital, alert or wide awake” through to ‘7’ of “no longer fighting sleep, sleep onset soon” with a score of “x” assigned if the participant is found to be asleep (Hoddes et al., 1972) (see Appendix D: Stanford Sleepiness Scale).

# 4. Motion Sickness

## 4.1. Introduction

Motion Sickness, as the name implies, is an illness effect which occurs as a response to a moving environment. When the sensation of motion disagrees with the brain's predicted input, biomechanical interference can occur. This perceptual mismatch is the leading theory as to the cause of motion sickness (Reason and Brand, 1975, Oman, 1982, Oman, 1990, Holly and Harmon, 2012).

Whilst visual-vestibular mismatch is the leading theory, the question as to why certain individuals experience its effect while others remain immune is still unknown (Miller and Graybiel, 1970). What is known, are the symptoms experienced by those who suffer its effects. These symptoms are wide ranging; from the well-documented nausea, vomiting, and pallor, to the less frequently experienced symptoms of apathy and blurred vision (Reason and Brand, 1975, Harm, 1990). The prevalence of these symptoms has been documented to peak over exposure and to decline as an individual adapts to the environment (Holly and Harmon, 2012, Lackner and Dizio, 2006, Stoffregen et al., 2013).

In 1998 the Motion Sickness Susceptibility Questionnaire (MSSQ) was devised (Golding, 1998, Golding, 2006). This questionnaire calculates motion sickness exposure from childhood to the current age of the participant. By analysing the prevalence of this condition, it is possible to predict which individual will experience Motion Sickness in the future. This is a useful tool when investigating motion sickness effects; however it does not take Simulator Sickness into account.

Simulator Sickness is a motion sickness condition that occurs as an effect of participating in a simulated visual-motion environment. It refers to both stationary and motion simulators. Whilst Motion Sickness and Simulator Sickness are linked in symptomatology, with headaches being more prevalent in the latter (Bruck and Watters, 2009, Kennedy et al., 1992, Kennedy and Fowlkes, 1992), there is no predictor to date for who will experience simulator sickness. In this study, the MSSQ is used in combination with a Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) to investigate the usefulness of such questionnaires for motion testing.

A number of studies have been conducted to determine the effect of Motion Sickness on task performance. From a military perspective, it is important to know to what degree a soldier's performance can be expected to be compromised based from the analysis of prior experience of Motion Sickness. Previous studies on performance suggest that motion sickness reduces perceptual, cognitive (Muth, 2009)and motor (Hettinger et al., 1989) function and short term memory (Joakim Dahlman et al., 2009) performance. However, a study into Mountain Sickness (Houston, 1992) by NASA found there to be no deterioration or reduction in performance. Participants in this study where only prevented from completing the tasks to an adequate standard when they had regurgitated over the input apparatus. This has only been found in one study, so further investigation is required with the specific Australian military task set, to determine the effect of motion sickness.

In this chapter, two studies are conducted to analyse performance as affected by motion sickness. Both studies involved elements of driving in a motion simulator with periodic stops where a participant was required to complete a defined task set before continuing. In the first study the BMSe tasks were used for military relevance. As is shown in the results, this first study showed no reduction in performance in the simulator-sickness-affected group, as compared to the unaffected participant group, with a trend for the nauseated participants to perform better. It is postulated that nauseous participants focused on the task to distract from their symptoms, whilst those unaffected became disassociated with the long tasks as the driving condition was more interesting. This hypothesis is tested in the second study where the tasks are replaced with a more engaging cognitive set and the driving times increased in order to minimise the tendency to disengage during task time.

## 4.2. Method

### 4.2.1. Participants

All participants were enrolled for this study through the University of Sydney, School of Psychology. In part one, twenty eight students were recruited consisting of fifteen male (*M*=19.3 years, SD=1.9) and thirteen female (*M*=21.3 years, SD = 3.65). In part two, a larger group of forty nine students participated of which twenty five were males (*M*= 19.36 years, SD = 1.93) and twenty four females (*M*=19.63 years, SD: 3.65). Participants in both studies provided informed written consent and were aware that they could terminate the study at any time. Irrespective of time of termination, all participants are awarded course credit according to standard department procedure.

### 4.2.2. Apparatus

Motion was delivered using the 6DOF motion platform described in 3.1.1 Motion Simulator. Participants were enclosed within the cabin and restrained using the four-point safety harness. In these studies, the task measures were completed on a Toshiba Toughbook located to the right of the participant. Communication was maintained throughout both studies using a headset intercom.

### 4.2.3. Design

For both studies, participants began the study by completing the MSSQ form. The participant was then fitted into the simulator and a baseline task measure completed. Once completed, the participant drove in the simulator until a ‘stop’ point. When stopped, the participant was asked to verbally relate their sense of nausea using the 7-point nausea scale (7-pNS) (3.4.2 Seven Point Nausea Scale) and then complete the task set. Once completed, they continued to drive.

That course chosen on rFactor for both studies is a course named “Desert Mesa”, a free-to-download add-on course created by user DDawg (Onofrey, 2010). This is a 5.05km desert based environment containing a number of corners and rolling hill sections (see overview in Figure 7) causing a turbulent motion effects that are linked to motion sickness (Setness and Van Beusekom, 2004). This original course was chosen by Dr Ian Brown in a pilot study of the Motion Sickness in the driving simulator. This choice was assessed by the author through vibration analysis using an industry XSENS MTx inertial measurement unit (XSENS Technologies B.V., Eschede, Netherlands). This course, when driven by an average participant, has a measured mean vibration of $1.68 m/s^2$. This level of vibration, according to the Australian Standard 2670.1-2001, is rated as “very uncomfortable” without reaching the $>2 m/s^2$ highest rating of “extremely uncomfortable” (Standards, 2001), validating this course as an appropriate design choice to elicit a motion sickness response whilst remaining within standard limits.

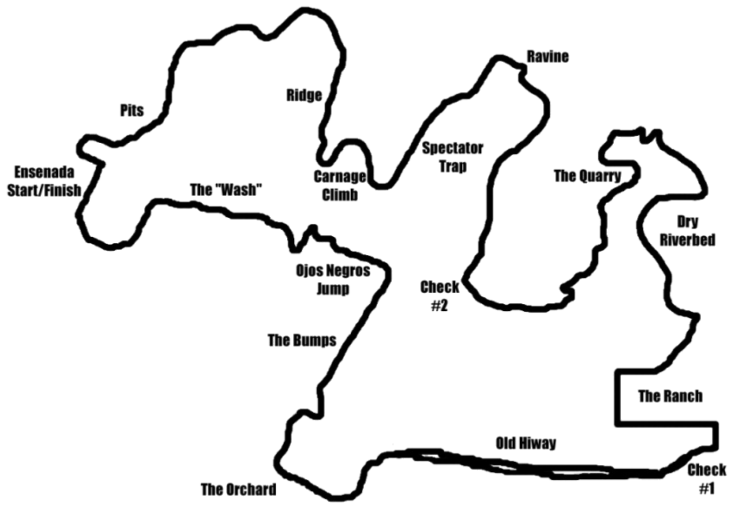


Figure 7 Desert Mesa track overview (Onofrey, 2010)

In Part One, the stop point occurred at the end of each lap completed. In Part Two, the stop point was time-based, taking place every 10 minutes. In both studies, the experiment continued in this manner for one hour or until the participant felt too ill to continue.

If participants became ill in the first 20 minutes, motion remained matched to the visual stimulus for their experiment. However, if the participant felt well, the motion was mismatched after this time. The motion profile used was a generated sum of sines developed in LabView. This change in motion is designed to provoke vestibular mismatch and induce motion/simulator sickness in an individual who would normally not suffer from these effects.

In the Part Two study, participants completed a Simulator Sickness Questionnaire (SSQ) (3.4.1 Simulator Sickness Questionnaire) prior to and post-simulation. This questionnaire allows for a numerical score on how the participant felt at the end of the simulation, rather than relying on the subjective measure presented by the 7-pNS, which is more prone to inflated scores by participants who may have desired to exit early.

### 4.2.4. Task sets

In Part One the tasks used as the performance measure was carried out as two iterations of the BMSe, as outlined in 3.1.2 Emulated Battle Management System simulator (BMSe). Performance measures were based on the output of this task as described in this earlier chapter.

In Part Two three cognitive-based tasks were chosen from a set of tasks developed by the Human Aerospace Laboratory of the Mount Sinai School of Medicine affiliated with the University of Sydney in research with NASA pilots (Dilda et al., 2012). These collaborators have proven these tests extensively with their own CKAS 6DOF motion platform justifying their position as a choice. The three tasks were chosen for their ease of use to minimize learning effects and for their level of engagement to reduce the boredom effect that was encountered with the BMSe task set. In order to maintain engagement, two of the three tasks were randomly selected for each participant.

The tasks chosen were; the Test of Basic Aviation Skills (TBAS) Dot task (spatial intelligence), a Match task (working memory), and a Reaction Time task.

#### 4.2.4.1. TBAS Dot Task

Thirty two participants were assigned the TBAS Dot task, with 16 male and 16 female participants. This task is a well-known pilot orientation task that measures navigational spatial intelligence. The participant is given a map view with North facing upwards. There is a plane orientated in one of the four coordinate directions: North, South, East or West. The user is then asked to click which direction a Cardinal point is in relation to the cockpit view, that is, where the plane is facing. For example, the plane may be facing to the West and the user is asked: “Where is East?” In this situation, East is behind the plane, so the correct answer is to press the ‘Down’ arrow key. Similarly, if with the same plane orientation the user was asked for the direction of North, this would be to the right of the plane, so the answer would be the ‘Right’ arrow key and so forth.


Figure 8 TBAS Dot example given to participant at start (left) and view as given to participant in test (right)

This task involves thirty two such questions for which the participants took an average time of 2 minutes to complete. Performance for this task was based on the total time to complete and on the percentage of correct responses. Results are normalised according to baseline performance for each individual.

#### 4.2.4.2. Match Test

Thirty one participants were assigned to this task, of which 16 were male and 15 female. This task tested short-term working memory. In this task, an image appears at the centre of the screen for three seconds. No display is presented for three seconds, after which time two patterned images appear side by side. The participant uses the arrow keys to select which of the two images presented (right or left) is the match to the original image.

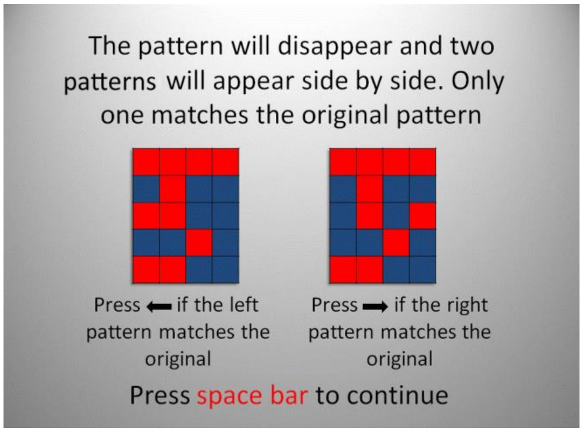


**Figure 9 Instruction example of Match Test given to participant at start**

This task involves 22 image iterations which take an average time of 3 minutes for participants to complete. Performance is measured on time taken and percentage of correct responses. Results are normalised according to baseline performance for each individual.

#### 4.2.4.3. Reaction Time

Thirty five participants were assigned this task of which 18 were male and 17 female. In this task, a white dot appears in the centre of a black screen. This dot signifies the marker to which the participant must respond as quickly as possible by pressing down on the left mouse button every time the marker appears. The time between appearances is randomised between 2-4 seconds. There are 41 iterations in all, taking a total time of 2 minutes to complete.

Performance is judged on the mean time taken to react to a dot appearance and the number of false clicks (pre-emptive clicks when no dot was present). A false click rate of five or more was removed from the dataset based on the assumption that the individual did not understand the instructions.

## 4.3. Results

### 4.3.1. Motion Sickness Symptom breakdown

In both sets of studies, participants appeared to be grouped into three distinct response categories in relation to the development of Motion Sickness symptoms:

1. Progressive Nausea (PN) response: participants in this group experienced a gradual increase in nausea sensation, progressing through each stage of the 7-pNS.
2. Adapted Nausea (AN) response: participants in this group experienced a slight nausea (approaching a '3' of the 7-pNS) which diminished in subsequent laps.
3. No Nausea (NoN) response: participants in this group were unaffected by the simulation, regardless of matched or mismatched motion.

The division for each study in these groups is presented in Table 3 and graphically in Figure 10. In both groups, the proportion of those in the Progressive nausea group remains reasonably constant irrespective of the different group sizes in each. The change in Adapted Nausea and No Nausea groups between these studies is not statistically significant ($\chi^2_{(2)}$=0.14 , $p$=.70) and may indicate an increased likelihood to feel more nauseous with an extended drive time between breaks, as experienced in Part Two, as opposed to stopping for a break after every lap.

**Table 3 Grouped responses based on development of nauseous motion sickness symptoms for each study**

| | **Part One** | | | | | **Part Two** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Male** | | **Female** | | **Total** | **Male** | | **Female** | | **Total** |
| | Total | Percentage | Total | Percentage | % | Total | Percentage | Total | Percentage | % |
| PN | 6 | 40 | 4 | 30.77 | 35.7 | 7 | 28 | 12 | 50 | 38.8 |
| AN | 3 | 20 | 3 | 23.08 | 21.4 | 6 | 24 | 7 | 29.17 | 26.5 |
| NoN | 6 | 40 | 6 | 46.15 | 42.9 | 12 | 48 | 5 | 20.83 | 34.7 |

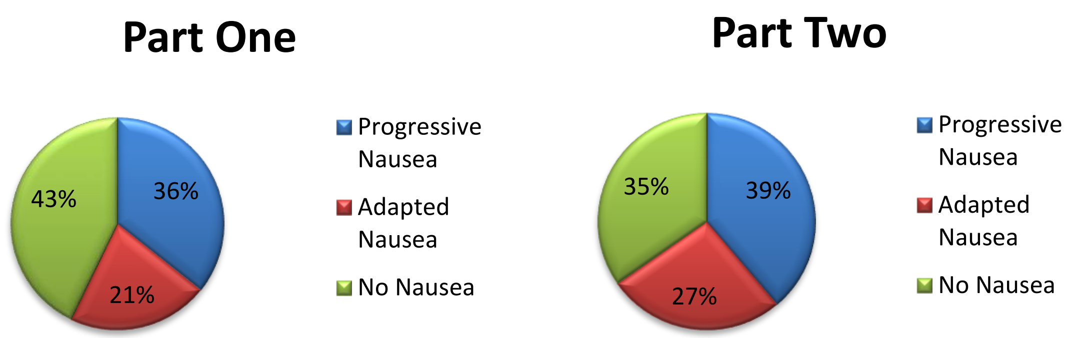


Figure 10 Group splits in Study One (left) and study Two (right)

In gender breakdowns for each study, Part One shows a very similar split between genders with no statistical difference between each group in assignment to motion groups ($\chi^2_{(2)}$=0.26 , $p$=.88). In Part Two, where an extended fixed driving time is implemented in place of driving to a fixed location, there is no overall statistical difference between the three groups ($\chi^2_{(2)}$=4.26 , $p$=.11). There appears to be a trend for males to be more likely to fit into the No Nausea group than females as seen in Figure 11, which is significant when Yates correction for continuity is ignored ($\chi^2_{(1)}$=3.99 , $p$ <.05).

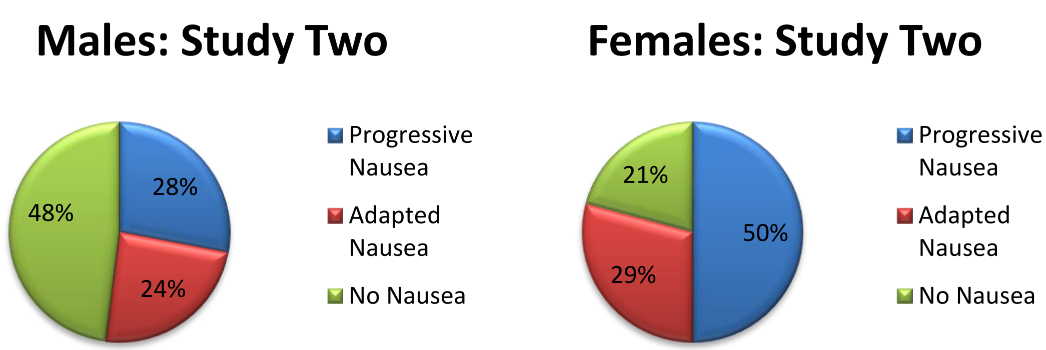


Figure 11 Gender breakdowns for each reaction group in Study Two

## 4.3.2. Questionnaire Results

### 4.3.2.1. Motion Sickness Susceptibility Questionnaire

For the MSSQ to be used as a predictor for Simulator Sickness in this study, it was assumed that those who scored above the mean value should fall into the Progressive Nausea group. For the statistical analysis of MSSQ scores in Part One, there was a significant difference in MSSQ score and Nausea response group ($F_{(2,25)}$=7.50, $p$ <0.01). Post Hoc analysis in the form of the Dunnet t-test revealed that the mean scores for the PN group (*M*=45.85, SD=17.54) and the AN group (*M*=36.27, SD=23.42) were significantly different from that of the NoN group (*M*=17.02, SD=14.59) though the PN and AN groups did not differ significantly from each other. In this study it is shown that the MSSQ score could be used to predict if a participant would likely suffer from any form of nausea in the simulator. However these results should be viewed with caution as there is large error factor in the mean for the AN group as seen in Figure 12.

In Part Two a significant difference in MSSQ score and Nausea response group was also found ($F_{(2,46)}$=3.68, $p$ <0.05). This time though, rather than the NoN group being different to the others, Post Hoc analysis in the form of the Dunnet t-tests revealed that statistically the mean scores of the PN group (*M*=29.18, SD=27.29) significantly differed from both the AN group(*M*=13.61, SD=11.24) and the NoN group(*M*=13.61, SD=13.26) (Figure 12).

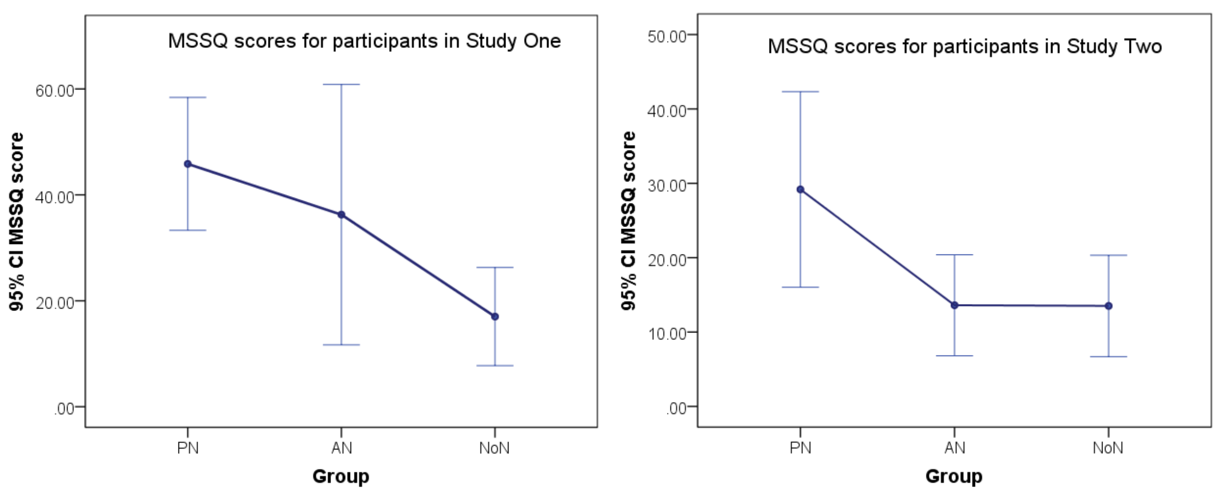


**Figure 12 Error Graphs of MSSQ scores for each Nausea group rating in Study One (Left) and Study Two (Right)**

Both studies showed different trends in terms of those grouped in the AN condition. It is unknown whether this change is due to the group chosen, or the change in the style of testing (one lap of driving vs. fixed exposure to the driving condition). What is known is that in both cases the scores of the PN group and the NoN group are statistically different thereby allowing this measure to be used as an indicator of how likely a participant may fall into one of these two opposing measures.

### 4.3.2.2. Simulator Sickness Questionnaire – Study Two only

The SSQ scores are split into three categories: Nausea, Oculomotor, and Disorientation to categorise how a participant feels pre- and post-simulation. The graph of these measures for each nausea group is seen in Figure 13.

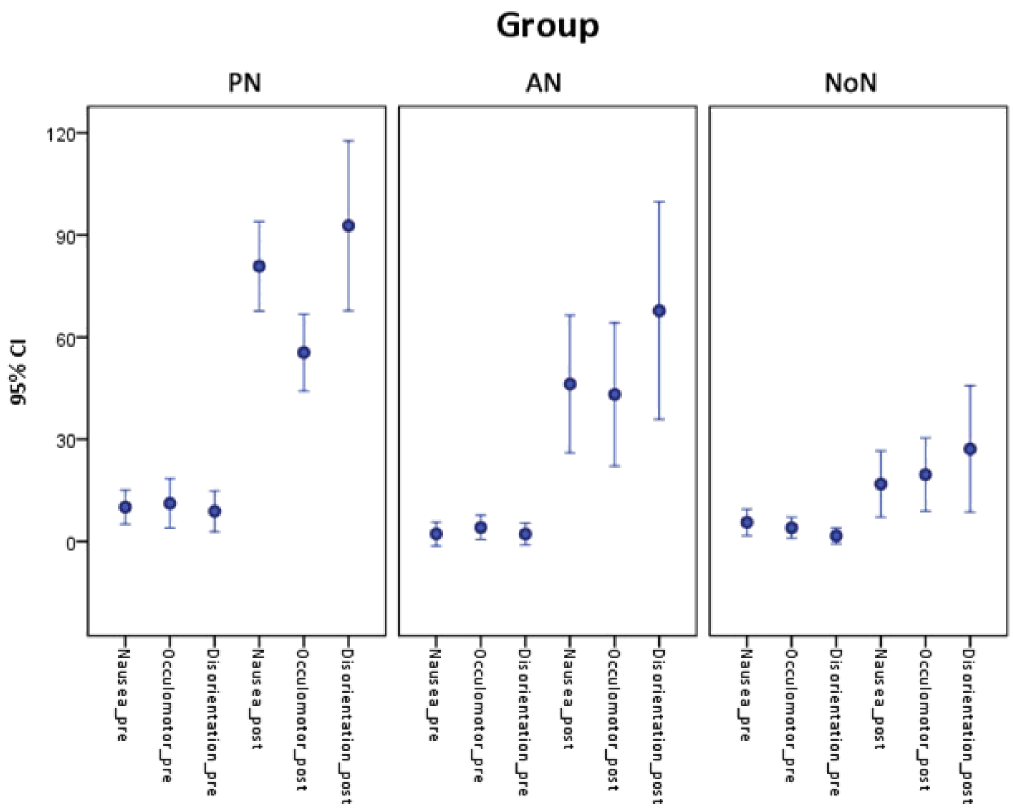


Figure 13 Error bands and mean scores for each SSQ subcategory in pre- and post- testing across each reaction group; Study 2

In pre-simulation scoring, there is a statistical difference in Nausea and Disorientation scores between nausea groups ($F_{(2,46)}=3.51$, $p < 0.05$ and $F_{(2,46)}=3.73$, $p < 0.05$ respectively). The occulomotor score was not significant as a measure between groups ($F_{(2,46)}=2.68$, ns). Post-Hoc analysis revealed a significant difference in mean scores for the Nausea score in the PN (*M*=10.04, *SD*=10.29) and AN (*M*=2.20, SD=5.72) group, but not the PN and NoN (*M*=5.61, SD=7.59) group, nor the AN and NoN score. In Disorientation scores, there is a significant difference between the means of the PN (*M*=8.83, SD=12.51) group with both the AN (*M*=2.15, SD=5.25) and NoN (*M*=1.64, SD=4.64) group. There was no significant difference between the means of the AN and NoN group.

Post-simulation scores and final nausea group was found to be significantly correlated across all seperation measures of Nausea ($F_{(2,46)} = 26.11$, $p < 0.01$), Occulomotor ($F_{(2,46)} = 8.581$, $p < 0.01$) and

Disorientation ($F_{(2,46)} = 8.72$, $p < 0.01$) scores. Within the Nausea group, post-score measures were found, through post-hoc analysis, to have statstically different means across all comparisons: PN (*M*=80.84, *SD*=27.24) to AN (*M*=46.23, *SD*=33.47), PN to NoN (*M*=16.84, *SD*=18.94) and AN to NoN. This score confirms that separation to these groups by the use of the 7-pNS is justified in terms of nausea. Post-Hoc analysis for the Occulomotor measure found a statistically significant difference between mean scores of PN (*M*=55.45, *SD*=23.44) to NoN (*M*=19.62, *SD*=20.94) and AN (*M*=43.15, *SD*=34.79) to NoN scores. These same pairings were found to have statistically different means in the Disorientation scores; PN (*M*=92.71, *SD*=51.73) to NoN (*M*=27.14, *SD*=36.14) and AN (*M*=67.75, *SD*=52.88) to NoN.

As can be expected from the individual significances between pre-and post-scores, the total pre-score, post-score and total SSQ score (post-score minus pre-score) were also shown to have a significant change in scores across reaction groups ($F_{(2,46)} = 4.319$, $p < 0.05$, $F_{(2,46)} = 14.39$, $p < 0.01$ and $F_{(2,46)} = 12.44$, $p < 0.01$ respectively), as viewed in Figure 14. This figure shows an almost linear trend in post- and total-SSQ scores, decreasing across Nausea groups as would be expected by the group definitions.

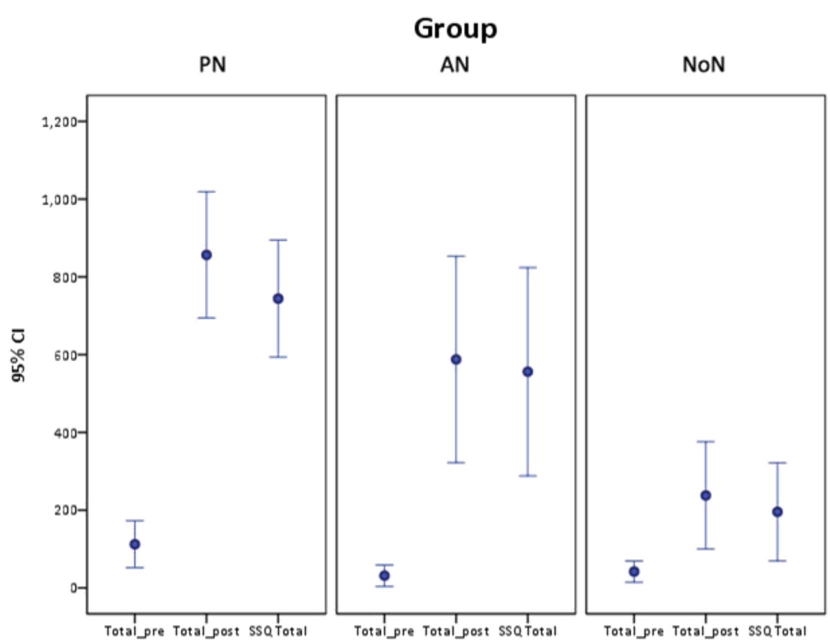


**Figure 14 Total SSQ scores, with total weighted pre-simulator score, total weighted post simulator score and total SSQ (post score - pre-score) for each Nausea group in Study Two.**

Through Post-Hoc analysis, a statistically significant difference is found in the mean total pre-simulator score between the PN (*M*=112.38, *SD*=125.11) and AN (*M*=31.54, *SD*=45.10) and PN and NoN (*M*=42.15, *SD*=52.98) groups, using the Dunnett t-test. This test also comfirms a statistically significant difference in the means of the post-simulator total scores between PN (*M*=856.47, *SD*=336.17) and AN (*M*=587.663, *SD*=438.86) scores and PN and NoN (*M*=237.83, *SD*=268.09) scores, although Turkey HSD analysis shows no significance between the AN and NoN scores. In the total score, a statistically significant difference is only seen in the change of means between the PN (*M*=744.11, *SD*=312.61) and NoN (*M*=195.69, *SD*=245.14) score with no significance in comparison of means with the AN (*M*=556.12, *SD*=443.41) score.

### 4.3.3. Part One Tasks

The Pan-Zoom task is the first in the series with the BMSe. Whilst usually performed correctly, there were complications where students would accidentally 'skip' this task without realising their mistake. The PN group, with 25% of all participants accidentally skipping the task, were significantly less likely to skip the task than both the AN group ($\chi^2_{(1)} = 5.61$, $p = .02$) and the NoN group ($\chi^2_{(1)} = 7.42$, $p < .01$) of which 80% and 75% of the participants skipped the task respectively.

In terms of time measures and errors made across all groups, the only measure with statistically significant differences was in the number of errors made in the Create Line task ($F_{(2,199)} = 6.38$, $p < 0.01$). All other measures were not significantly correlated with nausea. Interestingly, this significance for the Create Line task found that the mean error for the PN group was significantly less than the mean errors in both the AN group and the NoN group as can be seen in Figure 15.

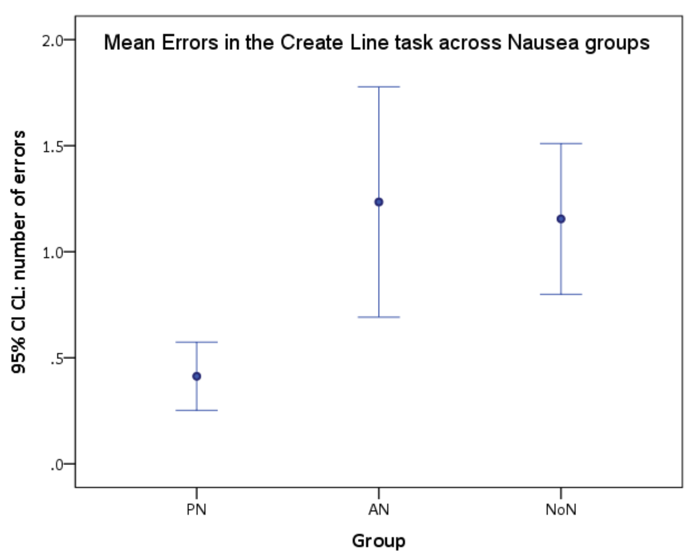


Figure 15 Mean errors in Create Line task by Nausea group

It is worth noting that in the PN groups, errors only occurred at low levels of nausea – a 2-3 out of a maximum score of 6 on the 7-pNS. For the AN group, this same trend was shown with all errors occurring at a nausea score of 0-1 out of a maximum score of 3 on the 7-pNS for this group. This implies that for the BMSe tasks, for the group tested, nausea does not appear to have a negative impact on performance.

Analysis was also carried out to investigate any effects from task order, that is, the practice effect. This time only the total time taken to complete the Read Unit Task was found to have any relevance to the order of tasks ($F_{(7,186)} = .88$, $p < 0.01$). Viewing these results in Figure 16, there is an almost steady linear decrease in total time taken. Post-hoc analysis showed that the total times to all but the first task differed significantly from the weighted baseline measure (see Appendix F: Read Unit Output for all measures).

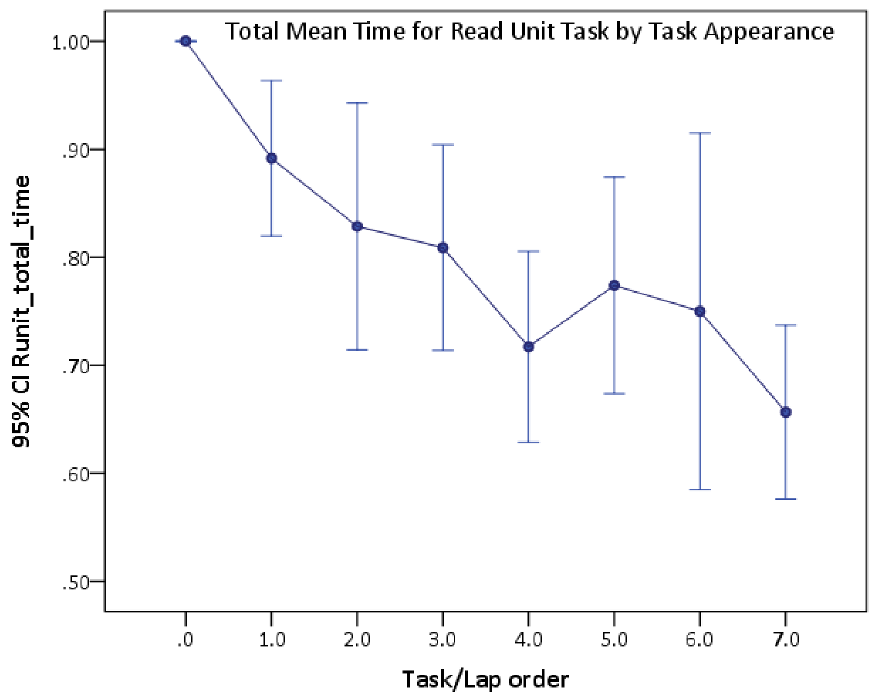


**Figure 16 Mean Total Time taken to complete the Read Unit Task for participants in Study One by order of appearance of the tasks.**

## 4.3.4. Part Two Tasks

In the tasks undertaken for Part Two, participants completed only three of the four tasks at up to four intervals in a one hour period. Fewer tasks were completed if the participant had to terminate early as was the case in Part One. Due to the nature of the task delivery, where not all participants completed the same task, each task has been analysed using separate One-Way ANOVAs.

### 4.3.4.1. TBAS Dot task

In the TBAS Dot task, the score of correct responses (as a percentage) was found to be significantly related to the nausea group that a participant was a part of ($F_{(2,114)} = 3.00$, $p = .05$). Post-Hoc analysis showed, using LSD correctness measure, that there was a statistical difference in the means of the PN (*M*=85.66, SD=20.65) group and the NoN (*M*=92.90, SD=10.781) group, but not in the AN (*M*=84.31, SD=23.95) and NoN groups (see Figure 17a). The mean time taken to complete this task was not found to be significantly related to group assignment ($F_{(2,114)} = 0.86$, $p = .43$). Whilst not significant, there is a trend, as can be seen in Figure 17b of a decrease in timing as less nausea is experienced.

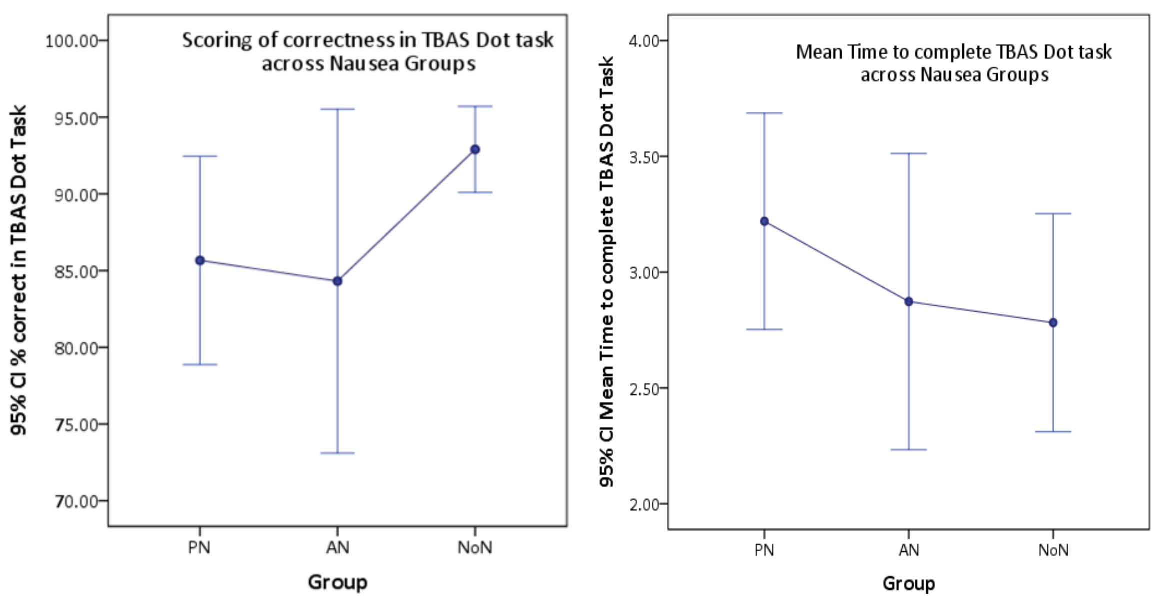


**Figure 17 TBAS Dot task performance measures by Nausea group with a) scoring of percentage correct (Left) and b) Mean time taken to complete the task (Right).**

There is significant correlation of learning factors, with the time to complete the TBAS Dot task ($F_{(3,113)} = 9.79$, $p < 0.01$), although not with the percentage of correctness ($F_{(3,113)} = 1.95$, $p = .13$). In timing, subsequent trials were significantly different in mean time compared to the first iteration, although further repeats were not significantly different from each other (see Appendix G: TBAS Dot Mean Time

(MS)). Whilst not significant, there is a trend for the percentage of correct answers to increase with iterations of task as can be seen in Figure 18. As only the NoN group (and some AN group) were able to complete all four repeats, it can be argued that the significance found previously in percentage of correctness with nausea is affected by this repeat effect.

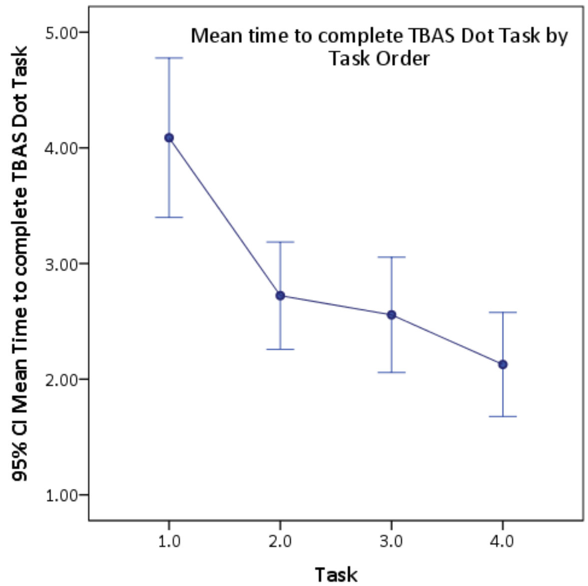


Figure 18 Mean Time taken to complete TBAS Dot task as arranged by order of Task Appearance.

#### 4.3.4.2. Match task

For participants who were assigned the Match test, One-way ANOVA showed a significant correlation between the Nausea Group assignment and the mean time to complete the task ($F_{(2,112)} = 3.13$, $p < 0.05$). Post-hoc analysis with Turkey HSD showed the means of the AN (*M*=1.66, SD=.45) and NoN (*M*=2.02, SD=.51) group to be statistically different, although no significance was found with comparisons to the PN (*M*=1.76, SD=.66) group as seen in Figure 19a. Investigating any practice effects the task order may have on this result, there is a statistically significant difference in task order and mean time ($F_{(3,111)} = 2.95$, $p < 0.05$), although post-hoc analysis showed that this significance was only in the difference in the means of the task order 2 (*M*=1.73, SD=.48), task order 3 (*M*=1.71, SD=.53) and task order 4 (*M*=1.60, SD=.51) from task 1 (*M*=2.02, SD=.67), with a trend in decreasing time as seen in Figure 19b. As some of the participants in the AN group did complete all task iterations, this does not have an impact on the original nausea group.

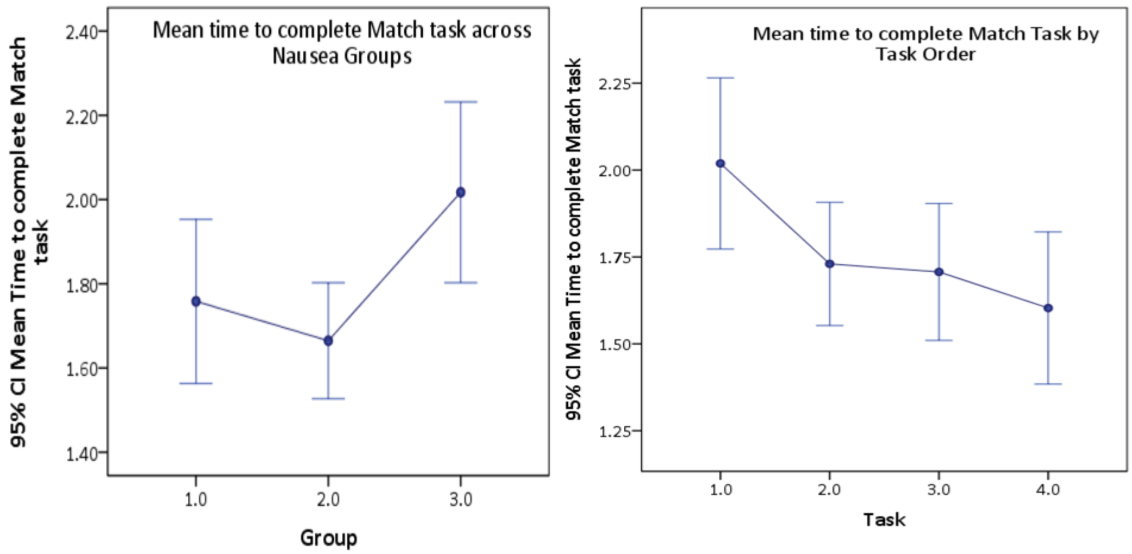


**Figure 19 Match task measure of mean time to complete measures by a) Nausea group (Left) and b) order of Task Appearance (Right).**

In terms of percentage correctness, there was no significance with Nausea group and performance ($F_{(2,112)} = 1.53$, $p = .22$) or task order and performance ($F_{(3,111)} = 0.10$, $p = .96$). Although not significant, there does seem to be a trend of improved performance with less severe Nausea symptoms as seen in Figure 20.

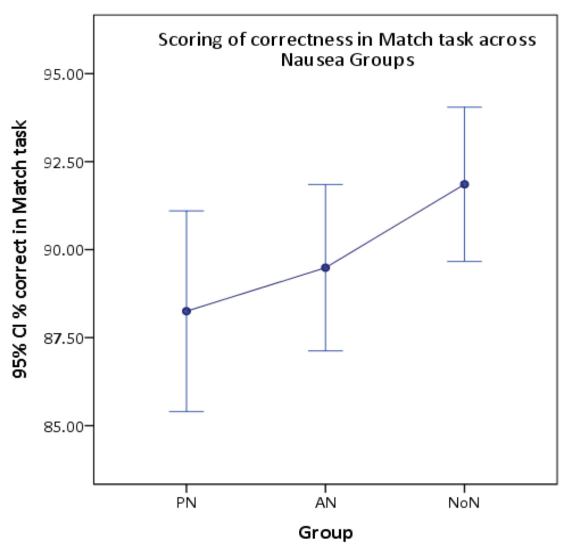


**Figure 20 Scoring of correctness (percentage) in Match task by Nausea group.**

#### 4.3.4.3. Reaction Time task

For the Reaction Time task, statistical analysis showed a significant relationship in the number of false presses made by the participant and their nausea rating ($F_{(2,132)} = 6.16$, $p < 0.01$), with false clicks occurring more often in the PN group (*M*=2.27, SD=1.97) as opposed to the AN (M=1.5, SD=0.73) and NoN (*M*=1.35, SD=.89) groups, as seen in Figure 21. There was no significant relationship with the timing ($F_{(2,132)} = 2.32$, $p = .10$), nor was there any practice effects to be found in either the false press measure ($F_{(3,131)} = .58$, $p = .63$) or timing measure ($F_{(3,131)} = 2.16$, $p = .10$). For this task, false clicks were indicative of the PN group scoring slightly worse than other Nausea groups as expected by the hypothesis.

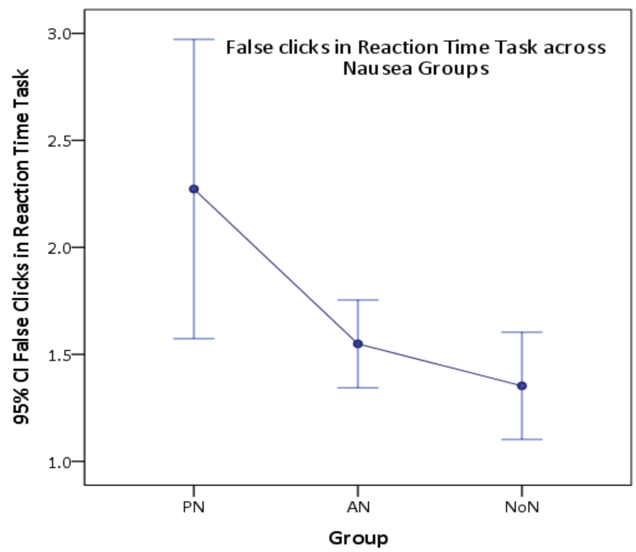


**Figure 21 Number of False clicks in Reaction Time task across Nausea groups.**

## 4.4. Discussion

This study looks into two different task types and methods (consistent task work as opposed to extended drive time) in regards to the effect of nausea on task performance. In the first part of the study, with consistent BMSe task iterations, it was found that, in most cases, there is no difference between nauseated participants and non-nauseated participants in terms of task performance. In fact, the most difficult task of the set – Create Line, showed an improvement by the most nauseated participants having statistically fewer errors than their non-nauseated counterparts. A number of theories could explain this unexpected result. The most obvious theory is that the nauseated subjects use the tasks as a method of distraction from their symptoms and so may have had greater focus than their non-nauseated counterparts, who preferred the driving segment. By fixing the driving segment to a set time, reducing task time and altering the tasks to those that are more of a challenge (such as the CL task in Part One), this hypothesis could be verified.

In Part Two it was found that the PN group did perform worse in the Reaction Time task. They also performed worse in the TBAS Dot task in terms of accuracy; however this task is shown to have practice effects which may explain why the group did poorly, as they did not experience as many iterations of the test as the NoN group. Interestingly, the AN group was found to be worse than the NoN group timing wise in the Match test. These findings imply that when there are long breaks between tasks, the benefit of using the task as a distraction no longer counteracts the negative effect of nausea on task performance.

There are a number of restrictions and considerations from this experiment. Firstly, in regards to the first study, the BMSe tasks, it is shown that consistently performing on this device does not appear to have any negative consequences on performance, that is, until the participant can no longer continue due to their symptoms. This was supported by the observation that errors in tasks tended to occur at low self-reported nausea levels. In the second study, the Match and TBAS Dot were found to be affected by practice effects on the same measures that showed a difference in Nausea groups. Practice effects are not ideal in such an experimental design where nauseated subjects can terminate early, thus having scores that are compromised by the lack of repetition. The fewer AN individuals in the study can bring into question the Match task result. In this case, a larger group of participants should be used in future studies to confirm this effect. The only strong outcome was the PN group performing worse in the Reaction Time task. Though on average, this is one extra click, as opposed to the Non Nauseated group, which, while statistically significant, may not be significant in terms of Military considerations of the effect of Motion Sickness on their land operations team.

This study did find the MSSQ to be a reliable indicator of what reaction group a participant will belong to. This has future implications in the use of the MSSQ as a predictor to determine whether or not a participant will experience nausea in the driving simulation used throughout this thesis. The SSQ is also a valid measure, with an expected change in measures across each of the nausea group ratings. The Nausea measure being statistically significant with the group definitions, justifies the use of the 7-pNS as an accurate fast measure to determine nausea reaction. This measure is also found to be the most relevant in regard to changes of simulator sickness from the particular simulator and simulation used in this thesis work.

Future work is needed to mitigate practice effects of tasks and to determine if long exposure to driving does show a negative effect of Nausea symptoms or if continuous work can mitigate the perceived negative outcomes that the current literature reports as mentioned in the Introduction. A larger participant pool is also desired so that close-to even numbers across all three reaction groups can be measured to determine exact trends across groups.

## 4.5. Conclusion

To conclude, for the studies shown here, nausea has very little effect on task performance. In long exposure to nauseating symptoms there is a slight negative effect on a reaction time task where errors are more apparent in nauseated participants. However, when working consistently on a task in the case of the BMSe task set, there is indication that there could be a positive effect of nauseated participants concentrating more closely on a task, in an effort to mitigate their symptoms. Further research is needed in both effects of nausea with more difficult task measures in order to further investigate the reliability of these findings.

# 5. Motion Fatigue

## 5.1. Introduction

### 5.1.1. History

Fatigue has been a point of interest throughout history. Its definition, understanding of and measurement mechanisms have been an area of debate, and research that still continues today with often only vague understandings of the term being agreed on by researchers.

The study of fatigue came into vogue in the 1940s. The sudden popularity in this field originated from the prevalence of radar operators missing obvious signals across the screens when they were monitoring for enemy aircraft during World War II (Warm, 1984). It was found that, as time progressed, the observers became less efficient at detecting signals (Mackworth, 1948, Mackworth, 1950). This was, understandably, an area of great concern for safety. Hence it was of paramount importance to gain a better understanding of fatigue so that methods could be found to mitigate its effects to ensure that there would not be any detrimental effects when performing critical tasks.

Due to the re-emergence of studies in fatigue in recent times, academics have felt the need to develop a satisfactory understanding of what in fact fatigue is and how it is separated from other conditions. In one article based on this issue, fatigue was assigned the definition *The awareness of a decreased capacity for physical and/or mental activity due to an imbalance in the availability, utilization and/or restoration of resources needed to perform the activity* (Aaronson et al., 1999). This is the definition used for this thesis.

Apart from the ‘missed inputs’ result noted in 1948 and 1950, fatigue has been shown to have a detrimental effect on all motor functions. These detrimental effects include a reduction in: performance in decision making ability (Baranski et al., 2007), complex planning (Johnson, 1982), communication, productivity and performance (Pilcher and Huffcutt, 1996, Hartley and Arnold, 1995, Rosekind, 1999), attention (block phenomenon) (Bills, 1931), ability to cope with stress, ability to self-monitor performance (Harrison and Horne, 2000) and reaction time (OH&S, 2012). These effects can also be seen in an increase in: risk taking behaviours, forgetfulness, errors in judgment, sick time, and accidents (OH&S, 2012). With these effects in mind, for a given critical task a clear understanding of the impact on accuracy and performance due to fatigue is crucial as the exact effect can vary based on the fatigue condition and the mode of task presented. In a military context, this knowledge is of paramount importance.

### 5.1.2. Current measures available

With accepting the importance of fatigue, there needs to be an acceptable measure of fatigue, outside of task performance, so that results can be linked empirically to this condition. There are a number of markers of fatigue that have been developed and used in research, from subjective scales, biofeedback units, blink characteristics and brain monitoring devices.

The most commonly used subjective scales for tasks and work are the NASA Task Load indeX (NASA TLX) (Hart and Straveland, 1988), the Boredom Susceptibility Scale (Zuckerman, 1979) and the Boredom Proneness Scale (Farmer and Sundberg, 1986).

The NASA TLX is a scale used to define workload estimates for different operations. It is usually utilised in interface design or evaluation (Hart, 2006). In a survey of 500 studies over 20 years since the implementation of this index, it was found that only 2% involved measurement of fatigue in performance (Hart, 2006). The reason it is very rarely used for fatigue is that the focus of the questionnaire is better set as a predictor of performance of an individual in a task (Rubio et al., 2004) rather than a measure of attention resource.

The Boredom Susceptibility Scale, otherwise referred to as a subscale of the Sensation Seeking Scale, is a 10 item questionnaire of which participants choose statement ‘A’ or ‘B’ as applying to them the most. In each case, one response relates to a ‘boredom response’. This study looks at the ability to tolerate monotonous activity (Mercer-Lynn et al., 2011).

The Boredom Proneness scale, developed 17 years later, is a list of 28 items to which participants mark a 7 point format of how likely the items apply to them: 1 being *highly disagree* to 7 being *highly agree*. The factors within the study reflect an inability of an individual to be *meaningfully connected* to elements of the world (Mercer-Lynn et al., 2011). The Boredom Proneness Scale is a more in-depth analysis that the Boredom Susceptibility Scale as it allows for great variance in responses by asking the participant to scale their response.

As with the NASA TLX, both Boredom Scales are not developed for use in fatigue, though some studies have included them. The questionnaires are created in such a way that responses are static – not a scale that would change during an experimental procedure. The scales question elements about the individual's view of life situations and circumstances which should not change during a given task situation. The relevance of these scales for fatigue is in the scale being used as a marker in registering how 'prone' an individual may be to suffering fatigue. A High Boredom Susceptibility Scale response would most likely correspond to the individual feeling fatigued faster than an individual who did not score as highly. As an in-test measure of developing fatigue however, none of these subjective scales would be indicative of feeling fatigue. For these reasons, none of these scales has been used in this testing. Rather, the participants were asked to relay information of sleepiness' based on the Stanford Sleepiness Scale (Hoddes et al., 1972) – a seven point scale relating to their alertness, and their response to level of 'fatigue' as presented in the Simulator Sickness Questionnaire (SSQ) is used as the subjective markers of fatigue. The Sleepiness Scale has an advantage in that it is a quick identifier. It is able to be asked without bringing too much attention to the sensation of fatigue. The level of actual 'fatigue' measures pre- and post- simulation with the SSQ is a direct subjective measure on a 4-point scale for this element.

Of the biomarkers used for fatigue, a participants heart rate has been shown to be a significant marker of fatigue, with the rate decreasing with increased fatigue (Zhang et al., 2014). In the measure of Heart-rate variability, experiments have suggested that changes in the RR-interval (interval between successive R peaks of the QRS complex in an ECG wave) could be a good marker of alertness, with increased intervals corresponding to decreased alertness (Chua et al., 2012). Heat rate and heart rate variability can easily be monitored with a chest bioharness in a way that does not intrude or negatively impact a study making it an ideal measure both in lab and in real world scenarios.

Another biomarker used widely in fatigue research is that of eye motion and changes in pupil characteristics. Trends such as drift focus, reductions in saccadic speed (Johns, 2003) and rapid blinking are linked to fatigue. The most documented measure that changes over time is the PERCLOS. PERCLOS, an acronym for PERcentage of eye CLOSure which was a developed fatigue measurement concept from 1998 (Dinges et al., 1998). The system at the time was regulated by human observer ratings of subjects faces, rating eye closure at a rate of open, 70% closed, 80% closed or closed. PERCLOS was then defined by the percentage of time when the eyelid covered the pupil by more than 80%.The test was based on vigilance performance over an extended time of keeping subjects awake. Trained staff remained with subjects to ensure they stayed awake.

The experiment first developed monitoring the PERCLOS concept also monitored 2 different EEG algorithms, a head tracking device and two wearable eye-blink monitors as ways of measuring vigilance. Out of all the tested methods at the time, PERCLOS was found to yield the highest correlation with psychomotor vigilance performance (Dinges et al., 1998) compared to all others. Since this initial experiment, more robust technology has been developed to monitor percentage of eye closure and to relate these findings to measurements of vigilance and fatigue. In an evaluation in 2010, PERCLOS was measured with EEG and EOG to determine the best factors for measuring fatigue (Sommer and Golz, 2010). This study had subjects driving a simulator over two night time drives, running from 11:30pm to 8:30am each time. In this study, it was concluded that a combination of EEG/EOG was a greater measure of strong fatigue than PERCLOS using the current technology. This doesn't mean that eye measures are no longer relevant as a measure of fatigue. Optalert (Richmond, Victoria, Australia) is one company developing eye monitoring devices that advertise themselves as a 'drowsiness detection system'. These glasses appear to monitor blink velocity as a ratio of eye closure to eye opening. Using tests and a link to the Stanford Sleepiness scale, their glassware provides a unit measure of fatigue. The Optalert system is quite expensive. However, the use of high sample rate in-house recorders means a similar product can be developed to measure blink ratio using a video frame rate of 350 frames per second in a raw format, much as the Optalert system would, but without the numeric score the system provides. This in-house system was used in our testing. The advantage to this system is that there are no mysterious values assigned to fatigue, so clear changes can be observed. The type of hardware used (see Chapter 3.2.2: Video Goggles) means that measures of Pupil dilation (and PERCLOS) can be measured simultaneously.

Electroencephalography (EEG), the measure of brainwaves, has long been thought to be linked to different mental states. Beta waves in particular have been classified to being linked with agitated, anxious and alert stated in high frequency (18-30 Hz) and focused in low frequencies (12-15Hz) (Associates, 2004) with Theta waves (4-8Hz) linked to drowsiness (Tatum et al., 2008). Lower frequencies are classified as Delta waves where there is a state of deep sleep or unconsciousness (Associates, 2004). Fluctuations in Beta and Theta waves could theoretically show a link to fatigue states.

At the time of this thesis, Beta waves are thought to have symmetrical distribution along both sides of the head and frontally, though Theta waves are unspecified in region. Frontal electrode systems that are currently mass-marketed cannot be described as accurate measures, without further (external) research to justify their use as a fatigue monitor. The most ideal system is a 16 or 64 gel electrode system to obtain precise measures. Such a system is not convenient in our simulator laboratory setup. For this reason, this measure was not used in our testing.

### 5.1.3. Motion fatigue

Fatigue due to boredom, that is, cognitive under-load, is well researched in literature (Thackray et al., 1977, Hitchcock et al., 1999, Pattyn et al., 2008). The resulting effects are all those taken to be related to fatigue as discussed above. Likewise, fatigue due to cognitive overload has been well documented (Pattyn et al., 2008, Cooper, 1998, Kanfer, 2011). What has not been well documented is fatigue from a depletion of resources due to constant motion. This gap in literature is what this study aims to address.

In this chapter, two studies are conducted to analyse two opposing aspects of fatigue that are relevant to military context: Fatigue from depletion of resources due to over stimulation and constant motion effects and fatigue from boredom – i.e. fatigue from lack of stimulant or arousal. Both studies had students split into the 'Boring' – that is, an under stimulated low motion driving condition, or the 'Motion' – that is, a highly stimulating high motion condition. The first study used cognitive tasks as the performance measure. This was to set a baseline for expectation in how a human would respond to simple set tasks. The second study was a repeat using the tasks in the Emulated Battle Management System (BMSe) to ensure a reference back to actual tasks that are utilised by the defence force was provided.

## 5.2. Method

### 5.2.1. Participants

All participants were enrolled for this study through the University of Sydney, School of Psychology. To sign up for this study participants were asked to be free from the effects of alcohol, have had a driver's license for a minimum of 6 months and not be prone to motion sickness. This exclusion criteria is designed to ensure that the participants were sober, did not need to be taught how to drive the simulator and were unlikely to become simulator sick during the fatigue drive. Motion sickness was shown in the study of motion sickness (see Chapter 4: Motion Sickness) to be closely linked with simulator sickness such that any participant prone to the first would probably succumb to the latter. All procedures were in accordance with the Declaration of Helsinki and were approved by the University of Sydney Human Ethics Committee. Participants gave informed written consent and were free to terminate testing at any time and were given course credit in line with standard departmental procedures.

In part one a total of forty four participants signed up, of whom thirty one continued on for the Fatigue drive (Males =15; Females =16). In the second study, a total of thirty eight participants signed up of whom twenty nine continued on for the fatigue drive (Males = 14; Females = 12). Participants who did not continue on to the fatigue drive were those who either did not show up for the second drive (3 participants in study 1; 2 participants in study 2), could not complete/unusable data due to equipment failure (3 participants in study 2), or those who experienced nausea in the exposure drive (10 participants in study 1; 6 participants in study 2). Participants who became nauseous (as judged by scoring "3" or higher in the 7-pNS) in the exposure drive were excused from the fatigue drive segment of the study as they were unlikely to be able to comfortably drive from the hour of driving exposure without early termination of the study.

### 5.2.2. Apparatus

Motion was delivered using the 6DOF motion platform described in Chapter 3. Participants were enclosed within the cabin and fastened to the driver seat by the fitted four-point safety harness. Participants were exposed to a range of passive and active motion stimuli during a simulated driving task over various rFactor (Image Space Inc., Michigan, USA) courses.

### 5.2.3. Design

Two two-part studies were conducted to investigate Motion fatigue. In each study, the first part was an exposure condition. This condition (see 5.2.3.1 Exposure course below) involved three courses driven for short time periods. By changing tracks frequently students were able to become accustomed to the simulator and understand its full capabilities, ensuring that on their return, their excitement would be less peaked, especially when faced with a one hour drive on a single chosen course. It also allowed the elimination of any participants who developed simulator sickness as these participants would not be able to withstand the one hour drive condition. Lastly, the exposure course provided training in the different tasks in order to minimise learning effects in the actual fatigue drive.

The second part of the study involved a one hour drive in which participants were randomly assigned to a 'boring' fatigue condition or a 'motion' fatiguing condition. These tracks are described in full in Chapter 5.2.3.2: Boredom course and Chapter 5.2.3.3: Motion course respectively. In Study One, chosen participants were set with cognitive tasks to measure their performance for fatigue. These tests include a Reaction Time test and a Stroop test (see Chapter 5.2.4: Performance Measures). In Study Two, this task was replaced with the BMSe task set as used previously in the study of Motion Sickness (see also Chapter 3.1.2: Emulated Battle Management System simulator (BMSe)).

### 5.2.3.1. Exposure course

In the exposure condition all participants drove the three courses selected from rFactor. The first course, Joesville Speedway (Figure 22), is a simple 0.41 mile (0.66 kilometres) loop track that allowed the participant to adjust to the simulator. Most participants were able to clear a lap in less than 30 seconds. After three minutes of driving the course they are asked to stop and move on to the second course.


Figure 22 Joesville Speedway course, rFactor

The second course, Lienz Festival der Geschwindigkeit Week 3 (Figure 23), is a more complicated 3.89 miles mountain-range course. It is more stimulating than the first track, boasting superior visual detail and greater motion affects from the simulator. On average, participants took 7 minutes to complete a lap of this course. For this course, the participant drove for up to ten minutes before the course was changed.


Figure 23 Lienz Festival der Geschwindigkeit Week 3 course, rFactor

The third course was the Desert Mesa course (Figure 24) as used in the Motion Sickness study (Chapter 4.2.3: Design). Whilst navigation of the course is no more complicated than that of the second course, this course has increased complexity in terms of increased motion profiles due to the rough terrain. This choice of course serves a dual purpose. Firstly, the motion once again acts as a stimulant factor. Secondly, the increased vibration elements of this rough surface course, used previously to elicit a motion sickness response, meant that this course could be used as a type of filter to eliminate participants who are prone to simulator sickness, and therefore, would be unable to comfortably participate in the full hour fatigue drive. Participants who felt nauseous after the ten minute drive in this course were excused from taking part in Part Two of the study.

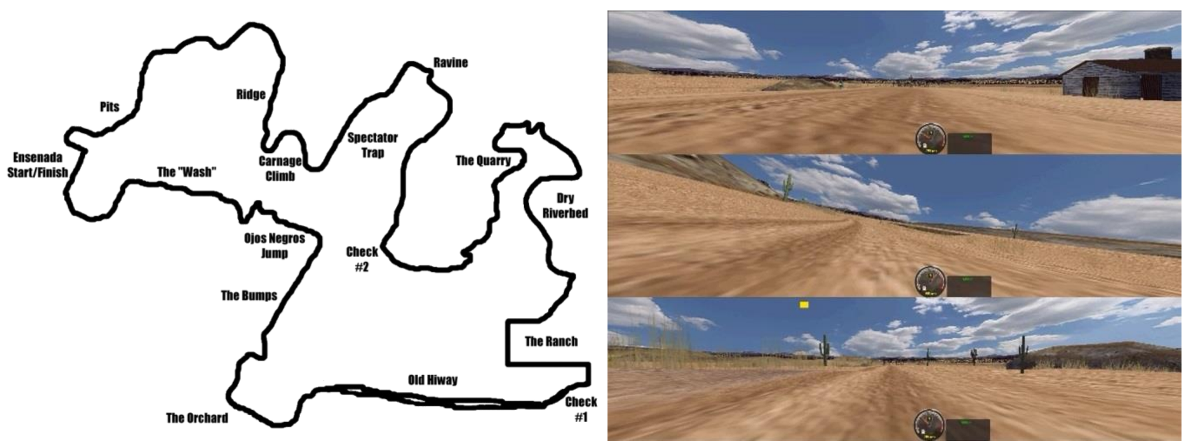


Figure 24 Desert Mesa course, rFactor

#### 5.2.3.2. Boredom course

The Boredom course was purpose-designed by the author for this study. It was developed using the software package Bob's Track Builder (see Chapter 3.3.5: Bob's Track Builder**)**. The main consideration for this course was to decrease stimulant factors as much as possible. The course features long elements of straight-ways with slight corners. These straight-ways are on a slight diagonal trajectory so that the participant has to control the steering angle at all times to remain centred. The participant was encouraged to remain on track through the raising of the course on either side of the road such that there was an obvious motion artefact when a participant strayed from the course. A fence was also placed three meters on either side of the course which was hidden by the elevation as a final measure to ensure that the participant was unable to deviate too far from the given course.

#### 5.2.3.3. Motion course

The motion course was a pre-set rFactor package course. Named Lienz Festival der Geschwindigkeit Week 6, this course is a variation of the second course driven in the exposure trial. The design specification for this course was to have a course with constant motion inputs such that fatigue due to 'motion' would be achieved. It had to be an interesting course in which the fatiguing element would be from the motion itself and not from any boredom. This enables us to make a direct comparison between these fatigue effects. Five courses were shortlisted using these specifications and analysed for their vibration using an industry XSENS MTx inertial measurement unit (XSENS Technologies B.V., Eschede, Netherlands). The output from this testing is presented below in Table 4. The final Week 6 course was chosen on the basis that, between its off road and on road components, it averaged a tolerable vibration by the Australian vibration standards (Standards, 2001). Furthermore, it remained interesting with the different course segments without needing constant mental work to navigate the course. The Rallye and Monaco courses, whilst at tolerable levels, are difficult courses to learn for those unaccustomed to racing games. It is believed that in these courses, mental fatigue would add to the overall 'fatigue' effect rather than becoming isolated which is the desired outcome of 'motion fatigue'.

Table 4 Course vibration ratings for Motion fatigue course selection

| rFactor course | | Acceleration ($m/s^2$) | Ranking according to AS2670.1-2001 |
|---|---|---|---|
| Lienz week 3 | | 1.518 | Level 4: uncomfortable |
| Lienz week 6 - | Off road segment | 1.377 | Level 4: uncomfortable |
| - | On road segment | 1.543 | Level 4: uncomfortable |
| Desert Mesa Pro | | 1.68 | Level 5: very uncomfortable |
| Rallye Alicante* | | 1.356 | Level 4: uncomfortable |
| Monaco Grand Prix* | | 1.594 | Level 4: uncomfortable |

*Difficult course

### 5.2.4. Performance Measures

In the first experiment three cognitive tasks were chosen. The first was a reaction time task to test the effect that fatigue had on response time (see Chapter 4.2.4.3: Reaction Time). This task was a very simple response task to which the participant responds to the input of a single visual dot appearing on the screen.

The second cognitive task utilised was a Colour-word Stroop test. The Stroop test is a standard inhibitory control cognitive test that examines how participants function on inhibitory (unexpected) and congruent (expected) control scenarios. In this version, participants were presented with a word relating to a colour, for example, the word “green”. This text also appeared in a fixed font colour. Should the colour and text be congruent (for example, the word “green” in green font colour) the participant was to respond with pressing the left key. If incongruent, (for example, the word “green” in purple font colour), the participant was to respond with the right key input.

The last test utilised from the cognitive task set is referred to as the TBAS Dot, essentially an orientation type task. This is a working memory task designed to also test spatial intelligence and how it is affected over time. More details of this study can be found in Chapter 4.2.4.1: TBAS Dot Task.

All of the selected tasks derived from a set of cognitive tasks developed by the Human Aerospace Laboratory of the Mount Sinai School of Medicine affiliated with the University of Sydney (Dilda et al., 2012). This research group has utilised these measures for the last few years using the same CKAS simulator base, in order to analyse the effect of prolonged exposure to space environments on the executive functioning control of the pilot.

In this first study, students did the task prior to and at the end of the 1 hour drive time.

In the second study, the tasks used as the performance measure were carried out as two iterations of the BMSe as outlined in Chapter 3.1.2 Emulated Battle Management System simulator (BMSe). Performance measures were based on the output of this task as previously described.

In this second study, the participant did the task prior to the drive, at the 20 minute mark into the drive and at the end of the one hour drive. This time point was selected as the heart rate variability data from the first experiment showed that there was a general decrease in alertness at 20 minutes into an activity across 60% of all students (see 5.3.3.1 Heart Rate and Respiratory Rate). This midpoint choice was also selected to increase test measures since having a task at the end of the activity, would increase the risk of an inaccurate measure on how participants would respond in a fatigued state due to the fact that they might be stimulated due to their eagerness to finish and to exit the simulator.

### 5.2.5. Biometric Measures

With task measures a number of biometric data sets were taken. These sets were respiratory rate, activity, heart rate and heart rate variability, as obtained from the use of a Zephyr Bioharness 3® (see Chapter 3.2.1 Bioharness ). Heart rate variability in particular has been shown to be a predictor of 'sleepiness' (Chua et al., 2012) and 'responsive' (Rowe et al., 1998) states.

In-house eye capture software described in Chapter 3.2.2 Video Goggles was a method used to measure fatigue by comparing the blink rate and ratio of blink velocity between eye-closed and eye-open (Johns, 2003, Dinges et al., 1998).

### 5.2.6. Subjective Scales

The Simulator Sickness Questionnaire (SSQ) (Kennedy et al., 1993) was completed prior and post drive to keep track of participant comfort. The Stanford Sleepiness Scale (SSS) (Hoddes et al., 1972) and a 7-point Nausea scale (7-pNS) (Golding and Kerguelen, 1992) was also utilised in this testing. Participants would report on these subjective scales any time they were stopped during a task. More information on these scales can be found in Chapter 3.4 Questionnaires.

## 5.3. Results

### 5.3.1. Subjective Scores

Three scales were used for this experiment: The 7-pNS, the SSS and the SSQ. One of the measure elements within the SSQ is a self-report measure of "fatigue" that can be rated from "none", "slight", "moderate" or "severe". This self-report measure of fatigue has been included in this analysis.

One of the initial points of analysis in this Motion Fatigue experiment is to look at these measures for comparison. It is unexpected that nausea should have any influence, as those with considerable nauseated effects were filtered out by the fatigue segment of the study.

#### 5.3.1.1. Within Score measures

For Study One, the cognitive group, scoring by the mean fatigue score in comparison to; the mean SSQ score ($F_{(2,121)}$ = 26.26, $p$ <0.01) , mean Nausea score ($F_{(2,121)}$ = 7.14, $p$ < 0.01) and mean Sleepiness score ($F_{(2,121)}$ = 27.66, $p$ < 0.01) statistically were significantly different. The relationship between mean fatigue and mean SSQ score is expected as, being the measure of fatigue is a subset component, when the fatigue level increases, so too will the mean SSQ score (see Appendix H: Study One Subjective Scales by Fatigue (MF) for all mean scores). Low level Nausea scores had means statistically significantly different from low level means of fatigue. There was not a statistically significantly change in relation at the higher level mean components of these factors (Appendix H: Study One Subjective Scales by Fatigue (MF)).

The link between Fatigue and the score of Sleepiness is predicted from the literature and confirmed by the data. There is a linear relationship between the two measures showing both increasing simultaneously (Figure 25). This relationship emerging from the subjective scales confirms that participants are able to estimate their own level of fatigue and relate it to a sense of sleepiness. In this study, the mean Sleepiness and Mean Nausea scores are statistically not significantly different ($F_{(9,114)}$ = 1.59, $p$ = .13).

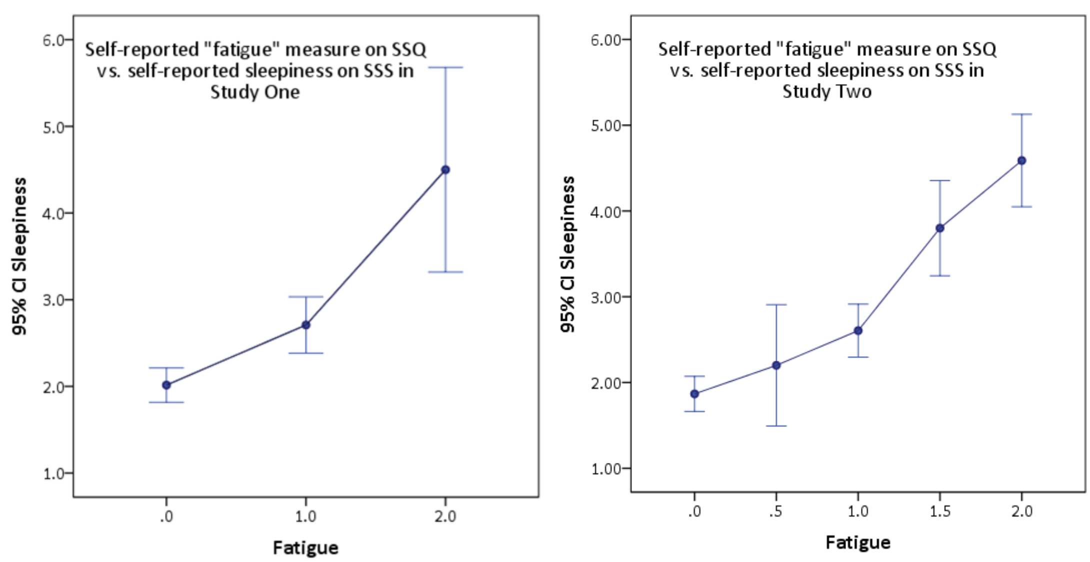


**Figure 25 Self-reported "fatigue" measure in the SSQ by self-reported Sleepiness on the SS by participants in Study One (right) and Study Two (left)**

For those in the defence task group, the nausea score was not significantly similar to the fatigue score ($F_{(4,121)}$ = .35, $p$ = .84). However, the relationship with the sleepiness score once again was found significant ($F_{(4,121)}$ = 30.06, $p < 0.01$), with post-hoc analysis revealing mean scores of both measures in SSS and fatigue to increase accordingly when compared with one another, as shown in Figure 25 (see Appendix I: Study Two: Sleepiness by Fatigue for all mean scores). The SSS score and 7-pNS score were also once again not significantly correlated ($F_{(12,113)}$ = .99, $p$ = .46).

#### 5.3.1.2. Score measures by simulator exposure

Measures were analysed across total scores for the exposure and fatigue run, as well as the pre-fatigue and post-fatigue run, to check compliance with measures whereby participants perceived themselves as "fatigued" or not by the study.

In the exposure condition to the fatigue condition, regardless of boredom track or motion track, participants within the cognitive group (Study One) and within the defence group (Study Two) had a significantly different scores in both sleepiness ($F_{(1,122)}$ = 13.75, $p < 0.01$ and $F_{(4,121)}$ = 15.94, $p < 0.01$ respectively) and fatigue ($F_{(1,122)}$ = 6.63, $p < 0.01$ and $F_{(4,121)}$ = 7.64, $p < 0.01$ respectively) ratings. In terms of pre- and post- fatigue scores in the cognitive group, all scale measures of SSQ ($F_{(1,122)}$ = 62.92, $p <$ 0.01), Nausea ($F_{(1,122)}$ = 68.09, $p < 0.01$), Fatigue ($F_{(1,122)}$ = 17.38, $p < 0.01$) and Sleepiness ($F_{(1,122)}$ = 14.40, $p$ < 0.01) were significantly different with scores increasing post-fatigue across all measures as seen in Figure 26.

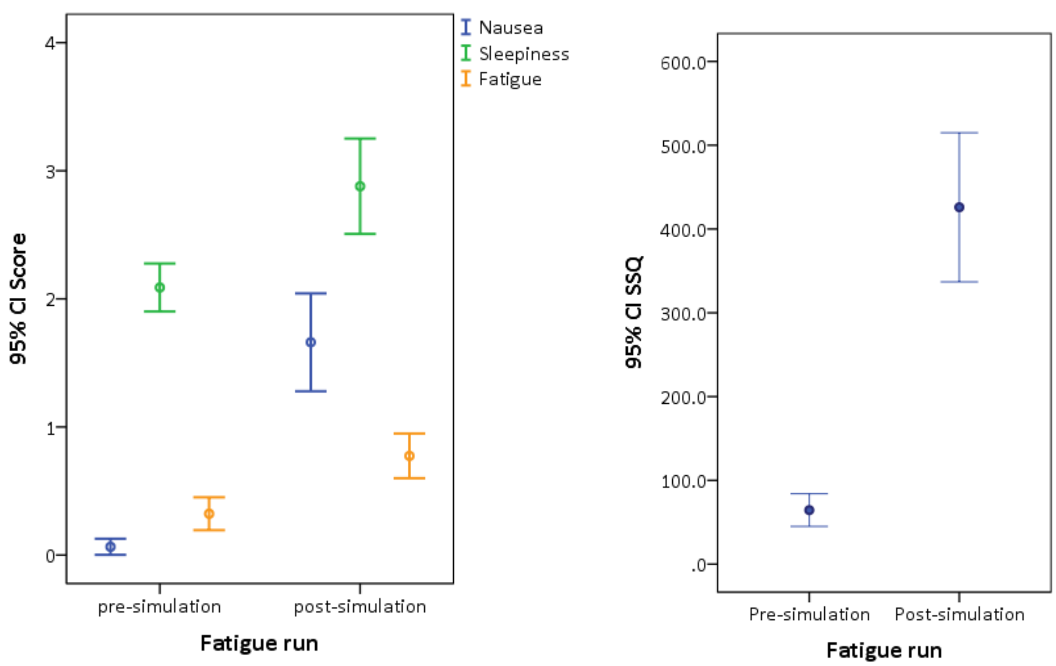


Figure 26 Fatigue, Sleepiness, Nausea (right) and SSQ scores (left) for pre- and post- simulation

## 5.3.2. Task Performance

### 5.3.2.1. Study One

For each task, measures were calculated according to changes in whether the participant was in the boring or motion conditions, changes with task order (learning effects) and changes with self-report scales. The main aim for this study is to determine whether fatigue measures from either boring or motion conditions have a greater detrimental effect on performance.

#### *5.3.2.1.1. Reaction Time task*

For the Reaction Time task, the task measure used was reaction time and errors in the form of 'false clicks'. A false click is any time the participant responds to a non-existent stimulus. For the reaction time there was no statistically significant differences in the comparison of the mean reaction time to the Boring vs. Motion condition ($F_{(1,116)}$ = .16, $p$ = .69), the task order ($F_{(7,110)}$ = .82, $p$ = .57), 7-pNS score ($F_{(8,109)}$ = .69, $p$ = .70), fatigue score ($F_{(2,115)}$ = .18, $p$ = .84) or SSS score ($F_{(5,112)}$ = 1.39, $p$ = .23)[1]. Whilst not statistically significant, there is a trend of mean time to increase as fatigue increases, as seen in Figure 27a.

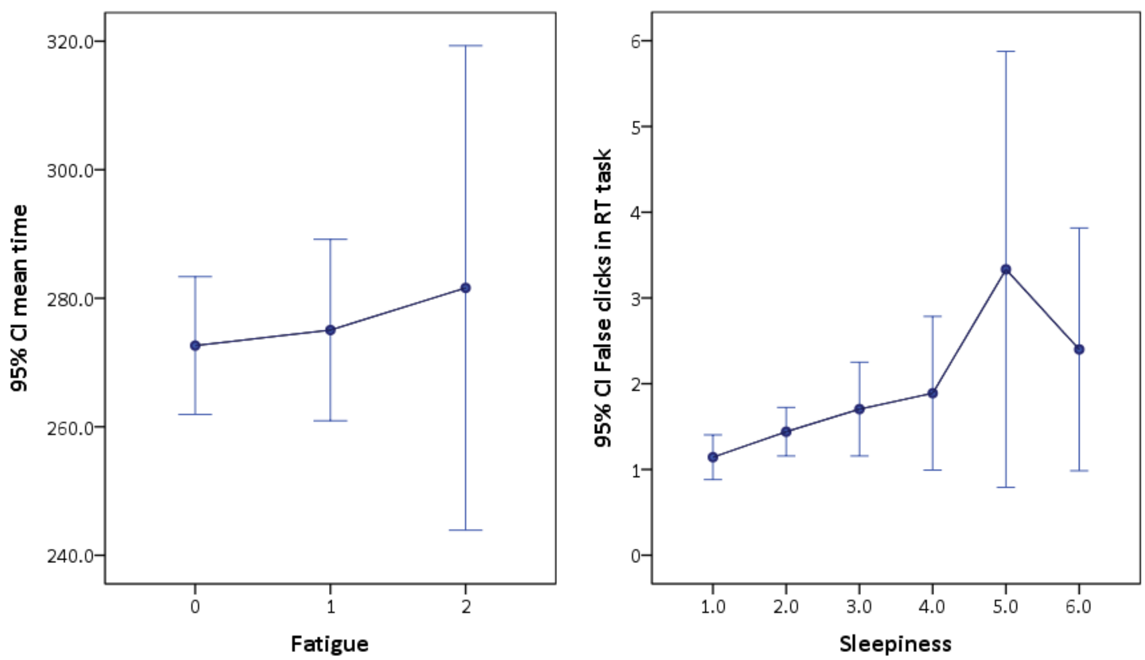


**Figure 27 Reaction time mean time on task with a) fatigue score (left) and b) Error rate by sleepiness (right) showing trends of worse performance with increased tiredness**

[1] Sleepiness score rounded up to nearest whole digit

In terms of errors made, there was once again no statistically significant difference between the mean error count in comparison to the mean fatigue condition ($F_{(1,116)} = 0.67$, $p = .42$), presented task order ($F_{(7,110)} = 0.54$, $p = .80$), mean nausea ($F_{(8,109)} = 0.41$, $p = .91$) and mean fatigue ($F_{(2,115)} = 0.76$, $p = .47$) measures. However there was for mean SSS score ($F_{(5,112)} = 4.17$, $p < 0.01$). Further analysis revealed a significant difference in the mean number of false clicks and mean score of '5' where there was a high average of error, as seen in Figure 27b. There is a small trend, though not significant at other measures, for the number of errors to increase with increasing self-reports of sleepiness.

##### *5.3.2.1.2. Stroop Task*

There is no statistically significant difference between the mean time on Stroop task and the mean difference between the Boring vs. Motion condition ($F_{(1,118)} = 0.003$ $p = .96$), mean Nausea score ($F_{(6,113)} = 1.41$, $p = .22$), mean fatigue score ($F_{(2,117)} = 0.83$, $p = .44$) or mean Sleepiness score ($F_{(9,110)} = 1.19$, $p = .31$). Calculations were also carried out to compare the congruent and incongruent Stroop conditions of which there was no statistically significant difference between the Stroop condition and the mean time taken ($F_{(1,118)} = 0.37$, $p = .55$).

For the Stroop task, there was likewise no statistically significant difference between the mean score and the fatigue condition ($F_{(1,118)} = 2.95$, $p = .08$), the mean Nausea score ($F_{(6,113)} = 0.30$, $p = .93$), the mean Fatigue score ($F_{(2,117)} = 1.92$, $p = .15$), the mean Sleepiness score ($F_{(9,110)} = 0.65$, $p = .75$), or the measures of congruency ($F_{(1,118)} = 0.57$, $p = .45$). Whilst not significant, there is a difference in scores between the boring and motion condition (Figure 28) which could suggest an improved score for participants in the motion condition.

To further explore this, the above measures were retaken on datasets isolating the boring condition and the motion condition. The only statistically significant difference in measurement was between the mean scores in the incongruent trials over the congruent trials between the Motion and Boring condition ($F_{(1,58)} = 5.42$, $p < 0.05$) (Figure 28), with the Motion condition having the improved score. There was no difference in mean time ($F_{(1,118)} = 1.55$, $p = .22$) and mean score ($F_{(1,118)} = 1.34$, $p = .25$) on pre- and post- simulator tests in both cases for this task.

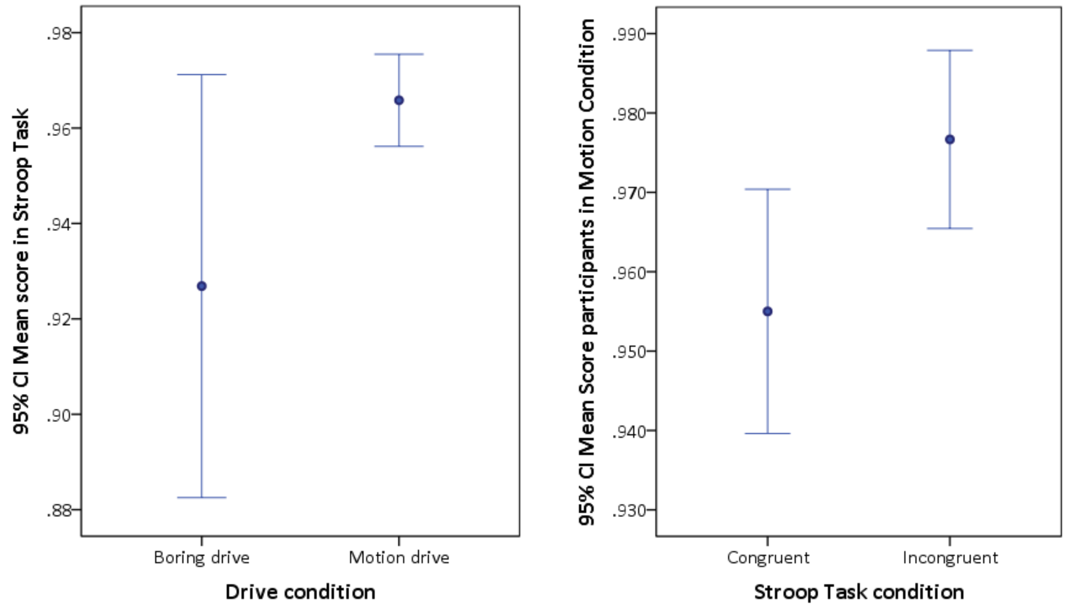


**Figure 28 Changes in mean score of Stroop task based on Fatigue drive participant was involved in (left) and incongruent and Congruent scores in the Motion condition (right)**

### 5.3.2.2. Study Two

Due to computational errors of the version of the BMSe used at the of this study in creating a time stamp data, impacted in part by participants incorrectly responding in the correct clicking procedure (the participant had to first ‘left click’ and then ‘right click’ using the mouse for the Create Unit task to correctly register an input), a lot of the timing data could not be calculated for the tests conducted (see 5.4 Discussion for more information). Only 10 datasets were intact so, for this thesis, only the total error in tasks will be reported on.

The mean Sleepiness scale was statistically significantly different to the mean score in the Create Line task ($F_{(6,119)} = 3.15$, $p < 0.01$)[2] where the mean errors in a score of ‘6’ differ significantly from mean errors at scores from 1-4 as seen in Figure 29 (see Appendix J: Create Line Errors and Sleepiness (MF) for mean scores).

[2] Score of Sleepiness rounded to the nearest whole number.

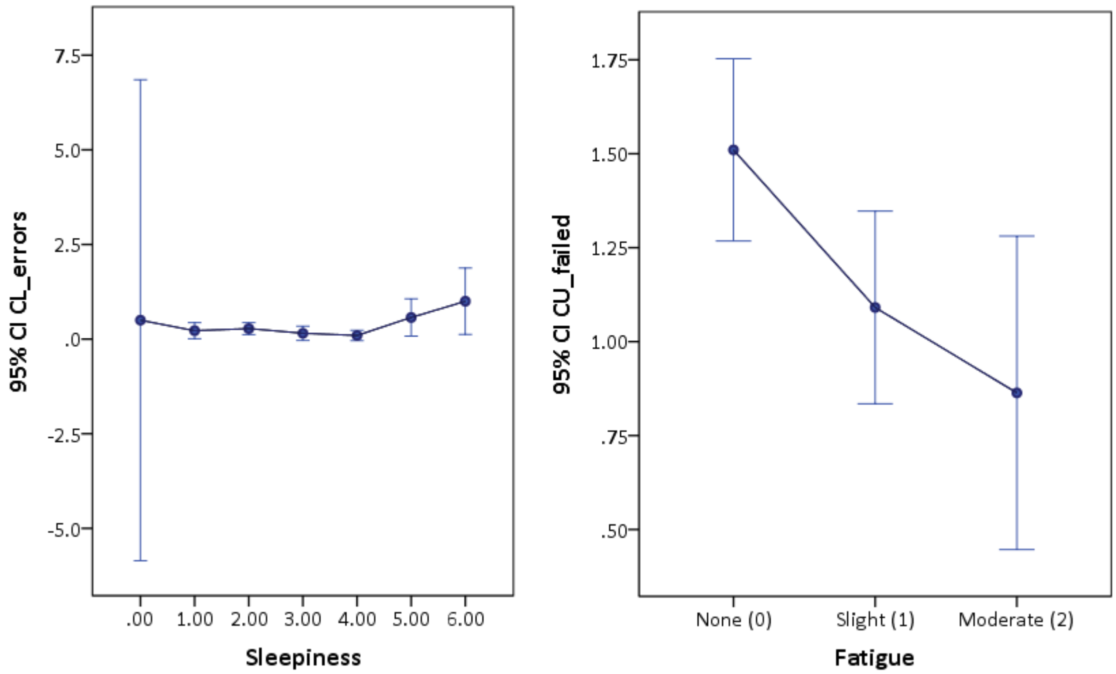


**Figure 29 Sleepiness trend with number of errors in CL task (Left) and failure in CU task by self-report of the SSQ fatigue measure (Right). Note: no participant selected 'severe' for the fatigue measure.**

The mean score of 'fatigue' is statistically significantly different to the mean error count in the Create Unit task ($F_{(2,123)} = 4.75$, $p < 0.05$)[3] with mean errors at mid test point (*M*=1.09, SD=.95) and end test point (*M*=.86, SD=.94) beings statistically different from the mean at the start of the fatigue drive (*M*=1.51, SD=.12) by LSD assumption. Interestingly this data implies that fewer failures were made as fatigue increased (see Figure 29). There are some issues with the errors in this task as will be further explained in Chapter 5.4: Discussion.

A comparison between the moments in which the task was presented shows a statistically significant difference between task presentation and mean score in the CL task ($F_{(4,121)} = 6.12$, $p < 0.01$) and the mean score in the RT task ($F_{(4,121)} = 6.26$, $p < 0.01$). For the CL task, participants all performed better than the last performance measure, that is, when they were most fatigued, as can be seen in Figure 30 (see Appendix K: Create Line and Read Text task by Session (MF) for mean scores). In the case of the RT task, it was the score at the mid-task point that had a significantly different mean from all others, as seen in Figure 30 (see Appendix K: Create Line and Read Text task by Session (MF) for mean scores). It is interesting to note in both cases the learning effect between the two-parts of the study. Participants performed worse across both tasks after the first exposure to the test. They subsequently performed

[3] Score of Fatigue rounded to the nearest whole number.

better on their return when they were no longer fatigued. The task performances indicated a worsening at the post-task for the CL and mid-task for the RT are discussed further in Chapter 5.4: Discussion.

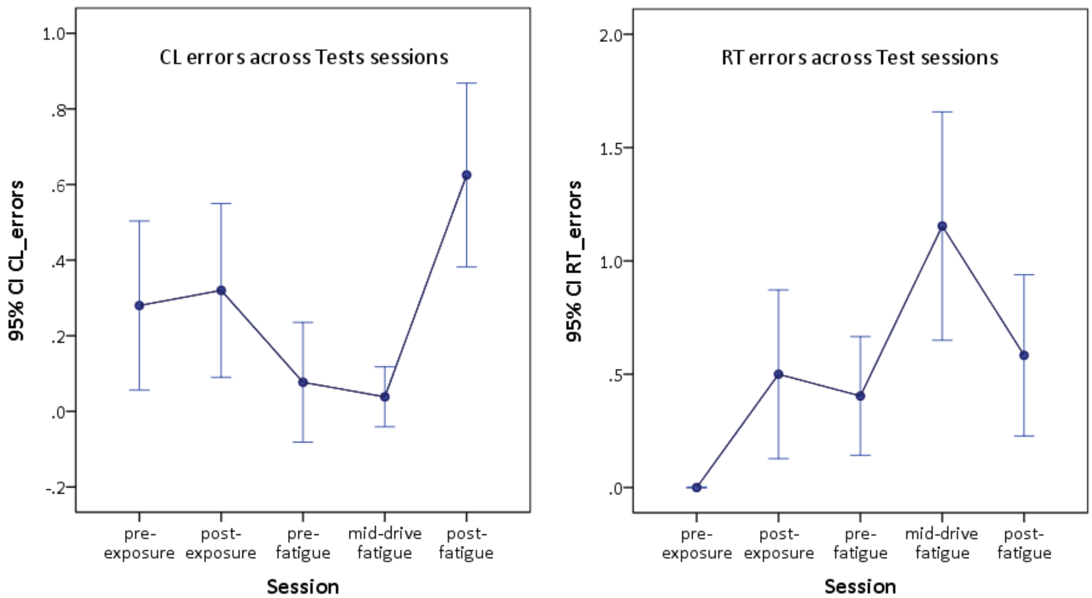


Figure 30 Change in CL errors (Left) and RT errors (Right) over sessions

Whilst Nausea is not a focus of the fatigue test, there was a statistically significant difference in the mean score of nausea and the errors of the RT task ($F_{(5,120)} = 3.43$, $p < 0.01$)[4] that had not been found previously in the Motion Sickness study (Chapter 4.3: Results). Post-Hoc analysis could, therefore, not be used as there are not enough cases of reported nausea level to be able to report conclusively on this case. This is clear from Figure 31 where only one participant gave a rating of “4” and one other a “5”.

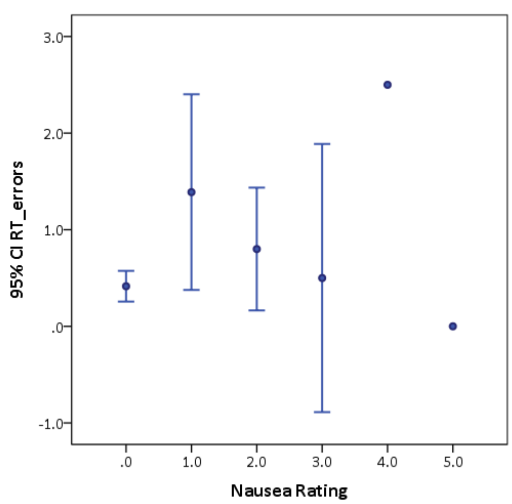


Figure 31 Self-reported Nausea with number of errors in the Read Text task

[4] Score of Nausea rounded to the nearest whole number.

By comparing the Boring and Motion groups, both unit-based tasks – RU and CU – were found to have a statistically significant difference in mean scores, based on which group the participant was a part of ($F_{(1,74)}$= 4.66 , $p < 0.05$ and $F_{(1,74)}$ = 11.22, $p < 0.01$ respectively). In the case of the CU task, there was a higher mean error rating in the Motion condition (*M*=1.58, SD=0.81) than in the Boring condition (*M*=0.9, SD=0.96). For the RU task however, the opposite was true where the error rate was higher in the Boring fatigue condition (*M*=.13, SD=0.25) as compared to the motion (*M*=0.3, SD= .12). The change errors by condition for all tasks can be seen in Figure 32. It is only the PZ and CU tasks that actually have a worse performance in the Motion condition, with the other four tasks from the BMSe set being worse in the Boring condition.

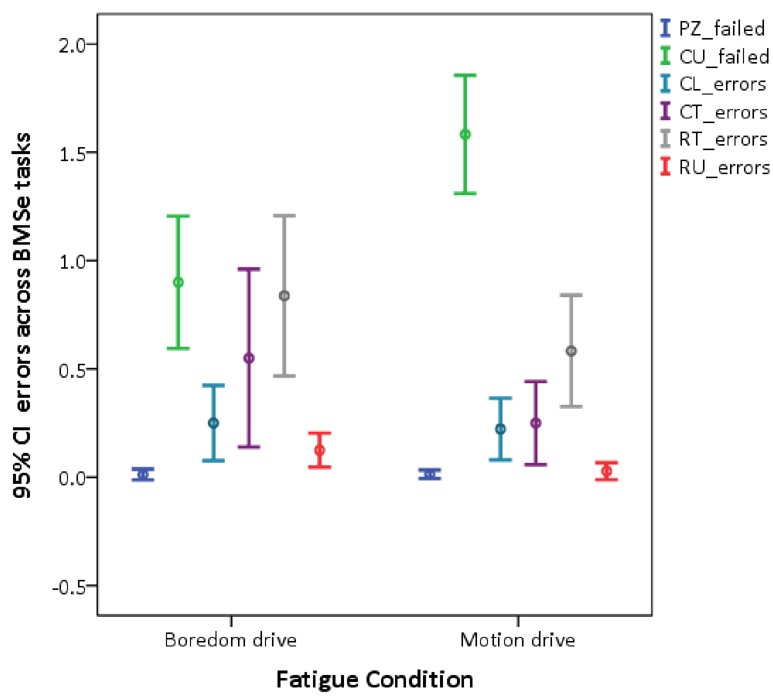


**Figure 32 Error changes across all BMSe tasks by fatigue drive condition**

Participants in the Boring group had no statistically significant difference between mean performance across the BMSe task and the mean Nausea, Sleepiness or Fatigue sores (see Appendix L: Study Two tasks, Boring condition by Nausea, sleepiness and Fatigue (MF) for mean scores). Unlike the Boring group, the participants in the Motion group did have a change in task performance. In the RU task, there was a statistically significant difference in the mean performance when compared to the mean Nausea[5] ($F_{(4,31)}$ = 6.89, $p < 0.01$) and mean Fatigue[5] scores ($F_{(2,33)}$ = 9.47, $p < 0.01$). For the Nausea score, post-hoc

[5] Score rounded to the nearest whole number prior to statistical analysis

analysis could not be performed as there were not enough instances of a nausea report. For the Fatigue, this significance was found that the mean of the highest recording of 2 (*M*=.2, SD=.27) was statistically significantly greater than the mean score at 0 or 1, where no errors in this task are recorded as seen in Figure 33. With the measure of mean Sleepiness[6], the mean errors in the CL task were once again calculated to be statistically significantly different to this self-report score ($F_{(5,30)} = 3.14$, $p < 0.05$) with more errors occurring at the higher sleepiness rating, although, as with nausea, there are not enough recordings at this higher level of sleepiness to perform accurate Post Hoc analysis (Figure 33).

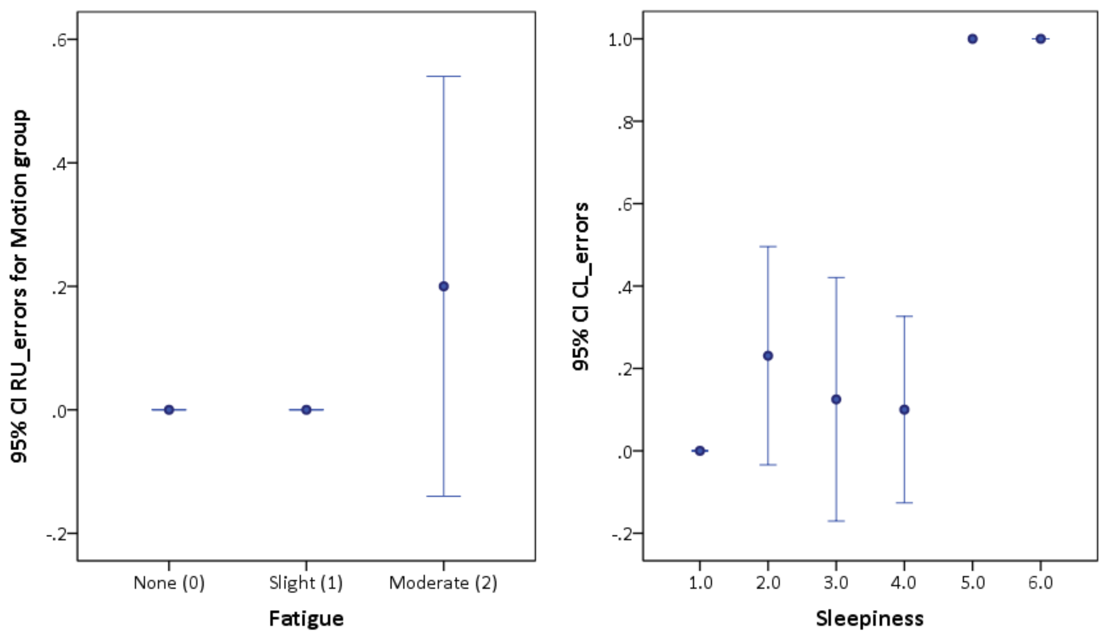


**Figure 33 RU errors and relation to Fatigue (Left) and CL errors in relation to Sleepiness score (Right)**

## 5.3.3. Biometric Analysis

### 5.3.3.1. Heart Rate and Respiratory Rate

In Study One, investigating the separate study sequences with changes in Heart Rate (HR) and Respiratory Rate (RR), the mean of HR was not found to be statistically significantly different to the drive sequence ($F_{(3,70)} = 1.45$, $p = .24$), despite the mean of the RR being ($F_{(3,70)} = 7.45$, $p < 0.01$). For the RR it was found that the mean of the RR during the fatigue drive (*M*=19.52, SD=3.62) was statistically significantly different to the means at baseline (*M*=14.11, SD=7.46) and pre-fatigue task (*M*=13.94, SD=3.47), with the mean at post-fatigue task (*M*=18.11, SD=3.78) also statistically significantly differing

[6] Score of Sleepiness rounded to the nearest whole number prior to statistical analysis

from the mean at the pre-fatigue task, as shown in Figure 34. In comparison of boring to motion conditions however, there was no statistically significant change in either the mean HR ($F_{(1,72)} = 0.09$, $p = .77$) or the mean RR ($F_{(1,72)} = 0.71$, $p = .40$) of the groups.

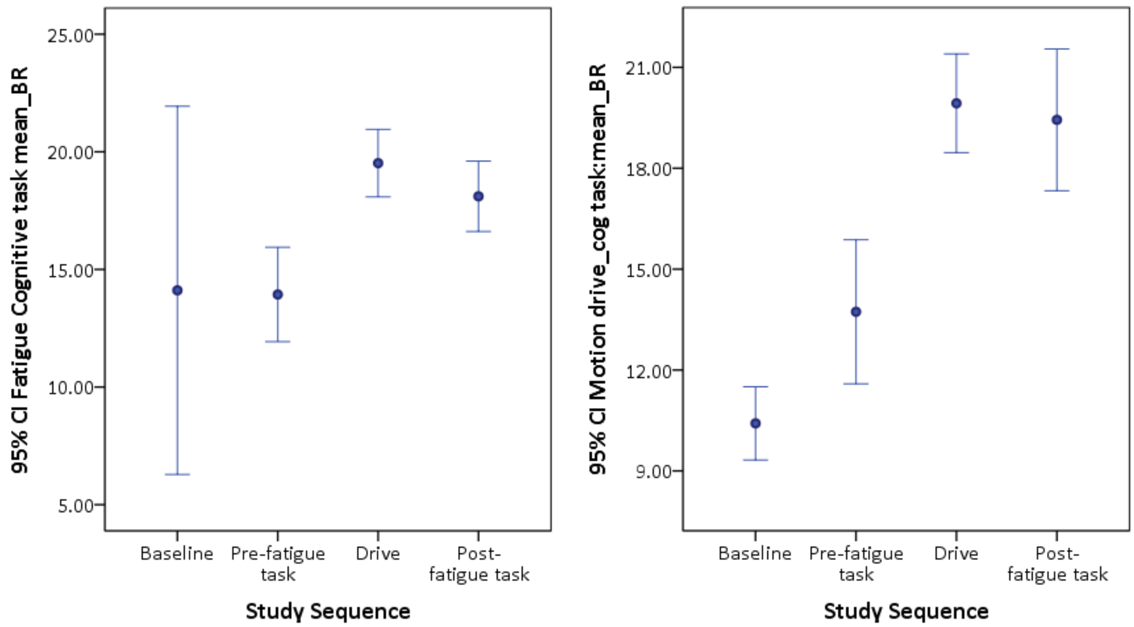


**Figure 34 Changes in respiratory rate over driving sequence for the combined participants in Study One (left) and the participants in the motion condition in Study One (Right)**

Isolating the data for the boring condition and the motion conditions in Study One, there was no statistically significant difference to the mean HR ($F_{(3,32)} = 0.65$, $p = .59$) and mean RR ($F_{(3,32)} = 1.55$, $p = .22$) across the boring condition or for mean HR ($F_{(3,34)} = 1.03$, $p = .38$) in the Motion condition. There was however a change in RR in the motion condition based on study sequence ($F_{(3,34)} = 12.78$, $p < 0.01$). As with the combined task set, it was found that the mean RR during the fatigue drive (*M*=19.93, SD=2.54) was significantly different to the means at baseline (*M*=10.41, SD=.12) and pre-fatigue task (*M*=13.73, SD=2.56), with the mean at post-fatigue task (*M*=19.44, SD=3.65) also differing significantly from the mean at the pre-fatigue task as shown in Figure 34

For those in Study Two, there was no statistically significant difference between the mean HR and task order ($F_{(5,124)} = 0.48$, $p = .79$) or mean RR and task order ($F_{(5,124)} = 2.02$, $p = .08$). There was however a statistically significant difference when comparing the type of fatigue condition, Boring or Motion, to the means of both the HR ($F_{(1,128)} = 5.40$, $p < 0.05$) and RR ($F_{(1,128)} = 7.25$, $p < 0.01$). In both cases, the mean HR

(*M*=77.97, SD=26.80) and RR (*M*=15.97, SD=3.45) for the boring group were lower than the mean HR (*M*=88.31, SD=21.96) and RR (*M*=17.82, SD=4.41) in the motion group as seen in Figure 35.

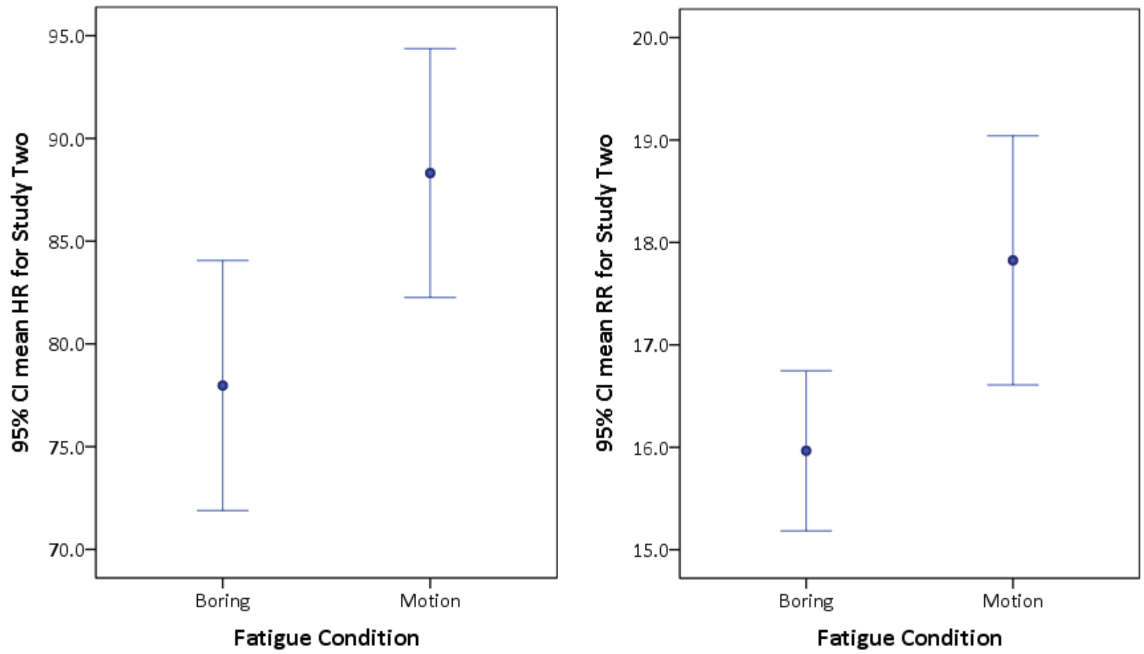


**Figure 35 Mean Heart Rate (Left) and Respiratory Rate (Right) changes when comparing Boring to Motion Fatigue Condition**

In separating the Boring and Motion groups, it was found for the Boring group that there was no statistically significant difference between times of drive and mean HR ($F_{(5,71)} = 0.42$, $p = .83$) or mean RR ($F_{(5,71)} = 1.83$, $p = .12$). This was also true for the mean HR ($F_{(5,47)} = 0.43$, $p = .83$) and mean RR ($F_{(5,47)} = 2.19$, $p = .07$) in the Motion group setting.

#### 5.3.3.2. Ratio of Blink Velocity

In both studies, the means of blink velocity were found to be not significantly different between the Boring and the Motion condition ($F_{(1,36)} = 3.93$, $p = .06$ and $F_{(1,121)} = 3.64$, $p = .06$ for Study One and Study Two respectively) or between the task sequence ($F_{(1,36)} = .86$, $p = .36$ and $F_{(4,118)} = 0.95$, $p = .44$ respectively). Isolating the Boring and Motion conditions for each study, there were no statistically significant differences the type of fatigue condition and the mean changes by the study sequence ($F_{(1,26)} = 0.70$, $p = .41$ and $F_{(1,8)} = 0.69$, $p = .43$ respectively for Study One, $F_{(4,58)} = 0.85$, $p = .50$ and $F_{(4,55)} = .73$, $p = .57$ respectively for Study Two).

Whilst not significant, there was a trend in both studies for the velocity of blink ratio to be lower in the Motion group than in the Boring group as seen in Figure 36.

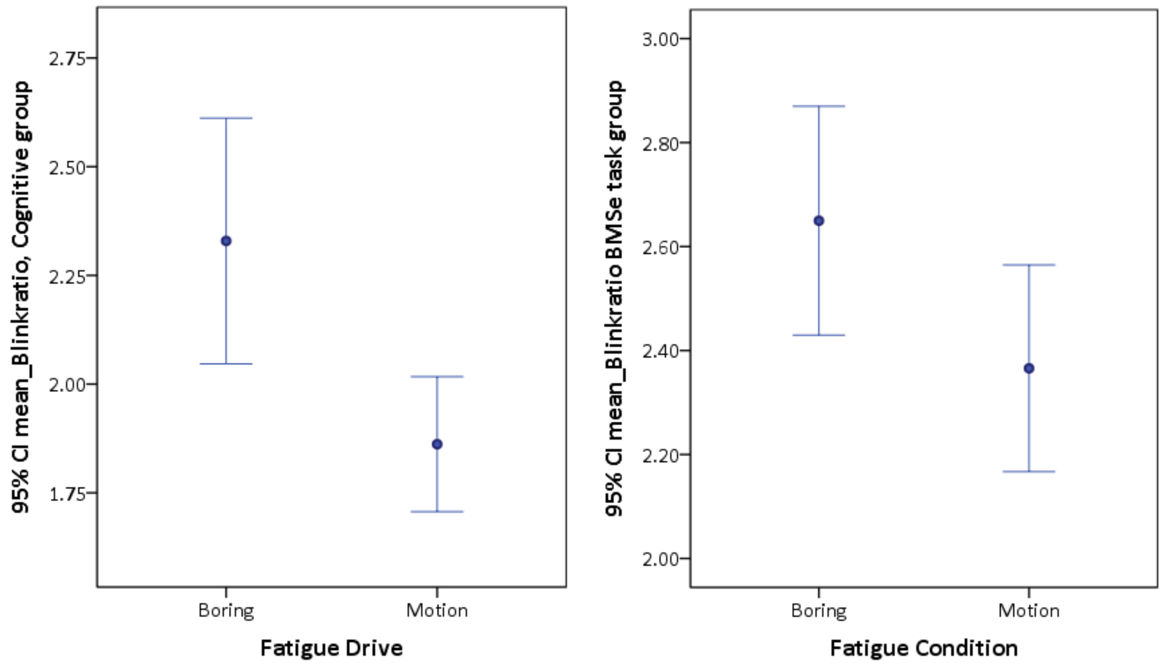


**Figure 36 Mean ratio of blink velocity (eye closure to eye opening) between Boring and Fatigue Condition in Study One (left) and Study Two (Right)**

#### 5.3.3.3. Measures of Heart Rate Variability

The Bioharness device, used for collecting of the HR and RR rates used in the previous analysis does output a Heart Rate Variability (HRV) reading. However this reading is not as accurate and drops signal at various intervals for certain participants. In order to recover this reading, the RR file output (that is, the output of all successive peaks in the QRS complex of the ECG output) that the Bioharness device provides, is coded and passed through the software program Kubios (Chapter 3.3.2: Kubios HRV package) to output various HRV parameters. The targeted HRV parameters analysed are; the Mean RR, the root mean of successive differences (RMSSD) between normal beats, the number of successive normal beats that differ by 50ms (NN50), and the peak frequency of the Fast Fourier Transform and High Frequency (Peak FFT HF).

Whilst the Bioharness' on-board HRV measurement is not used, it is useful as an overview. From this overview in Study One, it was noted that there was a dip in HRV recordings at ~20 minutes into driving for 60% of the participants. As a drop in HRV is linked to be a potential marker of fatigue, this observation led to the experiment design change in Study Two which was to include a task stop at the 20 minute mark.

In Study One, on drive condition, there was a statistically significant difference between drive scenario and the mean score of both the RMSSD ($F_{(2,72)} = 6.25$, $p < 0.01$) and the NN50 ($F_{(2,71)} = 18.55$, $p < 0.01$) measures. For the RMSSD condition, the baseline/pre-task (*M*=1588.98, SD=2582.66) measure was statistically significantly higher than the Drive (*M*=216.57, SD=316.09) and Post-task measure (*M*=343.95, SD=608.91). For the NN50 the drive measure (*M*=965.50, SD=955.89) was found to be statistically significantly higher than the pre- (*M*=35.96, SD=43.72) and post- (*M*=216.46, SD=178.82) task measures. That means that overall there was a large gap in heart beat rates in the drive – indicative of fatigue, with higher variability in beats as hypothesised in the pre-state since the heart rate becomes less variable with increasing fatigue. The changes in all four HRV parameters are shown in Figure 37.

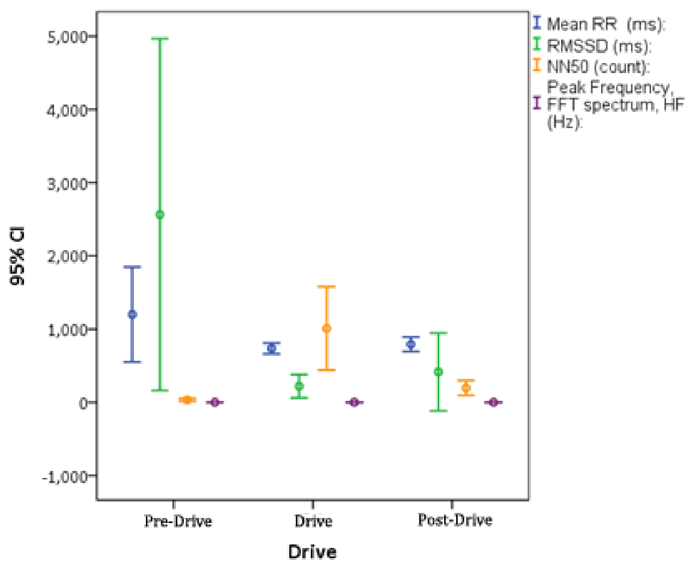


Figure 37 Changes in HRV measures by drive for participants in Study One

In comparing the two fatigue drive types, Boring and Motion, there was no statistically significant difference between the type of drive and the HRV parameters assessed. For the NN50 scores, there was a statistically significant difference in mean score compared to the drive type in both the Boring ($F_{(2,38)} = 7.85$, $p < 0.01$) and Motion ($F_{(2,31)} = 10.62$, $p < 0.01$) scenarios, with the drive condition (*M*=928.07, SD=1035.83 and *M*=1009.17, SD=897.08) being higher than both the pre- (*M*=38.38, SD=53.75 and *M*=32.80, SD=28.28) and post- (*M*=233.43, SD=199.90 and *M*=196.67, SD=157.01) task condition in both cases. The plots of these cases are shown in Figure 38.

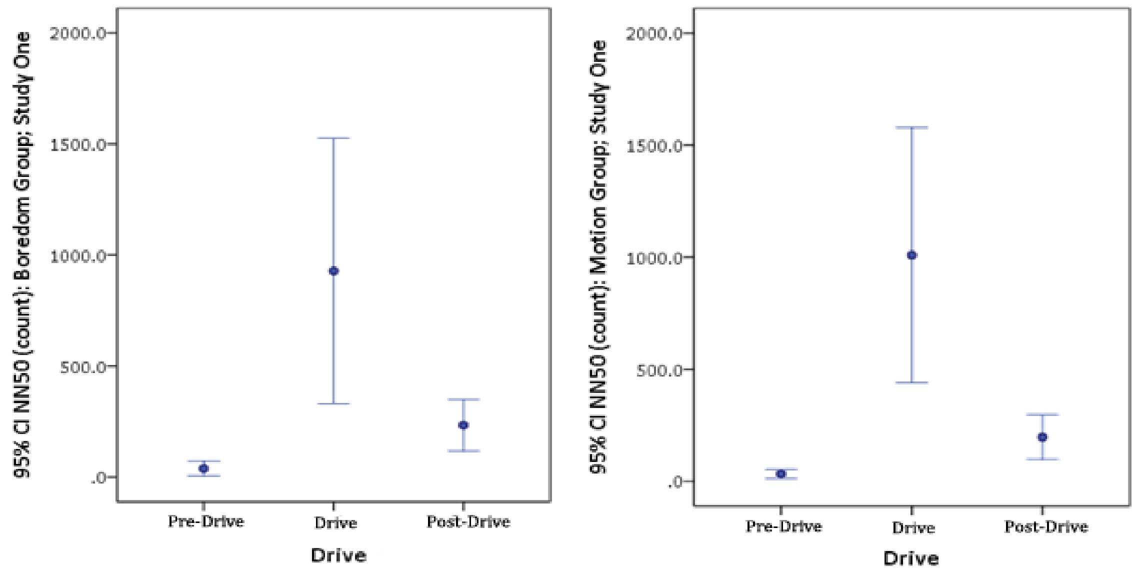


**Figure 38 Plot of NN50 score for Study One participants in the Boredom (Left) and Motion (Right) fatigue conditions**

In the Motion condition in Study One, there is a statistically significant difference between the RMSSD value and drive condition ($F_{(2,31)}=5.06$, $p<0.05$), with the pre-task measure mean (*M*=2564.56, SD=3357.43) being significantly higher than the mean drive value(*M*=220.30, SD=250.03) and post-task value (*M*=415.15, SD=838.91).

In Study Two there are statistically significant differences between the drive sequence mean scores of the NN50($F_{(5,142)}=11.16$, $p<0.01$), RMSSD($F_{(5,142)}=11.53$, $p<0.01$) and Peak FFT HF($F_{(5,142)}=3.06$, $p<0.05$). The mean changes are located in Appendix M: Mean HRV scores in Study Two (overall) (MF). The NN50 count was higher than other counts during the drive whilst the Peak FFT was the inverse, with peaks at the mid and post- task times. The RMSSD value decreased during the experiment. The changes in all four measures are seen in Figure 39.

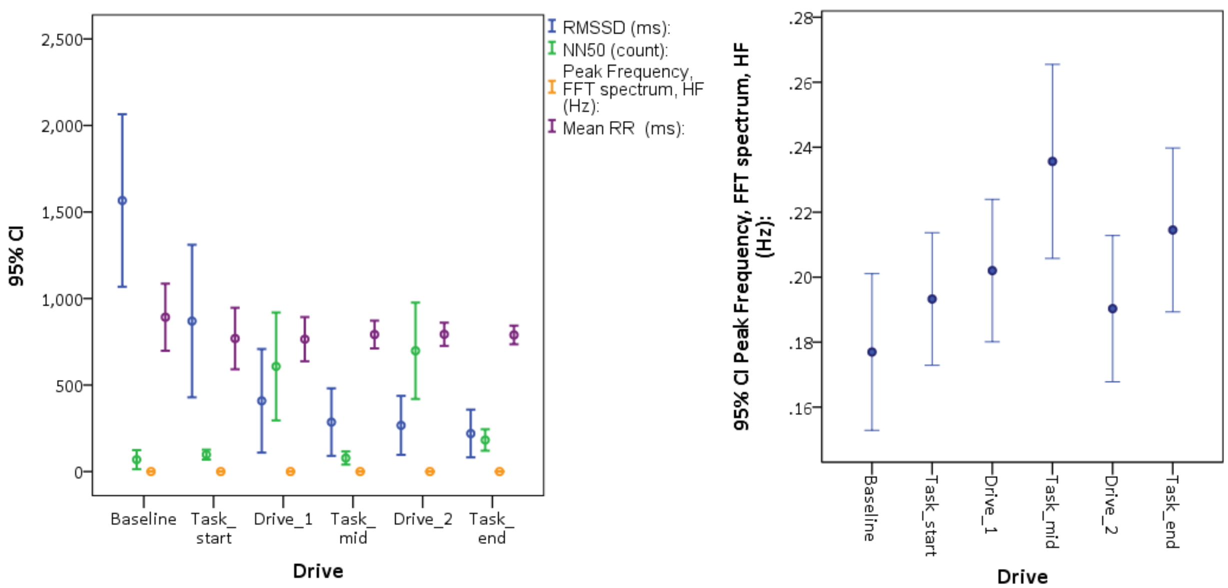


**Figure 39 Changes in HRV measures by drive for participants in Study Two (Left) with changes in Peak FFT HR by drive (Right)**

Comparing the Boring drive group to the Motion group in Study Two, there was a statistically significant difference between the group and the mean Peak FFT HF ($F_{(1,146)} = 7.81$, $p < 0.01$), with the mean frequency being higher in the Boring group (*M*=0.22 , SD=0.06) than the Motion group (*M*=0.19, SD=0.05). These changes are seen in Figure 40.

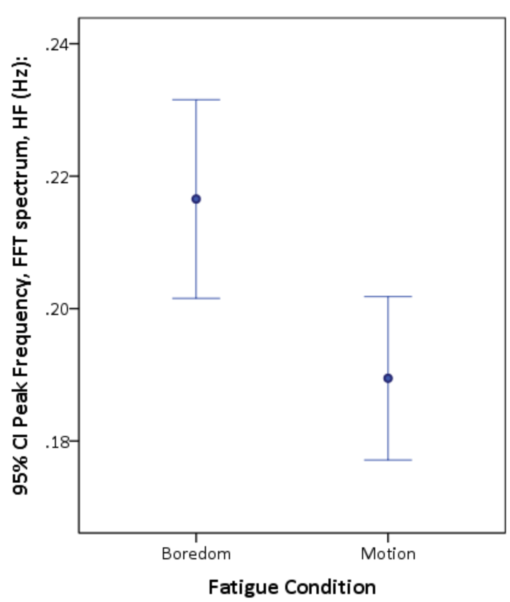


**Figure 40 Change in Peak Frequency, Fast Fourier Transform, High Frequency Band (Hz) across the two fatigue conditions in Study Two**

The participants in the Boring group had changes in RMSSD and NN50 scores that were statistically significantly different to the drive point in the study ($F_{(5,65)} = 2.78$, $p < 0.05$ and $F_{(5,65)} = 4.90$, $p < 0.01$ respectively). For the RMSSD, the mean at the end of the fatigue test (*M*=193.79, SD=201.60) was found to be statistically different to the mean at the baseline (*M*=1161.09, SD=254.91). The NN50 had more differences (see Appendix N: Mean HRV scores in Study Two (Boredom Condition) (MF) for means between drive codes). The main changes for the NN50 score was a statistically significant increase in both Drive_1 and Drive_2 conditions compared to the baseline and task times. The changes across all four HRV measures can be seen in Figure 41.

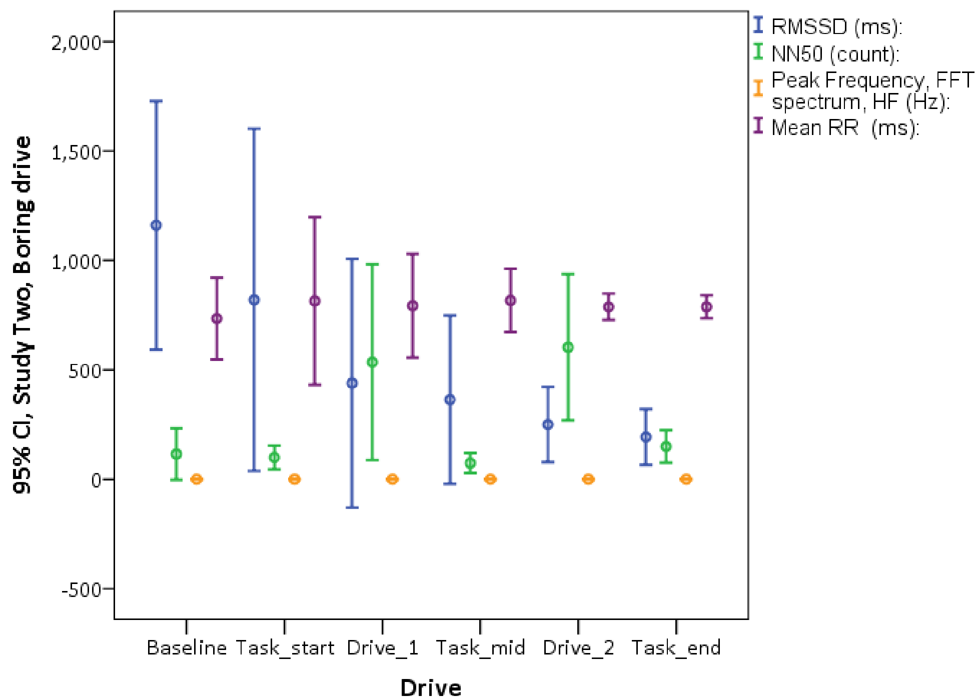


Figure 41 Changes in HRV measures over drive condition in Study Two for participants in the 'Boring' Drive

A similar trend is viewed for the Motion group participants, with means of the RMSSD score ($F_{(5,71)} = 10.04$, $p < 0.01$) and NN50 score ($F_{(5,71)} = 6.10$, $p < 0.01$) being significantly different between drive occurrences. For the RMSSD score, using LSD assumption, all mean drives differed significantly from the baseline HRV measure (see Appendix O: Mean HRV scores in Study Two (Motion Condition) (MF)) as shown in Figure 42. In NN50 again the scores at Drive_1 and Drive_2 differed statistically significantly from all other drive points (see Appendix O). The mean score changes are also shown in Figure 42.

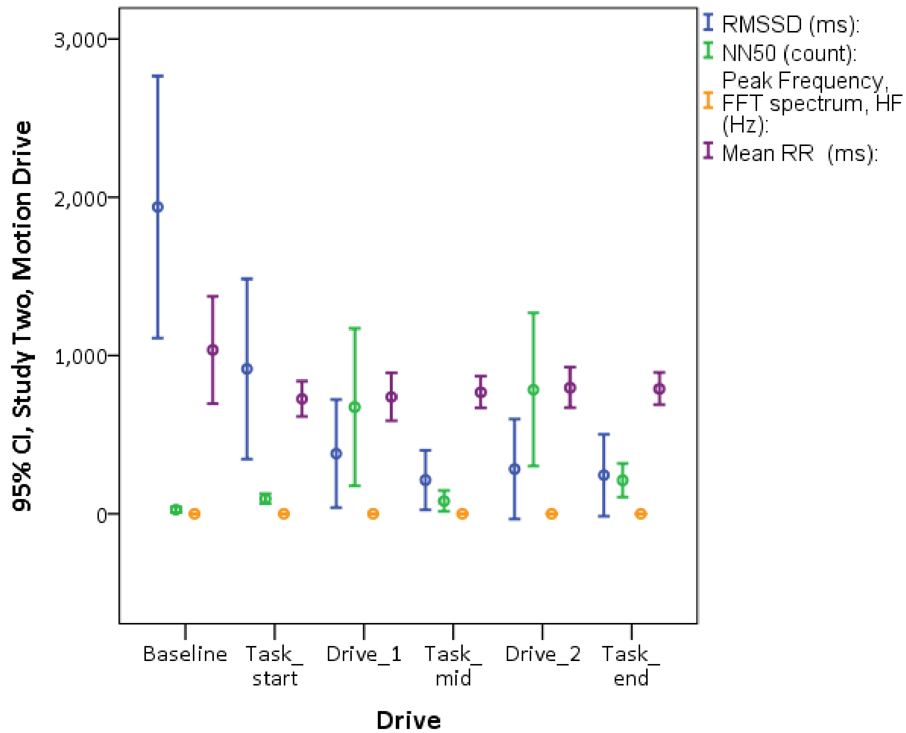


Figure 42 Changes in HRV measures over drive condition in Study Two for participants in the 'Motion' Drive

## 5.4. Discussion

This study compares, for the first time, the concept of fatigue and its effect on task performance caused by the body under constant motion and fatigue due to boredom and lack of stimuli. In the test on changes to cognitive task performance, simple reaction time is affected by fatigue as expected from the literature, with neither fatigue condition having a significantly different effect on the other in terms of performance reduction. In the study of changes to the defence task set, it is demonstrated that the fatiguing condition has different effects on different types of tasks. The Read Unit task performance is affected more by the boring condition with the Create Unit task more affected by the motion condition. Looking at overall trends, there are more tasks in the BMSe that have an increased error rating in the boring condition than in the motion condition. The data suggests that if we assume even criticality of all task presented, for the participants in this study, it is the boring condition that has a larger detrimental effect than the motion condition when comparing fatigue types. The mental fatigue of under-arousal appears to be worse in the BMSe tasks than the physical fatigue due to motion.

The results of the biomeasures point to trends in increased heart rate and respiratory rate in the Motion condition over the Boring condition in Study Two, with overall respiratory rate also increasing in the Motion group in Study One. These measures suggest the boring scenario is the most fatiguing, according to the current literature interpretation of biological reactions to fatigue. Elevated readings that would express an engagement and alertness were not found to change in the boring group. The measures of Heart Rate and Respiratory Rate across both studies did not show any changes as expected with a change in the task type. In the short term that these measures are tested, this lack of alteration to measure suggests that these measures may not be a reliable indicator of fatigue. The HRV measure however, is shown in the data to be a more robust measure for this study, with both RMSSD and NN50 scores corresponding to changes in fatigue, as would be expected, with NN50 peaking during drive conditions and RMSSD showing a steady decline as the participant becomes more fatigued.

The Reaction Time task showed no change over the exposure test results and the fatigue drive results. This lack of change in values establishes that this task is a good predictor for this participant pool, as it is unaffected by learning factors. It is a task the participants are familiar with, with no participant needing further explanation on how to perform the task. Whilst not significant, there was a trend of reaction time increasing according to fatigue, with a spike of errors corresponding to self-reported sleepiness. These corresponding changes in fatigue suggest that the task is a good indicator, though it may need an increased level of difficulty in future studies of fatigue, so that a significant change in performance would become evident.

The colour Stroop test showed neither learning effect nor fatigue effect in these trials. This result could be due to the nature of this Stroop test. Alternatively, it could suggest that for the cognitive tasks, the post-test acted as a stimulant as participants knew the study was almost over after they completed the test. This hypothesis requires further comparative studies on a random number of trials on fatigue. In this particular study on investigating task performance with this simulator, the Stroop task showed no remarkable changes.

Following on from the lack of findings in changes in the BMSe task set in the Motion Sickness study, it was unexpected to find such positive correlations in the fatigue study. Once more the most difficult task from the set, Create Line Task, proved significant. In this case, it was with the sleepiness recording and at the end-point of a fatigue drive that a statistically significant decrease in performance in this task was found, compared to the rested state. The repeat of this decrease in task performance following on from the Motion Sickness study (Chapter 4: Motion Sickness) is interesting and reinforces the concept that a task has to have a certain level of difficulty for a change to be seen by the simulator effects over a short term.

The Create Line task was not the only task affected by fatigue. Fatigue self-report scores were found to be correlated with Create Unit errors, so that more errors occurred at lower fatigue levels. This is unexpected; however this task was unique in the input response protocol. For the BMSe to correctly identify that a response was made, the participant had to first 'left click' and then 'right click' using the mouse. Failure to 'left click' in the first instance led to a missed input for this task. Whilst all participants were instructed to perform the task correctly, some failed to do so, compounding their errors. This error factor casts certain doubts on the Create Unit results, particularly since the findings indicate that participants in this task performed worse under Motion condition than the Boring condition, unlike most other tasks. If these errors are ignored, the only other task to have a trend with a worse performance under the Motion condition is the Pan-Zoom task, in which the change between the two conditions is slight. With the Read Unit task having a significant difference in the opposite direction and all other tasks trending in the Boring condition to having increased errors compared to the Motion condition. This study favours the Boring condition as having a larger detrimental fatigue effect than Motion in the context of military styled tasks.

Interestingly for the military tasks, when looking at the order of tasks, at the 20 minute mark in the drive the Read Text task had statistically worse performance than in the pre- and post- tasks. This is a curious trend that requires further investigation. Two possible theories are that the post-task still had a stimulant factor, as proposed earlier, that may have maintained a higher level of performance than might have otherwise occurred at this increased fatigue. Alternatively, this initial fatigue point (first discovered as a dip in the HRV total) may have an effect of speech that is later minimised. This would be a good future investigation point when studying fatigue in a motion scenario.

Apart from task response, the biomeasure scores were analysed to determine what external measures could be used as the best indicator of fatigue, and to ensure that the condition was indeed fatiguing. That RR increased in the Motion condition in both studies, highlighting once more that this condition is less 'fatiguing' as the term has been ascribed to previous fatigue studies. HR was also found to increase in the Motion scenario for Study Two, though its lack of repetition in trend for Study One reveals that it is not such a good an indicator of fatigue. It is still a somewhat better indicator than blink velocity.

Blink velocity was measured for this study following on from research of similar devices used in the field today that advertise themselves as 'fatigue monitors'. The scientific bases behind commercial glassware is that the velocity of a blink can correlate, with a specialised algorithm using the SSS, to fatigue as is the case with the Optalert (Optalert, Victoria, Australia) system. In using the raw velocity data for this study, there were no obvious changes or indicators to be found correlating to fatigue.

In both studies, the NN50 score was seen to increase during the 'drive' condition of the fatigue experiment in a statistically significant way when compared to the other testing conditions. This shows that there are greater changes in normal heart beat in a constant drive scenario that could indicate an increased relaxed state during this drive condition. However, this measure is a 'count' style measure that doesn't correct itself based on exposure time, so the result may be misleading without further investigation. The RMSSD score, however, appears to be a robust measure of fatigue, with results showing a steady decline in Study Two across all drive conditions, as would be anticipated from an increase of fatigue. In Study One it was shown to be higher in the drive than in the end task. However, this could be explained by assuming that the end task acts as a stimulant in this scenario as mentioned previously.

## 5.5. Conclusion

In investigating task performance, it is found that both the Motion and Boring scenarios elicit fatigue and have an equivalently detrimental effect on performance, with each fatigue type affecting different tasks. When considering task trends on performance (irrespective of significance), the Boring condition is seen to have a more negative impact on performance than the Motion condition for the tasks analysed in this chapter. From this, it could be inferred that the less stimulating effect of a motion environment is worse for task performance than a condition that required attention and motion for periods of one hour of driving.

Out of all biomeasures used for fatigue, heart rate and blink velocity do not appear to be reliable indicators of a fatigued state. Respiratory rate is seen as more ideal with the best indicator being the root mean of successive differences (RMSSD) between normal beats of the Heart Rate Variability measure. In terms of Subjective scales, the Stanford Sleepiness Scale and the 'fatigue' elements of the Simulator Sickness Questionnaire were found to be relatable methods to the monitoring of fatigue effects, with best results when using a combination of both measures.

# 6. Motion perception effects under workload

## 6.1. Introduction

How we perceive motion, and how that perception affects our ability to do work, is an area of great military interest. This knowledge has repercussions on vehicle design and terrain considerations when creating a land operations military unit. However, real knowledge in this area is quite limited. Recent research has shown that motion along a Z axis (up-down) has greater detrimental effects on performance during tasks such as reading (Bhiwapurkar et al., 2010) when compared to motion along the X or the Y axis. Many of these studies in motion though are restrictive in their results as they represent data measured along linear axes only, often missing either whole body motion or motion of the whole visual field (Marlinsky, 1999, Zheng et al., 2011, Parsons and Griffin, 1978, Zheng et al., 2012). The real world is not so limited in motion profiles, involving constant potential motion along six degrees-of-freedom (6 DOF) with 3 linear and 3 angular axes of motion. To accurately approach the question of how perception affects task performance, it must be possible to test perturbations along six axes where both body and the visual field also move in accordance to the perturbation.

Currently and according to my knowledge, the effects of motion perturbation and its effect on task performance has not yet been systematically studied along all 6 DOF. This chapter of this thesis has been developed to address this gap in research. The 6 DOF CKAS base used in all studies in this work (see Chapter 3.1.1: Motion Simulator) is unique in that it allows for exploration of motion in each individual axis of motion and allows for whole body motion in an enclosed cabin and with a controlled visual environment.

In testing perception along six axes, a choice of the intensity of motion must be made. Unlike the effects of 6DOF testing, studies of motion intensity and vibration have been widely conducted along a single axis. An increase in intensity along a single axis has been shown to have increasing negative consequences on specific areas of an individual such as gastrointestinal and urinary problems (Standards, 2001) and lower back, head and neck discomfort (Matsumoto et al., 2011, Basri and Griffin, 2012). From studies of these effects, the Australia Standard AS 2670.1-2001: Evaluation of human exposure to whole-body vibration (ISO 2631-1:1997) (Standards, 2001) was established to provide limits of allowable vibration for Occupational Health and Safety considerations. The limits set by this standard have been used in this study at three varying vibration levels classified from ‘mild’ (0.4725 $m/s^2$) to ‘very uncomfortable’ (2.5$m/s^2$) in order to study intensities and different axes of motion that could be expected from a soldier travelling in a land operation vehicle.

## 6.2. Method

### 6.2.1. Participants

Thirty-three first year psychology students from the University of Sydney participated in this study (Males = 8; Females =25). To sign up for this study, participants were asked to be free from the effects of alcohol, have no history of motion sickness and to not wear glasses. Participants were unable to wear corrective lenses for this study due to the video goggles (see Chapter 3.2.2: Video Goggles) used to evaluate ocular response. The participants were allowed to wear contact lenses, if needed, to correct near vision. All procedures were in accordance with the Declaration of Helsinki and were approved by the University of Sydney Human Ethics Committee. Participants gave informed written consent and were free to terminate testing at any time. Participants received course credit for their time in line with standard departmental procedures. Four participants were excluded from this analysis, three from early termination of the study and the fourth due to technical problems during that testing session.

### 6.2.2. Apparatus

Motion was delivered using the 6DOF motion platform described in Chapter 3.1.1: Motion Simulator. Participants were enclosed within the cabin and fastened to the driver seat by the fitted four-point safety harness. A fluorescent light was fitted inside the simulator as the screens were not lit for this study as they were used for all the other motion studies. Communication via intercom was maintained at all times.

#### 6.2.2.1. Motion Profile Generation

The standard Hixson et al. (1966) convention was adopted for labelling of axes of motion: X for forward-back, Y left-right, and Z for the vertical axis with the Roll, Pitch and Yaw directions in the appropriate definitions of their motion as shown in Figure 43. In addition, three intensity profiles were chosen to modulate the level of motion intensity and were consistent with those outlined in the Australian Vibration standards (Standards, 2001) : Level 2: 0.315 $m/s^2$ - 0.63 $m/s^2$; Level 4: 0.8-1.6 $m/s^2$; Level 6: Greater than 2 $m/s^2$. The Australian vibration standard defines level 2 to be mild and almost unnoticeable by the participant with level 6 as 'uncomfortable'. Motion profiles at level 6 intensity are where the greatest effect of motion is predicted.

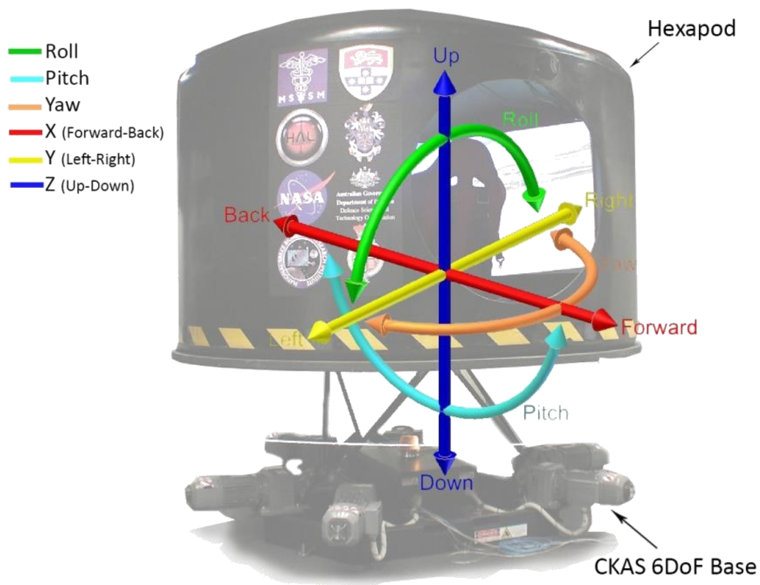


Figure 43 Motion Simulator with all 6 axis of motion highlighted

For the low and medium levels of motion intensity delivered, the midpoints from the standard ranges were chosen, that is, for the low and medium intensities, accelerations of 0.4725 $m/s^2$ and, 1.2 $m/s^2$ were used respectively. For the High intensity condition an acceleration of 2.5$m/s^2$ was used. These profiles are generated using a LabView (National Instruments, Austin, Texas; USA) program custom-created by Dr Hamish MacDougall for this task. The profiles were validated using an industry standard XSENS MTx inertial measurement unit (XSENS, Culver City, California; USA; Vydhyanathan et al. 2014) to ensure that the motion was consistent with these values.

#### 6.2.2.2. Biomeasure Units

The Zephyr Bioharness 3® as described in Chapter 3.2.1: Bioharness is used to collect Heart Rate (HR), Respiratory Rate (RR) and raw Heart Rate Variability (HRV) measures. Participants wear this strapped across their chest for the duration of the study. In addition, participants wear calibrated video goggles as described in Chapter 3.2.2: Video Goggles to monitor their blink velocity during the motion profile testing.

### 6.2.3. Design

#### 6.2.3.1. Overview

This study involved 18 repetitions of the BMSe task set (see Chapter 3.1.2: Emulated Battle Management System simulator (BMSe) ) with each repeat corresponding to one of the 18 motion profiles. At the start of the study, each participant was fitted with a Zephyr Bioharness 3 and video goggles. Once fitted, the participant was seated upright in the motion simulator and secured to the seat by the four-point safety harness. Prior to any motion, each participant completed an introduction of each of the 6 BMSe tasks in order to familiarise themselves with the control inputs and understand what was required for this study. The operator remained with the participant throughout this introduction to provide guidance through the tasks as required. On satisfactory completion of the BMSe requirements, the operator exited the simulator maintaining verbal contact via intercom.

Participants were instructed to complete the tasks as presented whilst the cabin moved. As the participant returned to the first task of each task set of the BMSe, i.e. the Pan-Zoom task, a new motion profile was initiated at random and continued in such a format until all 18 profiles had been completed. This randomisation was designed to minimise practice effects to a certain axis of motion. Task time to completion and total errors were used for analysis in this chapter.

#### 6.2.3.2. Tasks

Due to the focus on defence applications in this study, the tasks utilised as the performance measure are the 6 tasks of the BMSE as outlined in Table 1 (Chapter 3.1.2). Performance measures are based on the output of this task as described in this earlier chapter. The difference to the tasks is that, rather than the standard two iterations used for analysis to date, a single iteration was conducted for all six motion profiles at three intensities for a total of 18 task repeats. Each repeat maintained the same task order as used in all studies thus far, beginning with the Pan-Zoom task and ending in the Read Unit task.

#### 6.2.3.3. Subjective Scales

All participants completed the Simulator Sickness Questionnaire (SSQ) (See Chapter 3.4.1: Simulator Sickness Questionnaire) prior- to and post- motion exposure. Whilst there was an effort to minimize simulator sickness by the exclusion criteria of 'no history of motion sickness', it was impossible to completely screen for its effects as simulator sickness is different to motion sickness and a participant would not have knowledge of their susceptibility to this condition, unless they had had previous exposure to this environment. For this reason the Seven Point Nausea Scale (7-PNS) (see Chapter 3.4.2: Seven Point Nausea Scale) was utilised on which a participant used as a scale in the event of feeling ill. Reaching a level "6" on this scale meant immediate termination of the study. Participants could terminate at a lower level if they felt they no longer wished to continue due to nausea symptoms.

## 6.3. Results

Four participants, all male, terminated this study due to Simulator Sickness. Their results are excluded from analysis. Four other participants (Males =1; Females =3) mentioned slight simulator illness effects – such as headaches and eye strain, but had elected to complete all 18 of the Motion Profiles. The results of these participants are included in this analysis. For all eight participants, it was noted that the nausea sensation became apparent during or just after completing a task set in the Pitch profile. This profile was noted to be uncomfortable by other participants who did not mention any ill effects.

All task analyses, unless otherwise stated, were conducted using repeated measures ANOVA in order to look at the effect of axis as a function of intensity on task performance. For statistical tests where the assumption of sphericity was violated, the degrees of freedom are corrected using Greenhouse-Geisser estimates of sphericity.

This study focused on task performance, with focus on total time taken for each task, errors made and practice effects. Non-performance biomeasures were used as a monitoring device to monitor alertness and fatigue during the study. However, the results of these measures have not been analysed in this chapter.

### 6.3.1. Total Errors

Across all 6 tasks of the BMSe task set, participants in general made very few errors with the exception of the CT tasks, where participants typed out a message that appeared in the instruction box, and the CL tasks, were participants were instructed to create a path of four lines originating at a specified coordinate according to instructions. The errors for the CL task were calculated by grading an error at any deviation of 10 or more units away from the specific coordinate location. Should the deviation be further than 100 units (i.e. the wrong location), the subsequent errors were justified to account for this initial error in order to minimize the inflated error. Each of the four coordinate points in the CL task is assigned a pass (0) or fail (1) mark for a total possible error rating of 4.

Repeated measures ANOVA were carried out for each of the six tasks separately to look at the effect of motion as a function of intensity on errors made. The plots of these effects for each task PZ, CU, CL, CT, RT and RU are seen in Figure 44, Figure 45, Figure 46, Figure 47, Figure 48 and Figure 49 respectively. The only effect that was statistically significant was the interaction between intensity and motion direction in the CT task. For the analysis of this interaction effect the Mauchly's test indicated that the assumption of sphericity had been violated, $\chi^2_{(54)} = 75.10$, $p < 0.05$. Thus, the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.64$) and the interaction between intensity and motion direction was then $F_{(6.4,\ 180.4)} = 2.62$, $p < 0.05$. This indicated a distinct relationship between the intensity and number of errors depending on which axis of motion was experienced. The within-subject contrasts can be seen in Appendix P: Mean errors in Create Text task (MP), with Low and High intensity being significant in mean errors along the X, Y and Pitch compared to the Roll axis. There was also a significant change in mean errors in the Medium to High Intensity across the Y, Z, Pitch and Yaw axes compared to that along the Roll axis. Looking at Figure 47, it is interesting to note that it is not necessarily the High intensity that leads to more errors as would be expected, with both Roll and Yaw conditions having fewer errors in the High condition when compared to the Medium and Low intensities.

The errors in the CT task should be interpreted with caution however, due to the way errors were coded in this task. For example, if participants missed one letter when typing a word, each subsequent letter in that word (until the space) was considered an error, possibly inflating the error count.

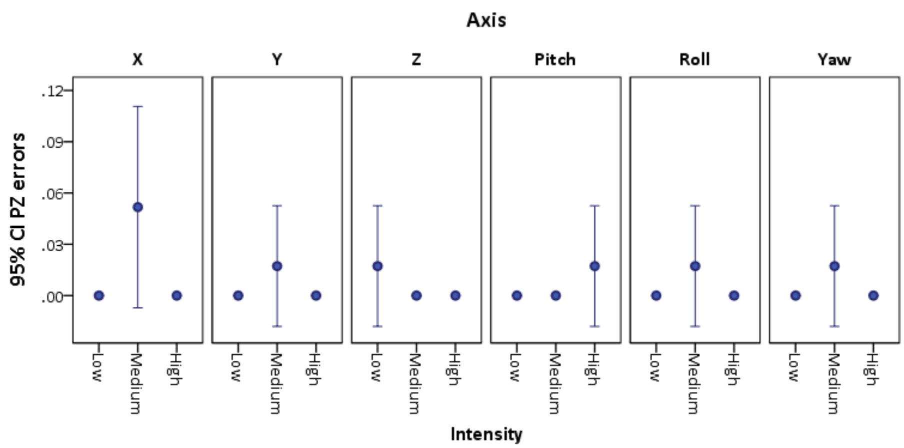


Figure 44 Mean errors in Pan-Zoom task[7]

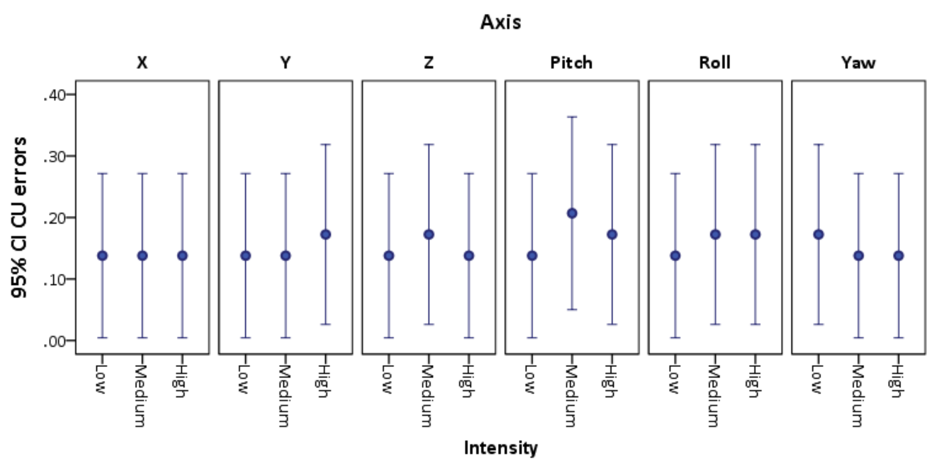


Figure 45 Mean errors in Create Unit task

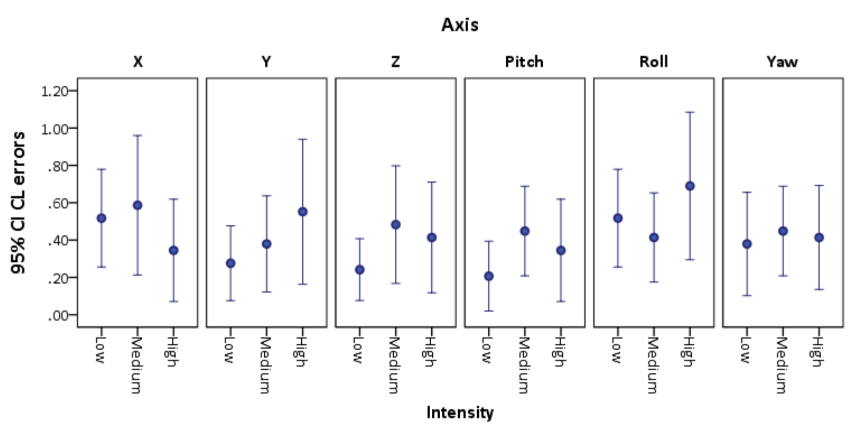


Figure 46 Mean errors in Create Line task

[7] Certain profiles had no errors across all subjects as indicated by lack of error bars.

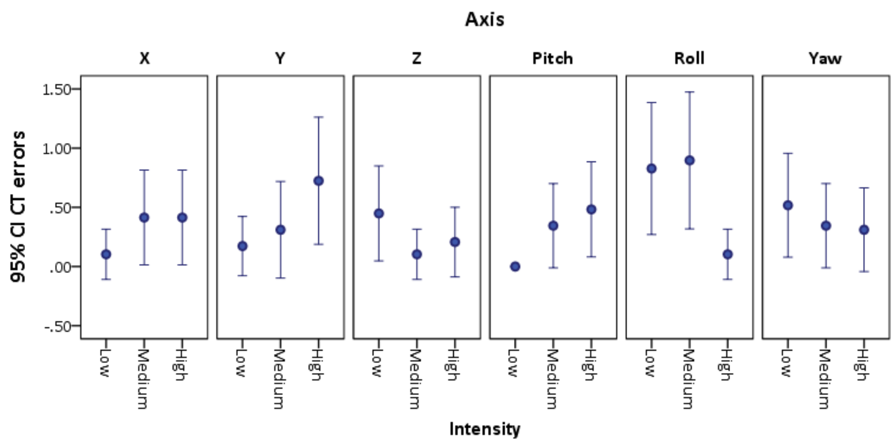


Figure 47 Mean errors in Create Text task

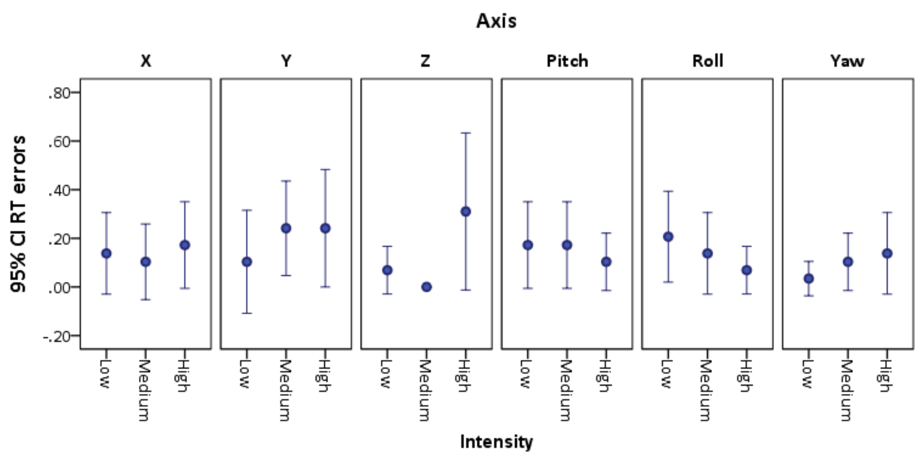


Figure 48 Mean errors in Read Text task

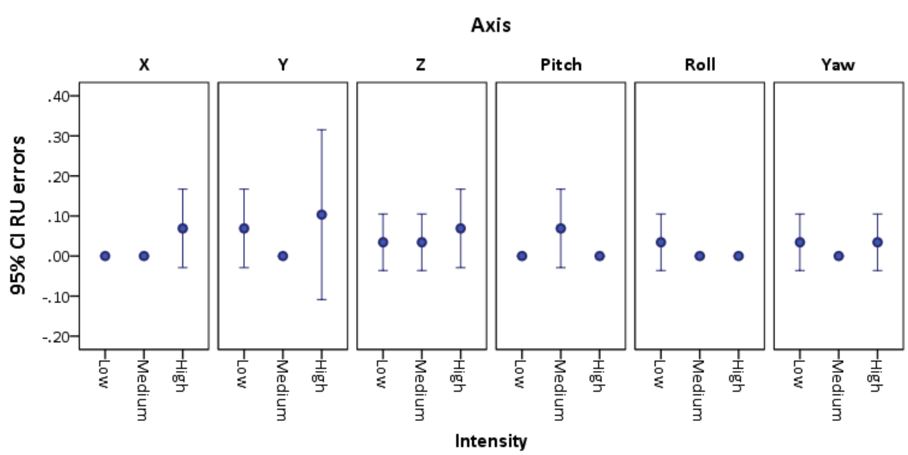


Figure 49 Mean errors in Read Unit task[8]

[8] Certain profiles had no errors across all subjects as indicated by lack of error bars.

A one-way ANOVA was conducted on all task errors for each axis of motion, combining all the intensities. Whilst no task showed significance in this measure (see Appendix Q: Combined Errors by Axis only (MP)), Figure 50 does show a marked increase in the Roll axis with the Pitch and Z axis having an apparently less effect on all tasks. Averaging errors across tasks does not lead to any significance by axis type ($F_{(5, 3120)} = 1.50$, $p = .19$), although the graph in Figure 51 does show a trend of an increase in errors in the Roll condition.

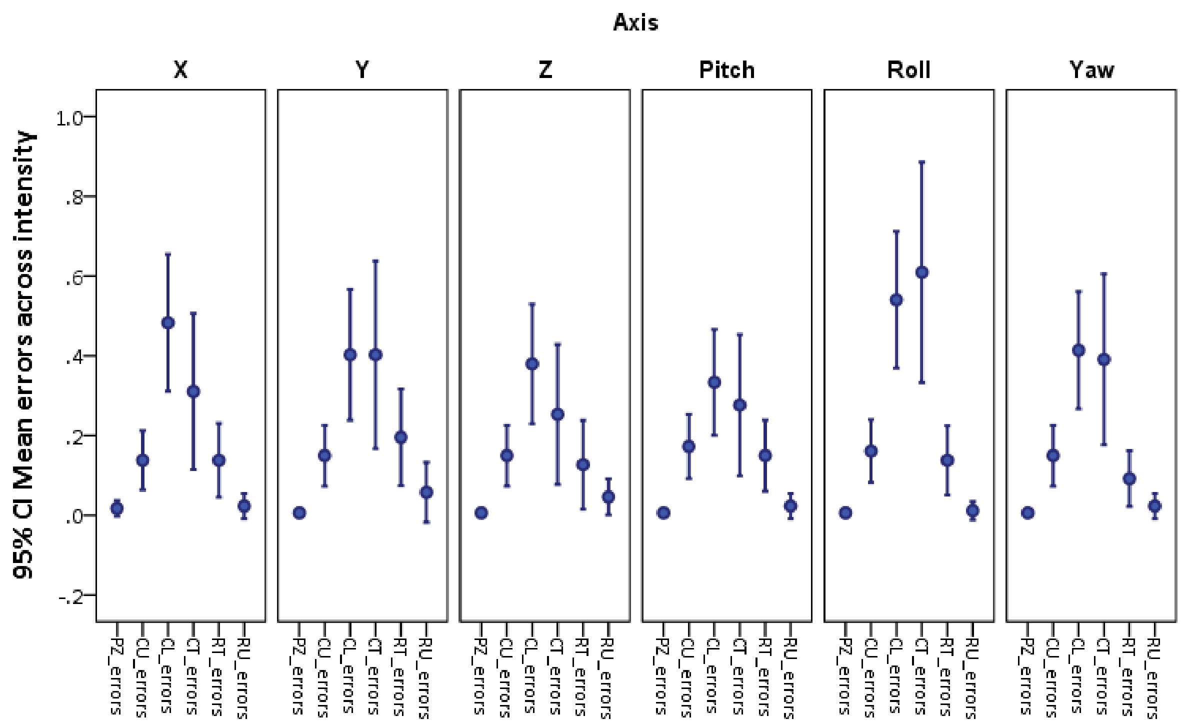


Figure 50 Errors per task by Axis only

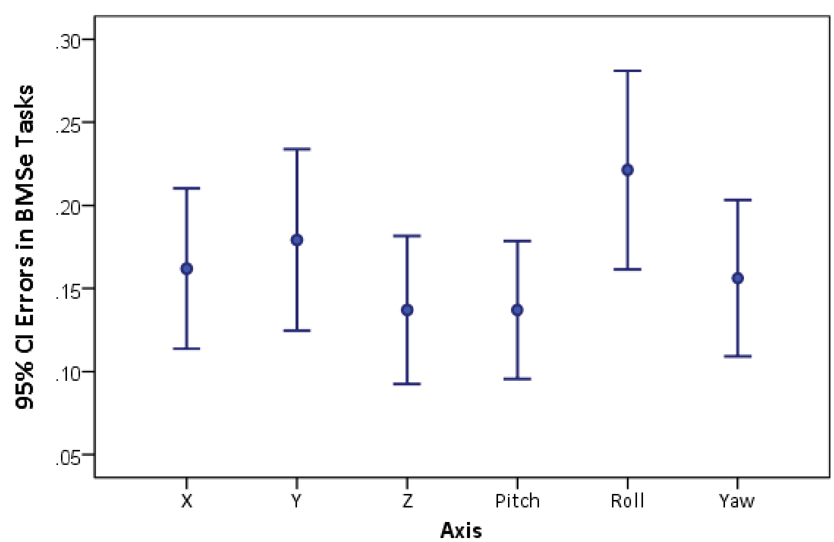


Figure 51 Mean errors across all tasks by Axis only

A one-way ANOVA was also carried out to compare Intensity (irrespective of Axis) on task performance (see Appendix R: Combined Errors and Time by Intensity only (MP)). The PZ task was shown to be the only task found to be statistically relevant ($F_{(2, 519)} = 3.19$, $p < 0.05$). Post-hoc analysis showed, though not statistically significant, that the Medium intensity has more errors than Low and High. Looking back, Figure 44 shows that only in the Z axis was there was an error in the Low intensity. Pitch only had errors in the High Intensity. All other motion profiles only contained errors at Medium intensity. All tasks are graphed by intensity in Figure 52a. Here the Medium and High intensities seem quite similar in task error outcome, being slightly higher than that in the Low condition.

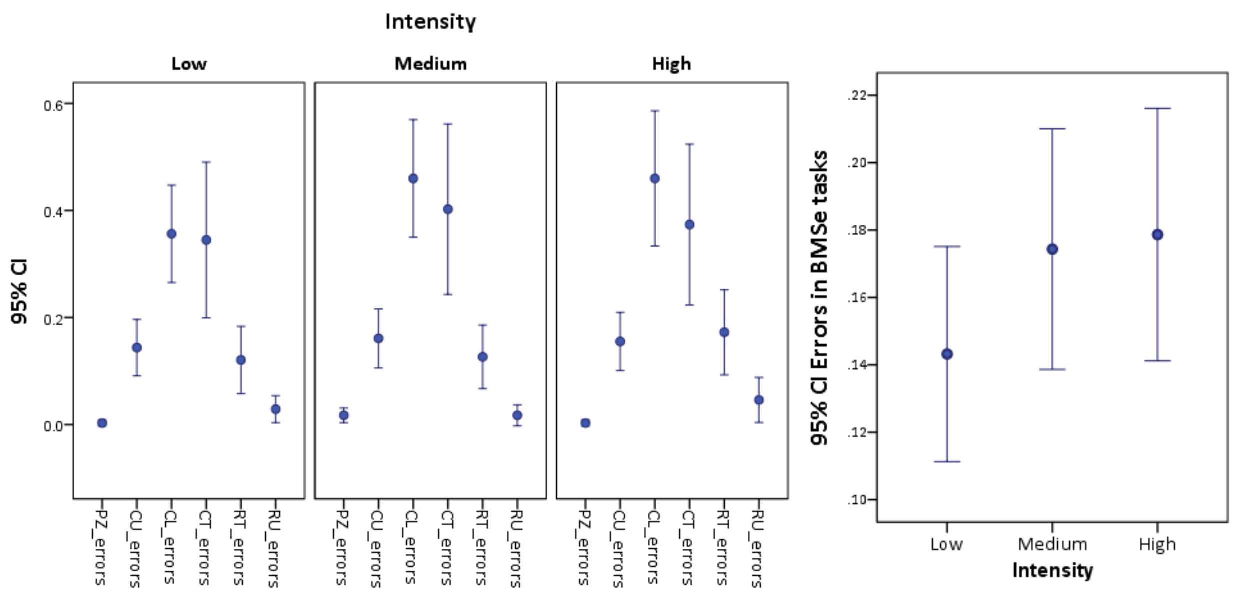


Figure 52 a) Errors per task (Left) and b)overall (Right) by Intensity only

In using the means across all tasks at the three intensities, there is no significance as to which axis is chosen and the errors found ($F_{(2, 3123)} = 1.15$, $p = .32$) as expected from the graph in Figure 52b.

## 6.3.2. Total Time

Repeated measures ANOVA were carried out for each of the six tasks separately, to look at the effect of motion as a function of intensity on the total time taken for a participant to complete each task. For the PZ task, the timing measure was the time taken to complete the task (TC) which is the difference between the Total Time for the task (TT) and the time it took to engage (Time to Initiate – TI) with the task. The reasoning behind this measure is that it was noted, with PZ being the first task in each repeat, that some participants had a delay in their response due to their uncertainty as to whether the new Profile had begun. This meant that the TI for this task had great variance as some participants continued without hesitation, whilst others needed affirmation. The TC measure is unaffected by this hesitation, or lack thereof, making it a better time-on-task measure. All other tasks in the BMSe (CU, CL, CT, RT and RU) have the TT used as the time measure.

The plots for the timing measures by motion and intensity are shown in Figure 53, Figure 54, Figure 55, Figure 56, Figure 57 and Figure 58, corresponding to the PZ, CU, CL, CT, RT and RU tasks respectively. For all tests, no significant measures were found across the motion, intensity or interaction between the two measures on time to complete. What can be noted from the figures over the next few pages are some shared trends across each task that, whilst not significant, are of interest.

For the PZ task (Figure 53), there is a trend of increase in TC between the Low and Medium intensities across the different axes of motion. There is an interesting small peak in the Medium Intensity condition across all participants in the X axis of motion that is shared by the CU (Figure 54) and RT (Figure 57) task. In comparison, the other three tasks, CL (Figure 55), CT (Figure 56) and RU (Figure 58) have a dip in TT at this same measure.

In the CU task there is very little change between the TT and intensities, except for the Z axis where there appears to be an increase in TT as Intensity increases with a peak at the High Intensity condition in this axis (Figure 54). This peak in High intensity in the Z axis can also be seen in the RT task (Figure 57) and the RU task (Figure 58).

The CL task shows a decrease in TT across all subjects in the Yaw direction with increased intensity and a corresponding increase in TT across all subjects in the Roll axis with intensity (Figure 55). This trend holds true for the CT (Figure 56), the RT (Figure 57) and the RU (Figure 58) task. The CL task also shows an increase, similar to the Roll in the Z axis with the CT task again sharing this trend.

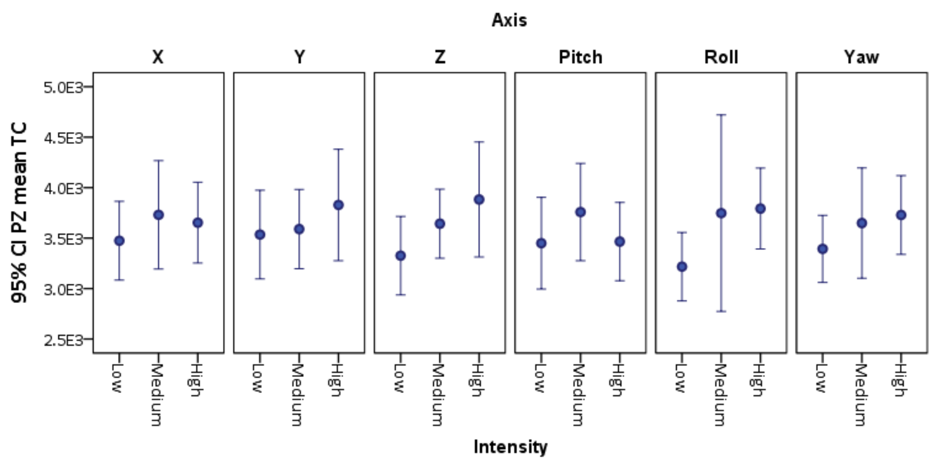


Figure 53 Mean Time-to-Complete the Pan-Zoom task

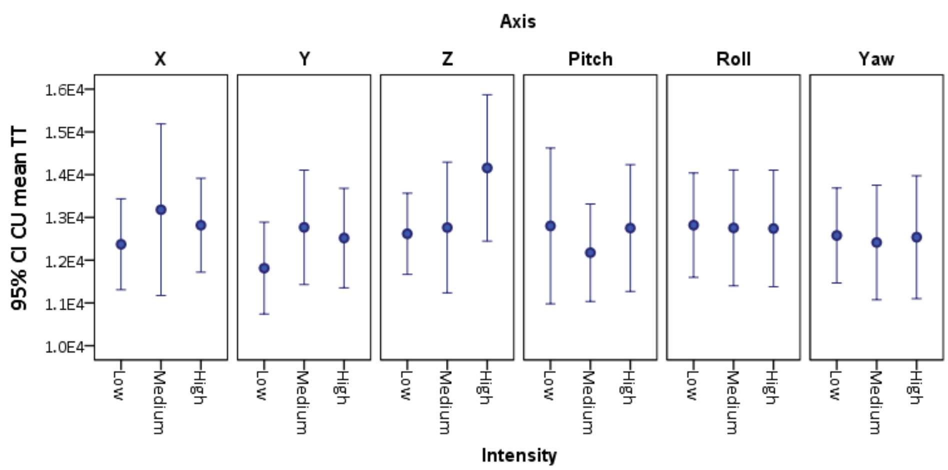


Figure 54 Mean Total Time taken for Create Unit task

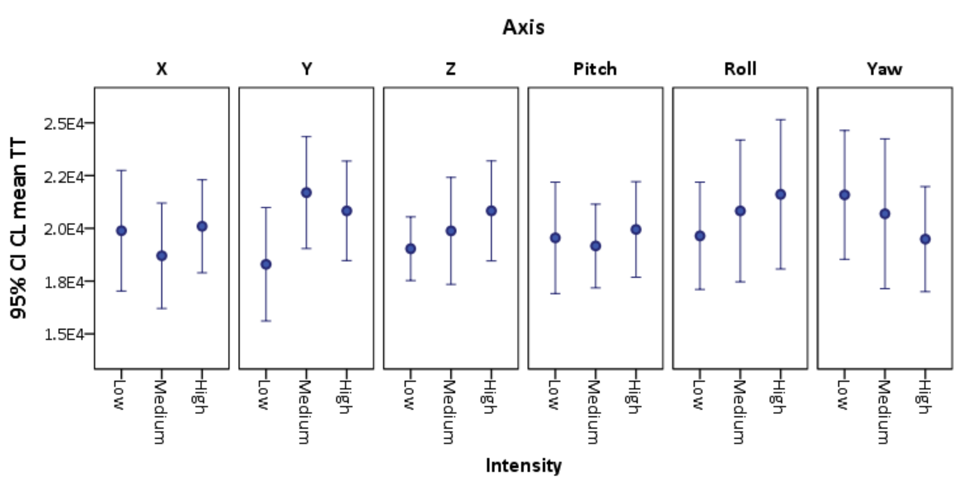


Figure 55 Mean Total Time taken for Create Line task

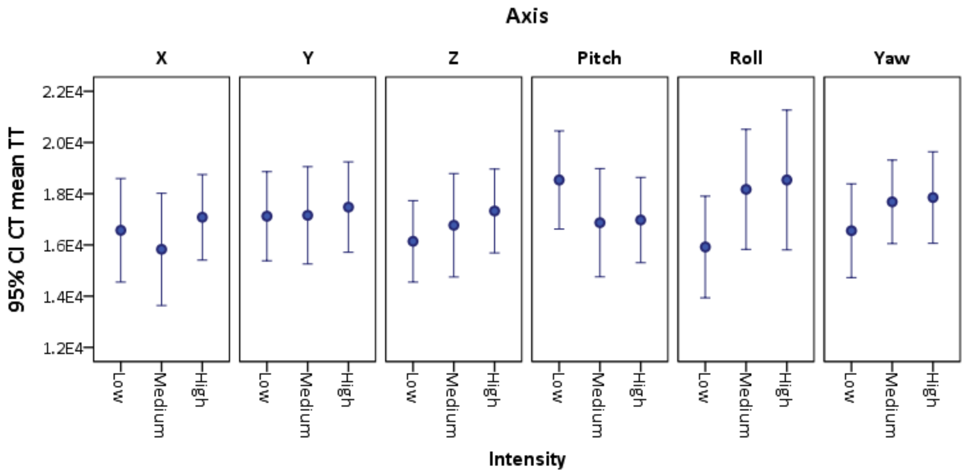


Figure 56 Mean Total Time taken for Create Text task

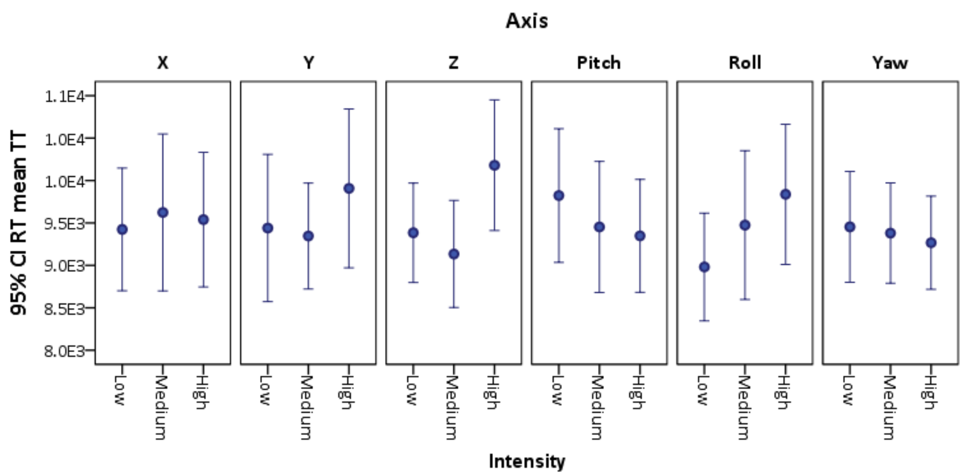


Figure 57 Mean Total Time taken for Read Text task

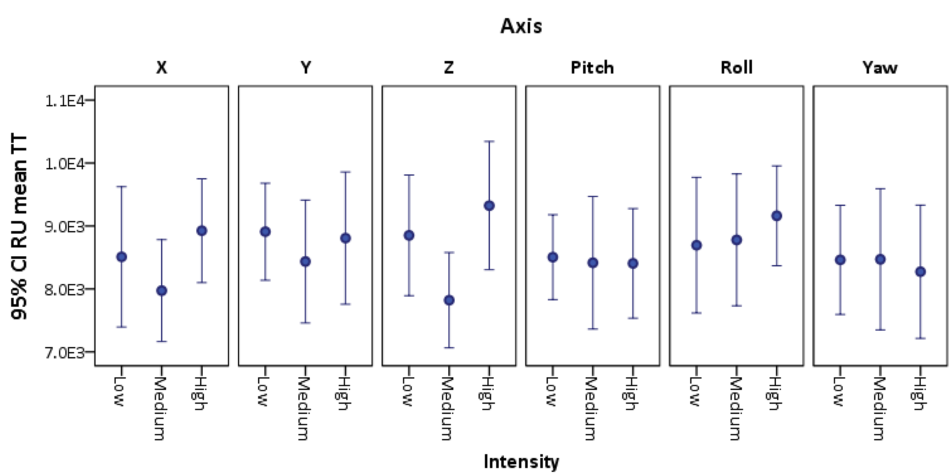


Figure 58 Mean Total Time taken for Read Unit task

A one-way ANOVA was conducted on all TC and TT measures by axis of motion, combining the Intensity (see Appendix S: Combined Errors and Time by Axis only (MP)). The mean time combining all tasks did not lead to any significance by axis type ($F_{(5, 3120)} = 0.18$, $p = .97$), which is again shown in Figure 59. Of interest is a slight increase in the time measure in the Roll condition that was also found in the analysis of combined errors.

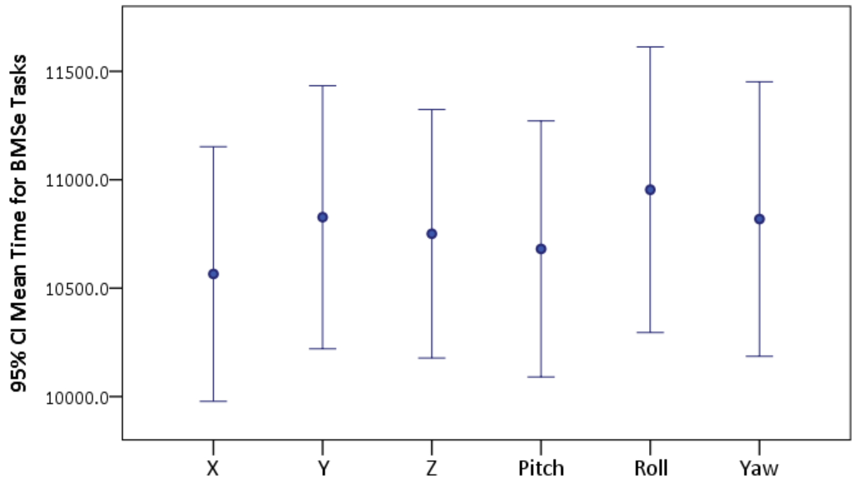


Figure 59 Mean Time measure across all tasks by Axis only

A one-way ANOVA was also carried out on PZ's TC and all other TT measures according to intensity (see Appendix R: Combined Errors and Time by Intensity only (MP)). The mean time combining all tasks did not lead to any significance by axis type ($F_{(2, 3123)} = 1.17$, $p = .31$). Whilst not significant, there is a trend of an increased total time measure with increased Intensity regardless of the Motion Profile as shown in Figure 60.

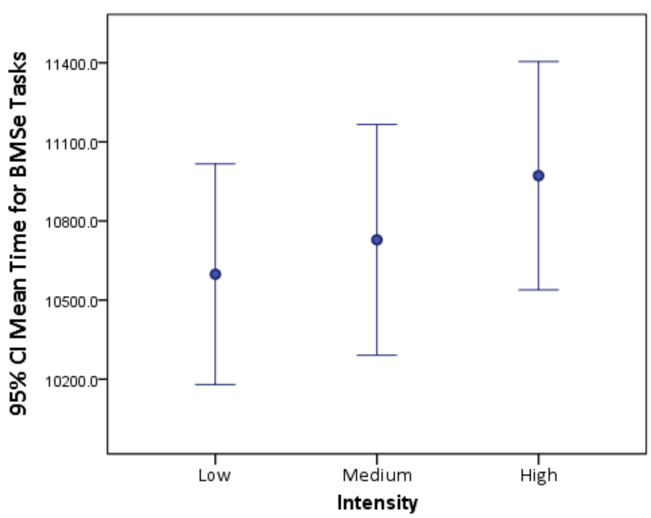


Figure 60 Mean Time measure across all tasks by Axis only

### 6.3.3. Practice Effects

The results presented until now have not taken into account the task order presented to the participant. In investigating these practice effects, there is no significant effect for the PZ ($F_{(17, 504)} = 1.14$, $p = .31$), CU ($F_{(17, 504)} = 0.16$, $p = 1.00$), CT ($F_{(17, 504)} = 1.50$, $p = .09$), RT ($F_{(17, 504)} = 1.00$, $p = .46$), or RU ($F_{(17, 504)} = 1.49$, $p = .09$) tasks as can be seen in Figure 61, Figure 62, Figure 63, Figure 64 and Figure 65 respectively.

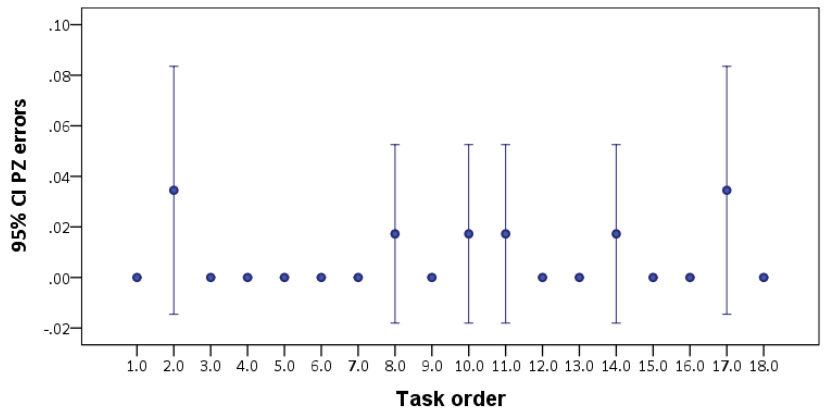


Figure 61 Mean errors in PZ task by task order

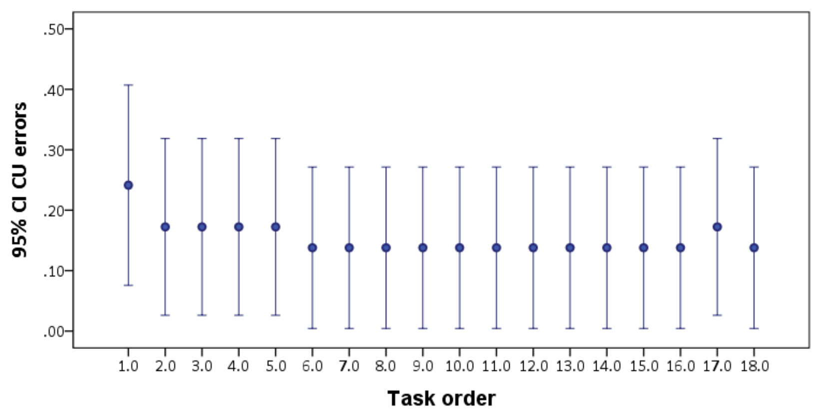


Figure 62 Mean errors in CU task by task order

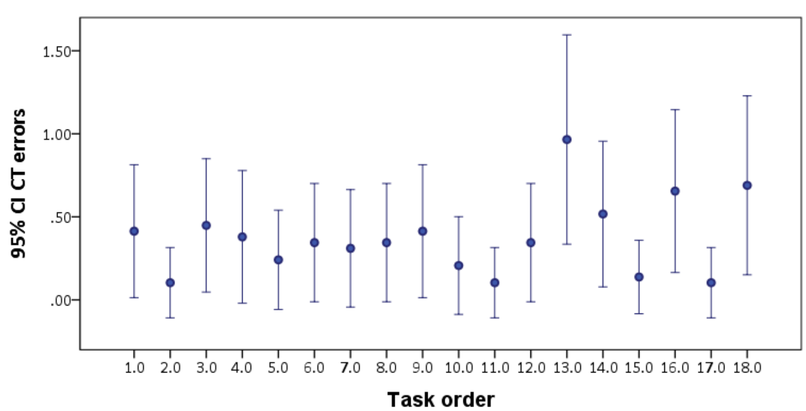


Figure 63 Mean errors in CT task by task order

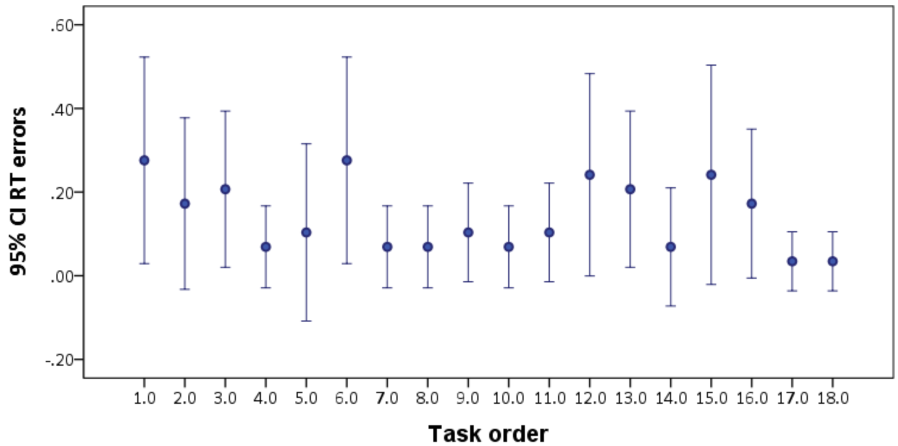


Figure 64 Mean errors in RT task by task order

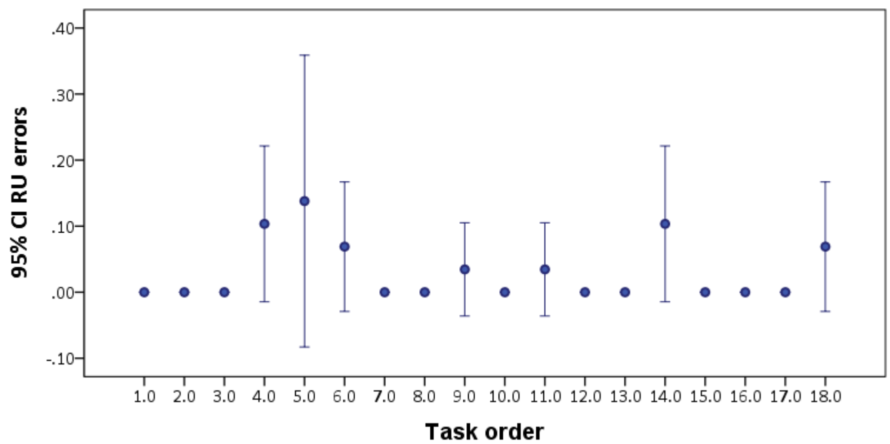


Figure 65 Mean errors in RU task by task order

Only the CL task shows a significant change in mean of errors with the presentation of tasks ($F_{(17, 504)}$ = 2.10, $p < 0.01$). For this CL task, it was only the mean error at Task 17 (*M*=1.01, SD=0.46) that differed significantly when compared to the means at Tasks 3 (*M*=0.38, SD=0.86 ), 4 (*M*=0.31, SD=0.66), 5 (*M*=0.31, SD=0.81), 7 (*M*=0.45, SD=0.83), 8 (*M*=0.31, SD=0.71), 9 (*M*=0.28, SD=0.65), 10 (*M*=0.24, SD=0.79), 15 (*M*=0.35, SD=0.61) and 18 (*M*=0.24, SD=0.58). As seen in Figure 66 the error in this task is higher than any other task and suggests that the combination of the coordinates at this point may have been more difficult than any of other iteration of the task rather than the result being a reflection of any practice effects. All relevant statistics can be found in Appendix T: Practice Effects on Errors and Time (MP)

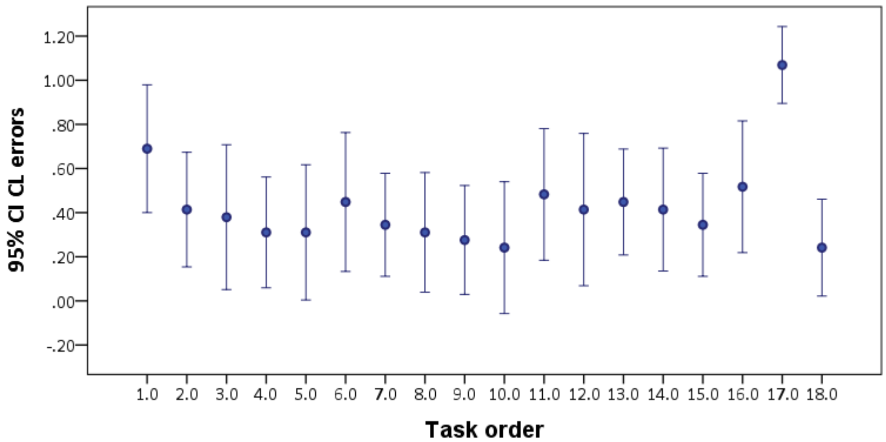


Figure 66 Mean errors in CL task by task order

Mean time on task and task order was found to be significant across all tasks: PZ ($F_{(17, 504)} = 3.89$, $p < 0.01$), CU ($F_{(17, 504)} = 6.12$, $p < 0.01$), CL ($F_{(17, 504)} = 3.59$, $p < 0.01$), CT ($F_{(17, 504)} = 3.31$, $p < 0.01$), RT ($F_{(17, 504)} = 4.66$, $p < 0.01$) and RU ($F_{(17, 504)} = 17.44$, $p < 0.01$) as seen in Figure 67, Figure 68, Figure 69, Figure 70, Figure 71, and Figure 72 respectively. The significant pairings are marked in each figure with relevant statistics in Appendix T: Practice Effects on Errors and Time (MP). For all but the CT task there was a general trend in improvement in timing as they repeated the task. Dunnet t-tests reveal that the last three iterations of the tasks (Task 16, 17 and 18) were significantly lower in total time measures when compared to the first task iteration with the reading tasks, RT and RU having improved times from Task 3 through to Task 18 when compared to Task 1.

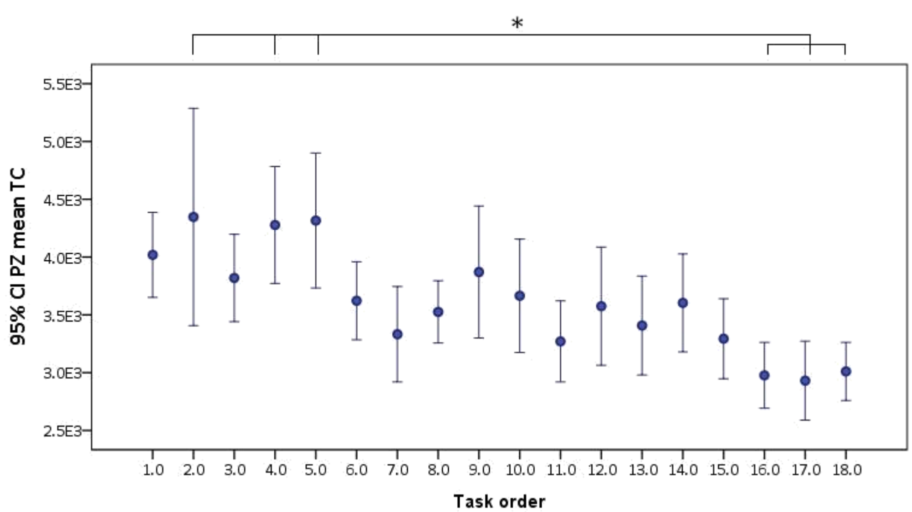


Figure 67 Mean Time to Complete PZ task by Task order

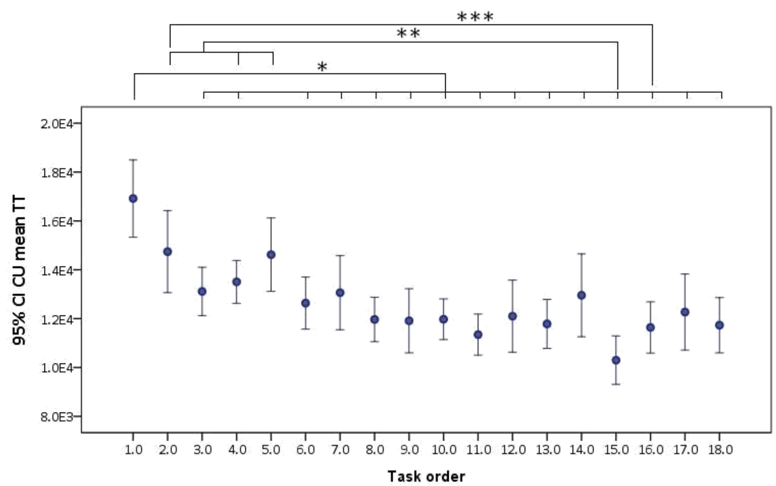


Figure 68 Mean Total Time taken for CU task by Task order

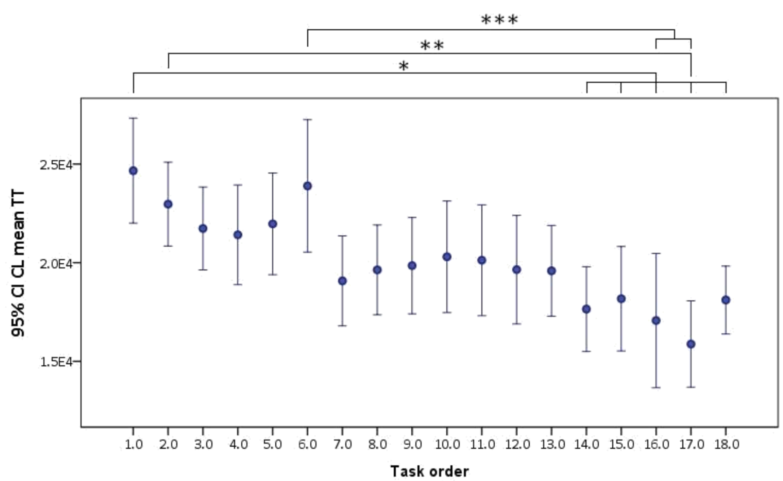


Figure 69 Mean Total Time taken for CL task by Task order

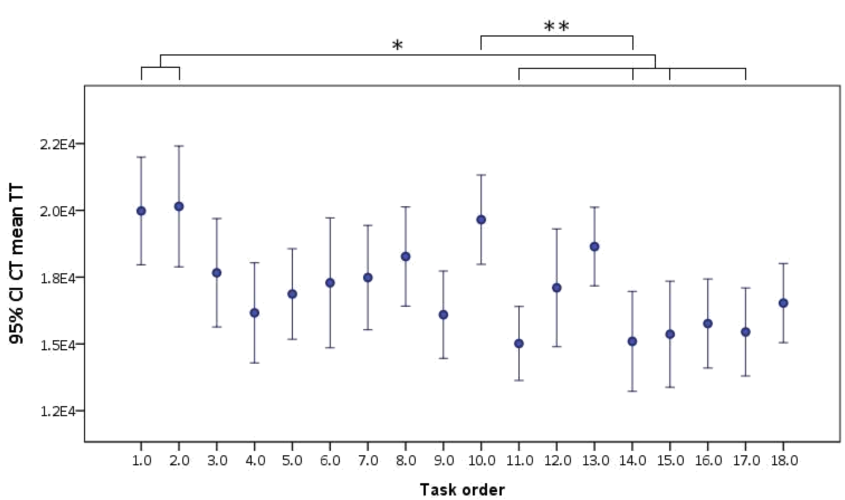


Figure 70 Mean Total Time taken for CT task by Task order

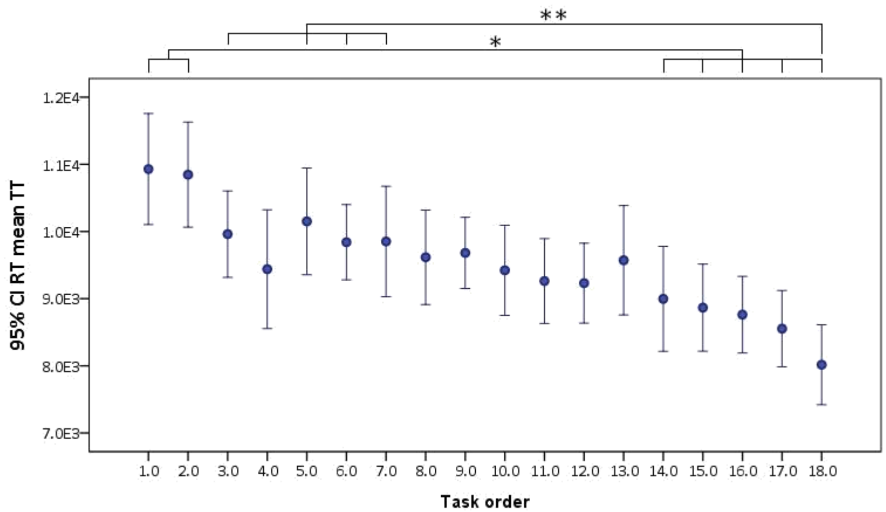


Figure 71 Mean Total Time taken for RT task by Task order

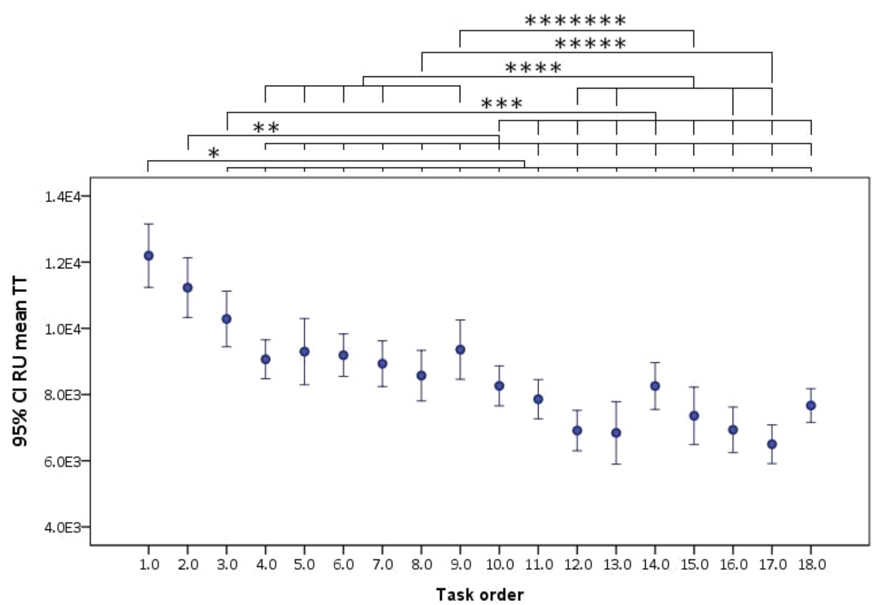


Figure 72 Mean Total Time taken for RU task by Task order

## 6.4. Discussion

In this study, the Pitch condition was found to be the most uncomfortable for all participants who had simulator sickness symptoms. Though not significant, motion along the Roll axis had the highest mean of task errors and a higher mean in total time on task than any other motion condition. There is an increase in errors at Medium and High intensity when compared to Low Intensity and an overall trend of a steady increase in errors as intensity increases. There was a trend across most tasks of an improved completion time, with each repetition of the set task measured in terms of total time taken to complete the task, even though there were no significant practice effects in terms of errors (see below for more on CL task).

Eight participants felt some form of simulator sickness effects during this study. Of the eight, four terminated either during or shortly after an experience of motion in the Pitch condition. Of the eight who did not terminate, they verbally remarked on the odd sensation they experienced with this motion profile. Though this motion may be the least comfortable, there was no evidence of a negative effect of this profile on task performance measures. Even though the comfort is irrelevant from the aim of Motion Perception, this observation is worth further investigative research in order to test if there is a link between simulator sickness and the motion along the Pitch axis.

Interestingly, for the Create Text task along the Roll axis, errors are actually lower at the High intensity than the Medium and Low intensity tests despite the fact that the Roll condition in general had more errors. This sets apart this condition from the X, Y and Pitch motions across intensities with significant differences in errors in the Medium to High condition compared to the Yaw motion.

The trends in timing noted are very slight. It is interesting that the Roll condition fared worse as an overall trend, once more suggesting that this motion may be linked to worse performance. Unlike in the preceding case of the errors, there is a more distinct trend of worse time with increasing Intensity of motion.

Within the time measures, the Medium intensity at the X axis had a peak in time in three of the tasks: PZ, CU and CT. Interestingly though, the other three tasks: CL, CT and RU had a corresponding decrease in total time at this measure compared to the other intensities. Taken as a complete set task, this trend cancels itself out.

At High intensity motion in the Z axis there is an increase in total time of all tasks compared to the Low and Medium intensity with a peak at CU, RT and RU. Whilst not significant, this trend highlights the need for further investigation in the case of this axis and this motion profile along with the Roll axis.

Practice effects had a statistically significant effect on TI and TT across all tasks. In general there was a trend of less time taken as the task was repeated. The randomisation of the motion effects would have spread out this effect, but it may have meant that some of the timing effects were less affected at certain motion profiles than they otherwise may have been. In future studies, it would be advisable to have a repeated exposure to tasks and a return to perform the same tasks under different motion profiles in order to balance this effect even further.

Mean errors and practice effects only showed significance in the CL task. Within this task it was iteration 17 that differed from all others. As the task questions at each iteration point were the same (i.e. the coordinates asked at 17 are the same for all participants) it is possible that this error was from the particular location and line task rather than a reflection of performance at this repetition point. In future studies, randomization of the task order would assist in accounting for these factors.

Overall, very few errors were made across all tasks. As seen in Figure 61- Figure 66, many cases especially in the PZ and RU tasks had no errors at all for a given motion profile. With the complete absence of errors, it is difficult to determine if the tasks are difficult enough so as to be affected by a given profile.

## 6.5. Conclusion

In investigating task performance and Motion perception, higher errors are seen in the Roll motion with a trend in both errors and timing set to increase as the intensity increased from Low to High. Whilst not significant, High intensity on the Z axis is seen to have a detrimental effect on total time on task. All other motion profiles have little-to-no effect.

Throughout this study, the Pitch motion was seen as least comfortable by all simulator sickness prone participants. This condition did not show any adverse effects on performance. Given the nature of the defence tasks and the sequential task order, this is a similar finding to that reported in Chapter 4: Motion Sickness. In terms of participant wellbeing over performance, this axis should be considered pending further investigation.

# 7. Mental workload under motion conditions

## 7.1. Introduction

Developing a measure to quantify how much mental work a person is experiencing and alerting the point of mental fatigue is an area of great interest in modern research. From 1921 when it was written that it was not possible to measure mental workload/fatigue (Muscio, 1921), to 1979 when the response to the question “Is measurement not possible?’ was ‘not yet’ (Broadbent, 1979), the race has been on to develop a device which can produce a concise measure of mental workload. The most accepted measures used to date consist of a range of subjective scales (Rubio et al., 2004, Reid and Nygren, 1988, Tsang and Velaquez, 1996) and measure of performance decrement in a primary task (Dember and Warm, 1979, Davies and Parasuraman, 1982, Russell C. Grant et al., 2013). These measures can be used as a baseline to evaluate the effectiveness of the measurement tools developed to indicate mental workload.

This study sees the importance of gathering raw empirical data that can analyse whether it is possible to measure mental workload. This responds to questionable promises by different companies to produce devices guaranteeing they can measure mental workload even though, as a concept, mental workload has yet to be properly defined. In most experiments to date, the only non-subjective measure of mental workload is the measure of reduction in task performance. For this reason performance reduction is used as a marker to regulate if the results from a ‘mental workload’ measurement device are real.

In using performance decrement as a baseline, the choice of primary task performed is important. Sufficient cognitive resources need to be utilised to complete the task such that a change in workload can be seen. Complex cognitive processes that satisfy this criterion are defined by the umbrella term ‘executive function’. This term covers mental processes such as; problem solving, action sequences, coordination and flexible reasoning (Elliot, 2003). A few executive function domain examples include task-switching (Monsell, 2003), working memory (Elliot, 2003)and inhibitory control (MacLeod, 2007). Each domain has a collection of scientifically accepted cognitive tests of different levels of difficulty that can be further explored.

As the task choice is important for measuring performance decrement due to mental workload, so too is the selection of a subjective scale. A number of subjective scales have been developed and used in literature to examine mental workload. Five popular assessments include The NASA Task Load indeX (NASA TLX) (Hart and Straveland, 1988), the Subjective Workload Assessment Technique (SWAT) (Reid and Nygren, 1988), the Bedford scale (Roscoe, 1987), the Instantaneous self-assessment of workload (ISA) (Tattersall and Foord, 1996), and the VACP: Visual, Audio, Cognitive and Psychomotor assessment (Keller, 2002).

The NASA TLX is a scale used to define workload estimates for different operations. Usually it is used for interface design or evaluation (Hart, 2006). This scale measures across six measures: mental demand, physical demand, temporal demand, performance, effort, and frustration level, with the final score being used as a predictor of an individual's performance in a task (Rubio et al., 2004).

The SWAT questionnaire uses three measures: Time Load, Mental Effort Load and Psychological Stress Load. The participant has a three point scale to rate their experience on each of these measures. This creates 27 possible outcomes where the user then applies a numeric score ranging from 1-100 (Rubio et al., 2004).

The Bedford Workload scale is a uni-dimensional scale ideal for on-task ratings where answering longer scales is not feasible (Adams, 1998, Tsang and Velaquez, 1996). It is an ordinal scale with a 3 step flow-diagram response with a final score given by a 10 point ranking to express spare mental capacity (Lysaght et al., 1989). Similarly the ISA is designed to give an immediate score of work demand during primary work tasks (Tattersall and Foord, 1996). Both the Bedford and the ISA are designed to provide a quick output without multidimensional response.

The VACP covers four task demand channels: Visual, Audio, Cognitive and Psychomotor. It is an analysis which had been based on findings in a 1984 study on workload for light helicopter experimental scout and attack missions (MacCracken and Aldrich, 1984). The participant indicates on a scale out of 10 how they found the task across all four channels.

Of all subjective workload measures mentioned, the most commonly assessed measures are the NASA TLX and the SWAT. In comparisons with the SWAT and NASA TLX measures, the NASA TLX was found to have a higher sensitivity to mental workload and a higher correlation with performance (Rubio et al., 2004). As performance is useful when combined with a scale in determining workload, the TLX is a better choice.

From a time and task-critical perspective, it is not good enough to use performance and subjective score measures alone as a reference of mental workload. The results of such measures are post-analysis and cannot be displayed in real-time. A number of biological measures for mental workload have been proposed since the 1980s which could act as real-time indicators of the ideal level of mental workload when it drops passed a level desired to handle the work tasked to an individual. These include Respiration, Heart rate, Heart Rate Variability (HRV), Task Evoked Pupillary Response (TEPR), Blink velocity and Electroencephalography (EEG). All measures have been extensively researched and have their own advantages.

Respiration can easily be measured in real life conditions without causing discomfort or distraction from primary task completion. It has been shown to increase with mental workload (Wilson, 1992, Mulder, 1992, Wientjes, 1992, Wilson, 1993). Likewise Heart rate is also easy to test and should rise with mental workload with HRV decreasing (Mulder, 1992). Caution needs to be taken with the interpretation of HRV readings because in low frequency ranges, HRV is affected by respiration patterns – similar to what is present in speech (Mulder, 1992).

TEPR refers to the phenomenon of pupil dilation under increased cognitive load (Beatty, 1982, Klingner et al., 2008, Kahneman, 1973). It's a small involuntary change in pupil diameter, usually less than 0.5mm is diameter (Klingner et al., 2008). Attention is needed with this measure as pupil dilation is also sensitive to changes in lighting conditions, but these can be facilitated in laboratory conditions (Pomplun and Sunkara, 2003).

Blink rate has been selected as a measure in this study to provide a direct correlation to the measures utilized by the current fatigue monitoring glasses available in the market today. The theory behind blink rate and mental workload is that increased mental workload should correspond to an increase measured blink rate, although visual demand (Recarte et al., 2008) and repetition of predictable stimuli will reduce this rate (Bauer et al., 1987). By taking the velocity of an eye closure to eye open rate, measures are taken describing the count but also the reaction. A slower 'eye open' rate would imply a fatiguing condition in response to the workload, whilst a fast rate (low ratio of eye close to eye open rate) should in theory, respond to an active mental state. As the current fatigue glasses on the market only respond to a 'scale' of fatigue or mental state, accessing the raw data and analysing it separately is ideal in terms of conducting a comparison between changing mental workload measures.

For electroencephalography systems, Beta waves (12-30Hz) are related to wakefulness and attention whilst Theta waves relate to drowsiness (4-8 Hz). Measuring this change in waveform could relate to the levels of mental workload. Beta waves can be measured on the side of the head and frontally. The measurement area for Theta waves has not yet been specified in current literature. Beta waves could theoretically be measured by many of the current EEG systems on the market that use frontal electrodes such as the Xwave (PLX Devices, Sunnyvale, California, USA), The Neurosky or Mindwave/MindSet (NeuroSky, San Jose, California, USA), the Muse (InteraXon, Toronto, Ontario, Canada) or the SmartCap (SmartCap, Queensland, Australia). The most ideal system would be a 16 or more electrode system that allows for clearer measure of Theta waves, but such devices are not practical for in-field tests at this stage.

Of the practical measures with in-field capabilities, the bio data that are explored in this study for relevance as a mental workload monitor are Respiratory rate, Heart rate, Heart Rate Variability, Blink Rate and Pupil Dilation. Respiration, heart rate and heart rate variability can be affected by external factors such as metabolic demands over task demand (Wilson, 1993). The hypothesis therefore, is that either blink rate or pupil dilation will be the better measure in controlled lighting laboratory conditions.

## 7.2. Method

### 7.2.1. Participants

Twenty eight first year psychology students that reported no history of motion sickness were recruited from the University of Sydney (Males = 12, Females =16). Participants were unable to wear corrective glasses due to the video goggles used to evaluate eye movement responses, so only subjects with good visual acuity (unaided) or who wore contact lenses were able to participate. All procedures were in accordance with the Declaration of Helsinki and were approved by the University of Sydney Human Ethics Committee. Participants gave informed written consent and were free to terminate testing at any time and were given course credit according to standard departmental procedures. Twelve participants (Males=5, Females=7) were excluded from analysis as they reported a level of motion sickness that made it too uncomfortable for them to continue.

### 7.2.2. Apparatus

Motion was delivered using the 6-Degree- of-Freedom (6-DoF) base and fitted as described in Chapter 3.1.1: Motion Simulator. Intercom communication was maintained with the participants throughout the experiment using headsets.

Participants were exposed to a range of passive and active motion stimuli during a simulated driving task over three rFactor (Image Space Inc., Michigan, USA) courses.

A Zephyr Bioharness 3® chest harness (see Chapter 3.2.1: Bioharness) was used to measure respiration heart rate, and heart rate variability. To permit measurements of blink rate, blink velocity and pupil dilation, participants were also required to wear a pair of video goggles as described in Chapter 3.2.2: Video Goggles.

### 7.2.3. Design

Participants completed three tasks to determine changes in mental workload. These tasks were repeated after a drive under increasingly difficult conditions in an effort to use up cognitive resources. Task performance was then investigated to note if it could be related to changes in biological response during that task. After completing each task, participants are presented with the NASA Task Load Index (TLX) form (see Appendix U: NASA Task Load Index ) that they must fill out before continuing the study.

At the beginning of each study the participant was fitted with a Zephyr Bioharness 3® and the video goggles. Participants were seated upright within the simulator enclosure, secured to the seat with a four-point safety harness, and instructed on how to operate the circuit breaker if at any point during the study they wanted to stop the motion. Prior to any motion, the participants were guided through the three task measures to form a baseline of performance. Participants completed tasks using a trackball, standard keyboard and 19 inch LCD screen. Participants were instructed that once they had completed the given task, they were to fill out the NASA TLX form which appeared digitally on the display. Communication with the operator via headset was maintained at all times.

Three courses from rFactor were selected for this study. The first course, Joesville Speedway, is a simple 0.41 mile loop track that allows the participant to adjust to the simulator. This is a low skill track chosen to use up very little mental resources. Most participants are able to clear a lap in less than 30 seconds. After three minutes of driving the assigned course, they are asked to stop and randomly assigned one of the three cognitive tasks. After the task they completed the NASA TLX again. On completion, they continue driving for another three minutes and the process was repeated until all tasks were completed.


Figure 73 Joesville Speedway course, rFactor

The second course, Lienz Festival der Geschwindigkeit Week 3, was a more complicated 3.89 miles mountain range course. This track has more turns and sloping roads so requires more thought and process power. On average, participants took 7 minutes to complete a lap of this course. For this second course, the participant drove for 5 minutes before being stopped for a task and the NASA TLX. The process was again repeated until all three tasks were performed.


Figure 74 Lienz Festival der Geschwindigkeit Week 3 course, Rfactor

The last course, Monaco Grand Prix, was a Formulae One styled course and requires the highest mental demand. This course had tight corners and very few straight-away drives.  Unlike the other courses, this track presented a race format and the participants were instructed to race against the other cars on the track in order to increase the mental demand needed to complete the course. Keeping in time with these cars is a near-impossible condition for the average participant. Due to the difficulty of this track, participants could take any time from 3 minutes to 8 minutes to complete a lap. The participant drove for 5 minutes before being stopped in order to complete the task and NASA TLX form. The race was reset and the process repeated.


Figure 75 Monaco Grand Prix course, rFactor

### 7.2.4. Task Measures

In this set of experiments, the emulated Battle Management system is dismissed in favour of a set of cognitive tests. This was done for two main reasons. The most important reason for this choice is that in previous experiments in which the BMSe was used, it was apparent that the participants found the tasks too simple. As such, they were never ‘overworked’ by these tasks as they did not use much mental processing power. For a study that’s focused on mental workload measures, tasks that are mentally demanding are necessary.

To preserve the military context of this study, it was paramount not to lose the essential areas of measure that the BMSe took in order to better correlate the results. The BMSe analyses executive function in spatial understanding (identification on map), inhibitory control (referring to new data appearances), working memory (ability to read, report and analyse) and task switching (moving from driving control to task control). This BMSe analyses can be mapped according to corresponding cognitive tests that can be done whilst driving. The drive and tasks given can be adjusted to different levels of difficulty to get a range of underworked and overworked measures.

Three specific tasks where chosen that can also be translates on a computer from the Executive Function Domain. The measures used were a **Spatial Stroop** task (Stroop, 1935, Wühr, 2007), mapping to inhibitory control and spatial understanding, a **Running letters** task to analyse working memory and **Number Switch** task which addresses the task switch fluid intelligence measures. More detail about these tasks can be found in Chapter 2.2.2: Cognitive Tasks.

In the Spatial Stroop test, the participant is presented with an arrow on the screen that appears either on the Left hand side, the right hand side, or in the centre. They have to respond as fast as possible (using keyboard response) to judge whether the arrow is pointing to the left or to the right direction.


Figure 76 Spatial Stroop test incongruent scenario sample with arrow pointing towards the Right from the Left-Hand side of the screen

The Running Letters test is a short-term memorisation test. Here the participant was asked to remember a set of letters that appeared at the end of a string of an unknown pre-set amount of letters. For example, a text instruction was given to remember the last three letters that appeared. Six letters flashed across the screen and the participants were asked to note which of the last three letters were by selecting them in order from a grid showing 12 letter options (see Figure 77). Each round had an increasing amount of letters to remember and it ended in a memory recall of 7 letters that appeared at the end of a string of 8 random letters.

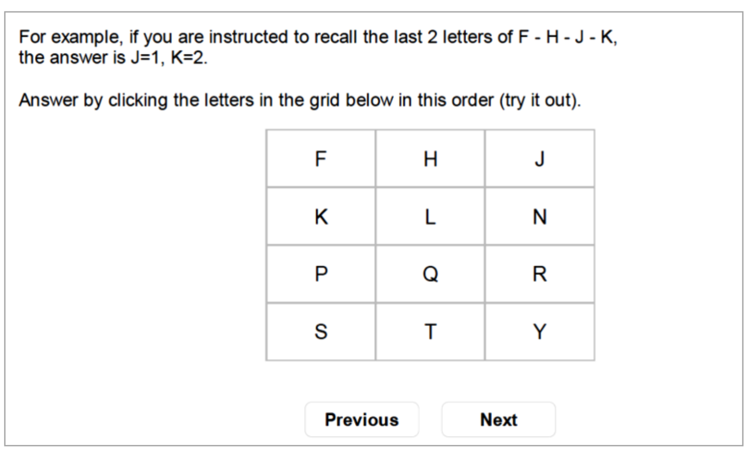


Figure 77 Instruction set for Running Letters Task showing answer output format

The final task of the set, Number Switching, had two switching task conditions that eventually had a change of response from the participant. Participants are presented with a 2x2 grid. Numbers appear in this grid in a clockwise sequence. When the number appeared in one of the top two squares, the participants had to respond, with keyboard inputs indicating whether the number was ‘Less than’, or ‘Greater than’ 5. When the number appeared in the bottom two squares of the grid, however, the condition was changed by having the participant respond with keyboard inputs as to whether the number is ‘Odd’ or ‘Even’. This was repeated until numbers were no longer displayed.

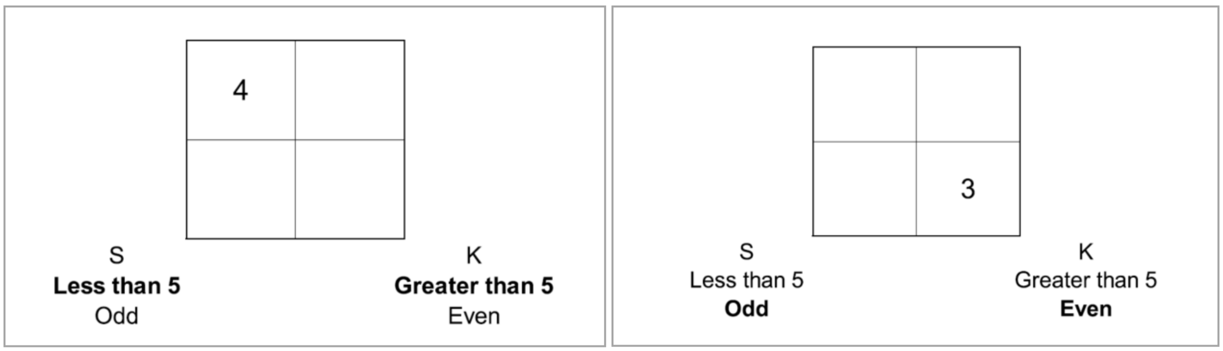


Figure 78 First condition (Left) and Second condition (Right) for Number Switching task

These tasks have been developed and used thanks to Dr Kleitman’s team at the University of Sydney, School of Psychology.

## 7.3. Results

### 7.3.1. Task performance

There was a comparative analysis between various task performance measures specific to each test, the drive condition and the six self-report measures of the NASA TLX. The results of the Repeated Measure ANOVAs for each measure are presented in Table 5 (full statistical analysis in SPSS Mental Workload folder on CD).

**Table 5 Task measures**

| | | Drive | NASA TLX Measures | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mental Demand | Physical Demand | Temporal Demand | Performance | Effort | Frustration |
| Stroop | difIC | NS | * $F_{(15,43)} = 6.53$ | NS | NS | ** $F_{(15,43)} = 2.20$ | NS | * $F_{(13,45)} = 12.10$ |
| | difIN | NS | * $F_{(15,43)} = 4.61$ | NS | NS | NS | NS | * $F_{(13,45)} = 7.93$ |
| | difNC | NS | NS | * $F_{(10,48)} = 3.87$ | NS | NS | NS | NS |
| | meanI | NS | NS | * $F_{(10,48)} = 2.30$ | NS | ** $F_{(15,43)} = 2.63$ | NS | * $F_{(13,45)} = 3.68$ |
| | meanC | NS | * $F_{(15,43)} = 2.77$ | NS | NS | NS | NS | ** $F_{(13,45)} = 2.49$ |
| | meanN | NS | NS | * $F_{(10,48)} = 3.06$ | NS | NS | NS | NS |
| | errI | NS | * $F_{(15,43)} = 3.36$ | NS | NS | ** $F_{(15,43)} = 2.16$ | NS | * $F_{(13,45)} = 4.40$ |
| | errC | ** $F_{(3,56)} = 3.63$ | NS | ** $F_{(10,48)} = 2.16$ | NS | NS | NS | * $F_{(13,45)} = 2.88$ |
| | errN | NS | NS | * $F_{(10,48)} = 2.95$ | NS | * $F_{(15,43)} = 2.81$ | NS | ** $F_{(13,45)} = 2.19$ |
| | lapseI | NS | * $F_{(15,43)} = 17.98$ | NS | NS | NS | NS | NS |
| | lapseC | NS | NS | NS | NS | NS | NS | NS |
| | lapseN | NS | * $F_{(15,43)} = 17.98$ | NS | NS | NS | NS | * $F_{(13,45)} = 15.18$ |
| Running Letters | Acc | NS | NS | ** $F_{(13,44)} = 2.18$ | * $F_{(16,41)} = 2.59$ | NS | NS | NS |
| Number switch | difSR | NS | NS | NS | NS | NS | NS | ** $F_{(16,41)} = 1.91$ |
| | meanS | * $F_{(3,56)} = 7.41$ | * $F_{(17,40)} = 2.52$ | NS | ** $F_{(15,42)} = 2.48$ | NS | NS | NS |
| | meanR | NS | * $F_{(17,40)} = 2.73$ | NS | * $F_{(15,42)} = 3.24$ | NS | NS | NS |
| | errS | NS | ** $F_{(17,40)} = 2.12$ | NS | ** $F_{(15,42)} = 2.42$ | NS | NS | * $F_{(16,41)} = 2.95$ |
| | errR | NS | * $F_{(17,40)} = 3.91$ | NS | * $F_{(15,42)} = 3.03$ | NS | * $F_{(16,57)} = 2.49$ | * $F_{(16,41)} = 4.03$ |
| | lapseS | * $F_{(3,56)} = 4.81$ | * $F_{(17,40)} = 9.17$ | NS | * $F_{(15,42)} = 3.75$ | NS | NS | * $F_{(16,41)} = 3.37$ |
| | lapseR | ** $F_{(3,56)} = 2.90$ | * $F_{(17,40)} = 14.93$ | NS | * $F_{(15,42)} = 7.55$ | NS | NS | * $F_{(16,41)} = 3.54$ |

* $p<0.01$ ** $p<0.05$

#### 7.3.1.1. Task performance and Drive condition

The task scores and specific drive condition (Baseline, Easy, Mountain or Formulae One) had little to no statistically significant effect on the results of most task measures. In the Stroop test the only statistically significant finding was on the errC measure, i.e. the Error on Congruent trials, where the mean of errors on task after the final drive (*M*= 0, SD=0) was significantly different to the mean on errors in this trial from the baseline (*M*= 0.73, SD= 0.96) (see Figure 79). This could be a result of the practice effects from this task. The lack of other measures with this significant drop across drives could imply that there was an effect from the increasing mental workload as the task improvement was not as extreme.

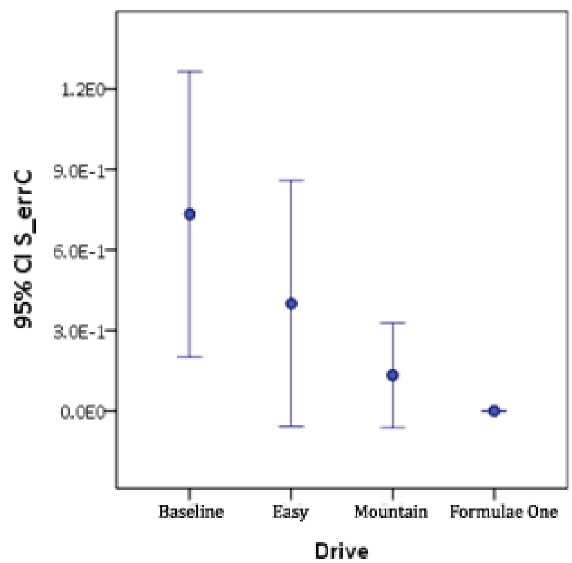


Figure 79 Stroop mean errors on congruent tasks compared to Drive condition

Interestingly, in this case, the task measures do not have a steady decline as would be expected from practice effects. Figure 80 displays the mean measures with 95% Confidence Interval relating to the Stroop task by each Drive condition. In the Errors for Congruent and Incongruent trials and the Lapse time in Neutral trials, there was a mean increase on the final drive. Whilst not significant, this increase opposes what would be expected in practice effects, indicating the possibility that this increase in mental workload demand negatively affects performance along these measures.

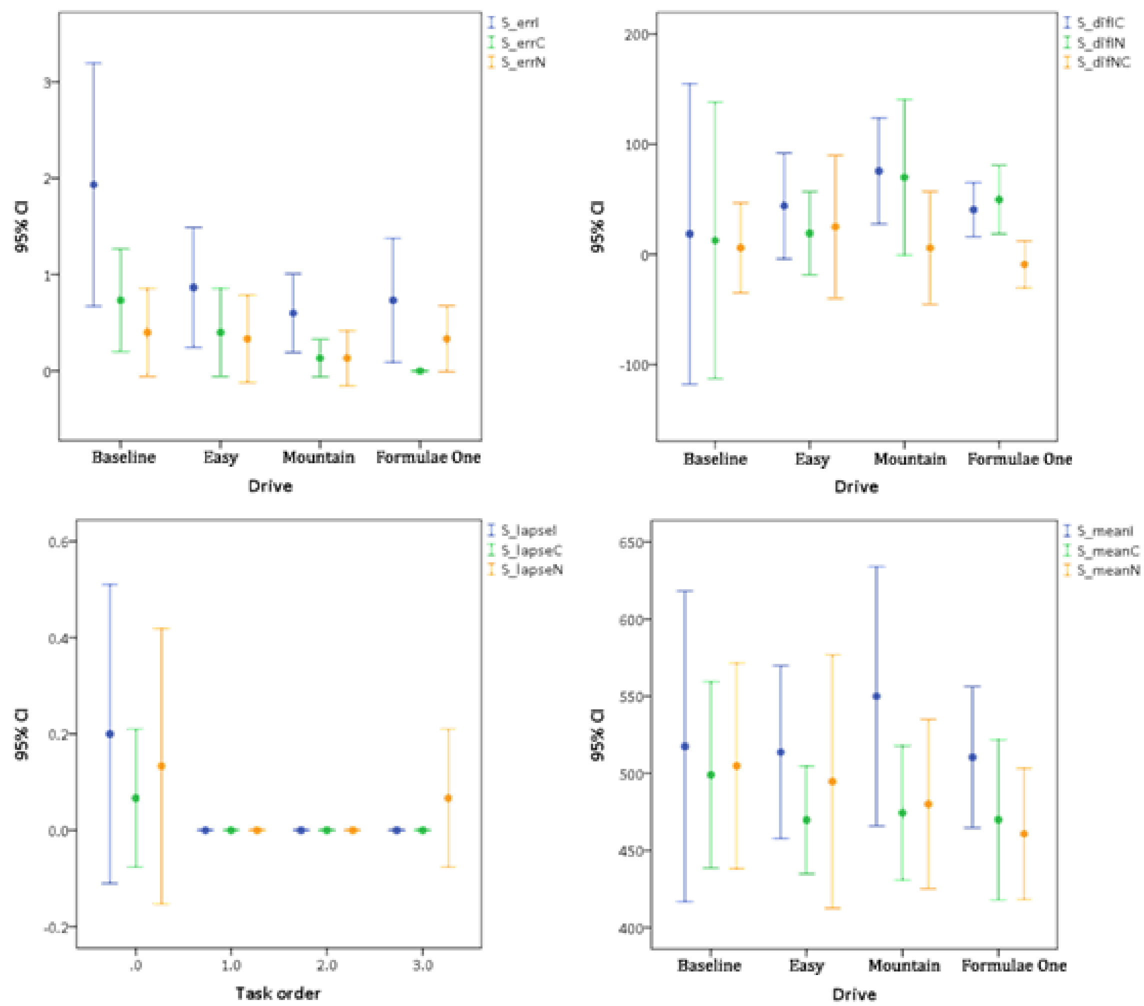


**Figure 80 (Top Left) Mean Error count, (Top Right) Mean Differences in Time between Neutral, Congruent and Incongruent trials, (Bottom Left) Mean Lapse Time and (Bottom right) Mean Time in Stroop Task by Drive**

It is significant to note that for the difference in times for Incongruent Trials to both Congruent (difIC) and Neutral (difIN) trials, and for the mean time in Incongruent trials (meanI), there was an increase at the second drive condition and then a decrease suggesting small increases in mental workload could have an effect on the mental processing time in incongruent conditions, though this effect on accuracy is not prominent at a higher level of mental workload.

There is no statistically significant difference in the accuracy score in the Running Letters task and the Drive condition. As seen in Figure 81, there was a slight improvement in accuracy after the second drive, which then falls again by the third. The expectation is that there should be an improvement in accuracy due to practice. As such, this slight drop could imply that the mental workload had affected performance on task. A baseline practice-effect test is needed to confirm this.

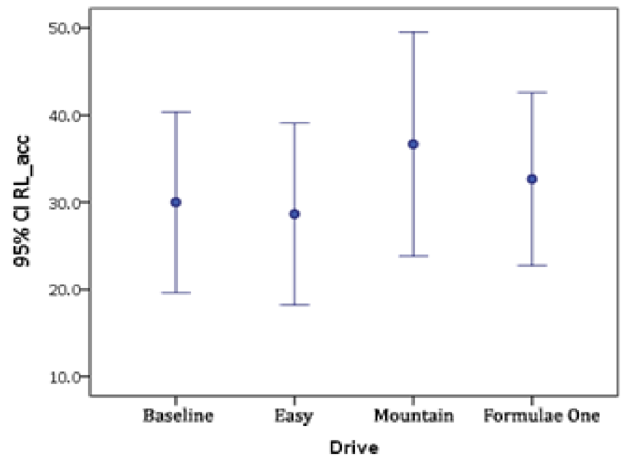


**Figure 81 Running Letters Mean Accuracy Score by Drive condition**

In the Number Switch condition, there was a statistically significant difference in the score of the mean time taken on Switch trials, the mean lapse time in Switch trials, and the mean lapse time in Repeat trials as compared to the drive condition. In all cases, the mean trial sub score at the Baseline (Drive 0) measure was significantly different to the means at the other drive conditions. It's possible that one task is needed for participants to become accustomed to the task before significantly improving. For the mean time in Switch trials, the participants improved linearly as seen in Figure 82, until the last trial where this time seems to plateau. This could be indicative of the mental workload overcoming the practice effects, or of reaching a saturation point in how quickly this task can be processed.

For the Lapse data, there was a marked improvement from the drive trials. The mean lapse time in the Switch trials, whilst not statistically significant, was slightly worse after the first increase in mental workload (Mountain drive) with a subsequent decrease in the Formulae One drive. Whilst not statistically significant, in the mean lapse time in Repeat trials there was a slight trend in the final drive to have an increase in mean time when compared to the Mountain drive, which could have been an effect of the increased mental workload on this task.

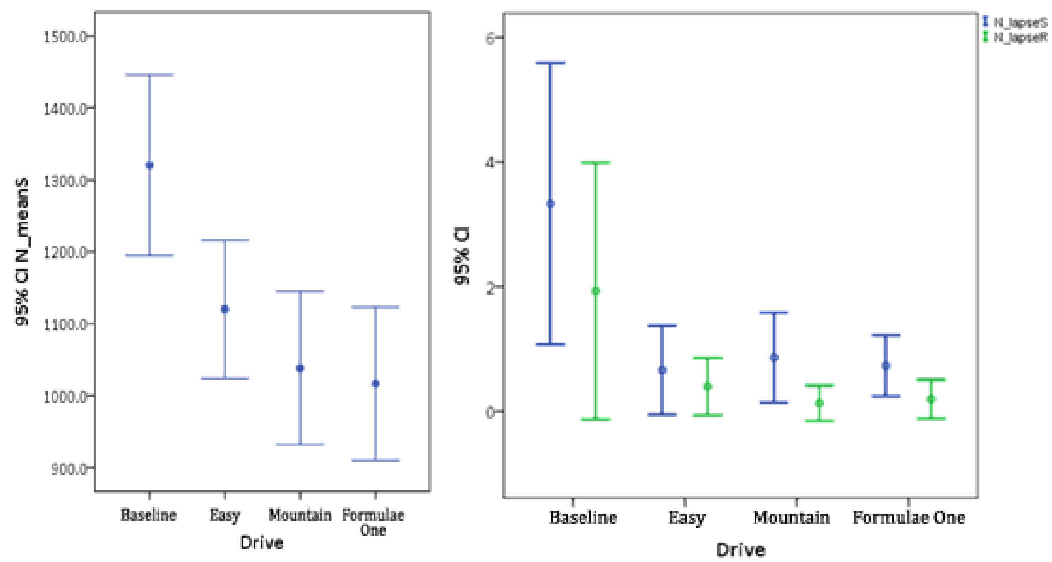


Figure 82 Number switch Task results of Mean time on Switch Task (Right) and mean Lapse time on Switch and Repeat Tasks (Left) by Drive condition

For the errors count in the Number Switch task, the errors in the Switch trials increased in the final drive. It would be expected that the error counts in both trials would decrease due to practice effects unless affected by mental workload implying that the third driving condition was more taxing across participants, affecting their performance in this measure.

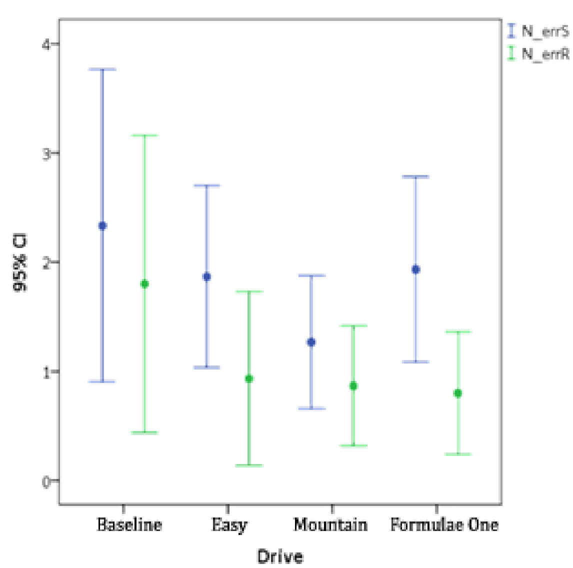


Figure 83 Mean Error Count by Drive in the Number Switch Task

#### 7.3.1.2. Task Performance and the NASA TLX

Out of all six sub-categories of the NASA TLX, the two that are highlighted most as being statistically significant across task measures are Frustration and Mental Demand. Mental Demand was hypothesised at the start of this study to be affected by Mental Workload. Frustration should be noted as it could be used to measure when mental workload is exceeding saturation point. Interestingly, neither of these measures was statistically significant for the Running Letters task. As the NASA TLX has 20 scale points to select from for each measure, there are too few occurrences of each exact scale point to conduct post-hoc tests on these measures for each task.

##### *7.3.1.2.1. Task Performance and Mental Demand*

For the measures of statistical significance in Mental Demand, a few trends were noted in the Stroop Task. In the measure of error in the Incongruent trials, there was an increase in error count from a self-report of a score of 2 to a score of 13. Very few participants scored a response higher than a 13 in the Stroop task. This level at 13 is quite variable as seen in Figure 84, as more trials are needed to make a proper note on this trend. In the Lapse count for Incongruent trials and Neutral trials there was a peak at the self-report score of '11'. However, this was only for one participant and thus cannot be documented without further testing. This was likewise the case in the time measure of the difference between Congruent and Incongruent trials (difIC) and the difference between Incongruent and Neutral Trials (difIN) where there was a drop in time at the self-report of '11' but only for the one participant (see Figure 84). In mean time for Congruent trials in the Stroop test there is too much variability at the higher end of the scale to accurately report on measures.

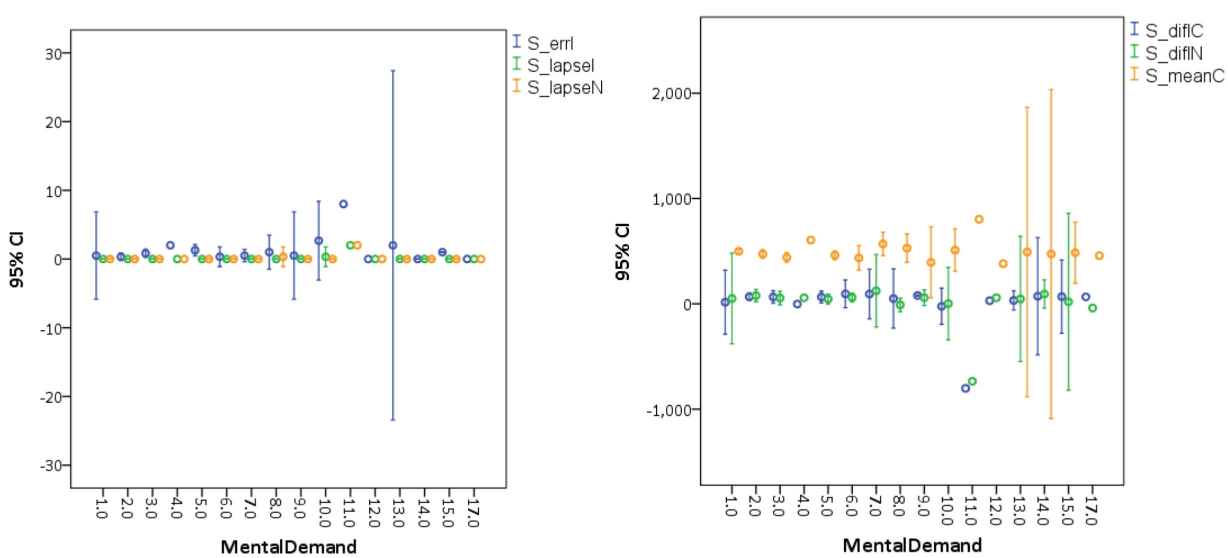


Figure 84 Stroop task measures and Mental Demand

Statistically there was no significant measure for Running Letters task and Mental Demand.

For the Number Switch task, all task measures except for the difference in time between Repeat and Switch trials were found to have statistically significantly different means to the Mental Demand measures. Looking at the mean times for the Switch and Repeat tasks (see Figure 85), there appears to be an increase in time taken for those who scored the task at the higher end of the Mental Demand spectrum, however this did not affect enough participants for post hoc analysis to be conducted.

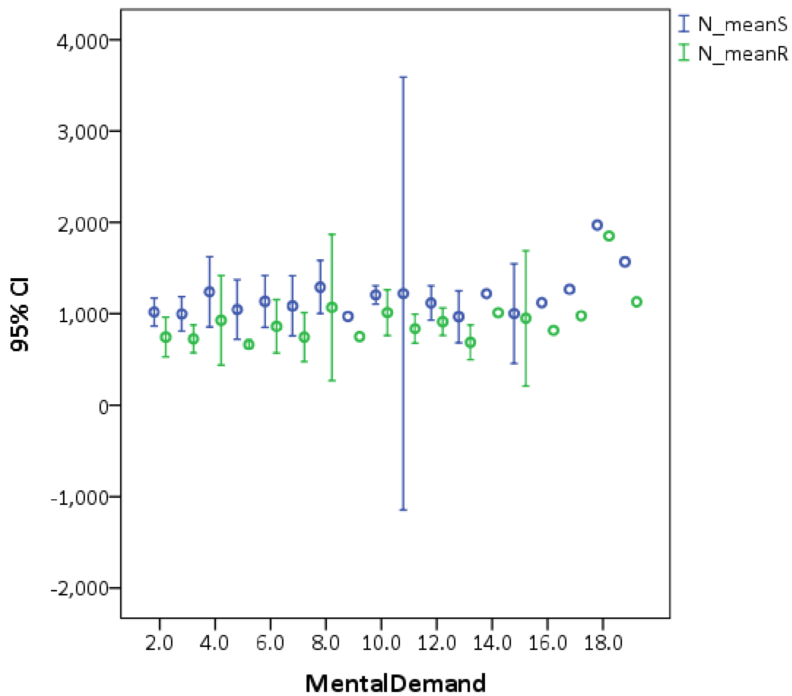


Figure 85 Number switch mean time measures and Mental Demand

In terms of the error scores, there was a trend of errors exponentially increasing with an increase in self-report for Mental Demand, though more participant data are needed to confirm this finding. This trend is also seen in the lapse score where the few participants scoring highly in this task on the mental demand also performed worse in the task. This verifies the present data meeting performance expectations under high mental workload for these few participants. On the lower side of the Mental Demand scale, there was no obvious effect noted for the Number Switch task.

For all switch trial measures, there is a great diversity in the measure for participants who scaled the Mental Demand at the score of ‘11’ for this task as seen in Figure 85 and Figure 86.

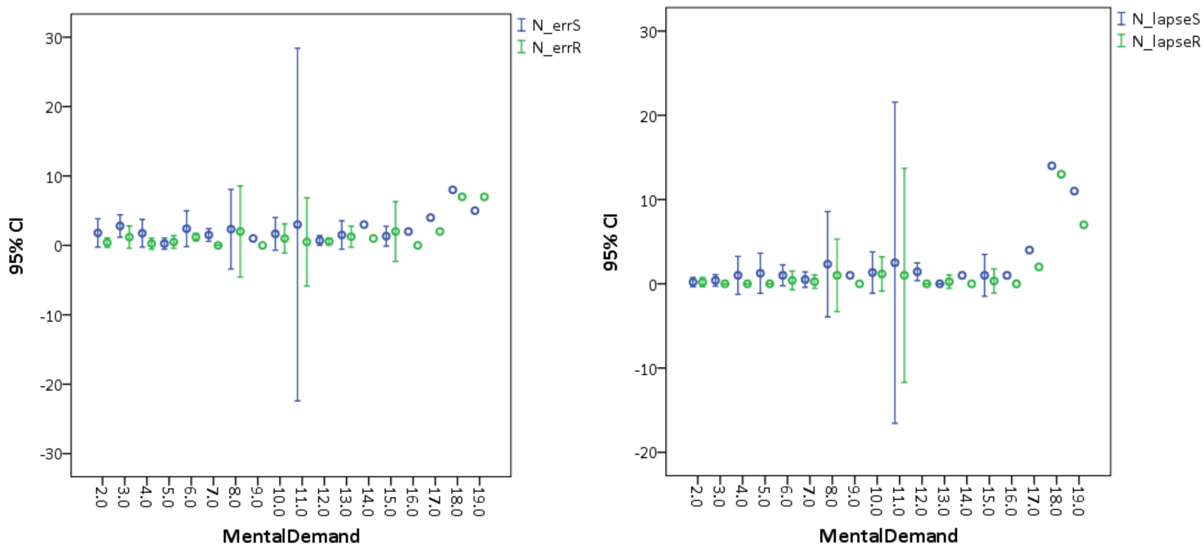


Figure 86 Number switch Error (Left) and Lapse (Right) scores by Mental Demand

### *7.3.1.2.2. Task Performance and Physical Demand*

For the Stroop data, all measures that showed statistical significance have outlier measures that were only seen in one participant from the group (see Figure 87). As these measures are subjective, more participants are needed to conduct a thorough post hoc analysis to test whether increased self-report of Physical Demand does have an effect on task performance.

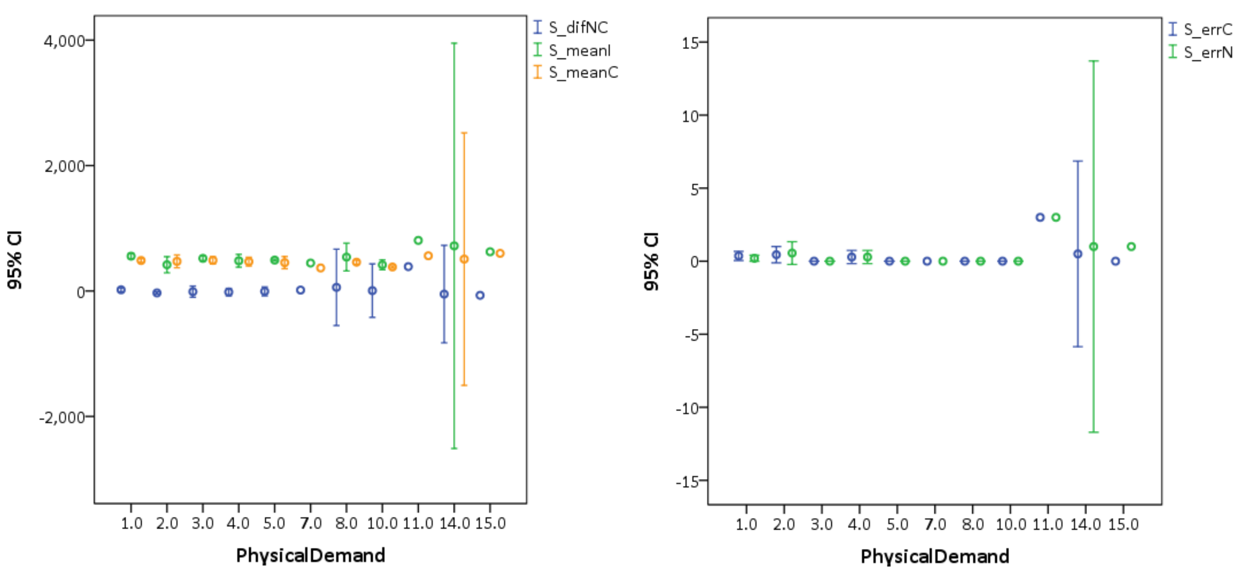


Figure 87 Stroop time (left) and error (right) measures by Physical Demand

There was little correlation between the self-report measure Physical Demand and the measure of Accuracy in the Running Letters task, with some participants scoring 0% accuracy at opposite ends of the

Physical Demand spectrum (5 and 15) and other participants scoring highly in accuracy (60%) at self-reports ranging in the low, mid, and high range of Physical Demand as seen in Figure 88. It should be noted that the measure of Physical Demand was questioned by most participants as they did not see a computer task as requiring any physical resource, which may explain these mixed results.

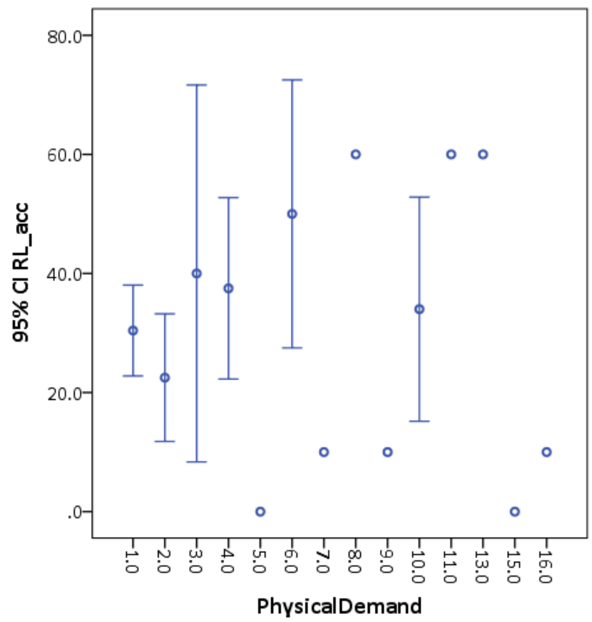


Figure 88 Accuracy (%) in Running Letters task by Physical Demand

### *7.3.1.2.3. Task Performance and Temporal Demand*

For the Stroop task, no measure was found to be statistically significant different to the measure of Temporal Demand.

The relationship between the Running Letters task accuracy and Temporal Demand was not clearly defined as seen in Figure 89. Up to the self-report of '15' there appears to have been a slight linear trend of actual improved accuracy with higher self-reports of temporal demand. This is interesting as it was assumed that the less rushed a participant felt by this particular task, the better they would perform. Past this self-reported measure of '15' the mean accuracy drops again (with a few peaks for some individuals at '17'). From this it can be inferred that there is a trade-off, with the sensation of increase in temporal demand actually improving concentration up until a certain level, at which point any further increase in temporal demand begins to negatively impact on performance in this task.

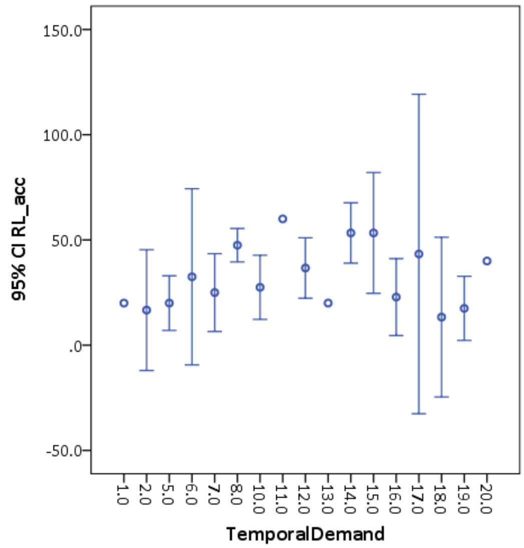


Figure 89 Accuracy (%) in Running Letters task by Temporal Demand

In the Number Switch task, all task measures but the measure of mean time between Switch and Repeat trials were statistically found to be significantly different to the self-report measure of Temporal Demand. As expected, the mean time for Switch task was higher than the mean time for Repeat tasks across nearly all participants. Post-hoc tests could not be performed due to the lack of multiple participants scoring at each level as seen in Figure 90. This trend was also true for the changes in the error count for the Switch condition compared to the error count for the Repeat Condition (Figure 91) and for the Lapse time for the Switch condition compared to the Lapse time for the Repeat condition (Figure 92).

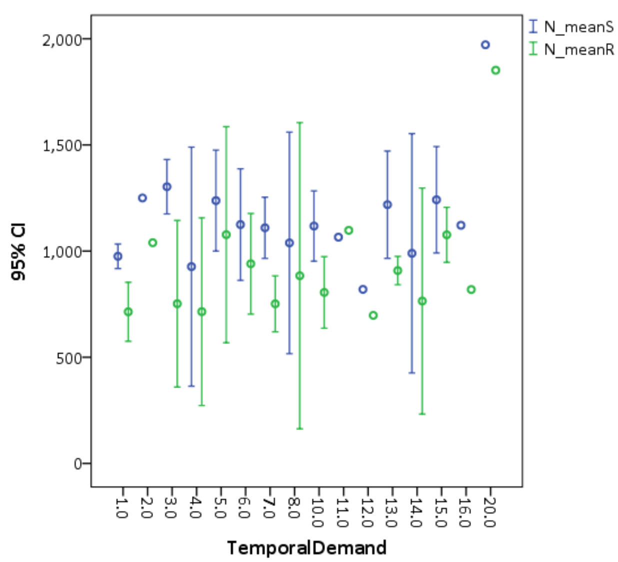


Figure 90 Means of total time in Number Switch task by Temporal Demand

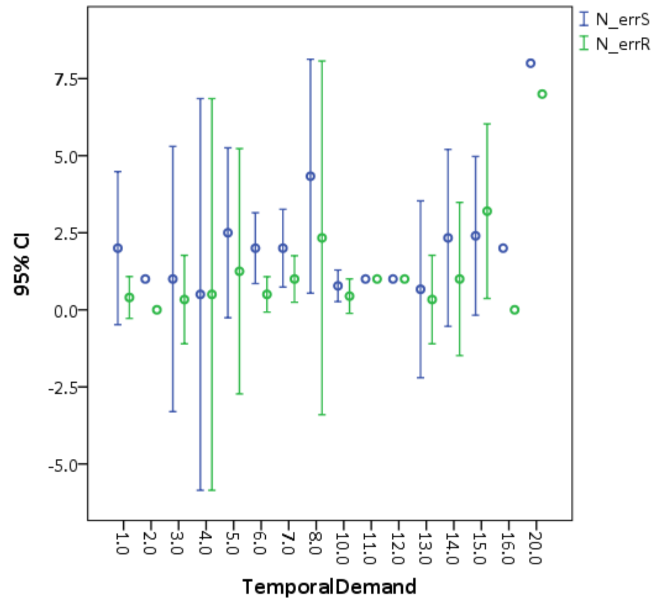


Figure 91 Total errors (Left) and Lapse count (right) in Number Switch task by Temporal Demand

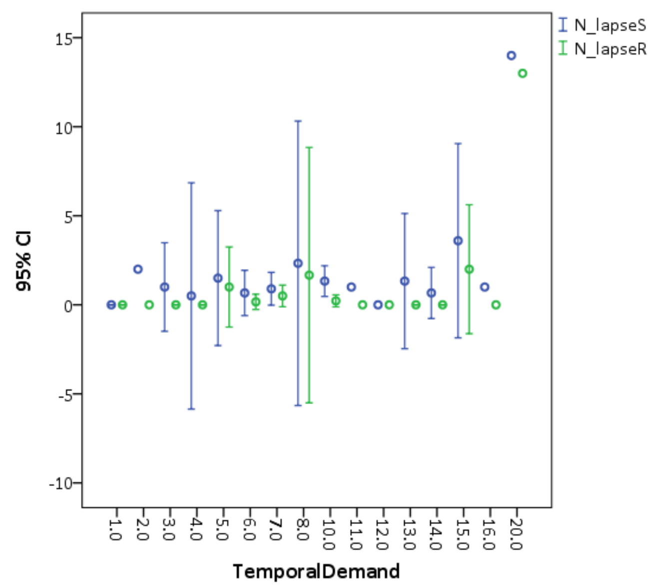


Figure 92 Lapse count (right) in Number Switch task by Temporal Demand

To develop a better understanding, the responses for individuals were grouped into a scale of 4 rather than 20. In this scale, a '1' corresponds to a self-report at the lower end of the Temporal Demand, that is, from 1-5 with '4' corresponding to a self-report from 15-20. The results of statistically significant differences are shown in Table 6. Note that the score for mean time and error count for the Switch condition are statistically no longer significantly different between the weighted Temporal Demand groups.

**Table 6 One-Way ANOVA for task measures in Number Switch task by grouped self-report measure of Temporal Demand**

**One-Way ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| N_difSR | Between Groups | 85774.3 | 3 | 28591.4 | .783 | .509 |
| | Within Groups | 1972392.2 | 54 | 36525.8 | | |
| | Total | 2058166.6 | 57 | | | |
| N_meanS | Between Groups | 361134.4 | 3 | 120378.1 | 2.615 | .060 |
| | Within Groups | 2485442.3 | 54 | 46026.7 | | |
| | Total | 2846576.7 | 57 | | | |
| N_meanR | Between Groups | 567278.0 | 3 | 189092.7 | 3.390 | .024 |
| | Within Groups | 3011740.3 | 54 | 55773.0 | | |
| | Total | 3579018.2 | 57 | | | |
| N_errS | Between Groups | 20.3 | 3 | 6.8 | 2.298 | .088 |
| | Within Groups | 159.1 | 54 | 2.9 | | |
| | Total | 179.4 | 57 | | | |
| N_errR | Between Groups | 21.4 | 3 | 7.1 | 3.054 | .036 |
| | Within Groups | 126.3 | 54 | 2.3 | | |
| | Total | 147.7 | 57 | | | |
| N_lapseS | Between Groups | 85.1 | 3 | 28.4 | 5.525 | .002 |
| | Within Groups | 277.3 | 54 | 5.1 | | |
| | Total | 362.3 | 57 | | | |
| N_lapseR | Between Groups | 71.7 | 3 | 23.9 | 7.561 | .000 |
| | Within Groups | 170.7 | 54 | 3.2 | | |
| | Total | 242.4 | 57 | | | |

In the analysis the change in mean times, for both the Switch and Repeat condition, using Dunnet t-test, levels 1 and 2 (a low self-report measure of Temporal Demand) was significantly different to the level of 4, which is, the highest grouping of self-report measures. In the Switch condition there was statistically also a significant difference in the mean time between levels 3 and 4. In both cases, it was seen that at the highest level of participants' noting to feeling an effect on Temporal Demand, their mean time correspondingly increases. This is also seen in the error count as shown in Table 7.

Table 7 Dunnet t test comparisons for measures in Number Switch Test by grouped self-report measure of Temporal Demand

**Multiple Comparisons - Dunnett t test(2-sided)**

| Dependent Variable | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| N_difSR | 1.0 | 4.0 | 71.24 | 143.87 | 0.82 | -251.91 | 394.39 |
| | 2.0 | 4.0 | 73.25 | 139.88 | 0.80 | -240.96 | 387.45 |
| | 3.0 | 4.0 | -17.30 | 145.16 | 1.00 | -343.36 | 308.76 |
| N_meanS | 1.0 | 4.0 | -423.80* | 161.50 | 0.02 | -786.55 | -61.04 |
| | 2.0 | 4.0 | -438.57* | 157.03 | 0.01 | -791.28 | -85.86 |
| | 3.0 | 4.0 | -414.38* | 162.95 | 0.03 | -780.40 | -48.36 |
| N_meanR | 1.0 | 4.0 | -495.04* | 177.78 | 0.01 | -894.36 | -95.72 |
| | 2.0 | 4.0 | -511.82* | 172.85 | 0.01 | -900.07 | -123.56 |
| | 3.0 | 4.0 | -397.08 | 179.38 | 0.05 | -799.99 | 5.84 |
| N_errS | 1.0 | 4.0 | -3.33* | 1.29 | 0.02 | -6.24 | -0.43 |
| | 2.0 | 4.0 | -3.14* | 1.26 | 0.03 | -5.96 | -0.32 |
| | 3.0 | 4.0 | -3.23* | 1.30 | 0.03 | -6.16 | -0.30 |
| N_errR | 1.0 | 4.0 | -2.90* | 1.15 | 0.03 | -5.49 | -0.31 |
| | 2.0 | 4.0 | -2.64* | 1.12 | 0.04 | -5.16 | -0.13 |
| | 3.0 | 4.0 | -1.81 | 1.16 | 0.20 | -4.42 | 0.80 |
| N_lapseS | 1.0 | 4.0 | -6.70* | 1.71 | 0.00 | -10.53 | -2.87 |
| | 2.0 | 4.0 | -6.36* | 1.66 | 0.00 | -10.08 | -2.63 |
| | 3.0 | 4.0 | -5.58* | 1.72 | 0.00 | -9.44 | -1.71 |
| N_lapseR | 1.0 | 4.0 | -6.23* | 1.34 | 0.00 | -9.24 | -3.23 |
| | 2.0 | 4.0 | -6.04* | 1.30 | 0.00 | -8.96 | -3.11 |
| | 3.0 | 4.0 | -5.73* | 1.35 | 0.00 | -8.76 | -2.70 |

*. The mean difference is significant at the 0.05 level.

For the lapse time in Switch and Repeat conditions, level 4 was significantly different to the mean lapse time at all other levels, with an increase in total lapse time with this highest increase of temporal demand. These should all be read with caution as the ungrouped temporal demands show that the participant scoring the highest mark had a greatly higher time and error factor in the Number Switch task. This outlier effect can be seen by the large 95% confidence intervals at each measure as shown in all 4 subplots in Figure 93.

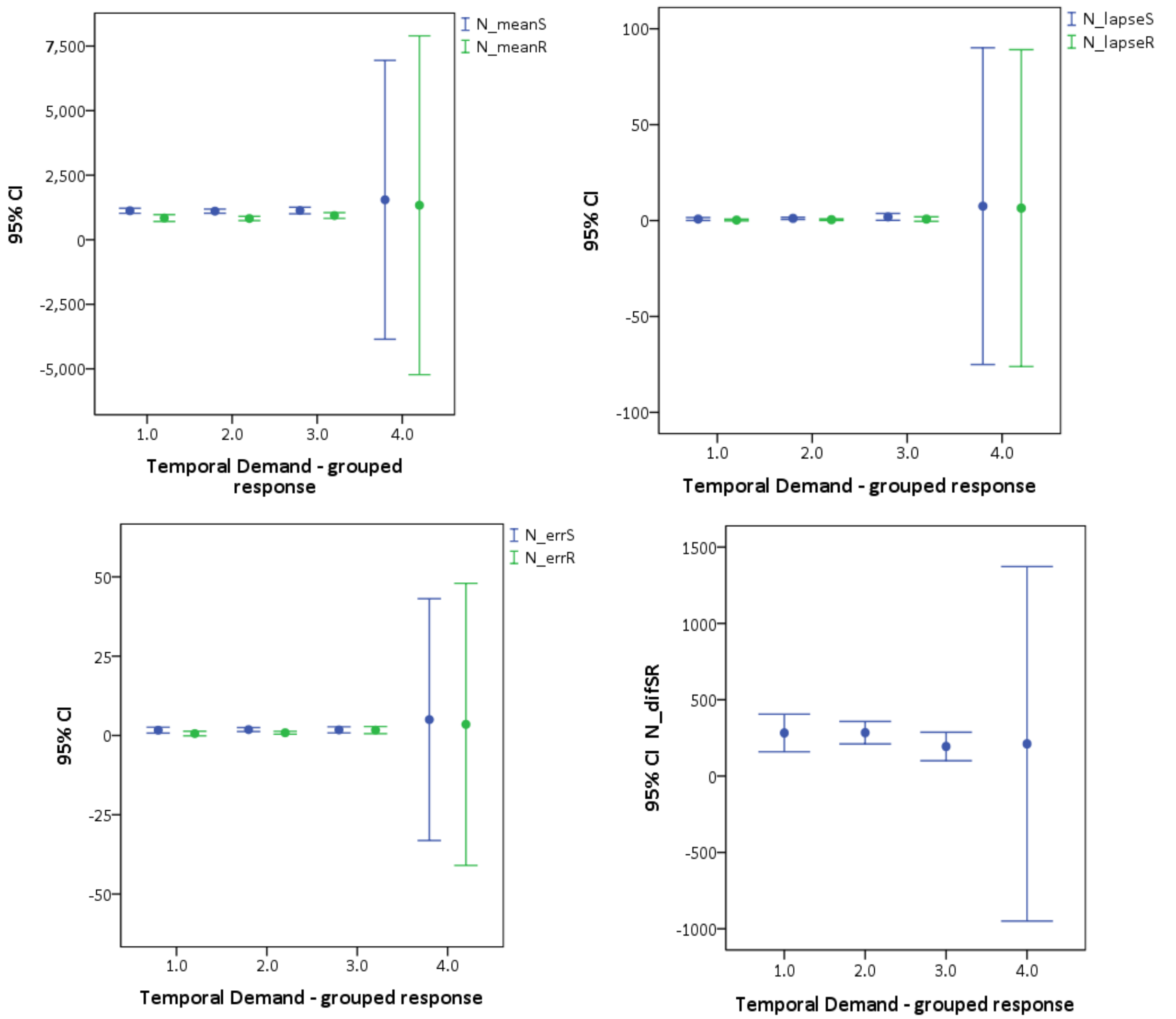


**Figure 93 Mean Time (Top Left), mean Lapse Time (Top Right), mean Error Count (Bottom Left) and mean change in time between Switch and Repeat Trials by grouped Temporal Demand (Bottom Right)**

#### *7.3.1.2.4. Task Performance and self-report Performance*

The self-report measure of 'Performance' was unique in all NASA TLX measures because its scale works in the opposite direction. The other measures work on the basis of a '1' indicating *Very Low* to '20' indicating *Very High*. In this measure however, a '1' indicates a *Perfect* score whilst '20' indicates *Failure*. Therefore the highest score is in fact the scenario where the participant has no confidence in his or her task performance. This opposing measure keeps to the format of the NASA TLX since the higher measures in each domain should be relatable to a higher task loading – i.e. performance would be expected to drop at an increased workload compared to a low workload. Whilst it conforms to the style its opposite scoring mechanism can lead to confusion for the participant.

The measure of Performance was only found to have statistically significant differences to certain mean scores of the Stroop task. No measures within the Running Letters task and the Number Switch task were statistically significant when compared to the self-report measure of Performance.

Within the Stroop task, the measures of interest are the change in time between Incongruent and Congruent trials, the mean time for Incongruent trials, and the error count in both Incongruent and Neutral trials as indicated in Table 5 and displayed in Figure 94. As previous, there were not enough participants at each measure to perform a post-hoc analysis that would indicate where these statistically significant changes would be. There does appear to be a drop in the time measures that are at a performance level of '14' showing that the faster the participant was in responding to incongruent trials, the less confident they were in their results. When the scores are weighted in groups, neither time measure statistically has a significant mean compared to the Performance measure (see Appendix V: Stroop task results by weighted measure of Performance (MW)).

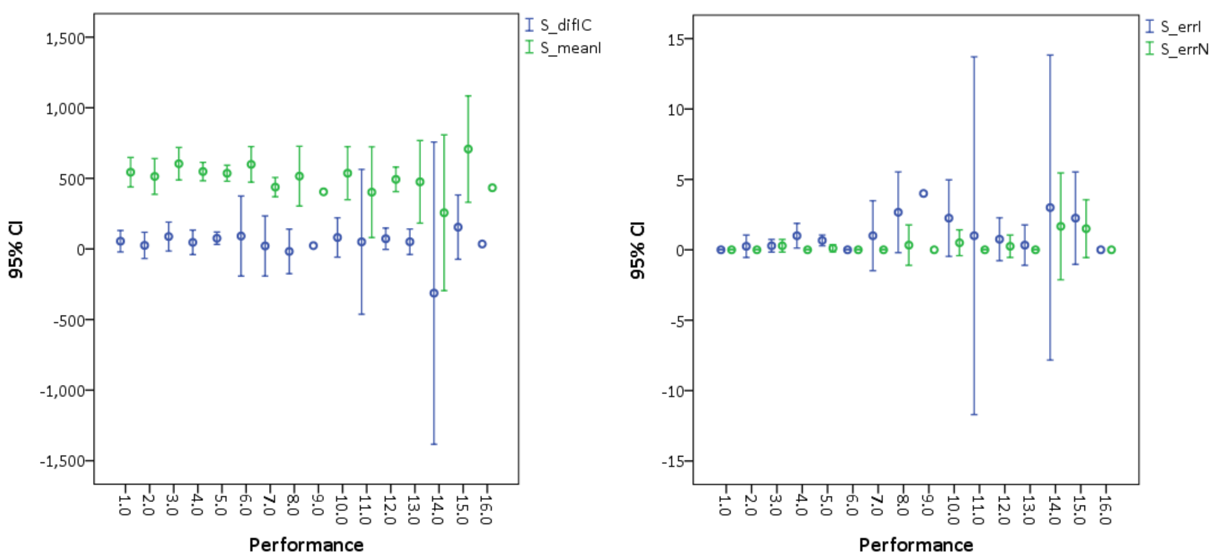


Figure 94 Time measures of Incongruent trials (Left) and error count (right) in the Stroop task by Performance

With the measure of errors, from Figure 94 it appears that for most participants, the error rate increased as the 'Performance' report increases. This is expected and indicates that participants were able to recognise their failure more obviously in Neutral and Incongruent conditions. The one participant with no errors at a self-report level of '16' is interesting. It is possible that they misunderstood the scaling for this measure.

When the measure of performance is grouped, the error count for Incongruent trials ($F_{(3,55)} = 3.62$, $p < 0.05$) and Neutral trials ($F_{(3,55)} = 3.45$, $p < 0.05$) is found statistically to have a significant difference in means scores compared to performance. Post-hoc analysis is still not possible as only one participant scored at this higher end. Ignoring this participant and analysing the graphical output of these grouping as shown in Figure 96, the error count in Neutral trials obviously follows the expected upwards trend, increasing with increased perception of failure. That which is of interest is a peak in the errors for Incongruent trials at a performance level at two. There are two possibilities for this. The first is that participants did not readily recognise their errors in Incongruent situations. However, as the task is designed to give feedback for incorrect and correct responses, the second theory that participants may have confused the scaling on this measure, may be the more likely option.

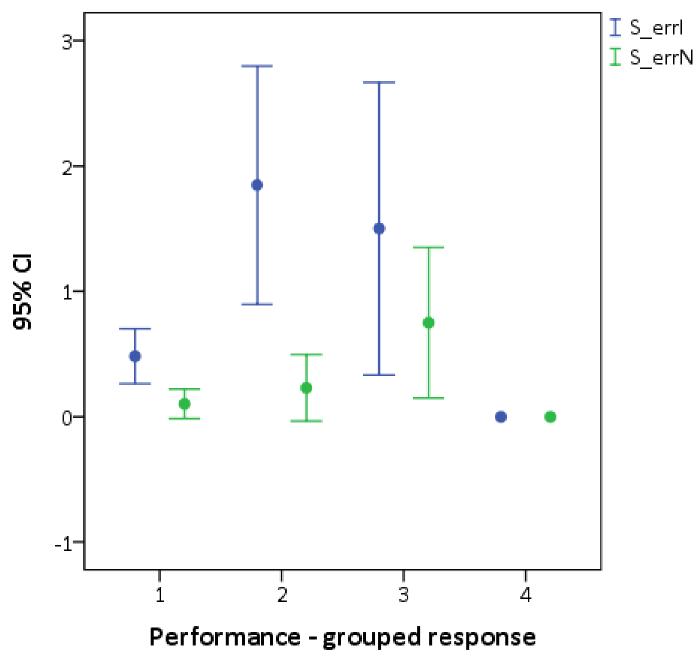


Figure 95 Mean Error Count in Incongruent and Neutral Trials by Grouped Performance measure

#### 7.3.1.2.5. *Task Performance and Effort*

In the self-report measure of Effort, only the mean error count in the Repeat trials of the Number Switch Task was statistically significantly different. Once again, post-hoc analysis was not possible due to the spread of responses and lack of multiple participants scoring at each level as seen in Figure 96.

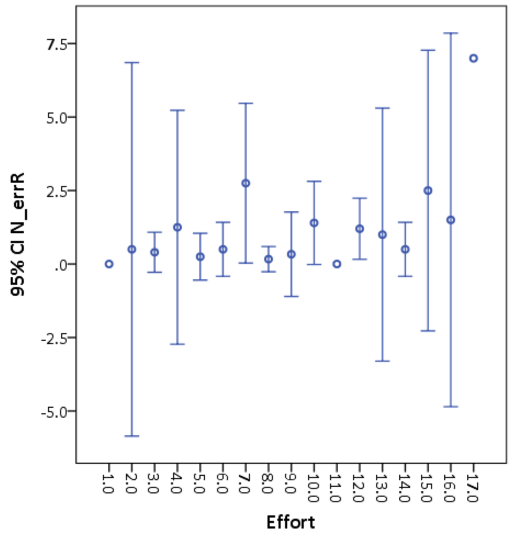


**Figure 96 Error count in Repeat trials of Number Switching task by Effort**

In grouping the self-report measure, the Error count for Repeat trials were statistically different to the grouped effort measure ($F_{(3,54)} = 2.83$, $p < 0.05$) as is the Lapse time in the Switch trials ($F_{(3,54)} = 3.23$, $p < 0.05$) (see Appendix W: Number Switching task results by weighted measure of Effort (MW)). Post-Hoc analysis using the Tukey comparison showed a significant difference in the mean error at Effort of Level 1 (*M*=0.56, SD=1.26) compared to mean error at Level 4 (*M*=3.33, SD=3.25) for Repeat Trials. In the Lapse Time in Switch trials, the mean time at Level 4 (*M*=5.33, SD=5.13) is significantly different to those at Level 1 (*M*=0.88, SD=1.45) and Level 2 (*M*=1.09, SD=1.37). This increase at Level 4 is seen in Figure 97 for both data sets. From this it can be stated that, at higher levels of perceived effort, there was a negative impact on both the error rate for Repeat trials and the Lapse time between Switch trials.

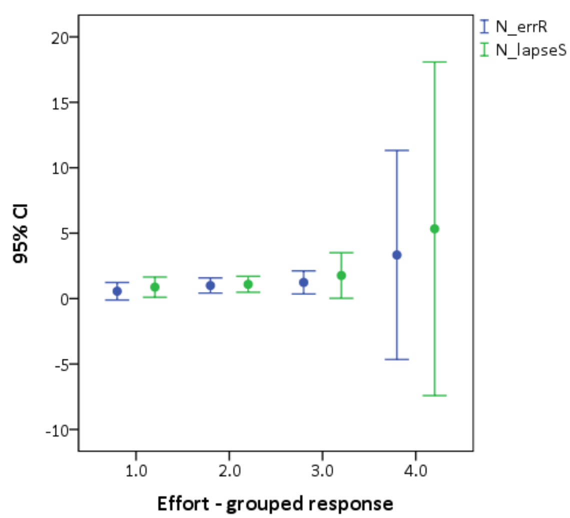


**Figure 97 Mean Error count in Repeat Trials and Mean Lapse time in Switch Trials by grouped Effort measure**

### 7.3.1.2.6. Task Performance and Frustration

Frustration was statistically the measure with the most significant changes in mean task performance in relation to the self-report value. None of these measures involved the Running Letters task as presented in Table 5.

Eight outcome measures from the Stroop Test were calculated to have significantly different means relating to change in Frustration. The outputs of these mean measures are shown in Figure 98. What was evident in all outputs is a lack of participants reporting a high level of frustration for this task. From level ‘7’ – ‘15’, most scores are listed in single digits with some grouping at ‘10’ and ‘12’. In the Difference between Incongruent, and both Congruent and Neutral scores, there were no evident trends (Figure 98). The measures of mean time do seem to slightly increase with increased Frustration. Error counts were relatively constant across changes in reported frustration, with a trend in the Incongruent error count increasing with increased Frustration as was expected. The error count in Congruent and Neutral trials did not appear to share this trend, with only one individual showing a peaked error count at the highest Frustration level of 15. This trend was the same for the lapse time in Neutral trials.

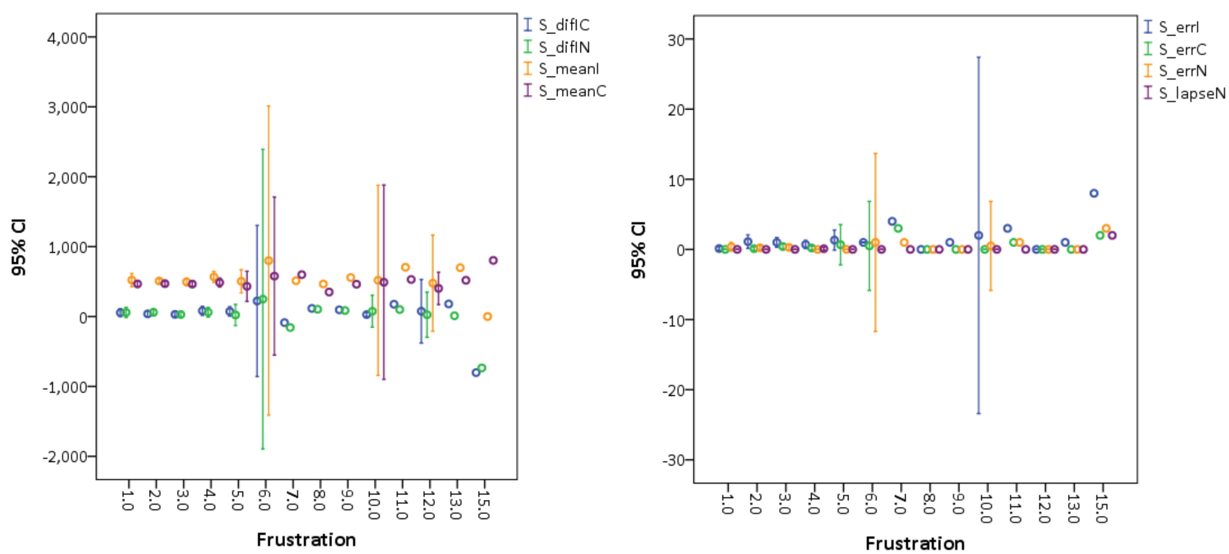


**Figure 98 Stroop task time measures (left), error and lapse count (right) by Frustration**

When the Frustration score is grouped to a scale out of 4 rather than 20 for Post-Hoc analysis, only the measures of Difference in time between Incongruent and Neutral trials ($F_{(2,56)} = 4.32$, $p < 0.05$) and the Lapse time in Neutral trials ($F_{(2,56)} = 4.48$, $p < 0.05$) statistically remained significantly different to the new Frustration score (see Appendix X: Stroop Task results by weighted measure of Frustration (MW)).

Interestingly, the Lapse time for the Congruent ($F_{(2, 56)} = 4.11$, $p < 0.05$) and Incongruent ($F_{(2, 58)} = 5.45$, *p* < 0.01) trials were also significant. Using the Tukey comparison in Post-Hoc Analysis, for the time difference between Incongruent and Neutral trials, the mean at a Frustration Level of 3 (i.e. 10-15 on NASA TLX) (*M*=-114.95, SD =349.05) statistically was significantly different to that at a Level of 1 (*M*=46.42, SD =78.39) and 2 (*M*=97.195, SD =167.98). This trend is shown in Figure 99 with the mean at the increased frustration actually dropping at the highest Frustration range.

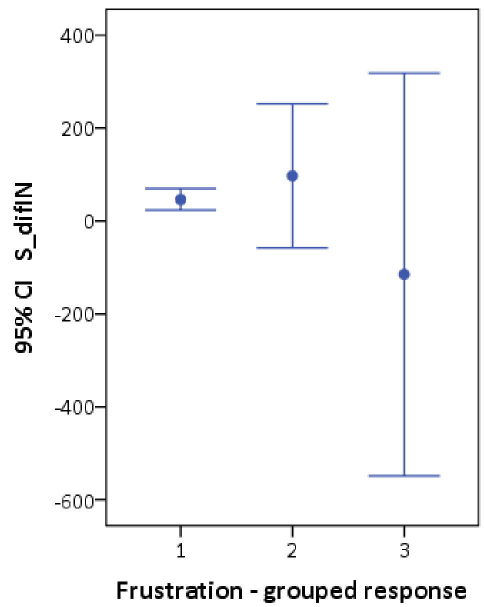


**Figure 99 Mean Difference in time measure between Incongruent and Neutral Stroop Tasks by grouped measure of Frustration**

Whilst there were no significant differences in the scaled score of frustration, the mean time and error measures in the Stroop task still have a trend to increase with increased frustration. This trend is shown in Figure 100.

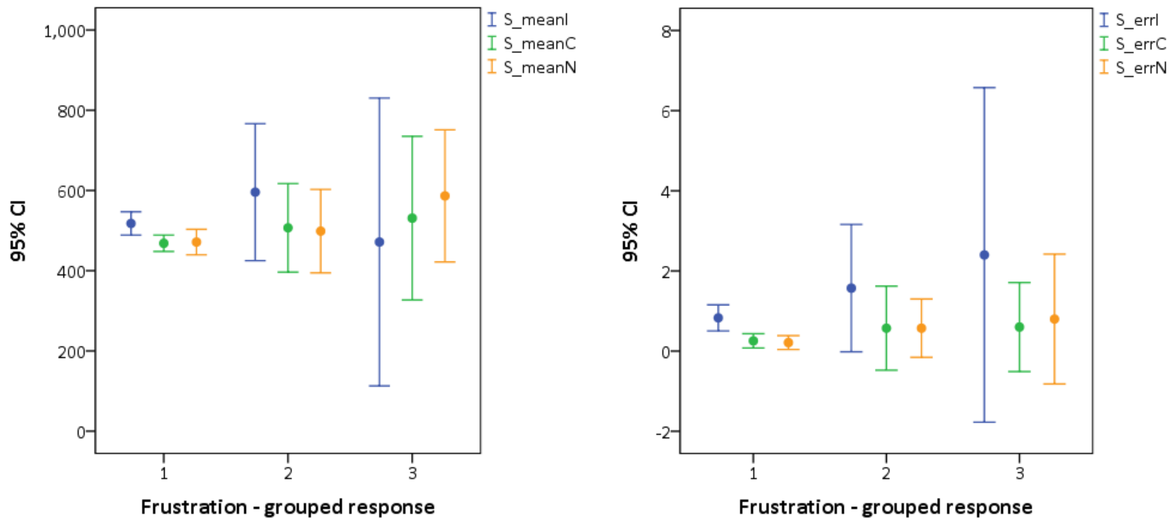


**Figure 100 (Left) Mean time and (Right) Mean error count in Stroop task by grouped measure of Frustration**

In the Lapse time for Neutral Stroop Trials, the Tukey comparison showed the mean at Level 3 (*M*=0.40, SD=0.89) statistically to be significantly different to that at 1 (*M*=0.02, SD=0.15) and 2 (*M*=0, SD=0). This time, the difference was an increase in Lapse time as expected with Frustration. In the Lapse time for Incongruent trials, the mean time at Level 3 (*M*=.40, SD =0.89) was once again different to Level 1(*M*=0, SD =0), also indicative of this increase in time. Only the Lapse time in Congruent trials fails to meet this trend, with the Lapse mean time at Level 2 (*M*=.14, SD =0.38) being significantly different to the mean at level 1 (*M*=0, SD =0). However, this mean time decreased at Level 3 as the no Lapse time for the five participants who rated frustration at this level. Measures of congruent trials were slightly affected by Frustration but not to a great deal. Conversely, Neutral and Incongruent trials which require slightly more mental processing were significantly affected as self-report of Frustration increased. These trends can be seen in Figure 101.

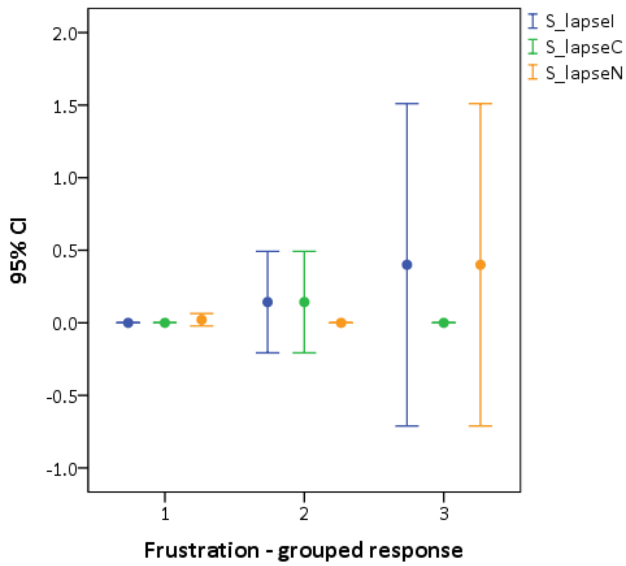


Figure 101 Lapse time measure in Stroop Task by grouped measure of Frustration

In the Number Switch task it is difficult to pinpoint where the changes occur most between the mean times of the difference between Switch and Repeat trials, mean time for Switch trails and Mean Time for Repeat trials as seen in Figure 102.

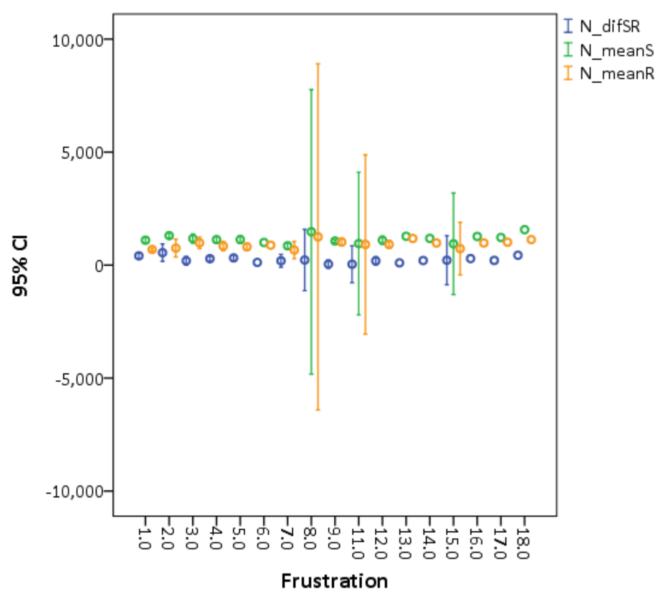


Figure 102 Time measures in Number Switch task by Frustration

In Figure 103 , the Error count appears to increase with Frustration in both Switch and Repeat trials, with a peak at the self-report level of '8'. This peak was also seen in the Lapse Time measures. Likewise there appears to be a trend where the Lapse time increased with the measure of Frustration.

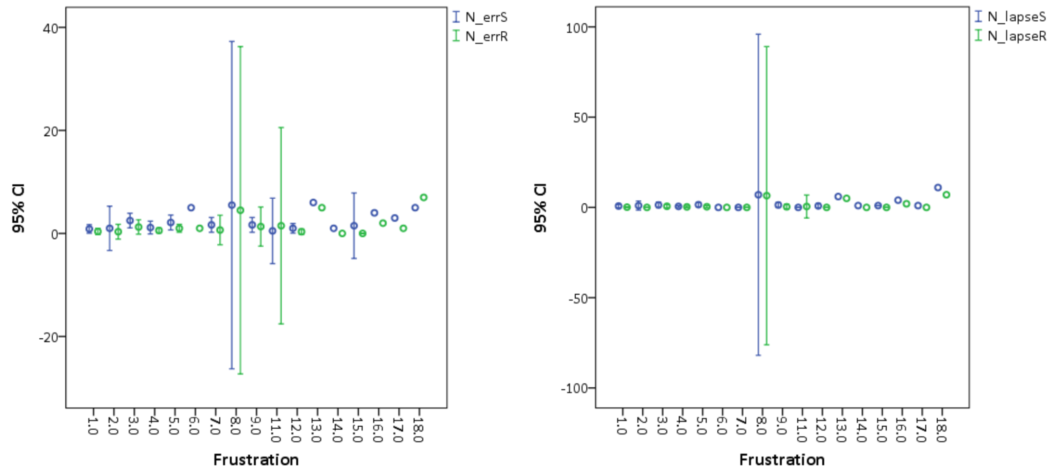


Figure 103 Error (left) and Lapse (right) count in Number Switching task by Frustration

These trends are not meaningful without Post-Hoc analysis. Reducing the Frustration score to a scale of 4, instead of a scale of 20, assists the identification of significant patterns of this measure. The Lapse time in Repeat trials was no longer significant with this reduced scale ($F_{(3, 54)}$ = 2.33, $p$ = .08), however statistically there is a significant difference in scores across the measures previously highlighted and the grouped Frustration measure as shown in Table 8.

Table 8 One-way ANOVA for task measures in Number Switch task by grouped self-report measure of Frustration

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| N_difSR | Between Groups | 386324.41 | 3 | 128774.80 | 4.159 | .010 |
| | Within Groups | 1671842.14 | 54 | 30960.04 | | |
| | Total | 2058166.55 | 57 | | | |
| N_meanS | Between Groups | 220360.90 | 3 | 73453.63 | 1.510 | .222 |
| | Within Groups | 2626215.79 | 54 | 48633.63 | | |
| | Total | 2846576.69 | 57 | | | |
| N_meanR | Between Groups | 220985.38 | 3 | 73661.79 | 1.185 | .324 |
| | Within Groups | 3358032.84 | 54 | 62185.79 | | |
| | Total | 3579018.22 | 57 | | | |
| N_errS | Between Groups | 27.54 | 3 | 9.18 | 3.265 | .028 |
| | Within Groups | 151.83 | 54 | 2.81 | | |
| | Total | 179.38 | 57 | | | |
| N_errR | Between Groups | 23.72 | 3 | 7.91 | 3.443 | .023 |
| | Within Groups | 124.01 | 54 | 2.30 | | |
| | Total | 147.72 | 57 | | | |
| N_lapseS | Between Groups | 54.13 | 3 | 18.04 | 3.161 | .032 |
| | Within Groups | 308.22 | 54 | 5.71 | | |
| | Total | 362.34 | 57 | | | |
| N_lapseR | Between Groups | 27.75 | 3 | 9.25 | 2.327 | .085 |
| | Within Groups | 214.66 | 54 | 3.98 | | |
| | Total | 242.414 | 57 | | | |

Using the Tukey comparison for Post-Hoc analysis for the difference in time between the Switch and Repeat Trials, the mean score at a grouped Frustration Level 1 ($M$=323.34, SD =199.58) was significantly different to that at Level 2 (*M*=141.66, SD =117.73) and Level 3 (*M*=161.79, SD =141.29) (see Appendix Y: Number Switching task results by weighted measure of Frustration (MW)). Looking at Figure 104, it is interesting that this change is actually a decrease in change time at this higher level of Frustration. The comparison at the mean at Level 4 *(M*=312.33, SD =115.96) was not significant. From this it could be proposed that some frustration actually helps motivate concentration on task, minimizing this time between trials.

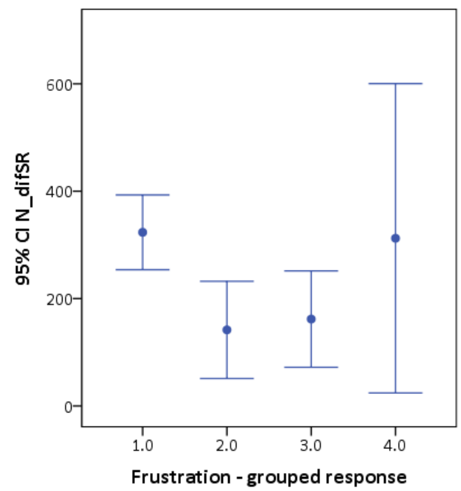


Figure 104 Mean Difference in Time between Switch and Repeat responses by grouped measure of Frustration

In the Error Count measure, the Dunnet T-Test Post-Hoc analysis showed the grouped measure at Level 4 to having a significant difference when compared to the mean Error count at Levels 1 and 3 as shown in Table 9. This was also the case for the Lapse time in the Switch trial.

Table 9 Dunnet t test comparisons for measures in Number Switch Test by grouped self-report measure of Frustration

| Dependent Variable | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| N_errS | 1.0 | 4.0 | -2.3824* | 1.0099 | .044 | -4.705 | -.060 |
| | 2.0 | 4.0 | -1.1111 | 1.1179 | .511 | -3.682 | 1.460 |
| | 3.0 | 4.0 | -2.5833* | 1.0824 | .041 | -5.073 | -.094 |
| N_errR | 1.0 | 4.0 | -2.5686* | .9127 | .014 | -4.668 | -.470 |
| | 2.0 | 4.0 | -1.5556 | 1.0103 | .226 | -3.879 | .768 |
| | 3.0 | 4.0 | -2.5000* | .9782 | .027 | -4.750 | -.250 |
| N_lapseS | 1.0 | 4.0 | -4.2745* | 1.4389 | .010 | -7.584 | -.965 |
| | 2.0 | 4.0 | -3.3333 | 1.5927 | .079 | -6.996 | .330 |
| | 3.0 | 4.0 | -4.1667* | 1.5421 | .019 | -7.713 | -.620 |
| N_lapseR | 1.0 | 4.0 | -2.6765 | 1.2008 | .059 | -5.438 | .085 |
| | 2.0 | 4.0 | -1.4444 | 1.3292 | .452 | -4.501 | 1.613 |
| | 3.0 | 4.0 | -2.5000 | 1.2870 | .107 | -5.460 | .460 |

*. The mean difference is significant at the 0.05 level.

Looking at Figure 105, it can be seen that at the higher level of frustration, there was quite an increase in Error count, especially in the Switch trials. The cause for the drop at a Level 3 is interesting, when compared to the Level 2 of Frustration and may be more an indication of participants likely to score one way or another within these two mid-region areas of Frustration. What is shown is that, in both cases, the Error count and Lapse time were negatively affected by a large increase in Frustration.

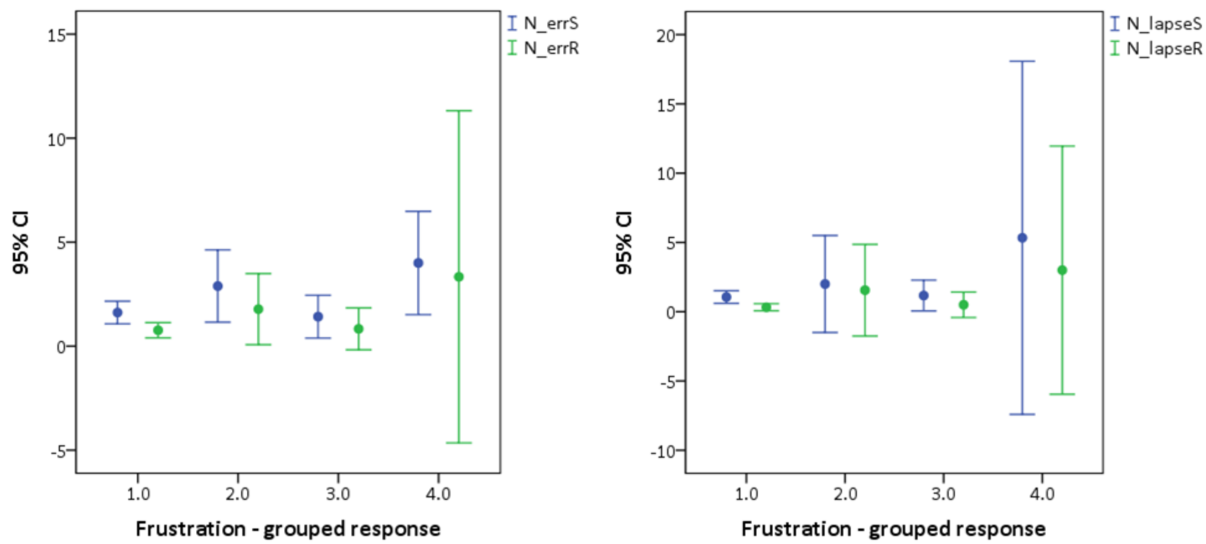


Figure 105 (Right) Mean Error count and (Left) Mean Lapse time in Repeat and Switch Trials by grouped measure of Frustration

### 7.3.2. NASA TLX and Drive condition

Comparing the NASA TLX scores to the drive condition, self-report measures of Physical Demand increased in each condition as seen in Figure 106, with the Baseline score and the Monaco drive having a statistically significant change in mean scores across these self-reported measures. From this it is assumed that participants found the more mentally demanding tasks to also be physically demanding on their system.

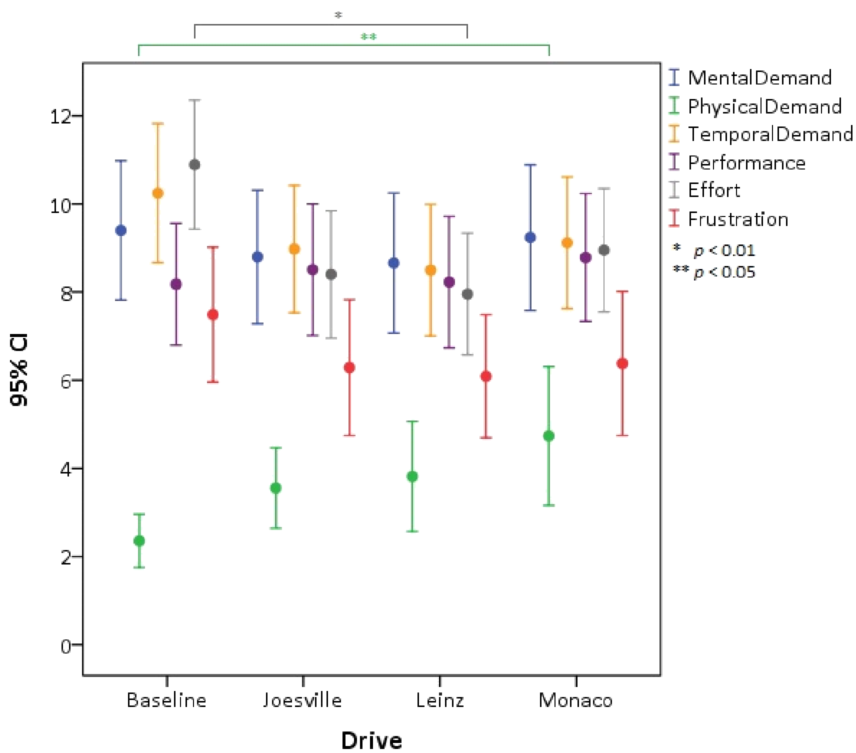


**Figure 106 NASA TLX scores by Drive condition**

Mental Demand did not change much across Drive conditions, although there was a slight increase in the Monaco track because of a trend of decreasing Mental Demand across drives. This same pattern holds true for Temporal Demand, Performance and Frustration. All drive measures for Effort were lower than at Baseline. In particular, the change in mean Effort in the Leinz drive condition to the baseline was statistically significant. This could be an indication of practice effects as continuation of tasks could translate to less Effort needed to complete the task as the participant becomes accustomed to the testing protocol. This effect could have been managed by a pre-exposure study as used in the Motion Fatigue study in Chapter 5: Motion Fatigue.

Across the three tasks all NASA TLX measures, excluding Physical Demand measure, changed depending on which task was undertaken (Figure 107). In every other case, statistically there was a significant difference between the mean TLX score in the Running Letters Task compared to the score of the Stroop task and the Number switching task with the means for the Running Letters task having the statistically higher mean score. For Mental Demand and Frustration statistically there was also a significant difference between mean scores assigned to the Number Switching and the Stroop task, with the Stroop task having the lower measure in both. From this data it is shown that participants found the Stroop task the least mentally demanding and least frustrating of all tasks, followed by the Number Switching Task with the Running Letters task deemed most difficult.

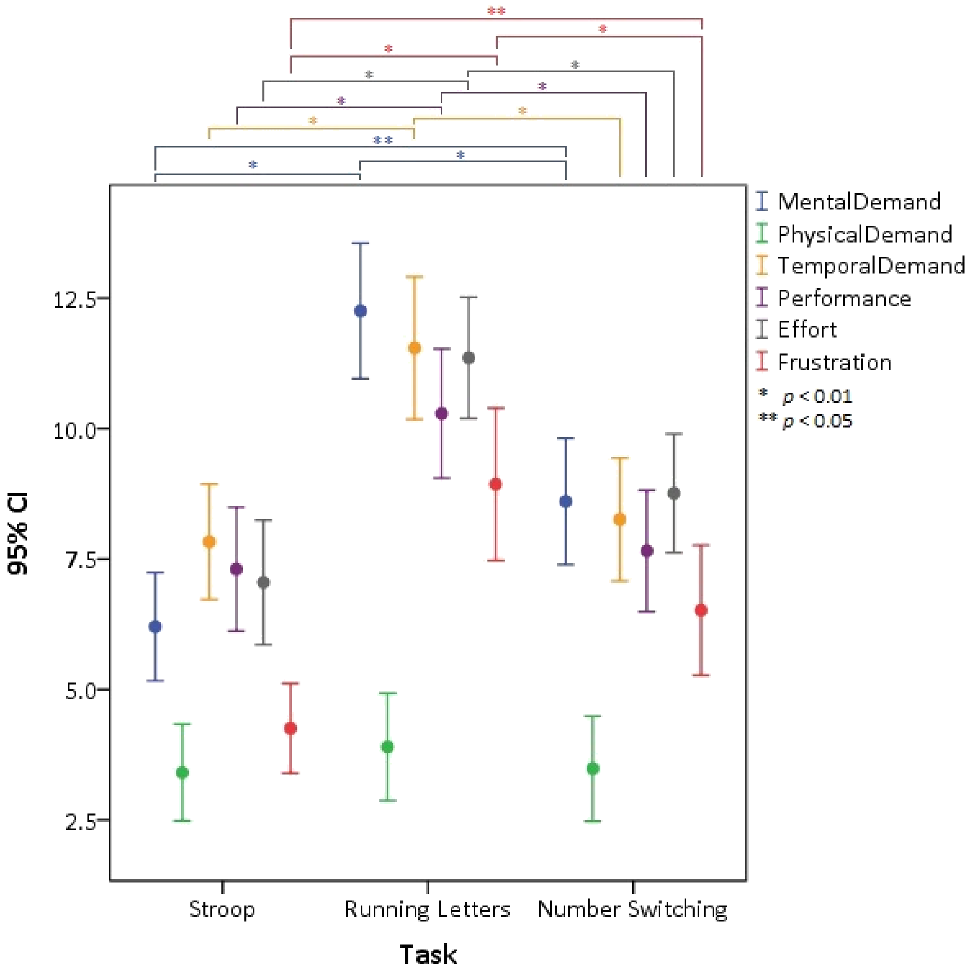


Figure 107 NASA TLX scores by Task

### 7.3.3. Biomeasures

All bio-measures taken were analysed based on Drive condition, task completed and the interaction between Drive condition and Task. The results for each measure are presented in Table 10. The measures of Blink velocity and Heart rate had no significant effect with the drive condition or the task condition (see Appendix Z: Biomeasures by Drive, Task and Drive*Task (MW)).

**Table 10 Table of significance between biomeasures and measures of drive, task and the interaction between drive and task**

| Biomeasure | | Drive | Task | Drive*Task |
|---|---|---|---|---|
| **Blink velocity** | | NS | NS | NS |
| **Pupil Diameter** | | Significant * $F_{(1.99, 25.90)} = 7.66$ # | Significant * $F_{(3,39)} = 16.14$ | NS |
| **Heart Rate** | | NS | NS | NS |
| **Heart Rate Variability** | **Mean RR** | NS | NS | NS |
| | **NN50** | NS | Significant * $F_{(1.15,12.70)} = 12.02$ % | NS |
| | **pNN50** | NS | NS | NS |
| | **RMSSD** | NS | NS | NS |
| | **FFT** | NS | NS | NS |
| **Respiratory rate** | | Significant ** $F_{(1.60, 22.46)} = 6.03$ ## | Significant ** $F_{(3,42)} = 4.18$ | Significant * $F_{(9,126)} = 6.82$ |

* $p < 0.01$ ** $p < 0.05$

\# Mauchly's Test of Sphericity violated $\chi^2_{(5)} = 11.27$, $p < 0.01$. Corrected using the Greenhouse-Geisser estimates for sphericity (e=.664)

\#\# Mauchly's Test of Sphericity violated $\chi^2_{(5)} = 16.81$, $p < 0.05$. Corrected using the Greenhouse-Geisser estimates for sphericity (e=.535)

% Mauchly's Test of Sphericity violated $\chi^2_{(5)} = 35.65$, $p < 0.01$. Corrected using the Greenhouse-Geisser estimates for sphericity (e=.385)

In terms of driving, the Baseline ($F_{(1,13)} = 10.44$, $p < 0.01$), Easy ($F_{(1,13)} = 14.66$, $p < 0.01$), Mountain ($F_{(1,13)} = 5.65$, $p < 0.05$) conditions all had statistically larger mean pupil diameters than in the Formulae one drive. As the Drive conditions increased in difficulty, the pupil diameter appears to decrease in a linear fashion as seen in the left hand plot in a Figure 108. For the tasks, combining the Baseline and Drive scenario together, this condition was statistically found to be significantly different to the diameter during the Stroop task ($F_{(1,13)} = 22.57$, $p < 0.01$), Running Letters task ($F_{(1,13)} = 41.49$, $p < 0.01$) and Number Switching task ($F_{(1,13)} = 20.18$, $p < 0.01$), with these tasks all having a higher standard mean diameter than during the Baseline and driving condition. Whilst the mean diameter in the tasks statistically were not significantly different between task measures, it is of interest that the task thought to be most difficult – The Running Letters task – has a higher mean diameter than the others.

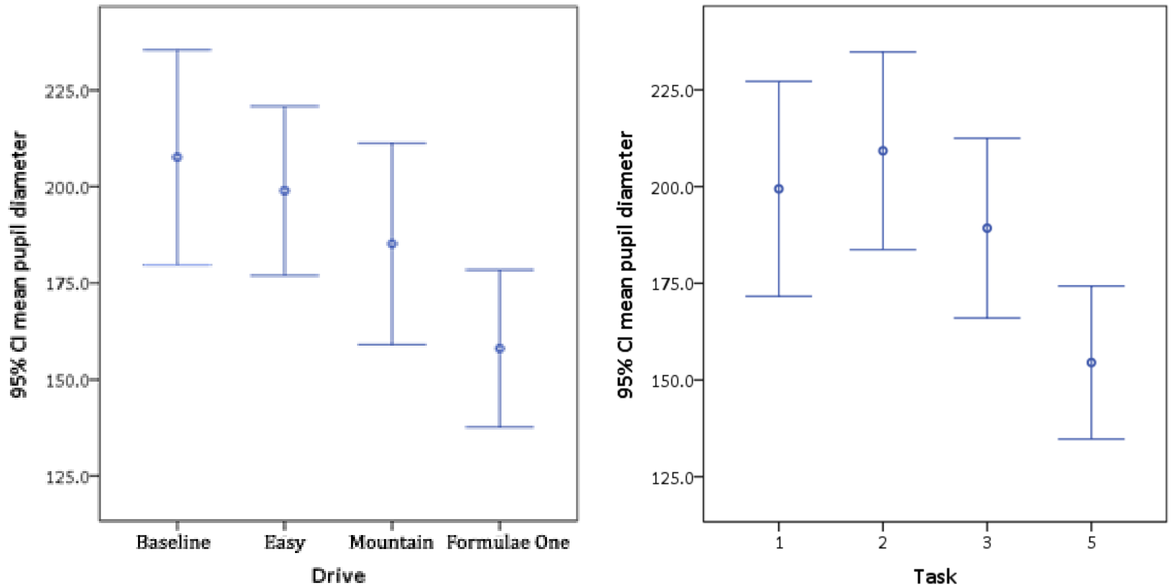


Figure 108 Mean pupil diameter by drive code (Left) and Task code (right)

In the measure of Heart Rate Variability, two participants had data removed due to inflation errors across all scores measured. Once removed, it was only the measure of NN50 statistically that was significant compared to the task. In this case, the combined measure of baseline and drive was found to have a significantly different NN50 count to that in the Stroop task ($F_{(1,11)} = 13.93$, $p < 0.01$), the Running Letters task ($F_{(1,11)} = 11.26$, $p < 0.01$) and the Number Switching task ($F_{(1,11)} = 12.33$, $p < 0.01$) as shown in Figure 109.

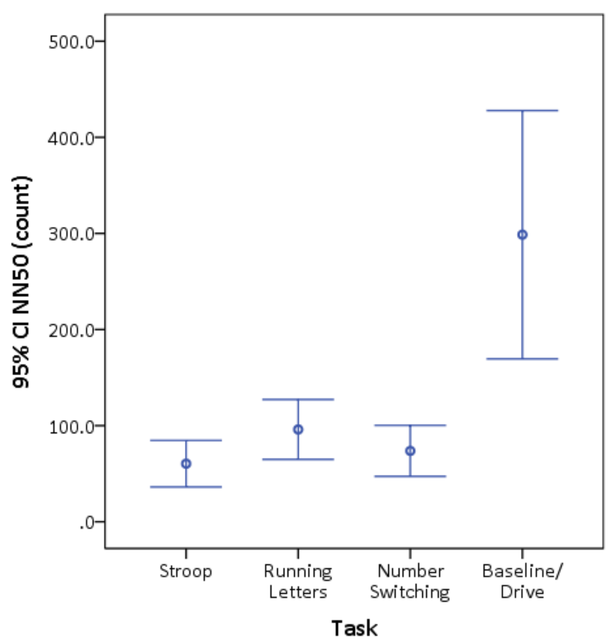


Figure 109 NN50 count by Task

Respiratory rate had statistically significant differences in mean rates across all measures of the Drive condition; the Task and the interaction between Drive and Task (see Table 10). Using a Bonferroni pairwise comparison, in the Drive condition, the mean respiratory rate in the first drive, Joesville speedway (*M*= 19.09, SD=0.87), was statistically significantly different at the .05 level to the mean respiratory rates at the Baseline (*M*= 17.33, SD=1.03), the Leinz drive (*M*= 17.40, SD=.77) and the Monaco drive (*M*= 16.54, SD=0.91). The increase in respiratory rate for the Joesville drive is shown in Figure 110. This increase was most likely due to the motion and simulation acting as a stimulant which drops in subsequent drives as the novelty of the motion decreased. For the task, the mean respiratory rate for the Running Letters task statistically was significantly different to that at the Baseline/Driving condition ($F_{(1,14)} = 10.01$, $p < 0.01$). As this is the most difficult task, this decrease could be indicative of the increased mental load needed to complete the task.

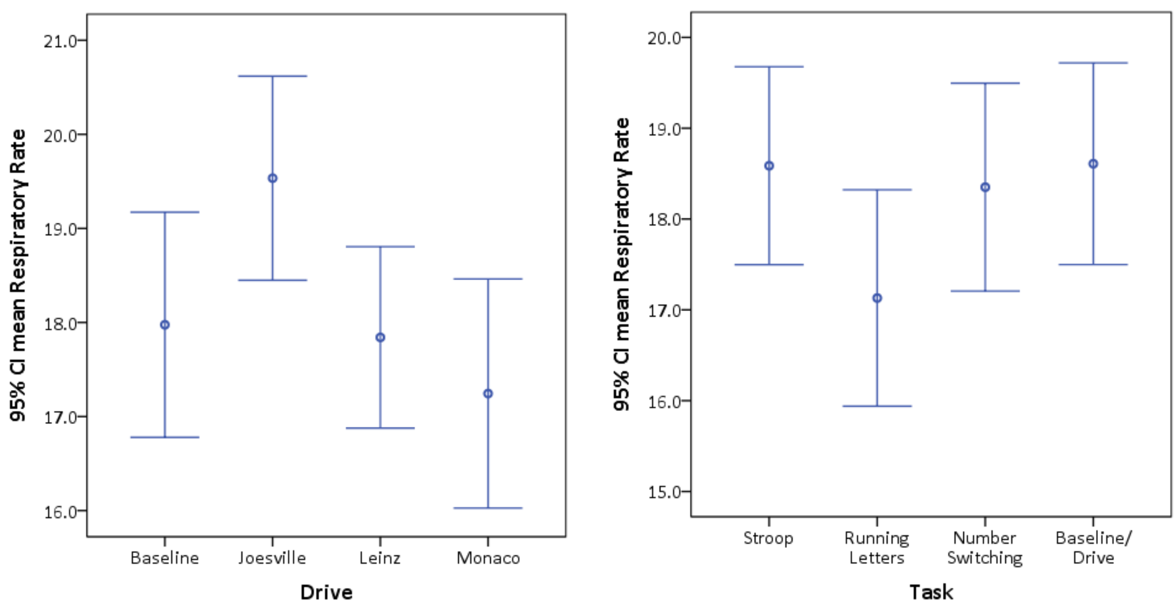


**Figure 110 Respiratory rate by Drive (Left) and Task (Right)**

For the Interaction between task and drive as shown in Figure 111, the comparison from the baseline and Monaco drive were statistically significant with the comparison of each task: Stroop ($F_{(1,14)} = 6.63$, $p < 0.05$), Running Letters ($F_{(1,14)} = 26.24$, $p < 0.01$) and Number Switching ($F_{(1,14)} = 15.64$, $p < 0.01$) as compared with the driving condition. Looking at the graph in Figure 111, there was a trend of the respiratory rate dropping across each drive for each task condition, including within the driving component.

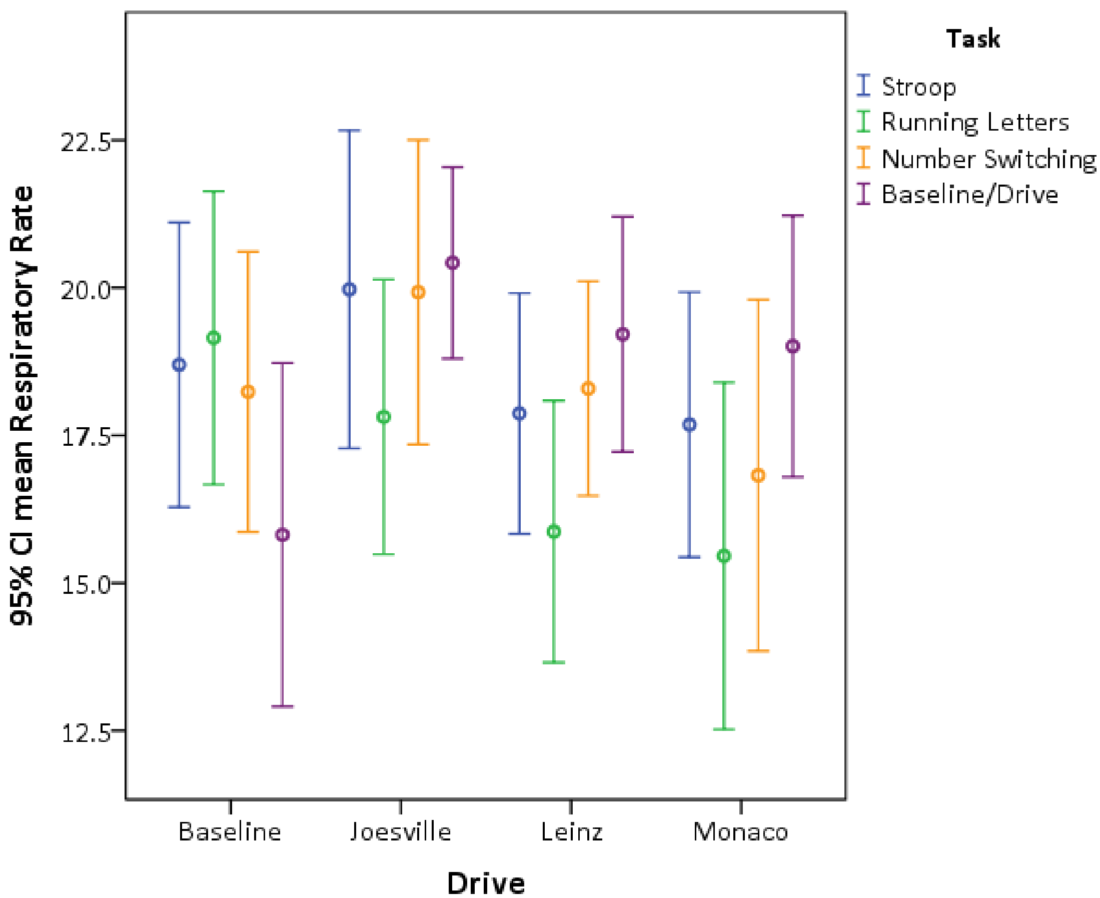


Figure 111 Respiratory rate and the interaction between Drive and Task

## 7.4. Discussion

In this study, there has been a report on the subjective measure of the NASA TLX and the objective bio-measures across three drive conditions of increasing mental workload and across three cognitive tasks known to use up changing cognitive resources. The aim of the output of this study was to suggest which subjective and objective measures are most indicative of mental workload, and which would be suitable in an outdoor operational environment. Of the tasks used in this study, the most mentally demanding task was the Running Letters task which focused on working memory. Each Drive condition steadily increased in difficulty from Joesville circuit, to the Leinz Week 3 trail, with the Formulae One Monaco track requiring the most mental resources. Two areas of the NASA TLX scores – Mental Demand and Frustration were found to be most linked to task performance. Interestingly, neither of these measures is related to the most difficult task of Running Letters. Perhaps this task was too difficult for the accuracy measure to be useful in which case the biomeasure is a better indicator of mental demand than the subjective scores. In regards to the bio-measure performance TEPR, the NN50 count of the HRV and Respiratory Rate were found to be the most indicative measures relating to mental state.

Looking solely at the Drive condition and Task performance in the more difficult Monaco track, there was an increase in errors in the Congruent and Incongruent trials of the Stroop task as well as an increase in errors in the Switch trials of the Number Switch task. Lapse time in Neutral trials for the Stroop task and mean time for the Switch trials in the Number Switch task had a trend of increasing in the Monaco track, as opposed to decreasing, as would be expected from Practice effects. These results are interesting, firstly because the accuracy in the Running Letters task statistically was not significantly affected by the Drive condition. There are two possibilities that could explain this occurrence. The first possibility is that the task was too difficult, thereby overwhelming the participant despite the changing workload measures within the drive. The second is that the mental workload needed to complete the task was at such a level that changing drive conditions have no effect. Regarding the measures affected, we can see that the Drive condition, particularly the last, does have an effect with the increased errors in incongruent conditions in both affected tasks, as would be expected from increased Mental Demand. This change validates the types of tracks chosen for this study. They have shown an increase in difficulty and in the demand upon mental resources needed to complete the tasks.

The practice effects are an unfortunate outcome of the style of testing where the mental demand is set to steadily increase. With the validation that the Monaco drive does require further mental resources, future studies in this area should be randomized in order to study conditional changes in Mental Workload. Beyond this, it would also be advisable to have an exposure trial with all tasks so as to minimize the practice effects and any stimulant effects from the initial drive.

In the examination of the NASA TLX measures, the Mental Demand measure highlights changes within the Number Switch Task, suggesting that it is the most recognisable task by participants when their mental reserves were being used. In this survey of self-response, trends indicated an increase in mean time, errors, and lapse time in both Switch and Repeat trails as the self-report of Mental Demand increased.

The results relating to the Physical Demand measure should be interpreted with caution. Most participants were confused how to respond to this measure of the NASA TLX as the tasks were not physically demanding. There was a trend of increased time in Incongruent and Congruent trials for the Stroop Test and increased errors in Congruent and Neutral trials and the Physical Demand self-measure increases, but because of the confusion and potential irrelevance of this measure in the context of simple cognitive tasks, little weighting has been placed on these results.

Of greater interest than Physical Demand is the measure of Temporal Demand. In the NASA TLX context, this measure relates to the subjective view of the pace of the task. Accuracy in the Running Letters task actually increased ¾ up the scale before dropping. The Mean time taken, total Errors and Lapse time in the Number Switch task all increased with Temporal Demand. It is of interest that across the Number Switch task, the more rushed the participant felt, the more errors were made. However, the Accuracy in the Running Letters task actually improved with a degree of Temporal Demand. This could reflect the styles of task; it is possible that memory holding is improved to some degree by quickness of pace while mental flexibility subsequently is negatively affected by a rushed pace. This should be considered when deciding the types of tasks military personnel are expected to complete and what the mean response time would be, and how it would affect the outcome in task performance.

The Performance measure of the NASA TLX is a self-reflection measure of how the participant views their performance, correlated to what their actual performance is. In the Stroop Task and the Number Switch task, participants knew if they passed or failed by the coloured signs displayed after each stimulus that the participant responded to. Even though both tasks had this feedback, it is only the Stroop task that showed a direct correlation with the participants being able to self-evaluate their performance. Error in Incongruent trials actually decreased with increased perceived ‘failure’ of performance which was unexpected. More to expectation, the errors in Neutral trials increased with increased perception of ‘failure’. This measure, like the Physical Demand, should also be treated with caution. In all measures, a high level response was indicative of negative performance e.g. high mental demand. However participants not paying attention could have assumed that a high rank of their Performance indicated good performance as opposed to bad performance as stated by the scale. If participants continued to work with the trend of a high scale being positive as opposed to negative, this would change results. It is also quite possible that only a few participants made this error, thus leading to such mixed results. As with Physical Demand, I would advise treating these results with great caution.

In Effort, the Number Switch task error in repeat trials and lapse time in Switch trials increased with Effort as would be expected. Many measures in the Effort domain actually showed Effort decreasing with repetition. This decrease may be indicative of practice effects. Supposedly the more often a task is repeated the less effort would be needed to complete a task. In this measure, the exposure and mixed trial format, commented on earlier, would be advisable for all future studies in this domain.

Frustration was the final measure in the NASA TLX and reflects an emotional response to the participant's workload. Once more the accuracy of the Running Letters task was not a measure found to be related to this sensation. The Stroop task had the difference in time between Incongruent and Neutral tasks decrease with increased frustration. This means that the time in tasks that had required more mental processing actually decreased with some frustration. The mean time for Congruent and Neutral tasks, the error count and the Lapse time for Neutral and Incongruent tasks also increased with Frustration showing Frustration to have a negative impact on Stroop task performance. In a similar effect, the difference between mean Switch and Repeat responses in the Number switch task decreased at mid-range Frustration but increased at the high end Frustration showing this measure to have a negative effect on this task. The Error count and Lapse time in the Number Switch task had a shared trend to increase at high levels after a small drop at a mid-high reading of Frustration. It is speculated that some degree of Frustration is beneficial in concentration for mental switching; however, high levels of Frustration will have a negative effect of performance.

Investigating the NASA TLX measures with the Drive condition, Physical Demand is actually shown to increase with increased difficulty across drives. Mental Demand, Temporal Demand, Effort, Performance and Frustration all decreased slightly across drives, increasing with the Monaco track. This shows the Monaco track was a good instigator of increasing the mental workload of the participant. In all, the Stroop task had the lowest scores of Frustration and Mental Demand as rated by participant self-report with the Running letters task having a statistically significant mean increases across all NASA TLX measures (bar Physical Demand) when compared to both of the other tasks. This highlights this task once more as using the most mental reserves, even though this was not reflected in the individual scores at each measure.

For the bio-measures, only three of the measures taken showed any relevance to the Drive and/or Task condition. These measures included the pupil diameter, the NN50 count of the Heart Rate Variability measures and the Respiratory Rate. Of the NN50 count, the only trend worth noting was that the Baseline and Drive conditions had a much higher count than the Tasks, showing that the changes in the mental workload of Tasks can affect this measure. The Pupil Diameter was somewhat more indicative. It decreased across each drive as the mental demand of the drive increased. It is most likely that this behaviour was in response to the arousal effect of the stimulant of being in a motion simulator that diminishes as time continued despite the increased mental workload required in the completion of the drive. In comparison of Tasks to Drive, each Task had a higher mean diameter than the Drive condition with the Running letters task having an overall increased mean diameter reflecting the increased mental workload. In this way, and as is indicated in these task-based analytic studies within a military context, pupil diameter can function as an effective measure to determine how individual mental demand increases in a way self-reports cannot. The only issue with TEPR is that, glasses such as those used for monitoring in this study are suited for enclosed environments with controlled lighting. Uncontrolled natural lighting will change pupil diameter and confound results.

Whilst Pupil Diameter may fail in an uncontrolled lighting situation, respiratory rate can be measured in any situation and has been shown to be significant across all measures involved in this study. As with the pupil diameter, there was an odd trend in the Drive condition with an increase in the Joesville track that was statistically significant over the Leinz and Monaco tracks. This again could be linked to the stimulant effect. As the Drives were conducted for longer periods then the task, its repetition would be expected to lead to a decreased respiratory rate and discussed from Bauer et al's paper in the Introduction of this chapter. It can also be proposed that this decrease in Respiratory Rate could be linked to the participants having increased concentration, entering a Flow-like state. This would explain why, compared to the drive condition, the Running Letters task statistically had a significantly lowered mean Respiratory Rate. It was also lower on average than the Stroop task and the Number Switch task that is indicative of the increased concentration needed for this style of cognitive load. Each task also had a decrease across each Drive so that, as the Drive difficulty increased, the respiratory rate in the corresponding task decreased. Further research is needed using a mixed drive scenario to test if this is from repetition or whether it is a true reflection of increased mental demand. From this study the indication does point to respiratory rate as an ideal objective measure for the military context.

In terms of NASA TLX performance and task performance, it appears that task change in the Number Switch mode is more indicative of mental workload. This could be due to the Running Letters task being too difficult for some participants. By analysis of the bio-measures, the Running Letters task is clearly defined as the task using the greatest mental resources. This change between the subjective scale and objective scale should be of great consideration in further studies. Where the mental flexibility task and accuracy are taken into account, a self-report measure is justified. However, for areas of working memory where there is no direct feedback on performance, it appears that the participant is unable to accurately rate their information on a subjective scale in the same way that an objective bio-measure, such as respiration, can.

## 7.5. Conclusion

A number of parameters within the NASA TLX subjective scale and bio-measures were analysed across a range of tasks and drives with varying difficulty. Of the Mental Workload parameters, for simpler tasks with performance feedback, participants were able to accurately gauge what their performance on a subjective scale was. However, in more difficult tasks with no feedback, their self-judgment appeared to be hindered. In this scenario, bio-measures proved to be more reliable. Of those measured in this study, participant respiratory rate proved to be the most consistent measure for reflecting mental workload and it is a measure that can easily be monitored in the field.

# 8. Summary, Conclusion & Future Work

The aim of this thesis was to explore four different motion effects; Motion Sickness, Motion Fatigue, Motion Perception, and Mental Workload under motion, in order to evaluate what such conditions would have on performance. In particular, this thesis focused on performance measures relating to a military context, in line with contract specifications and research as set out by the University of Sydney in conjunction with the Defence Science and Technology Organisation, Land Operations Division. Throughout this thesis, task performance, bio-measurements and subjective scales have been used extensively to broaden the understanding of participant reaction to these motion conditions. In most cases the task sets have, at least in part of each study, utilised the emulated Battle Management System emulator which simulates tasks that soldiers are expected to complete within the field. When these tasks have proved insufficient, due to lack of cognitive load, similar cognitive-based tasks have replaced, or are used in conjunction in order to report a greater understanding over how each motion condition affects a participant's performance ability.

The study of the effect of Motion/Simulator Sickness on participants was the first study conducted in this thesis and the first to reveal the lack of discrimination factors of performance within the BMSe that compares various motion conditions. In this study, participants were classed as either having progressive nausea symptoms, adapted symptoms (feeling ill at the start but then becoming accustomed to the motion), or no nausea. In the BMSe task, there was no detrimental effect for nauseated participants as would be expected from previous literature. This could be due to a heightened engagement of nauseated participants that counteracts the detrimental effects, a lack of difficulty in the tasks to statistically find enough significant differences between scoring measures or a lack of engagement from the non-nauseated sufferers. To address each of these possibilities, the study was repeated with more interesting tasks presented at regular exposure intervals to improve both the levels of engagement and difficulty of the task sets. Three tasks: Reaction time, TBAS Dot and Memory Match were used in this part of the study. Of the task measures takes, the measure of errors in the Reaction time task was statistically significantly higher for those in the PN group as compared to the other groups. There were indications that the PN had lower accuracy in the TBAS Dot task and that the AN group did worse in the Match test. However, both the TBAS DOT test and the Match test were affected by practice effects. As the AN and PN groups did not do as many iterations of this task, only the Reaction Time task data can be properly commented on at this time. A multiple-exposure run to the TBAS Dot and Memory Match test before the study would be recommended for any future work in order to better explore the outcomes of these test parameters. Future studies should also include a larger group set to accurately determine whether some of the data relating to the AN group, as separate to the PN group, holds true.

The study on Mental Fatigue was developed based on lessons learnt in the Motion Sickness study. From the motion sickness study three outcomes were found that needed to be taken into account for the experimental design:

1. The idea of exposure to tasks was highlighted as a necessary step for the cognitive task sets to reduce learning effects.
2. The simulator is a stimulant – participants are excited by the novelty.
3. Those likely to get sick will do so within half an hour of driving the desert track as selected for the Motion Sickness study, having been found to be the most nauseating track of the rFactor track designs.
4. The BMSe task set may not be difficult enough to see changes in task performance.

Using this knowledge, this segment on Motion Fatigue developed as a two-part study. The first part acted as an exposure test. By exposing participants to the simulator environment it allowed for training in its use, for training in tasks in order to minimise practice effects and for an exposure to motion to expose if a participant would develop simulator sickness symptoms or not. As ethical guidelines for this thesis ruled that participants could leave at any time they felt too ill to continue, it was paramount to remove from this study at an early stage those participants who would be unable to be involved for the entire 1.5 hours of the study (1 hour of which is solely driving the simulator). Participants needed to drive the entire 1 hour to allow for a proper comparison between fatigue condition types. Those who felt ill in the exposure drive could thus be excused from returning for the longer fatigue drive.

To address the issues of the BMSe task set, the study was first performed using cognitive tasks (Reaction Time and Colour Stroop test) as a proof of concept – to test that the study did accurately show participants could be fatigued in a measureable way. The study was repeated again with BMSe tasks in order to maintain the relevance of the outcomes found for the Defence Force context.

The outcomes of the study were to see if motion fatigue or fatigue due to boredom was worse for a participant and to test what bio-measure is best at predicting fatigue. From the first outcome, knowledge of the worse condition has a direct correlation to looking at task vehicle design and engagement of soldiers within a vehicle. Is it worse if they are bored, or is it worse if they are too uncomfortable due to bad suspension over bumpy terrain?

The study of Motion Fatigue using cognitive tasks confirmed the test procedure, with a trend in Reaction Task time measure to increase with exposure time. There was very little change in the Stroop task measures, as was the case in the Motion Sickness study. From the repeat of the study using the Defence force task set, there were more errors in the BMSe in the Boring condition than in the Motion condition. This suggests that under-arousal is worse than physical fatigue as far as soldier performance is concerned. This theory is supported by the biomeasures used in this study where the heart rate and respiratory rates were higher in the motion condition, suggesting higher engagement in this condition over the boring measure. It should be remembered however that there were some issues in the Create Line and Read Unit measures within the BMSe tasks in this study that need to be further investigated.

Of the bio-measures used, the most reliable in relation to fatigue was the respiratory rate and the measure of RMSSD between normal beats of the Heart Rate Variability measure. Both measures can be taken in the field with minimal discomfort to any military personnel. Of the subjective scales used, both the Stanford Sleepiness scale and self-report of pre- and post- simulator fatigue were found to be closely linked to actual fatigue measures, showing that the participants in this study were able to accurately report on their own level of fatigue.

Fatigue was compounded in this study by minimising ambient light and having lowered to no sound feedback. However, it is still limited by the total time of participant exposure within the constraints of the experiment. It would be worth repeating the experiment for a longer period of time where resources allow for such a study.

The exploration of Motion Perception effects under workload was an attempt to address a question very rarely seen or properly analysed in literature: Is there an axis, or intensity along an axis of motion that is worse for performance than others? This has great impact on vehicle design and considerations. In vehicle design if one axis is worse than another, this could be considered in chassis design and suspension parameters. For travel in vehicles that already exist and are used in the field, should one axis be found worse than another, this would need to be accounted for when assigning workloads and when regarding expectations on a given situation on the ability of military personnel to effectively execute a given task.

The three levels of intensity of motion were limited in accordance to the Australian standards such that the highest intensity was at most ‘uncomfortable’ according to this specification. It is mostly trends, however, that can be reported on in each test for Motion Perception, rather than findings of statistical significance as there was no statistical significance found.

The experimental design can be greatly improved from the addition of further practice of tasks prior to motion and by increasing the task difficulty. As an overall trend, higher intensity of motion leads to an increase in errors across tasks as would be expected. The Roll condition has the highest errors across all combined tasks when compared to all other axes. Performance in the Pan-Zoom, Create Unit and Create Text tasks were negatively affected by motion along the X axis, however, performance along the three other tasks in this axis were actually improved. Based on this, it is advised that if one task measure is more important than another from the task set, the Defence Force should closely examine the trends listed in the Motion Perception chapter for that task. An example of such a task case is that the Create Unit, Read Text and Read Unit tasks take longer to complete when motion is along the Z-axis in a High intensity condition whereas the other tasks in the set take less time to complete in this same motion.

The Pitch axis may require further consideration for future studies. Whilst not apparent in this study to have has an effect on performance for the BMSe task, there was a suggestion from participant response that this motion could be linked to the development of symptoms relation to motion sickness. This bears implications for the comfort of personnel.

The Mental Workload segment was the last study of the DSTO contract and the final study conducted for this thesis. It differs from the other studies in that the BMSe tasks were not used at all. It was found from the previous studies that this task set was not sufficiently difficult for participants, showing very little changes over the conditions of Motion Sickness, Motion Fatigue and Motion Perception. For a study focused on identifying mental resources being used and analysing the best measure of mental workload in a task, the tasks had to have a sufficient level of difficulty to utilise mental resources. It also differs from the other studies in that the concentration is shifted from a focus on task performance to that of determining the best measurement device to monitor this condition.

This study was designed to have an increasing workload in the style of drive condition with three separate cognitive tasks of varying difficulty being presented randomly across the three drives of increasing difficulty. The design had the aim of steadily increasing mental workload to test if there was an upper limit of workload to be reached by the final drive. This worked but, as always in such studies, practice effects need to be considered. The experimental design in the future should include base training of tasks and another study should be completed using randomised drives presented to ensure the data presented here can be accurately stated.

In terms of self-report, it was found that participants are able to accurately self-judge their own workload when given a simple task. More complex tasks with no feedback however lead to a decrease in accuracy of self-reporting their own performance. This is where bio-measures are needed to better signal how a participant is being affected. Of the bio-measures analysed in this study, pupil diameter and respiratory rate were both good indicators of changing mental workload, responding appropriately to mental workload as expected from previous research in this area. Between the two, pupil diameter needs to be viewed with caution. In an enclosed cabin-style vehicle such as a tank, pupil diameter can be an effective measure. However, vehicles with windows exposed to a changing ambient light source will be negatively affected due to the uncontrolled external lighting conditions. Respiratory rate is not affected by lighting changes and so, from a field perspective, it is the recommended choice for the DSTO to incorporate in their own monitoring conditions.

There are a number of limitations to these experiments to be kept in mind for future studies. First and foremost that, whilst the simulator used is effective in measuring the six axes in having motion closely resembling that of the gaming environment, it is still not a perfect correlation to the real world. This needs to be remembered for all study outcomes – the data shown is for this specific simulated environment. Real-world paralleled tests would need to be carried out to confirm the findings.

Ethical guidelines also limit the exposure time of participants within the simulator. For the study of Motion Sickness in particular, this restriction may have meant that effects in performance for those in the PN and AN group were missed due to participants exiting early. Such an early exit is often not an option in the military context and so further investigation may be needed to confirm the findings of this study.

The number of participants is also a limitation. Only one simulator could be driven at any time. The number of students that could be enlisted is limited in two thirteen week semesters each year with the study needing to be completed at the time of this thesis. A larger pool of participants would help confirm the findings listed here in regards to the cognitive findings (the BMSe tasks need to be made more difficult before use in future tests) and in regards to testing if Pitch is truly the most uncomfortable axis of motion when trying to complete a task.

Along with a larger subject pool, there are some failings in sequence of tasks and task choices as discussed earlier and in the discussions relating to each chapter. These should be taken into account for all future studies of this type in the future. Adding the exposure trial, as used in the Fatigue test, is an ideal study parameter for each study if time allows for such a measure.

In terms of the military context, the suggestions made throughout this thesis are those relating to the findings in a simulator with first year psychology students. Whilst students feel involved in the study in order to obtain task credit, their attention and engagement would be different to that of a soldier acting in the field. Laboratory studies repeating these experiments with soldiers would be ideal to test the exact parallels between the two groups.

This thesis has investigated four motion effects with reports on the impact on task performance, subjective response and biological response measures. It aimed to address many current gaps in literature relating to how participants respond to various motion conditions from a defence force task perspective. Whilst further investigation is needed, it is the start of improving our understanding in how motion and simulation can affect how we perform and react to different scenarios.

# 9. References

2012. *Test of Basic Aviation Skills (TBAS)* [Online]. Baseops. Available: http://www.baseops.net/militarypilot/tbas.html [Accessed 26/11/2014 2014].

2014. *Battle Management Systems BMS* [Online]. Elbit Systems. Available: https://www.elbitsystems.com/elbitmain/area-in2.asp?parent=4&num=41&num2=41 [Accessed 26/11/2014 2014].

AARONSON, L. S., TEEL, C. S., CASSMEYER, V., NEUBERGER, G. B., PALLIKKATHAYIL, L., PIERCE, J., PRESS, A. N., WILLIAMS, P. D. & WINGATE, A. 1999. Defining and Measuring Fatigue. *Journal of Nursing Scholarship,* 31**,** 45-50.

ADAMS, S. Practical Considerations for Measuring Situational Awareness. Third Annual Symposium and Exhibition on Situational Awareness in the Tactical Air Environment, 1998 Piney Point, Maryland. Defense Technical Information Center, 157-163.

ASSOCIATES, N. 2004. *The Language of the Brain* [Online]. Lombard IL: Neurohealth Associates. Available: http://www.nhahealth.com/science.htm [Accessed 08-02-2013 2013].

BARANSKI, J. V., THOMPSON, M. M., LICHACZ, F. M. J., MCCANN, C., GIL, V., PASTO, L. & PIGEAU, R. 2007. Effects of sleep loss on team decision making: Motivational loss or motivational gain? *Human Factors***,** 646-660.

BASRI, B. & GRIFFIN, M. J. 2012. Predicting discomfort from whole-body vertical vibration when sitting with an inclined backrest. *Applied Ergonomics,* 44**,** 423-434.

BAUER, L., GOLDSTEIN, R., STERN, J. & WALRATH, L. 1987. Auditory Discrimination and the Eye Blink. *Psychophysiology,* 22**,** 636-641.

BEATTY, J. 1982. Task Evoked Pupillary Responses, Process Load, and the Structure of Processing Resources. *Psychological Bulletin,* 91**,** 276-292.

BHIWAPURKAR, M. K., SARAN, V. H., HARSHA, S. P., GOEL, V. K. & BERG, M. 2010. Influence of Mono-axis Random Vibration on Reading Activity. *Industrial Health,* 48**,** 675-681.

BILLS, A. G. 1931. Blocking: A new principle of mental fatigue. *American Journal of Psychology***,** 230-245.

BROADBENT, D. E. 1979. Is a fatigue test now possible? *Ergonomics***,** 1277-1290.

BROWN, I. 2011. *Correlation of affective and cognitive variables in computer based tasks.* Doctor of Philosophy, University of Sydney.

BROZEK, J. 1970. CONTRIBUTIONS TO THE HISTORY OF PSYCHOLOGY: XII WAYWARD HISTORY: FC DONDERS (1818-1889) AND THE TIMING OF MENTAL OPERATIONS. *Psychological reports,* 26**,** 563-569.

BRUCK, S. & WATTERS, P. A. Estimating cybersickness of simulated motion using the Simulator Sickness Questionnaire (SSQ): a controlled study. Computer Graphics, Imaging and Visualization, 2009. CGIV'09. Sixth International Conference on, 2009. IEEE, 486-488.

CHUA, E. C.-P., TAN, W.-Q., TEO, S.-C., LAU, P., LEE, I., MIEN, I. H., PUVANENDRAN, K. & GOOLEY, J. J. 2012. Heart rate variability can be used to estimate sleepiness-related decrements in psychomotor vigilance during total sleep deprivation *Sleep,* 35**,** 325-334.

COOPER, G. 1998. *Research into Cognitive Load Theory and Instructional Design at UNSW* [Online]. University of New South Wales. Available: http://dwb4.unl.edu/Diss/Cooper/UNSW.htm [Accessed 31 July 2013 2013].

DAVIES, D. R. & PARASURAMAN, R. 1982. *The psychology of vigilance,* London, Academic Press.

DEMBER, W. N. & WARM, J. S. 1979. *Psychology of Perception,* New York, Holt, Rinehart and Winston.

DILDA, V., MACDOUGALL, H. G., CURTHOYS, I. S. & MOORE, S. T. 2012. Effects of Galvanic Vestibular Stimulation on Cognitive Function. *Exp Brain Res.,* 216**,** 275-285.

DINGES, D. F., MALLIS, M. M., MAISLIN, G. & POWELL, J. W. 1998. Final Report: Evaluation of Techniques for Ocular Measurement as an Index of Fatigue and as the Basis for Alertness Management. Washington, DC: National Highway Traffic Safety Administration.

ELLIOT, R. 2003. Executive functions and their disorders. *British Medical Bulletin,* 65**,** 49-59.

FARMER, R. & SUNDBERG, N. D. 1986. Boredom proneness: The development and correlates of a new scale. *Journal of Personality Assessment***,** 4-17.

GOLDING, J. F. 1998. Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. *Brain Research Bulletin,* 47**,** 507-516.

GOLDING, J. F. 2006. Predicting individual differences in motion sickness susceptibility by questionnaire. *Personality and Individual Differences,* 41**,** 237-248.

GOLDING, J. F. & KERGUELEN, M. 1992. A comparison of the nauseogenic potential of low-frequency vertical versus horizontal linear oscillation. *Aerospace Medical Association* 63**,** 491-497.

GOLDSMAN, D., NANCE, R. E. & WILSON, J. R. A Brief History of Simulation. *In:* M. D. ROSSETTI, R. R. H., B. JOHANSSON, A. DUNKIN, AND R. G. INGALLS, ed. Winter Simulation Conference, 2009 Austin, Texas, USA.

GORDON, G. 1978. The development of the General Purpose Simulation System (GPSS). *SIGPLAN Not.,* 13**,** 183-198.

GREENYER, F. 2008. A History of Simulation. *MS&T Magazine.*

HARM, D. L. 1990. Physiology of Motion Sickness Symptoms. *In:* CRAMPTON, G. H. (ed.) *Motion and Space Sickness.* Boca Raton, Florida: CRC Press.

HARRISON, Y. & HORNE, J. A. 2000. The impact of sleep deprivation on decision making: A review. *Journal of Experimental Psychology: Applied***,** 236-249.

HART, S. G. NASA-Task Load Index (NASA-TLX); 20 years later. Human Factors and Ergonomics Society 50th Annual Meeting, October 2006 2006 San Francisco, USA. 904-908.

HART, S. G. & STRAVELAND, L. E. 1988. Development of the NASA-TLX (Task Load Index): Results of empirical and theoretical research. *In:* HANCOCK, P. A. & MESHKATI, N. (eds.) *Human Mental Workload.* Amsterdam: North Holland Press.

HARTLEY, L. R. & ARNOLD, P. K. 1995. Subjective and Objective Measures of Fatigue when Driving. Institute for Research in Safety and Transport.

HERGENHAHN, B. & HENLEY, T. 2013. *An Introduction to the History of Psychology*, Cengage Learning.

HETTINGER, L. J., KENNEDY, R. S. & MCCAULEY, M. E. 1989. Motion Sickness and Human Performance. *In:* CRAMPTON, G. H. (ed.) *Motion and Space Sickness.* Boca Raton, Florida: CRC Press.

HIRA & GUPTA 1998. *Operations Research*, Dhanpat Rai & Sons.

HITCHCOCK, E. M., DEMBER, W. N., WARM, J. S., MORONEY, B. W. & SEE, J. E. 1999. Effects of cueing and knowledge of results on workload and boredom in sustained attention. *Human Factors and Ergonomics Society,* 41**,** 365-374.

HIXSON, W. C., NIVEN, J. I. & CORREIA, M. J. 1966. Kinetics nomenclature for physiological accelerations: with special reference to vestibular applications. *Us Nav Aerospace Med Inst [Pensacola] Monogr,* 14**,** 1-81.

HODDES, E., DEMENT, W. & ZARCONE, V. 1972. The Development and use of the Stanford Sleepiness Scale (SSS). *Psychophysiology,* 9**,** 150.

HOLLOCKS, B. W. 2008. Intelligence, innovation and integrity - KD Tocher and the dawn of simulation. *Journal of Simulation,* 2**,** 128-137.

HOLLY, J. E. & HARMON, S. M. 2012. Sensory conflict compared in microgravity, artificial gravity, motion sickness, and vestibular disorders. *Journal of Vestibular Research-Equilibrium & Orientation,* 22**,** 81-94.

HOUSTON, C. S. 1992. Mountain Sickness. *Scientific American.* Scientific American, Inc.

JOAKIM DAHLMAN, SJÖRS, A., LINDSTRÖM, J., LEDIN, T. & FALKMER, T. 2009. Performance and Autonomic Response During Motion Sickness. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 51**,** 56-66.

JOHNS, M. 2003. The amplitude-velocity ratio of blinks: A new method for monitoring drowsiness. *SLEEP - Annual Meeting of the Associated Professional Sleep Societies (APSS).* Chicago, Illinois: SLEEP journal.

JOHNSON, L. C. 1982. Sleep Deprivation and Performance. *In:* WEBB, W. B. (ed.) *Biological Rhythms, Sleep, and performance.* John Wiley & Sons.

KAHNEMAN, D. 1973. *Attention and Effort,* Englewood Cliffs, New Kersey, U.S.A.

KANFER, R. 2011. Determinants and Consequences of Subjective Cognitive Fatigue. *In:* PHILLIP L. ACKERMAN, P. (ed.) *Cognitive Fatigue: Multidisciplinary Perspectives on Current Research and Future Applications.*

KELLER, J. Human performance modeling for discrete-event simulation: workload. Simulation Conference, 2002. Proceedings of the Winter, 2002. IEEE, 157-162.

KENNEDY, H. 1999. Simulation Reshaping Military Training. *National Defense Magazine.* Virginia, USA.

KENNEDY, R. S. & FOWLKES, J. E. 1992. Simulator sickness is polygenic and polysymptomatic: Implications for research. *The International Journal of Aviation Psychology,* 2**,** 23-38.

KENNEDY, R. S., LANE, N. E., BERBAUM, K. S. & LILIENTHAL, M. G. 1993. Simulator sickness questionnaire: an enhanced method for quantifying simulator sickness. *The International Journal of Aviation Psychology,* 3**,** 203-220.

KENNEDY, R. S., LANE, N. E., LILIENTHAL, M. G., BERBAUM, K. S. & HETTINGER, L. J. 1992. Profile analysis of simulator sickness symptoms: Application to virtual environment systems. *Presence,* 1**,** 295-301.

KLINGNER, J., KUMAR, R. & HANRAHAM, P. Measuring the Task-Evoked Pupillary Response with a Remote Eye Tracker. 2008 Symposium of Eye Tracking Research & Applications, 2008 Savannah, GA, USA. 69-72.

KOSINSKI, R. J. 2013. *A Literature Review on Reaction Time* [Online]. Clemson University. Available: http://biae.clemson.edu/bpc/bp/lab/110/reaction.htm [Accessed 02/12/2014 2014].

LACKNER, J. R. & DIZIO, P. 2006. Space motion sickness. *Exp Brain Res,* 175**,** 377-99.

LARSON, R. C. & ODONI, A. R. 1981. Functions of Random Variables and Geometric Probability. *Urban Operations Research.* Prentice-Hall.

LYSAGHT, R. J., HILL, S. G. & DICK, A. O. 1989. Operator Workload: Comprehensive Review and Evaluation of Operator Workload and Methodologies. United States Army Research Institute for the Behavioral and Social Sciences.

MACCRACKEN, J. H. & ALDRICH, T. B. 1984. Analyses of Selected LHX Mission Functions: Implications for Operator Workload and System Automation Goals. Alabama, U.S.A.: U.S. Army Research Institute.

MACKWORTH, N. H. 1948. The breakdown of vigilance during prolonged visual search. *Quarterly Journal of Experimental Psychology***,** 6-21.

MACKWORTH, N. H. 1950. Researches on the measurement of human performance. London: Medical Research Council Special Report Series 268.

MACLEOD, C. M. 1991. Half a century of research on the Stroop effect: An integrative review. *Psychological Review,* 109**,** 163-203.

MACLEOD, C. M. 2007. The Concept of Inhibition in Cognition. *In:* MACLEOD, D. S. G. A. C. M. (ed.) *Inhibition in Cognition.* American Psychological Association.

MARLINSKY, V. V. 1999. Vestibular and vestibulo-proprioceptive perception of motion in the horizontal plane in blindfolded man. *Neuroscience,* 90**,** 395-401.

MATSUMOTO, Y., MAEDA, S., IWANE, Y. & IWATA, Y. 2011. Factors affecting perception thresholds of vertical whole-body vibration in recumbent subjects: Gender and age of subjects, and vibration duration. *Journal of Sound and Vibration,* 330**,** 1810-1828.

MERCER-LYNN, K. B., FLORA, D. B., FAHLMAN, S. A. & EASTWOOD, J. D. 2011. The Measurement of Boredom: Differences between existing self-report scales. *In:* PUBLICATION, S. (ed.).

MILLER, E. F. & GRAYBIEL, A. 1970. The semicircular canals as a primary etiological factor in motion sickness. *Fourth Symposium on the Role of Vestibular Organs in Space Exploration.* Washington, DC: National Aeronautics and Space Administration.

MILLER, J. O. & LOW, K. 2001. Motor processes in simple, go/no-go, and choice reaction time tasks: a psychophysiological analysis. *J Exp Psychol Hum Percept Perform,* 27**,** 266-89.

MONSELL, S. 2003. Task switching. *TRENDS in Cognitive Sciences,* 7**,** 134-140.

MUELLER, S. T. 2009. *PEBL: The Psychology Experiment Building Language* [Online]. Available: http://pebl.sourceforge.net/ [Accessed 28/11/2014.

MULDER, L. J. M. 1992. Measurement and analysis of heart rate and respiration for use in applied environments. *Biological Psychology,* 34**,** 205-236.

MUSCIO, B. 1921. Is a fatigue test possible? *British Journal of Psychology***,** 31-46.

MUTH, E. R. 2009. The Challenge of Uncoupled Motion: Duration of Cognitive and Physiological Aftereffects. *Human Factors: The Journal of Human Factors and Ergonomics Society,* 51**,** 754-761.

OH&S, C. C. 2012. *Fatigue* [Online]. Canada. Available: http://www.ccohs.ca/oshanswers/psychosocial/fatigue.html [Accessed 19/02/2013 2013].

OKUDA, Y., BRYSON, E. O., DEMARIA, S. J., JACOBSON, L., QUINONES, J., SHEN, B. & LEVINE, A. 2009. The utility of simulation in medical education: what is the evidence? *The Mount Sinai Journal of Medicine,* 76**,** 330-343.

OMAN, C. M. 1982. A Heuristic Mathematical Model for the Dynamics of Sensory Conflict and Motion Sickness Hearing in Classical Musicians. *Acta Oto-Laryngologica,* 94**,** 4-44.

OMAN, C. M. 1990. Motion sickness: a synthesis and evaluation of the sensory conflict theory. *Canadian Journal of Physiology and Pharmacology,* 68**,** 294-303.

ONOFREY, J. 2010. *ProjecB v1.0.0 off-road track for rFactor* [Online]. Available: http://www.race2play.com/homepage/show_posts/16971 [Accessed 10/09/2014 2014].

PARSONS, K. C. & GRIFFIN, M. J. 1978. The effect of the position of the axis of rotation on the discomfort caused by whole-body roll and pitch vibrations of seated persons. *Journal of Sound and Vibration,* 58**,** 127-141.

PATTYN, N., NEYT, X., HENDRERICKX, D. & SOETENS, E. 2008. Psychophysiological investigation of vigilance decrement: Boredom or cognitive fatigue? *Physiology & Behavior,* 93**,** 369-378.

PEREZ, W. A., MASLINE, P. J., RAMSEY, E. G. & URBAN, K. E. 1987. Unified Tri-Services Cognitive Performance Assessment Battery: Review and Methodology. *In:* SYSTEMS RESEARCH LABORATORIES, I. (ed.). Harry G. Armstrong Aerospace Medical Research Laboratory.

PILCHER, J. & HUFFCUTT, A. 1996. Effects of sleep deprivation on performance: a meta-analysis. *Sleep,* 19**,** 318-325.

POMPLUN, M. & SUNKARA, S. Pupil dilation as an indicator of cognitive workload in human-computer interaction. Proceedings of the International Conference on HCI, 2003.

REASON, J. T. & BRAND, J. J. 1975. Motion Sickness. *Academic Press*.

RECARTE, M. A., PÉREZ, E., CONCHILLO, A. & NUNES, L. M. 2008. Mental Workload and Visual Impairment: Differences between Pupil, Blink and Subjective Rating. *The Spanish Journal of Psychology,* 11**,** 374-385.

REID, G. B. & NYGREN, T. E. 1988. The subjective workload assessment technique: a scaling procedure for measuring mental workload. *In:* MESHKATI, P. A. H. A. N. (ed.) *Human Mental Workload.* Amsterdam, North-Holland.

ROSCOE, A. H. 1987. The practical assessment of pilot workload. Neuilly Sur Seine, France: Advisory Group for Aerospace Research and Development.

ROSEKIND, M. 1999. Fatigue in transportation: Physiological, performance and safety issues. *Evaluation of US Department of Transportation Efforts in the 1990s to Address Operator Fatigue.* Washington, DC.

ROWE, D. W., SIBERT, J. & IRWIN, D. 1998. Heart Rate Variability: Indicator of User State as an aid to Human-Computer Interaction. *In:* ATWOOD, M. E., KARAT, C.-M., LUND, A. M., COUTAZ, J. & KARAT, J. (eds.) *CHI 98: Conference on Human Factors in Computing Systems.* Los Angeles Convention Center, Los Angeles, CA USA.

RUBIO, S., DIAZ, E., MARTIN, J. & PUENTE, J. M. 2004. Evaluation of Subjective Mental Workload: A Comparison of SWAT, NASA-TLX, and Workload Profile Methods. *Applied Psychology: An International Review,* 53**,** 61-86.

RUMSEY, M. G. 2012. Military Selection and Classification in the United States. *In:* LAURENCE, J. H. & MATTHEWS, M. D. (eds.) *The Oxford Handbook of Military Psychology.* New York, USA: Oxford University Press.

RUSSELL C. GRANT, CARSWELL, C. M., LIO, C. H. & SEALES, W. B. 2013. Measuring Surgeons' Mental Workload With a Time-Based Secondary Task. *Ergonomics in Design: The Quarterly of Human Factors Applications,* 21**,** 7-11.

SETNESS, P. & VAN BEUSEKOM, M. 2004. Motion Sickness. *Postgraduate Medicine,* 116**,** 64.

SKINNER, B. F. 1950. Are theories of learning necessary? *Psychological Review,* 57**,** 193-216.

SOMMER, D. & GOLZ, M. 2010. Evaluation of PERCLOS based Current Fatigue Monitoring Technologies. *32nd Annual International Conference of the IEE EMBS.* Buenos Aires, Argentina.

STANDARDS, A. 2001. ISO 2631.1:1997; AS 2670.1-2001; "Evaluation of human exposure to whole-body vibration". *Australian Standard.* Sydney: Standards Australia Internations Ltd.

STOFFREGEN, T. A., CHEN, F. C., VARLET, M., ALCANTARA, C. & BARDY, B. G. 2013. Getting Your Sea Legs. *Plos One,* 8.

STRICKLAND, J. 2011. *How can doctor's use virtual reality to treat phobias?* [Online]. Available: http://health.howstuffworks.com/medicine/modern/virtual-medicine.htm [Accessed 25 May 2011.

STROOP, J. R. 1935. Studies of interference in serial verbal reactions. *Journal of Experimental Psychology,* 18**,** 643-662.

TATTERSALL, A. J. & FOORD, P. S. 1996. An experimental evaluation of instantaneous self-assessment as a measure of workload. *Ergonomics,* 39**,** 740-748.

TATUM, W. O., HUSAIN, A. M., BENBADIS, S. R. & KAPLAN, P. W. 2008. Handbook of EEG Interpretation. *In:* PERCY, R. C. & JOHNSON, R. (eds.). Demos Medical Pub.

TECCE, J. J. & HAPP, S. J. 1964. Effects of shock-arousal on card-sorting test of color-word interference. *Perceptual and Motor Skills,* 19**,** 905-906.

THACKRAY, R. I., BAILEY, J. P. & TOUCHSTONE, R. M. 1977. Physiological, subjective, and performance correlates of reported boredom and monotony while performing a simulated radar control task. *In:* (ED.), R. R. M. (ed.) *Vigilance: theory operational performance and physiological correlates.* New York: Plenum Press.

TOCHER, K. D. 1963. *The Art of Simulation,* London, English Universities Press.

TSANG, P. S. & VELAQUEZ, V. L. 1996. Diagnosticity and multidimensional subjective workload ratings. *Ergonomics,* 39**,** 358-381.

UTTL, B. & GRAF, P. 1997. Color-Word Stroop Test Performance Across the Adult Life Span. *Journal of Clinical and Experimental Neuropsychology,* 19**,** 405-420.

VYDHYANATHAN, A., BELLUSCI, G., LUINGE, H. & SLYCKE, P. 2014. The Next Generation Xsens Motion Trackers for Industrial Applications. *XSENS***,** 1-9.

WARM, J. S. 1984. An Introduction to Vigilance. *In:* WARM, J. S. (ed.) *Sustained Attention in Human Performance.* John Wiley & Sons Ltd.

WIENTJES, C. J. E. 1992. Respiration in psychophysiology: methods and applications. *Biological Psychology,* 34**,** 179-203.

WILSON, G. F. 1992. Applied use of cardiac and respiration measures: practical considerations and precautions. *Biological Psychology,* 34**,** 163-178.

WILSON, G. F. 1993. Air-to-ground training missions: a psychophysiological workload analysis. *Ergonomics,* 36**,** 1071-1078.

WÜHR, P. 2007. A Stroop Effect for Spatial Orientation. *The Journal of General Psychology,* 134**,** 285-294.

ZHANG, X., ZHAO, X., DU, H. & RONG, J. 2014. A study on the Effects of Fatigue Driving and Drunk Driving on Drivers' Physical Characteristics. *Traffic Injury Prevention,* 15**,** 801-808.

ZHENG, G., QIU, Y. & GRIFFIN, M. J. 2012. Vertical and dual-axis vibration of the seated human body: Nonlinearity, cross-axis coupling, and associations between resonances in transmissibility and apparent mass. *Journal of Sound and Vibration***,** 5880-2894.

ZHENG, G., QUI, Y. & GRIFFIN, M. J. 2011. An analytical model of the in-line and cross-axis apparent mass of the seated human body exposed to vertical vibration with and without a backrest. *Journal of Sound and Vibration,* 330**,** 6507-6523.

ZUCKERMAN, M. 1979. *Sensation seeking: Beyond the optimal level of arousal,* Hillsdale, NJ, Lawrence Erlbaum.

# 10. Appendices

## A. Matlab script for processing data from BMSE by Dr Iain Brown

```
function [] = motion_sickness_analysis()

% A function to read the csv files and assess
pathname = uigetdir();
cd(pathname)
files = ls('4*');
subject_number = files(1,1:4);
data_column = {'Motion Sickness Study';'Subject Number';'Session';'Task';...
    'Nausea Rating (0-10)';'Reported Symptoms';'PanZoom Performace';...
    'PZ_time_to_initiate';'PZ_time_to_complete';...
    'PZ_total_time';'PZ_task_correctness';'CUnit Performance';...
    'CU_time_to_initiate';'CU_time_to_complete';...

'CU_total_time';'CU_correct_unit';'CU_xprec';'CU_yprec';'CU_totalprec';...
    'CU_failed';'CLine
Performance';'CL_time_to_initiate';'CL_time_to_complete';...
    'CL_total_time';'CL_time1';'CL_xprec1';...
    'CL_yprec1';'CL_totalprec1';'CL_time2';'CL_xprec2';'CL_yprec2';...
    'CL_totalprec2';'CL_time3';'CL_xprec3';'CL_yprec3';'CL_totalprec3';...
    'CL_time4';'CL_xprec4';'CL_yprec4';'CL_totalprec4';'CL_time5';...
    'CL_xprec5';'CL_yprec5';'CL_totalprec5';'CL_totalpathprec';...
    'CL_no_errors';'CText Performance';'CT_time_to_initiate';...
    'CT_no_errors'};
%'RText Performance';...
%'RT_time_to_complete';'RT_Clarity';'RT_no_errors';'RUnit Performance';...
%'RU_time_to_complete';'RU_correct_unit';...
%'RU_correct_size';'RU_correct_location';'RU_correctness'};

task_all =
xlsread(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),'sessions','b
4:z4');
nausea_rating_all =
xlsread(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),'sessions','b
5:z5');
[~, symptoms_all] =
xlsread(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),'sessions','b
6:z6');

[success] =
xlswrite(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),data_column,
'A','A1');
[success] =
xlswrite(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),data_column,
'B','A1');
[success] =
xlswrite(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),data_column,
'Mean','A1');


for k = 1 : size(files,1),
    task = task_all(k);
    nausea_rating = nausea_rating_all(k);
    symptoms = symptoms_all{k};
    if k == 1,
        % Baseline
        session = ls('*baseline*');
```

```
    session_number = 'Baseline';
else
    session = ls(strcat(subject_number,'_',num2str(k-1),'_*'));
    session_number = k-1;
end
fid = fopen(session);
messed_data = fread(fid);
fclose(fid);
c_returns = find(messed_data==10);
for i = 1 : length(c_returns),
    if i == 1
        line{1,:} = char(messed_data(1:c_returns(1)))';
    else
        line{i,:} = char(messed_data(c_returns(i-1)+1:c_returns(i),1))';
    end
    current_line = line{i,:};
    commas = find(current_line == ',');
    for j = 1 : length(commas),
        if j == 1,
            matrix{i,j} = current_line(1:commas(j)-1);
        else
            matrix{i,j} = current_line(commas(j-1)+1:commas(j)-1);
        end
    end

end

% Nausea Rating
% Reported Symptoms
% LOOP A-B-Mean
% -=- A -=-
% PanZoom
PZ_time_to_initiate = str2num(matrix{3,10})-str2num(matrix{3,9}); % A
PZ_time_to_complete = str2num(matrix{3,11})-str2num(matrix{3,10});
PZ_time_to_continue = str2num(matrix{3,12})-str2num(matrix{3,11});
PZ_total_time = str2num(matrix{3,12})-str2num(matrix{3,9});
if strfind(matrix{3,3},'UP'),
    PZ_required_actions(1,:) = 'U';
elseif strfind(matrix{3,3},'RIGHT'),
    PZ_required_actions(1,:) = 'R';
elseif strfind(matrix{3,3},'DOWN'),
    PZ_required_actions(1,:) = 'D';
elseif strfind(matrix{3,3},'LEFT'),
    PZ_required_actions(1,:) = 'L';
else
    errordlg('Cannot determine command')
end
if strfind(matrix{3,3},'OUT'),
    PZ_required_actions(2,:) = 'O';
elseif strfind(matrix{3,3},'IN'),
    PZ_required_actions(2,:) = 'I';
else
    errordlg('Cannot determine command')
end
PZ_performed_actions =[matrix{3,18}(1);matrix{3,19}(1)];
```

```
    PZ_task_correctness = 
sum([strcmpi(PZ_required_actions(1),PZ_performed_actions(1));strcmpi(PZ_requi
red_actions(2),PZ_performed_actions(2))]/2); %CHECK THE REQUIRED ACTION VS
PERFORMED ACTIONS

    % CUnit
    CU_time_to_initiate = str2num(matrix{4,10})-str2num(matrix{4,9});
    CU_time_to_complete = str2num(matrix{4,11})-str2num(matrix{4,10});
    CU_time_to_continue = str2num(matrix{4,12})-str2num(matrix{4,11});
    CU_total_time = str2num(matrix{4,12})-str2num(matrix{4,9});
    if strcmpi(matrix{4,15},'na'), % failed to report
        CU_correct_unit = -1;
        CU_xprec = [];
        CU_yprec = [];
        CU_totalprec = sqrt(CU_xprec.^2 + CU_yprec.^2);
        CU_failed = 1;
    else
        CU_correct_unit = strcmpi(matrix{4,7},matrix{4,13}); % 1 == correct,
0 == incorrect
        CU_xprec = abs(str2num(matrix{4,5})-str2num(matrix{4,15}));
        CU_yprec = abs(str2num(matrix{4,6})-str2num(matrix{4,16}));
        CU_totalprec = sqrt(CU_xprec.^2 + CU_yprec.^2);
        CU_failed = 0;
    end
    % CLine
    CL_time_to_initiate = str2num(matrix{5,10})-str2num(matrix{5,9});
    CL_time_to_complete = str2num(matrix{5,11})-str2num(matrix{5,10});
    CL_time_to_continue = str2num(matrix{5,12})-str2num(matrix{5,11});
    CL_total_time = str2num(matrix{5,12})-str2num(matrix{5,9});

    % Determine track
    u = strfind(matrix{5,3},'UP'); % U = [0,-1];
    u = [zeros(size(u')),-1*ones(size(u')),u'];
    l = strfind(matrix{5,3},'LEFT');  % L = [-1,0];
    l = [-1*ones(size(l')),zeros(size(l')),l'];
    d = strfind(matrix{5,3},'DOWN'); % D = [0,1];
    d = [zeros(size(d')),1*ones(size(d')),d'];
    r = strfind(matrix{5,3},'RIGHT'); % R = [1,0];
    r = [ones(size(r')),zeros(size(r')),r'];
    command = [u;l;d;r];
    command = sortrows(command,3);
    if strcmp(matrix{5,32},'na'), % Failed to complete

    else
        ckpt1 = [str2num(matrix{5,5}),str2num(matrix{5,6})];CL_xprec1 = 
str2num(matrix{5,20})- ckpt1(1); CL_yprec1 = str2num(matrix{5,21}) - 
ckpt1(2);
        ckpt2 = ckpt1+100*command(1,1:2);CL_xprec2 = str2num(matrix{5,23})-
ckpt2(1); CL_yprec2 = str2num(matrix{5,24}) - ckpt2(2);
        ckpt3 = ckpt2+100*command(2,1:2);CL_xprec3 = str2num(matrix{5,26})-
ckpt3(1); CL_yprec3 = str2num(matrix{5,27}) - ckpt3(2);
        ckpt4 = ckpt3+100*command(3,1:2);CL_xprec4 = str2num(matrix{5,29})-
ckpt4(1); CL_yprec4 = str2num(matrix{5,30}) - ckpt4(2);
        ckpt5 = ckpt4+100*command(4,1:2);CL_xprec5 = str2num(matrix{5,32})-
ckpt5(1); CL_yprec5 = str2num(matrix{5,33}) - ckpt5(2);
    end
```

```
    CL_time1 = str2num(matrix{5,22})-str2num(matrix{5,10}); % Need to address
issue of clicking in wrong place and ruining order... Unfixable, only 5
checkpoints recorded.
    CL_totalprec1 = sqrt(CL_xprec1.^2+CL_yprec1.^2);
    CL_time2 = str2num(matrix{5,25})-str2num(matrix{5,22});
    CL_totalprec2 = sqrt(CL_xprec2.^2+CL_yprec2.^2);
    CL_time3 = str2num(matrix{5,28})-str2num(matrix{5,25});
    CL_totalprec3 = sqrt(CL_xprec3.^2+CL_yprec3.^2);
    CL_time4 = str2num(matrix{5,31})-str2num(matrix{5,28});
    CL_totalprec4 = sqrt(CL_xprec4.^2+CL_yprec4.^2);
    CL_time5 = str2num(matrix{5,12})-str2num(matrix{5,31});
    CL_totalprec5 = sqrt(CL_xprec5.^2+CL_yprec5.^2);
    CL_totalpathprec =
sum(CL_totalprec1+CL_totalprec2+CL_totalprec3+CL_totalprec4+CL_totalprec5);
    CL_no_errors = 0; %! NEED TO DETERMINE IF THIS IS NEEDED

    % CText
    CT_time_to_initiate = str2num(matrix{6,10})-str2num(matrix{6,9});
    CT_time_to_complete = str2num(matrix{6,11})-str2num(matrix{6,10});
    CT_time_to_continue = str2num(matrix{6,12})-str2num(matrix{6,11});
    CT_total_time = str2num(matrix{6,12})-str2num(matrix{6,9});
    required_string = matrix{6,4};
    given_string = matrix{6,17};
    if ~isempty(given_string),
    written_errors = writing_task_analysis(required_string,given_string);
    CT_no_errors = sum(written_errors);
    else
        CT_no_errors = -1; % No input provided
    end
    %     RT_time_to_complete = str2num(matrix{7,12})-str2num(matrix{7,9});
    %     RT_clarity = [4]; % 0:4, 0 unintelligible, 1 some words understood
(meaning not conveyed), 2 meaning ambiguous, 3 meaning conveyed, 4 message
clear.
    %     RT_no_errors = [0]; % Pauses, repeats, incorrect words.
    %
    %     RU_time_to_complete = str2num(matrix{8,12})-str2num(matrix{8,9});
    %     RU_correct_unit = [1]; % 1 or 0
    %     RU_correct_size = [1];
    %     RU_correct_location = [1];
    %     RU_correctness = sum(RU_correct_unit,
    %     RU_correct_size,RU_correct_location)/3;

    data_column = {'';subject_number;session_number;task;...
        nausea_rating;symptoms;'';...
        PZ_time_to_initiate;PZ_time_to_complete;...
        PZ_total_time;PZ_task_correctness;'';...
        CU_time_to_initiate;CU_time_to_complete;...
        CU_total_time;CU_correct_unit;CU_xprec;CU_yprec;CU_totalprec;...
        CU_failed;'';CL_time_to_initiate;CL_time_to_complete;...
        CL_total_time;CL_time1;CL_xprec1;...
        CL_yprec1;CL_totalprec1;CL_time2;CL_xprec2;CL_yprec2;...
        CL_totalprec2;CL_time3;CL_xprec3;CL_yprec3;CL_totalprec3;...
        CL_time4;CL_xprec4;CL_yprec4;CL_totalprec4;CL_time5;...
        CL_xprec5;CL_yprec5;CL_totalprec5;CL_totalpathprec;...
        CL_no_errors;'';CT_time_to_initiate;CT_no_errors};
    %     '';...
```

```
    %         RT_time_to_complete;RT_Clarity;RT_no_errors;'';...
    %         RU_time_to_complete;RU_correct_unit;...
    %         RU_correct_size;RU_correct_location;RU_correctness'};

    [success] =
xlswrite(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),data_column,
'A',strcat(char(65+k),'1'));

    % -=- B -=-
    % PanZoom
    PZ_time_to_initiate = str2num(matrix{9,10})-str2num(matrix{9,9}); % A
    PZ_time_to_complete = str2num(matrix{9,11})-str2num(matrix{9,10});
    PZ_time_to_continue = str2num(matrix{9,12})-str2num(matrix{9,11});
    PZ_total_time = str2num(matrix{9,12})-str2num(matrix{9,9});
    if strfind(matrix{9,3},'UP'),
        PZ_required_actions(1,:) = 'U';
    elseif strfind(matrix{9,3},'RIGHT'),
        PZ_required_actions(1,:) = 'R';
    elseif strfind(matrix{9,3},'DOWN'),
        PZ_required_actions(1,:) = 'D';
    elseif strfind(matrix{9,3},'LEFT'),
        PZ_required_actions(1,:) = 'L';
    else
        errordlg('Cannot determine command')
    end
    if strfind(matrix{9,3},'OUT'),
        PZ_required_actions(2,:) = 'O';
    elseif strfind(matrix{9,3},'IN'),
        PZ_required_actions(2,:) = 'I';
    else
        errordlg('Cannot determine command')
    end
    PZ_performed_actions =[matrix{9,18}(1);matrix{9,19}(1)];
    PZ_task_correctness =
sum([strcmpi(PZ_required_actions(1),PZ_performed_actions(1));strcmpi(PZ_requi
red_actions(2),PZ_performed_actions(2))]/2); %CHECK THE REQUIRED ACTION VS
PERFORMED ACTIONS

    % CUnit
    CU_time_to_initiate = str2num(matrix{10,10})-str2num(matrix{10,9});
    CU_time_to_complete = str2num(matrix{10,11})-str2num(matrix{10,10});
    CU_time_to_continue = str2num(matrix{10,12})-str2num(matrix{10,11});
    CU_total_time = str2num(matrix{10,12})-str2num(matrix{10,9});
    if strcmpi(matrix{10,15},'na'), % failed to report
        CU_correct_unit = -1;
        CU_xprec = [];
        CU_yprec = [];
        CU_totalprec = sqrt(CU_xprec.^2 + CU_yprec.^2);
        CU_failed = 1;
    else
        CU_correct_unit = strcmpi(matrix{10,7},matrix{10,13}); % 1 ==
correct, 0 == incorrect
        CU_xprec = abs(str2num(matrix{10,5})-str2num(matrix{10,15}));
        CU_yprec = abs(str2num(matrix{10,6})-str2num(matrix{10,16}));
        CU_totalprec = sqrt(CU_xprec.^2 + CU_yprec.^2);
        CU_failed = 0;
```

```
    end
    % CLine
    CL_time_to_initiate = str2num(matrix{11,10})-str2num(matrix{11,9});
    CL_time_to_complete = str2num(matrix{11,11})-str2num(matrix{11,10});
    CL_time_to_continue = str2num(matrix{11,12})-str2num(matrix{11,11});
    CL_total_time = str2num(matrix{11,12})-str2num(matrix{11,9});

    % Determine track
    u = strfind(matrix{11,3},'UP'); % U = [0,-1];
    u = [zeros(size(u')),-1*ones(size(u')),u'];
    l = strfind(matrix{11,3},'LEFT');  % L = [-1,0];
    l = [-1*ones(size(l')),zeros(size(l')),l'];
    d = strfind(matrix{11,3},'DOWN'); % D = [0,1];
    d = [zeros(size(d')),1*ones(size(d')),d'];
    r = strfind(matrix{11,3},'RIGHT'); % R = [1,0];
    r = [ones(size(r')),zeros(size(r')),r'];
    command = [u;l;d;r];
    command = sortrows(command,3);
    if strcmp(matrix{11,32},'na'), % Failed to complete

    else
        ckpt1 = [str2num(matrix{11,5}),str2num(matrix{11,6})];CL_xprec1 =
str2num(matrix{11,20})- ckpt1(1); CL_yprec1 = str2num(matrix{11,21}) -
ckpt1(2);
        ckpt2 = ckpt1+100*command(1,1:2);CL_xprec2 = str2num(matrix{11,23})-
ckpt2(1); CL_yprec2 = str2num(matrix{11,24}) - ckpt2(2);
        ckpt3 = ckpt2+100*command(2,1:2);CL_xprec3 = str2num(matrix{11,26})-
ckpt3(1); CL_yprec3 = str2num(matrix{11,27}) - ckpt3(2);
        ckpt4 = ckpt3+100*command(3,1:2);CL_xprec4 = str2num(matrix{11,29})-
ckpt4(1); CL_yprec4 = str2num(matrix{11,30}) - ckpt4(2);
        ckpt5 = ckpt4+100*command(4,1:2);CL_xprec5 = str2num(matrix{11,32})-
ckpt5(1); CL_yprec5 = str2num(matrix{11,33}) - ckpt5(2);
    end
   CL_time1 = str2num(matrix{11,22})-str2num(matrix{11,10}); % Need to
address issue of clicking in wrong place and ruining order... Unfixable, only
5 checkpoints recorded.
    CL_totalprec1 = sqrt(CL_xprec1.^2+CL_yprec1.^2);
    CL_time2 = str2num(matrix{11,25})-str2num(matrix{11,22});
    CL_totalprec2 = sqrt(CL_xprec2.^2+CL_yprec2.^2);
    CL_time3 = str2num(matrix{11,28})-str2num(matrix{11,25});
    CL_totalprec3 = sqrt(CL_xprec3.^2+CL_yprec3.^2);
    CL_time4 = str2num(matrix{11,31})-str2num(matrix{11,28});
    CL_totalprec4 = sqrt(CL_xprec4.^2+CL_yprec4.^2);
    CL_time5 = str2num(matrix{11,12})-str2num(matrix{11,31});
    CL_totalpathprec =
sum(CL_totalprec1+CL_totalprec2+CL_totalprec3+CL_totalprec4+CL_totalprec5);
    CL_no_errors = 0; %! NEED TO DETERMINE IF THIS IS NEEDED

    % CText
    CT_time_to_initiate = str2num(matrix{12,10})-str2num(matrix{12,9});
    CT_time_to_complete = str2num(matrix{12,11})-str2num(matrix{12,10});
    CT_time_to_continue = str2num(matrix{12,12})-str2num(matrix{12,11});
    CT_total_time = str2num(matrix{12,12})-str2num(matrix{12,9});
    required_string = matrix{12,4};
    given_string = matrix{12,17};
    written_errors = writing_task_analysis(required_string,given_string);
```

```
    CT_no_errors = sum(written_errors);

    %     RT_time_to_complete = str2num(matrix{13,12})-str2num(matrix{13,9});
    %     RT_clarity = []; % 0:4, 0 unintelligible, 1 some words understood
(meaning not conveyed), 2 meaning ambiguous, 3 meaning conveyed, 4 message
clear.
    %     RT_no_errors = []; % Pauses, repeats, incorrect words.
    %
    %     RU_time_to_complete = str2num(matrix{14,12})-str2num(matrix{14,9});
    %     RU_correct_unit = []; % 1 or 0
    %     RU_correct_size = [];
    %     RU_correct_location = [];
    %     RU_correctness = sum(RU_correct_unit,
RU_correct_size,RU_correct_location)/3;

    data_column = {'';subject_number;session_number;task;...
        nausea_rating;symptoms;'';...
        PZ_time_to_initiate;PZ_time_to_complete;...
        PZ_total_time;PZ_task_correctness;'';...
        CU_time_to_initiate;CU_time_to_complete;...
        CU_total_time;CU_correct_unit;CU_xprec;CU_yprec;CU_totalprec;...
        CU_failed;'';CL_time_to_initiate;CL_time_to_complete;...
        CL_total_time;CL_time1;CL_xprec1;...
        CL_yprec1;CL_totalprec1;CL_time2;CL_xprec2;CL_yprec2;...
        CL_totalprec2;CL_time3;CL_xprec3;CL_yprec3;CL_totalprec3;...
        CL_time4;CL_xprec4;CL_yprec4;CL_totalprec4;CL_time5;...
        CL_xprec5;CL_yprec5;CL_totalprec5;CL_totalpathprec;...
        CL_no_errors;'';CT_time_to_initiate;CT_no_errors};
    %      '';...
    %          RT_time_to_complete;RT_Clarity;RT_no_errors;'';...
    %          RU_time_to_complete;RU_correct_unit;...
    %          RU_correct_size;RU_correct_location;RU_correctness'};

    [success] =
xlswrite(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),data_column,
'B',strcat(char(65+k),'1'));

    % -=- Mean -=-
    % PanZoom
    PZ_time_to_initiate = mean([str2num(matrix{3,10})-
str2num(matrix{3,9}),str2num(matrix{9,10})-str2num(matrix{9,9})]); % A
    PZ_time_to_complete = mean([str2num(matrix{3,11})-
str2num(matrix{3,10}),str2num(matrix{9,11})-str2num(matrix{9,10})]);
    PZ_time_to_continue = mean([str2num(matrix{3,12})-
str2num(matrix{3,11}),str2num(matrix{9,12})-str2num(matrix{9,11})]);
    PZ_total_time = mean([str2num(matrix{3,12})-
str2num(matrix{3,9}),str2num(matrix{9,12})-str2num(matrix{9,9})]);
    if strfind(matrix{3,3},'UP'),
        PZ_required_actionsA(1,:) = 'U';
    elseif strfind(matrix{3,3},'RIGHT'),
        PZ_required_actionsA(1,:) = 'R';
    elseif strfind(matrix{3,3},'DOWN'),
        PZ_required_actionsA(1,:) = 'D';
    elseif strfind(matrix{3,3},'LEFT'),
        PZ_required_actionsA(1,:) = 'L';
    else
```

```
        errordlg('Cannot determine command')
    end
    if strfind(matrix{3,3},'OUT'),
        PZ_required_actionsA(2,:) = 'O';
    elseif strfind(matrix{3,3},'IN'),
        PZ_required_actionsA(2,:) = 'I';
    else
        errordlg('Cannot determine command')
    end
    PZ_performed_actionsA =[matrix{3,18}(1);matrix{3,19}(1)];
    if strfind(matrix{9,3},'UP'),
        PZ_required_actionsB(1,:) = 'U';
    elseif strfind(matrix{9,3},'RIGHT'),
        PZ_required_actionsB(1,:) = 'R';
    elseif strfind(matrix{9,3},'DOWN'),
        PZ_required_actionsB(1,:) = 'D';
    elseif strfind(matrix{9,3},'LEFT'),
        PZ_required_actionsB(1,:) = 'L';
    else
        errordlg('Cannot determine command')
    end
    if strfind(matrix{9,3},'OUT'),
        PZ_required_actionsB(2,:) = 'O';
    elseif strfind(matrix{9,3},'IN'),
        PZ_required_actionsB(2,:) = 'I';
    else
        errordlg('Cannot determine command')
    end
    PZ_performed_actionsB =[matrix{9,18}(1);matrix{9,19}(1)];
    PZ_task_correctness =
mean([sum([strcmpi(PZ_required_actionsA(1),PZ_performed_actionsA(1));strcmpi(
PZ_required_actionsA(2),PZ_performed_actionsA(2))]/2),sum([strcmpi(PZ_require
d_actionsB(1),PZ_performed_actionsB(1));strcmpi(PZ_required_actionsB(2),PZ_pe
rformed_actionsB(2))]/2)]); %CHECK THE REQUIRED ACTION VS PERFORMED ACTIONS

    % CUnit
    CU_time_to_initiate = mean([str2num(matrix{4,10})-
str2num(matrix{4,9}),str2num(matrix{10,10})-str2num(matrix{10,9})]);
    CU_time_to_complete = mean([str2num(matrix{4,11})-
str2num(matrix{4,10}),str2num(matrix{10,11})-str2num(matrix{10,10})]);
    CU_time_to_continue = mean([str2num(matrix{4,12})-
str2num(matrix{4,11}),str2num(matrix{10,12})-str2num(matrix{10,11})]);
    CU_total_time = mean([str2num(matrix{4,12})-
str2num(matrix{4,9}),str2num(matrix{10,12})-str2num(matrix{10,9})]);
    if strcmpi(matrix{4,15},'na'), % failed to report
        CU_correct_unitA = -1;
        CU_xprecA = [];
        CU_yprecA = [];
        CU_totalprecA = 0;
        CU_failedA = 1;
    else
        CU_correct_unitA = strcmpi(matrix{4,7},matrix{4,13}); % 1 == correct,
0 == incorrect
        CU_xprecA = abs(str2num(matrix{4,5})-str2num(matrix{4,15}));
        CU_yprecA = abs(str2num(matrix{4,6})-str2num(matrix{4,16}));
        CU_totalprecA = sqrt(CU_xprec.^2 + CU_yprec.^2);
        CU_failedA = 0;
```

```
    end
    if strcmpi(matrix{10,15},'na'), % failed to report
        CU_correct_unitB = -1;
        CU_xprecB = [];
        CU_yprecB = [];
        CU_totalprecB = 0;
        CU_failedB = 1;
    else
        CU_correct_unitB = strcmpi(matrix{10,7},matrix{10,13}); % 1 ==
correct, 0 == incorrect
        CU_xprecB = abs(str2num(matrix{10,5})-str2num(matrix{10,15}));
        CU_yprecB = abs(str2num(matrix{10,6})-str2num(matrix{10,16}));
        CU_totalprecB = sqrt(CU_xprec.^2 + CU_yprec.^2);
        CU_failedB = 0;
    end

    CU_correct_unit = mean([CU_correct_unitA, CU_correct_unitB]); % 1 ==
correct, 0 == incorrect
    CU_xprec = mean([CU_xprecA,CU_xprecB]);
    CU_yprec = mean([CU_yprecA,CU_yprecB]);
    CU_totalprec = mean([CU_totalprecA,CU_totalprecB]);
    CU_failed = CU_failedA + CU_failedB;
    % CLine
    CL_time_to_initiate = mean([str2num(matrix{5,10})-
str2num(matrix{5,9}),str2num(matrix{11,10})-str2num(matrix{11,9})]);
    CL_time_to_complete = mean([str2num(matrix{5,11})-
str2num(matrix{5,10}),str2num(matrix{11,11})-str2num(matrix{11,10})]);
    CL_time_to_continue = mean([str2num(matrix{5,12})-
str2num(matrix{5,11}),str2num(matrix{11,12})-str2num(matrix{11,11})]);
    CL_total_time = mean([str2num(matrix{5,12})-
str2num(matrix{5,9}),str2num(matrix{11,12})-str2num(matrix{11,9})]);

    % Determine track A
    u = strfind(matrix{5,3},'UP'); % U = [0,-1];
    u = [zeros(size(u')),-1*ones(size(u')),u'];
    l = strfind(matrix{5,3},'LEFT');  % L = [-1,0];
    l = [-1*ones(size(l')),zeros(size(l')),l'];
    d = strfind(matrix{5,3},'DOWN'); % D = [0,1];
    d = [zeros(size(d')),1*ones(size(d')),d'];
    r = strfind(matrix{5,3},'RIGHT'); % R = [1,0];
    r = [ones(size(r')),zeros(size(r')),r'];
    command = [u;l;d;r];
    command = sortrows(command,3);
    if strcmp(matrix{5,32},'na'), % Failed to complete

    else
        ckpt1 = [str2num(matrix{5,5}),str2num(matrix{5,6})];CL_xprec1 =
str2num(matrix{5,20})- ckpt1(1); CL_yprec1 = str2num(matrix{5,21}) -
ckpt1(2);
        ckpt2 = ckpt1+100*command(1,1:2);CL_xprec2 = str2num(matrix{5,23})-
ckpt2(1); CL_yprec2 = str2num(matrix{5,24}) - ckpt2(2);
        ckpt3 = ckpt2+100*command(2,1:2);CL_xprec3 = str2num(matrix{5,26})-
ckpt3(1); CL_yprec3 = str2num(matrix{5,27}) - ckpt3(2);
        ckpt4 = ckpt3+100*command(3,1:2);CL_xprec4 = str2num(matrix{5,29})-
ckpt4(1); CL_yprec4 = str2num(matrix{5,30}) - ckpt4(2);
```

```
        ckpt5 = ckpt4+100*command(4,1:2);CL_xprec5 = str2num(matrix{5,32})-
ckpt5(1); CL_yprec5 = str2num(matrix{5,33}) - ckpt5(2);
    end
    CL_time1A = str2num(matrix{5,22})-str2num(matrix{5,10}); % Need to
address issue of clicking in wrong place and ruining order... Unfixable, only
5 checkpoints recorded.
    CL_totalprec1A = sqrt(CL_xprec1.^2+CL_yprec1.^2);
    CL_time2A = str2num(matrix{5,25})-str2num(matrix{5,22});
    CL_totalprec2A = sqrt(CL_xprec2.^2+CL_yprec2.^2);
    CL_time3A = str2num(matrix{5,28})-str2num(matrix{5,25});
    CL_totalprec3A = sqrt(CL_xprec3.^2+CL_yprec3.^2);
    CL_time4A = str2num(matrix{5,31})-str2num(matrix{5,28});
    CL_totalprec4A = sqrt(CL_xprec4.^2+CL_yprec4.^2);
    CL_time5A = str2num(matrix{5,12})-str2num(matrix{5,31});
    CL_totalprec5A = sqrt(CL_xprec5.^2+CL_yprec5.^2);
    CL_totalpathprecA =
CL_totalprec1+CL_totalprec2+CL_totalprec3+CL_totalprec4+CL_totalprec5;

    % Determine track B
    u = strfind(matrix{11,3},'UP'); % U = [0,-1];
    u = [zeros(size(u')),-1*ones(size(u')),u'];
    l = strfind(matrix{11,3},'LEFT');  % L = [-1,0];
    l = [-1*ones(size(l')),zeros(size(l')),l'];
    d = strfind(matrix{11,3},'DOWN'); % D = [0,1];
    d = [zeros(size(d')),1*ones(size(d')),d'];
    r = strfind(matrix{11,3},'RIGHT'); % R = [1,0];
    r = [ones(size(r')),zeros(size(r')),r'];
    command = [u;l;d;r];
    command = sortrows(command,3);
    if strcmp(matrix{11,32},'na'), % Failed to complete

    else
        ckpt1 = [str2num(matrix{11,5}),str2num(matrix{11,6})];CL_xprec1 =
str2num(matrix{11,20})- ckpt1(1); CL_yprec1 = str2num(matrix{11,21}) -
ckpt1(2);
        ckpt2 = ckpt1+100*command(1,1:2);CL_xprec2 = str2num(matrix{11,23})-
ckpt2(1); CL_yprec2 = str2num(matrix{11,24}) - ckpt2(2);
        ckpt3 = ckpt2+100*command(2,1:2);CL_xprec3 = str2num(matrix{11,26})-
ckpt3(1); CL_yprec3 = str2num(matrix{11,27}) - ckpt3(2);
        ckpt4 = ckpt3+100*command(3,1:2);CL_xprec4 = str2num(matrix{11,29})-
ckpt4(1); CL_yprec4 = str2num(matrix{11,30}) - ckpt4(2);
        ckpt5 = ckpt4+100*command(4,1:2);CL_xprec5 = str2num(matrix{11,32})-
ckpt5(1); CL_yprec5 = str2num(matrix{11,33}) - ckpt5(2);
    end
    CL_time1B = str2num(matrix{11,22})-str2num(matrix{11,10}); % Need to
address issue of clicking in wrong place and ruining order... Unfixable, only
5 checkpoints recorded.
    CL_totalprec1B = sqrt(CL_xprec1.^2+CL_yprec1.^2);
    CL_time2B = str2num(matrix{11,25})-str2num(matrix{11,22});
    CL_totalprec2B = sqrt(CL_xprec2.^2+CL_yprec2.^2);
    CL_time3B = str2num(matrix{11,28})-str2num(matrix{11,25});
    CL_totalprec3B = sqrt(CL_xprec3.^2+CL_yprec3.^2);
    CL_time4B = str2num(matrix{11,31})-str2num(matrix{11,28});
    CL_totalprec4B = sqrt(CL_xprec4.^2+CL_yprec4.^2);
    CL_time5B = str2num(matrix{11,12})-str2num(matrix{11,31});
    CL_totalprec5B = sqrt(CL_xprec5.^2+CL_yprec5.^2);
```

```
    CL_totalpathprecB =
CL_totalprec1+CL_totalprec2+CL_totalprec3+CL_totalprec4+CL_totalprec5;

    CL_time1 = mean([CL_time1A,CL_time1B]);
    CL_totalprec1 = mean([CL_totalprec1A,CL_totalprec1B]);
    CL_time2 = mean([CL_time2A,CL_time2B]);
    CL_totalprec2 = mean([CL_totalprec2A,CL_totalprec2B]);
    CL_time3 = mean([CL_time3A,CL_time3B]);
    CL_totalprec3 = mean([CL_totalprec3A,CL_totalprec3B]);
    CL_time4 = mean([CL_time4A,CL_time4B]);
    CL_totalprec4 = mean([CL_totalprec4A,CL_totalprec4B]);
    CL_time5 = mean([CL_time5A,CL_time5B]);
    CL_totalprec5 = mean([CL_totalprec5A,CL_totalprec5B]);
    CL_totalpathprec = mean([CL_totalpathprecA,CL_totalpathprecB]);
    CL_no_errors = 0; %! NEED TO DETERMINE IF THIS IS NEEDED

    % CText
    CT_time_to_initiate = mean([str2num(matrix{6,10})-
str2num(matrix{6,9}),str2num(matrix{12,10})-str2num(matrix{12,9})]);
    CT_time_to_complete = mean([str2num(matrix{6,11})-
str2num(matrix{6,10}),str2num(matrix{12,11})-str2num(matrix{12,10})]);
    CT_time_to_continue = mean([str2num(matrix{6,12})-
str2num(matrix{6,11}),str2num(matrix{12,12})-str2num(matrix{12,11})]);
    CT_total_time = mean([str2num(matrix{6,12})-
str2num(matrix{6,9}),str2num(matrix{12,12})-str2num(matrix{12,9})]);
    required_string = matrix{6,4};
    given_string = matrix{6,17};
    if ~isempty(given_string),
    written_errors = writing_task_analysis(required_string,given_string);
    CT_no_errorsA = sum(written_errors);
    else
        CT_no_errorsA = -1000; % No input provided
    end
    required_string = matrix{12,4};
    given_string = matrix{12,17};
    if ~isempty(given_string),
    written_errors = writing_task_analysis(required_string,given_string);
    CT_no_errorsB = sum(written_errors);
    else
        CT_no_errorsB = -1000; % No input provided
    end
    CT_no_errors = mean([CT_no_errorsA, CT_no_errorsB]);

    %     RT_time_to_complete = mean(str2num(matrix{7,12})-
str2num(matrix{7,9}),str2num(matrix{13,12})-str2num(matrix{13,9}));
    %     RT_clarity = []; % 0:4, 0 unintelligible, 1 some words understood
(meaning not conveyed), 2 meaning ambiguous, 3 meaning conveyed, 4 message
clear.
    %     RT_no_errors = []; % Pauses, repeats, incorrect words.
    %
    %     RU_time_to_complete = mean(str2num(matrix{8,12})-
str2num(matrix{8,9}),str2num(matrix{14,12})-str2num(matrix{14,9}));
    %     RU_correct_unit = []; % 1 or 0
    %     RU_correct_size = [];
    %     RU_correct_location = [];
```

```
    %     RU_correctness = sum(RU_correct_unit,
RU_correct_size,RU_correct_location)/3;

    data_column = {'';subject_number;session_number;task;...
        nausea_rating;symptoms;'';...
        PZ_time_to_initiate;PZ_time_to_complete;...
        PZ_total_time;PZ_task_correctness;'';...
        CU_time_to_initiate;CU_time_to_complete;...
        CU_total_time;CU_correct_unit;CU_xprec;CU_yprec;CU_totalprec;...
        CU_failed;'';CL_time_to_initiate;CL_time_to_complete;...
        CL_total_time;CL_time1;CL_xprec1;...
        CL_yprec1;CL_totalprec1;CL_time2;CL_xprec2;CL_yprec2;...
        CL_totalprec2;CL_time3;CL_xprec3;CL_yprec3;CL_totalprec3;...
        CL_time4;CL_xprec4;CL_yprec4;CL_totalprec4;CL_time5;...
        CL_xprec5;CL_yprec5;CL_totalprec5;CL_totalpathprec;...
        CL_no_errors;'';CT_time_to_initiate;CT_no_errors};
    %     '';...
    %         RT_time_to_complete;RT_Clarity;RT_no_errors;'';...
    %         RU_time_to_complete;RU_correct_unit;...
    %         RU_correct_size;RU_correct_location;RU_correctness'};

    [success] =
xlswrite(strcat(pathname,'\Subject_Data_',subject_number,'.xls'),data_column,
'Mean',strcat(char(65+k),'1'));

end
```

## B. Simulator Sickness Questionnaire

Simulator Sickness Questionnaire, Kennedy et al, International journal of Aviation Psychology, 1993

Simulator Sickness Questionnaire
Symptom Checklist

**PARTICPANT ID: _______ CONDITION: ___________ SESSION: ________**

| **PRE-Simulator** | | | | |
|---|---|---|---|---|
| *Circle below if any of the symptoms apply to you now* | | | | |
| *1. General discomfort* | *none* | *slight* | *moderate* | *severe* |
| *2. Fatigue* | *none* | *slight* | *moderate* | *severe* |
| *3. Headache* | *none* | *slight* | *moderate* | *severe* |
| *4. Eyestrain* | *none* | *slight* | *moderate* | *severe* |
| *5. Difficulty focusing* | *none* | *slight* | *moderate* | *severe* |
| *6. Increased salivation* | *none* | *slight* | *moderate* | *severe* |
| *7. Sweating* | *none* | *slight* | *moderate* | *severe* |
| *8. Nausea* | *none* | *slight* | *moderate* | *severe* |
| *9. Difficulty concentrating* | *none* | *slight* | *moderate* | *severe* |
| *10. Fullness of the head* | *none* | *slight* | *moderate* | *severe* |
| *11. Blurred vision* | *none* | *slight* | *moderate* | *severe* |

**Please stand up when assessing for symptoms 12 - 14**

| | | | | |
|---|---|---|---|---|
| *12. Dizziness (eyes open)* | *none* | *slight* | *moderate* | *severe* |
| *13. Dizziness (eyes closed)* | *none* | *slight* | *moderate* | *severe* |
| *14. Vertigo* | *none* | *slight* | *moderate* | *severe* |

| | | | | |
|---|---|---|---|---|
| *15. Stomach awareness* | *none* | *slight* | *moderate* | *severe* |
| *16. Burping* | *none* | *slight* | *moderate* | *severe* |

Simulator Sickness Questionnaire, Kennedy et al, International journal of Aviation Psychology, 1993

# Simulator Sickness Questionnaire
## Symptom Checklist

**PARTICPANT ID: _______ CONDITION: __________ SESSION: ______**

| **POST-Simulator** | | | | |
|---|---|---|---|---|
| *Circle below if any of the symptoms apply to you now* | | | | |
| *1. General discomfort* | *none* | *slight* | *moderate* | *severe* |
| *2. Fatigue* | *none* | *slight* | *moderate* | *severe* |
| *3. Headache* | *none* | *slight* | *moderate* | *severe* |
| *4. Eyestrain* | *none* | *slight* | *moderate* | *severe* |
| *5. Difficulty focusing* | *none* | *slight* | *moderate* | *severe* |
| *6. Increased salivation* | *none* | *slight* | *moderate* | *severe* |
| *7. Sweating* | *none* | *slight* | *moderate* | *severe* |
| *8. Nausea* | *none* | *slight* | *moderate* | *severe* |
| *9. Difficulty concentrating* | *none* | *slight* | *moderate* | *severe* |
| *10. Fullness of the head* | *none* | *slight* | *moderate* | *severe* |
| *11. Blurred vision* | *none* | *slight* | *moderate* | *severe* |

**Please stand up when assessing for symptoms 12 - 14**

| | | | | |
|---|---|---|---|---|
| *12. Dizziness (eyes open)* | *none* | *slight* | *moderate* | *severe* |
| *13. Dizziness (eyes closed)* | *none* | *slight* | *moderate* | *severe* |
| *14. Vertigo* | *none* | *slight* | *moderate* | *severe* |

| | | | | |
|---|---|---|---|---|
| *15. Stomach awareness* | *none* | *slight* | *moderate* | *severe* |
| *16. Burping* | *none* | *slight* | *moderate* | *severe* |

## C. Golding-Kerguelen Seven Point Nausea Scale

| Rating | Definition |
|---|---|
| 0 | No symptoms |
| 1 | Any  unpleasant symptoms ,however slight |
| 2 | Mild unpleasant symptoms, e.g. stomach awareness, sweating but no nausea |
| 3 | Mild nausea |
| 4 | Mild to moderate nausea |
| 5 | Moderate nausea but can continue |
| 6 | Moderate nausea, want to stop |

## D. Stanford Sleepiness Scale

| SCORE | DESCRIPTION |
|---|---|
| 1 | Feeling active, vital, alert, or wide awake |
| 2 | Functioning at high levels, but not at peak; able to concentrate |
| 3 | Awake, but relaxed; responsive but not fully alert |
| 4 | Somewhat foggy, let down |
| 5 | Foggy; losing interest in remaining awake; slowed down |
| 6 | Sleepy, woozy, fighting sleep; prefer to lie down |
| 7 | No longer fighting sleep, sleep onset soon; having dream-like thoughts |
| X | Asleep |

## E. Motion Sickness Susceptibility Questionnaire

Motion Sickness Susceptibility Questionnaire Short-form, Golding, JF, Personality and individual differences, 2006

### Motion Sickness Susceptibility Questionnaire Short-form (MSSQ-Short)

*1.* Please State Your **Age** .......... Years.    *2.* Please State Your Sex (tick box) **Male** [ ]1  **Female** [ ]2

This questionnaire is designed to find out how susceptible to motion sickness you are, and what sorts of motion are most effective in causing that sickness. Sickness here means feeling queasy or nauseated or actually vomiting.

**Your CHILDHOOD Experience Only** (before 12 years of age), for each of the following types of transport or entertainment please indicate:

*3.* **As a CHILD (before age 12),** how often you **Felt Sick or Nauseated** (tick boxes):

| | **Not Applicable - Never Travelled** | **Never Felt Sick** | **Rarely Felt Sick** | **Sometimes Felt Sick** | **Frequently Felt Sick** |
|---|---|---|---|---|---|
| Cars | | | | | |
| Buses or Coaches | | | | | |
| Trains | | | | | |
| Aircraft | | | | | |
| Small Boats | | | | | |
| Ships, e.g. Channel Ferries | | | | | |
| Swings in playgrounds | | | | | |
| Roundabouts in playgrounds | | | | | |
| Big Dippers, Funfair Rides | | | | | |
| | t | 0 | 1 | 2 | 3 |

**Your Experience over the LAST 10 YEARS (approximately),** for each of the following types of transport or entertainment please indicate:

*4.* **Over the LAST 10 YEARS,** how often you **Felt Sick or Nauseated** (tick boxes):

| | **Not Applicable - Never Travelled** | **Never Felt Sick** | **Rarely Felt Sick** | **Sometimes Felt Sick** | **Frequently Felt Sick** |
|---|---|---|---|---|---|
| Cars | | | | | |
| Buses or Coaches | | | | | |
| Trains | | | | | |
| Aircraft | | | | | |
| Small Boats | | | | | |
| Ships, e.g. Channel Ferries | | | | | |
| Swings in playgrounds | | | | | |
| Roundabouts in playgrounds | | | | | |
| Big Dippers, Funfair Rides | | | | | |
| | t | 0 | 1 | 2 | 3 |

Motion Sickness Susceptibility Questionnaire Short-form, Golding, JF, Personality and individual differences, 2006

# *Scoring the MSSQ- Short*

Section A (Child) (Question 3)

Score the number of types of transportation not experienced (i.e., total the number of ticks in the 't' column, maximum is 9).

Total the sickness scores for each mode of transportation, i.e. the nine types from 'cars' to 'big dippers' (use the 0-3 number score key at bottom, those scores in the 't' column count as zeroes).

MSA = (total sickness score child) x (9) / (9 - number of types not experienced as a child)

*Note 1.* Where a subject has not experienced any forms of transport a division by zero error occurs. It is not possible to estimate this subject's motion sickness susceptibility in the absence of any relevant motion exposure.
*Note 2.* The Section A (Child) score can be used as a pre-morbid indicator of motion sickness susceptibility in patients with vestibular disease.

Section B (Adult) (Question 4)

Repeat as for section A but using the data from section B.

MSB = (total sickness score adult) x (9) / (9 - number of types not experienced as an adult)

## Raw Score MSSQ-Short

Total the section A (Child) MSA score and the section B (Adult) MSB score to give the MSSQ-Short raw score (possible range from minimum 0 to maximum 54, the maximum being unlikely)

MSSQ raw score = MSA + MSB

## Percentile Score MSSQ-Short

The raw to percentile conversions are given below in the Table of Statistics & Figure, use interpolation where necessary.

Alternatively a close approximation is given by the fitted polynomial where y is percentile; x is raw score

$y = a.x + b.x^2 + c.x^3 + d.x^4$

a = 5.1160923 b = -0.055169904
c = -0.00067784495 d = 1.0714752e-005

Table of Means and Percentile Conversion Statistics for the MSSQ-Short (n=257)

| Percentiles Conversion | Raw Scores MSSQ-Short | | |
|---|---|---|---|
| | Child Section A | Adult Section B | Total A+B |
| 0 | 0 | 0 | 0 |
| 10 | .0 | .0 | .8 |
| 20 | 2.0 | 1.0 | 3.0 |
| 30 | 4.0 | 1.3 | 7.0 |
| 40 | 5.6 | 2.6 | 9.0 |
| 50 | 7.0 | 3.7 | 11.3 |
| 60 | 9.0 | 6.0 | 14.1 |
| 70 | 11.0 | 7.0 | 17.9 |
| 80 | 13.0 | 9.0 | 21.6 |
| 90 | 16.0 | 12.0 | 25.9 |
| 95 | 20.0 | 15.0 | 30.4 |
| 100 | 23.6 | 21.0 | 44.6 |
| | | | |
| Mean | 7.75 | 5.11 | 12.90 |
| Std. Deviation | 5.94 | 4.84 | 9.90 |

*Table note: numbers are rounded*

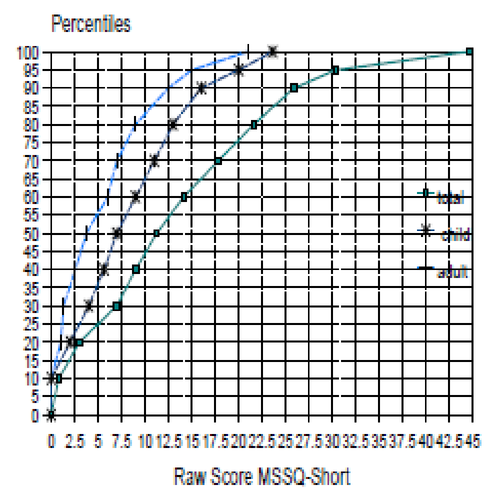


Figure: Cumulative distribution Percentiles of the Raw Scores of the MSSQ-Short (n=257 subjects).

*Reference Note*

For more background information and references to the original Reason & Brand MSSQ and to its revised version the 'MSSQ-Long', see:

Golding JF. Motion sickness susceptibility questionnaire revised and its relationship to other forms of sickness. **Brain Research Bulletin**, 1998; 47: 507-516.
Golding JF. (2006) Predicting Individual Differences in Motion Sickness Susceptibility by Questionnaire. **Personality and Individual differences, 41:** 237-248.

## F. Read Unit Output (MS)

Statistical output for ANOVA test between the Total time taken and task run in Motion Sickness testing.

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| Runit_total_time | 0 | 26 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| | 1 | 27 | 0.892 | 0.182 | 0.035 | 0.820 | 0.963 | 0.482 | 1.234 |
| | 2 | 27 | 0.829 | 0.289 | 0.056 | 0.714 | 0.943 | 0.567 | 2.019 |
| | 3 | 27 | 0.809 | 0.240 | 0.046 | 0.714 | 0.904 | 0.546 | 1.507 |
| | 4 | 27 | 0.717 | 0.223 | 0.043 | 0.629 | 0.805 | 0.440 | 1.369 |
| | 5 | 24 | 0.774 | 0.237 | 0.048 | 0.674 | 0.874 | 0.492 | 1.474 |
| | 6 | 20 | 0.750 | 0.352 | 0.079 | 0.585 | 0.915 | 0.369 | 2.033 |
| | 7 | 16 | 0.657 | 0.151 | 0.038 | 0.576 | 0.737 | 0.433 | 0.961 |
| | Total | 194 | 0.813 | 0.246 | 0.018 | 0.778 | 0.848 | 0.369 | 2.033 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Runit_total_time | Between Groups | 1.838 | 7 | .263 | 4.970 | .000 |
| | Within Groups | 9.824 | 186 | .053 | | |
| | Total | 11.661 | 193 | | | |

### Post-Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|---|
| Runit_total_time | Tukey HSD | .0 | 1.0 | .1084 | .0631 | .676 | -.0852 | .3020 |
| | | | 2.0 | .1714 | .0631 | .125 | -.0222 | .3650 |
| | | | 3.0 | .1912 | .0631 | .056 | -.0024 | .3848 |
| | | | 4.0 | .2829* | .0631 | .000 | .0893 | .4764 |
| | | | 5.0 | .2260* | .0651 | .014 | .0265 | .4254 |
| | | | 6.0 | .2500* | .0684 | .008 | .0405 | .4596 |
| | | | 7.0 | .3432* | .0730 | .000 | .1194 | .5671 |
| | | 1.0 | .0 | -.1084 | .0631 | .676 | -.3020 | .0852 |
| | | | 2.0 | .0629 | .0625 | .973 | -.1288 | .2547 |
| | | | 3.0 | .0827 | .0625 | .889 | -.1090 | .2745 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4.0 | .1744 | .0625 | .104 | -.0173 | .3662 |
| | | 5.0 | .1175 | .0645 | .605 | -.0801 | .3152 |
| | | 6.0 | .1416 | .0678 | .426 | -.0663 | .3494 |
| | | 7.0 | .2348* | .0725 | .030 | .0125 | .4571 |
| | 2.0 | .0 | -.1714 | .0631 | .125 | -.3650 | .0222 |
| | | 1.0 | -.0629 | .0625 | .973 | -.2547 | .1288 |
| | | 3.0 | .0198 | .0625 | 1.000 | -.1720 | .2116 |
| | | 4.0 | .1115 | .0625 | .633 | -.0803 | .3032 |
| | | 5.0 | .0546 | .0645 | .990 | -.1431 | .2523 |
| | | 6.0 | .0786 | .0678 | .942 | -.1292 | .2865 |
| | | 7.0 | .1719 | .0725 | .262 | -.0504 | .3942 |
| | 3.0 | .0 | -.1912 | .0631 | .056 | -.3848 | .0024 |
| | | 1.0 | -.0827 | .0625 | .889 | -.2745 | .1090 |
| | | 2.0 | -.0198 | .0625 | 1.000 | -.2116 | .1720 |
| | | 4.0 | .0917 | .0625 | .825 | -.1001 | .2834 |
| | | 5.0 | .0348 | .0645 | .999 | -.1629 | .2325 |
| | | 6.0 | .0588 | .0678 | .989 | -.1490 | .2667 |
| | | 7.0 | .1521 | .0725 | .420 | -.0702 | .3744 |
| | 4.0 | .0 | -.2829* | .0631 | .000 | -.4764 | -.0893 |
| | | 1.0 | -.1744 | .0625 | .104 | -.3662 | .0173 |
| | | 2.0 | -.1115 | .0625 | .633 | -.3032 | .0803 |
| | | 3.0 | -.0917 | .0625 | .825 | -.2834 | .1001 |
| | | 5.0 | -.0569 | .0645 | .987 | -.2545 | .1408 |
| | | 6.0 | -.0328 | .0678 | 1.000 | -.2407 | .1750 |
| | | 7.0 | .0604 | .0725 | .991 | -.1619 | .2827 |
| | 5.0 | .0 | -.2260* | .0651 | .014 | -.4254 | -.0265 |
| | | 1.0 | -.1175 | .0645 | .605 | -.3152 | .0801 |
| | | 2.0 | -.0546 | .0645 | .990 | -.2523 | .1431 |
| | | 3.0 | -.0348 | .0645 | .999 | -.2325 | .1629 |
| | | 4.0 | .0569 | .0645 | .987 | -.1408 | .2545 |
| | | 6.0 | .0240 | .0696 | 1.000 | -.1893 | .2374 |
| | | 7.0 | .1173 | .0742 | .761 | -.1101 | .3447 |
| | 6.0 | .0 | -.2500* | .0684 | .008 | -.4596 | -.0405 |
| | | 1.0 | -.1416 | .0678 | .426 | -.3494 | .0663 |
| | | 2.0 | -.0786 | .0678 | .942 | -.2865 | .1292 |
| | | 3.0 | -.0588 | .0678 | .989 | -.2667 | .1490 |
| | | 4.0 | .0328 | .0678 | 1.000 | -.1750 | .2407 |
| | | 5.0 | -.0240 | .0696 | 1.000 | -.2374 | .1893 |
| | | 7.0 | .0932 | .0771 | .928 | -.1431 | .3295 |
| | 7.0 | .0 | -.3432* | .0730 | .000 | -.5671 | -.1194 |
| | | 1.0 | -.2348* | .0725 | .030 | -.4571 | -.0125 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2.0 | -.1719 | .0725 | .262 | -.3942 | .0504 |
| | | | 3.0 | -.1521 | .0725 | .420 | -.3744 | .0702 |
| | | | 4.0 | -.0604 | .0725 | .991 | -.2827 | .1619 |
| | | | 5.0 | -.1173 | .0742 | .761 | -.3447 | .1101 |
| | | | 6.0 | -.0932 | .0771 | .928 | -.3295 | .1431 |
| | LSD | .0 | 1.0 | .1084 | .0631 | .088 | -.0161 | .2330 |
| | | | 2.0 | .1714* | .0631 | .007 | .0468 | .2960 |
| | | | 3.0 | .1912* | .0631 | .003 | .0666 | .3158 |
| | | | 4.0 | .2829* | .0631 | .000 | .1583 | .4074 |
| | | | 5.0 | .2260* | .0651 | .001 | .0976 | .3543 |
| | | | 6.0 | .2500* | .0684 | .000 | .1152 | .3849 |
| | | | 7.0 | .3432* | .0730 | .000 | .1992 | .4873 |
| | | 1.0 | .0 | -.1084 | .0631 | .088 | -.2330 | .0161 |
| | | | 2.0 | .0629 | .0625 | .316 | -.0604 | .1863 |
| | | | 3.0 | .0827 | .0625 | .188 | -.0407 | .2061 |
| | | | 4.0 | .1744* | .0625 | .006 | .0510 | .2978 |
| | | | 5.0 | .1175 | .0645 | .070 | -.0096 | .2447 |
| | | | 6.0 | .1416* | .0678 | .038 | .0078 | .2753 |
| | | | 7.0 | .2348* | .0725 | .001 | .0918 | .3779 |
| | | 2.0 | .0 | -.1714* | .0631 | .007 | -.2960 | -.0468 |
| | | | 1.0 | -.0629 | .0625 | .316 | -.1863 | .0604 |
| | | | 3.0 | .0198 | .0625 | .752 | -.1036 | .1432 |
| | | | 4.0 | .1115 | .0625 | .076 | -.0119 | .2349 |
| | | | 5.0 | .0546 | .0645 | .398 | -.0726 | .1818 |
| | | | 6.0 | .0786 | .0678 | .248 | -.0551 | .2124 |
| | | | 7.0 | .1719* | .0725 | .019 | .0288 | .3149 |
| | | 3.0 | .0 | -.1912* | .0631 | .003 | -.3158 | -.0666 |
| | | | 1.0 | -.0827 | .0625 | .188 | -.2061 | .0407 |
| | | | 2.0 | -.0198 | .0625 | .752 | -.1432 | .1036 |
| | | | 4.0 | .0917 | .0625 | .144 | -.0317 | .2151 |
| | | | 5.0 | .0348 | .0645 | .590 | -.0924 | .1620 |
| | | | 6.0 | .0588 | .0678 | .387 | -.0749 | .1926 |
| | | | 7.0 | .1521* | .0725 | .037 | .0090 | .2951 |
| | | 4.0 | .0 | -.2829 | .0631 | .000 | -.4074 | -.1583 |
| | | | 1.0 | -.1744* | .0625 | .006 | -.2978 | -.0510 |
| | | | 2.0 | -.1115 | .0625 | .076 | -.2349 | .0119 |
| | | | 3.0 | -.0917 | .0625 | .144 | -.2151 | .0317 |
| | | | 5.0 | -.0569 | .0645 | .379 | -.1841 | .0703 |
| | | | 6.0 | -.0328 | .0678 | .629 | -.1666 | .1009 |
| | | | 7.0 | .0604 | .0725 | .406 | -.0826 | .2034 |
| | | 5.0 | .0 | -.2260* | .0651 | .001 | -.3543 | -.0976 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1.0 | -.1175 | .0645 | .070 | -.2447 | .0096 |
| | | | 2.0 | -.0546 | .0645 | .398 | -.1818 | .0726 |
| | | | 3.0 | -.0348 | .0645 | .590 | -.1620 | .0924 |
| | | | 4.0 | .0569 | .0645 | .379 | -.0703 | .1841 |
| | | | 6.0 | .0240 | .0696 | .730 | -.1132 | .1613 |
| | | | 7.0 | .1173 | .0742 | .116 | -.0291 | .2636 |
| | | 6.0 | .0 | -.2500* | .0684 | .000 | -.3849 | -.1152 |
| | | | 1.0 | -.1416* | .0678 | .038 | -.2753 | -.0078 |
| | | | 2.0 | -.0786 | .0678 | .248 | -.2124 | .0551 |
| | | | 3.0 | -.0588 | .0678 | .387 | -.1926 | .0749 |
| | | | 4.0 | .0328 | .0678 | .629 | -.1009 | .1666 |
| | | | 5.0 | -.0240 | .0696 | .730 | -.1613 | .1132 |
| | | | 7.0 | .0932 | .0771 | .228 | -.0588 | .2453 |
| | | 7.0 | .0 | -.3432* | .0730 | .000 | -.4873 | -.1992 |
| | | | 1.0 | -.2348* | .0725 | .001 | -.3779 | -.0918 |
| | | | 2.0 | -.1719* | .0725 | .019 | -.3149 | -.0288 |
| | | | 3.0 | -.1521* | .0725 | .037 | -.2951 | -.0090 |
| | | | 4.0 | -.0604 | .0725 | .406 | -.2034 | .0826 |
| | | | 5.0 | -.1173 | .0742 | .116 | -.2636 | .0291 |
| | | | 6.0 | -.0932 | .0771 | .228 | -.2453 | .0588 |
| | Dunnett t (<control)[a] | 1.0 | .0 | -.10843 | .06315 | .187 | .0411 | |
| | | 2.0 | .0 | -.1714* | .06315 | .021 | -.0219 | |
| | | 3.0 | .0 | -.1912* | .06315 | .009 | -.0417 | |
| | | 4.0 | .0 | -.2829* | .06315 | .000 | -.1334 | |
| | | 5.0 | .0 | -.2260* | .06505 | .002 | -.0720 | |
| | | 6.0 | .0 | -.2500* | .06835 | .001 | -.0882 | |
| | | 7.0 | .0 | -.3432* | .07302 | .000 | -.1704 | |

*. The mean difference is significant at the 0.05 level.

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## G. TBAS Dot Mean Time (MS)

Changes in TBAS Dot over task order – an investigation of Practice Effects.

# Oneway

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| Mean Time | 1.0 | 32 | 4.0875 | 1.9108 | 0.3378 | 3.3986 | 4.7764 | 1.789375 | 10.073000 |
| | 2.0 | 32 | 2.7223 | 1.2869 | 0.2275 | 2.2583 | 3.1862 | 1.375625 | 6.806000 |
| | 3.0 | 31 | 2.5562 | 1.3581 | 0.2439 | 2.0581 | 3.0543 | 1.263396 | 6.838583 |
| | 4.0 | 22 | 2.1269 | 1.0139 | 0.2162 | 1.6774 | 2.5764 | 1.147437 | 4.956000 |
| | Total | 117 | 2.9397 | 1.6194 | 0.1497 | 2.6432 | 3.2362 | 1.147437 | 10.073000 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Mean Time | 3.910 | 3 | 113 | .011 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Mean Time | Between Groups | 62.766 | 3 | 20.922 | 9.792 | .000 |
| | Within Groups | 241.443 | 113 | 2.137 | | |
| | Total | 304.209 | 116 | | | |

# Post Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Mean Time | Tukey HSD | 1.0 | 2.0 | 1.365* | .365 | .002 | 0.412 | 2.318 |
| | | | 3.0 | 1.531* | .368 | .000 | 0.571 | 2.492 |
| | | | 4.0 | 1.961* | .405 | .000 | 0.905 | 3.016 |
| | | 2.0 | 1.0 | -1.365* | .365 | .002 | -2.318 | -.412 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3.0 | .166 | .368 | .969 | -0.795 | 1.127 |
| | | 4.0 | .595 | .405 | .459 | -0.460 | 1.651 |
| | 3.0 | 1.0 | -1.531* | .368 | .000 | -2.492 | -.571 |
| | | 2.0 | -.166 | .368 | .969 | -1.127 | .795 |
| | | 4.0 | .429 | .407 | .718 | -0.633 | 1.492 |
| | 4.0 | 1.0 | -1.961* | .405 | .000 | -3.016 | -.905 |
| | | 2.0 | -.595 | .405 | .459 | -1.651 | .460 |
| | | 3.0 | -.429 | .407 | .718 | -1.492 | .633 |
| Dunnett t (>control)[b] | 2.0 | 1.0 | -1.365 | .365 | 1.000 | -2.130 | |
| | 3.0 | 1.0 | -1.531 | .368 | 1.000 | -2.302 | |
| | 4.0 | 1.0 | -1.961 | .405 | 1.000 | -2.807 | |

*. The mean difference is significant at the 0.05 level.

b. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## H. Study One Subjective Scales by Fatigue (MF)

```
ONEWAY SSQ Nausea Sleepiness BY Fatigue
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /POSTHOC=TUKEY LSD BONFERRONI DUNNETT          ALPHA  (0.05  ).
```

# Oneway

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| SSQ | .0 | 66 | 127.926 | 190.300 | 23.424 | 81.145 | 174.708 | 0.0000 | 984.7420 |
| | 1.0 | 48 | 301.492 | 284.594 | 41.078 | 218.854 | 384.129 | 28.3492 | 992.0724 |
| | 2.0 | 10 | 749.331 | 487.263 | 154.086 | 400.764 | 1097.899 | 28.3492 | 1711.9480 |
| | Total | 124 | 245.226 | 311.027 | 27.931 | 189.938 | 300.514 | 0.0000 | 1711.9480 |
| Nausea | .0 | 66 | 0.500 | 0.920 | 0.113 | 0.274 | 0.726 | 0.0 | 4.0 |
| | 1.0 | 48 | 1.146 | 1.425 | 0.206 | 0.732 | 1.560 | 0.0 | 4.5 |
| | 2.0 | 10 | 1.900 | 2.283 | 0.722 | 0.267 | 3.533 | 0.0 | 6.0 |
| | Total | 124 | 0.863 | 1.339 | 0.120 | 0.625 | 1.101 | 0.0 | 6.0 |
| Sleepiness | .0 | 66 | 2.015 | 0.808 | 0.100 | 1.816 | 2.214 | 1.0 | 4.5 |
| | 1.0 | 48 | 2.708 | 1.120 | 0.162 | 2.383 | 3.033 | 1.0 | 6.0 |
| | 2.0 | 10 | 4.500 | 1.650 | 0.522 | 3.320 | 5.680 | 2.0 | 6.0 |
| | Total | 124 | 2.484 | 1.221 | 0.110 | 2.267 | 2.701 | 1.0 | 6.0 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| SSQ | 9.304 | 2 | 121 | .000 |
| Nausea | 11.853 | 2 | 121 | .000 |
| Sleepiness | 10.361 | 2 | 121 | .000 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| SSQ | Between Groups | 3601289.33 | 2 | 1800644.66 | 26.258 | .000 |
| | Within Groups | 8297449.61 | 121 | 68573.964 | | |
| | Total | 11898738.93 | 123 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Nausea | Between Groups | 23.290 | 2 | 11.645 | 7.139 | .001 |
| | Within Groups | 197.379 | 121 | 1.631 | | |
| | Total | 220.669 | 123 | | | |
| Sleepiness | Between Groups | 57.566 | 2 | 28.783 | 27.663 | .000 |
| | Within Groups | 125.902 | 121 | 1.041 | | |
| | Total | 183.468 | 123 | | | |

# Post Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| SSQ | Tukey HSD | .0 | 1.0 | -173.5651655* | 49.675 | 0.002 | -291.440 | -55.691 |
| | | | 2.0 | -621.4050764* | 88.862 | 0.000 | -832.265 | -410.545 |
| | | 1.0 | .0 | 173.5651655* | 49.675 | 0.002 | 55.691 | 291.440 |
| | | | 2.0 | -447.8399108* | 91.028 | 0.000 | -663.839 | -231.840 |
| | | 2.0 | .0 | 621.4050764* | 88.862 | 0.000 | 410.545 | 832.265 |
| | | | 1.0 | 447.8399108* | 91.028 | 0.000 | 231.840 | 663.839 |
| | LSD | .0 | 1.0 | -173.5651655* | 49.675 | 0.001 | -271.910 | -75.220 |
| | | | 2.0 | -621.4050764* | 88.862 | 0.000 | -797.330 | -445.480 |
| | | 1.0 | .0 | 173.5651655* | 49.675 | 0.001 | 75.220 | 271.910 |
| | | | 2.0 | -447.8399108* | 91.028 | 0.000 | -628.053 | -267.627 |
| | | 2.0 | .0 | 621.4050764* | 88.862 | 0.000 | 445.480 | 797.330 |
| | | | 1.0 | 447.8399108* | 91.028 | 0.000 | 267.627 | 628.053 |
| | Bonferroni | .0 | 1.0 | -173.5651655* | 49.675 | 0.002 | -294.163 | -52.968 |
| | | | 2.0 | -621.4050764* | 88.862 | 0.000 | -837.136 | -405.674 |
| | | 1.0 | .0 | 173.5651655* | 49.675 | 0.002 | 52.968 | 294.163 |
| | | | 2.0 | -447.8399108* | 91.028 | 0.000 | -668.829 | -226.851 |
| | | 2.0 | .0 | 621.4050764* | 88.862 | 0.000 | 405.674 | 837.136 |
| | | | 1.0 | 447.8399108* | 91.028 | 0.000 | 226.851 | 668.829 |
| | Dunnett t (2-sided)[b] | .0 | 2.0 | -621.4050764* | 88.862 | 0.000 | -813.157 | -429.654 |
| | | 1.0 | 2.0 | -447.8399108* | 91.028 | 0.000 | -644.265 | -251.415 |
| Nausea | Tukey HSD | .0 | 1.0 | -.6458* | .2423 | .024 | -1.221 | -.071 |
| | | | 2.0 | -1.4000* | .4334 | .005 | -2.428 | -.372 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1.0 | .0 | .6458* | .2423 | .024 | .071 | 1.221 |
| | | | 2.0 | -.7542 | .4440 | .210 | -1.808 | .299 |
| | | 2.0 | .0 | 1.4000* | .4334 | .005 | .372 | 2.428 |
| | | | 1.0 | .7542 | .4440 | .210 | -.299 | 1.808 |
| | LSD | .0 | 1.0 | -.6458* | .2423 | .009 | -1.125 | -.166 |
| | | | 2.0 | -1.4000* | .4334 | .002 | -2.258 | -.542 |
| | | 1.0 | .0 | .6458* | .2423 | .009 | .166 | 1.125 |
| | | | 2.0 | -.7542 | .4440 | .092 | -1.633 | .125 |
| | | 2.0 | .0 | 1.4000* | .4334 | .002 | .542 | 2.258 |
| | | | 1.0 | .7542 | .4440 | .092 | -.125 | 1.633 |
| | Bonferroni | .0 | 1.0 | -.6458* | .2423 | .026 | -1.234 | -.058 |
| | | | 2.0 | -1.4000* | .4334 | .005 | -2.452 | -.348 |
| | | 1.0 | .0 | .6458* | .2423 | .026 | .058 | 1.234 |
| | | | 2.0 | -.7542 | .4440 | .276 | -1.832 | .324 |
| | | 2.0 | .0 | 1.4000* | .4334 | .005 | .348 | 2.452 |
| | | | 1.0 | .7542 | .4440 | .276 | -.324 | 1.832 |
| | Dunnett t (2-sided)[b] | .0 | 2.0 | -1.4000* | .4334 | .003 | -2.335 | -.465 |
| | | 1.0 | 2.0 | -.7542 | .4440 | .133 | -1.712 | .204 |
| Sleepiness | Tukey HSD | .0 | 1.0 | -.6932* | .1935 | .001 | -1.152 | -.234 |
| | | | 2.0 | -2.4848* | .3461 | .000 | -3.306 | -1.663 |
| | | 1.0 | .0 | .6932* | .1935 | .001 | .234 | 1.152 |
| | | | 2.0 | -1.7917* | .3546 | .000 | -2.633 | -.950 |
| | | 2.0 | .0 | 2.4848* | .3461 | .000 | 1.663 | 3.306 |
| | | | 1.0 | 1.7917* | .3546 | .000 | .950 | 2.633 |
| | LSD | .0 | 1.0 | -.6932* | .1935 | .000 | -1.076 | -.310 |
| | | | 2.0 | -2.4848* | .3461 | .000 | -3.170 | -1.800 |
| | | 1.0 | .0 | .6932* | .1935 | .000 | .310 | 1.076 |
| | | | 2.0 | -1.7917* | .3546 | .000 | -2.494 | -1.090 |
| | | 2.0 | .0 | 2.4848* | .3461 | .000 | 1.800 | 3.170 |
| | | | 1.0 | 1.7917* | .3546 | .000 | 1.090 | 2.494 |
| | Bonferroni | .0 | 1.0 | -.6932* | .1935 | .001 | -1.163 | -.223 |
| | | | 2.0 | -2.4848* | .3461 | .000 | -3.325 | -1.645 |
| | | 1.0 | .0 | .6932* | .1935 | .001 | .223 | 1.163 |
| | | | 2.0 | -1.7917* | .3546 | .000 | -2.652 | -.931 |
| | | 2.0 | .0 | 2.4848* | .3461 | .000 | 1.645 | 3.325 |
| | | | 1.0 | 1.7917* | .3546 | .000 | .931 | 2.652 |
| | Dunnett t (2-sided)[b] | .0 | 2.0 | -2.4848* | .3461 | .000 | -3.232 | -1.738 |
| | | 1.0 | 2.0 | -1.7917* | .3546 | .000 | -2.557 | -1.027 |

*. The mean difference is significant at the 0.05 level.

b. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## I. Study Two: Sleepiness by Fatigue (MF)

```
  /COMPRESSED.

DATASET ACTIVATE DataSet7.

DATASET ACTIVATE DataSet7.

ONEWAY NauseaRating06 Sleepiness17 BY Fatigue03

  /STATISTICS DESCRIPTIVES HOMOGENEITY

  /PLOT MEANS

  /POSTHOC=TUKEY LSD DUNNETT ALPHA(0.05).
```

# Oneway

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| Nausea Rating (0-6) | .0 | 49 | .347 | .8114 | .1159 | .114 | .580 | 0.0 | 3.5 |
| | .5 | 5 | .400 | .5477 | .2449 | -.280 | 1.080 | 0.0 | 1.0 |
| | 1.0 | 50 | .400 | .8806 | .1245 | .150 | .650 | 0.0 | 3.0 |
| | 1.5 | 5 | .300 | .6708 | .3000 | -.533 | 1.133 | 0.0 | 1.5 |
| | 2.0 | 17 | .647 | 1.4116 | .3424 | -.079 | 1.373 | 0.0 | 5.0 |
| | Total | 126 | .409 | .9196 | .0819 | .247 | .571 | 0.0 | 5.0 |
| Sleepiness (1-7) | .0 | 49 | 1.8673 | .71280 | .10183 | 1.6626 | 2.0721 | 1.00 | 4.00 |
| | .5 | 5 | 2.2000 | .57009 | .25495 | 1.4921 | 2.9079 | 1.50 | 3.00 |
| | 1.0 | 50 | 2.6050 | 1.08807 | .15388 | 2.2958 | 2.9142 | 0.00 | 5.50 |
| | 1.5 | 5 | 3.8000 | .44721 | .20000 | 3.2447 | 4.3553 | 3.50 | 4.50 |
| | 2.0 | 17 | 4.5882 | 1.04933 | .25450 | 4.0487 | 5.1278 | 3.00 | 6.00 |
| | Total | 126 | 2.6171 | 1.27620 | .11369 | 2.3921 | 2.8421 | 0.00 | 6.00 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Sleepiness (1-7) | 4.169 | 4 | 121 | .003 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Nausea Rating (0-6) | Between Groups | 1.216 | 4 | .304 | .352 | .842 |
| | Within Groups | 104.484 | 121 | .864 | | |
| | Total | 105.700 | 125 | | | |
| Sleepiness (1-7) | Between Groups | 101.469 | 4 | 25.367 | 30.058 | .000 |
| | Within Groups | 102.117 | 121 | .844 | | |
| | Total | 203.586 | 125 | | | |

# Post Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Sleepiness (1-7) | Tukey HSD | .0 | .5 | -.33265 | .43129 | .938 | -1.5270 | .8617 |
| | | | 1.0 | -.73765* | .18467 | .001 | -1.2491 | -.2262 |
| | | | 1.5 | -1.93265* | .43129 | .000 | -3.1270 | -.7383 |
| | | | 2.0 | -2.72089* | .25859 | .000 | -3.4370 | -2.0048 |
| | | .5 | .0 | .33265 | .43129 | .938 | -.8617 | 1.5270 |
| | | | 1.0 | -.40500 | .43089 | .881 | -1.5983 | .7883 |
| | | | 1.5 | -1.60000 | .58101 | .052 | -3.2090 | .0090 |
| | | | 2.0 | -2.38824* | .46737 | .000 | -3.6825 | -1.0939 |
| | | 1.0 | .0 | .73765* | .18467 | .001 | .2262 | 1.2491 |
| | | | .5 | .40500 | .43089 | .881 | -.7883 | 1.5983 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1.5 | -1.19500* | .43089 | .049 | -2.3883 | -.0017 |
| | | 2.0 | -1.98324* | .25792 | .000 | -2.6975 | -1.2690 |
| | 1.5 | .0 | 1.93265* | .43129 | .000 | .7383 | 3.1270 |
| | | .5 | 1.60000 | .58101 | .052 | -.0090 | 3.2090 |
| | | 1.0 | 1.19500* | .43089 | .049 | .0017 | 2.3883 |
| | | 2.0 | -.78824 | .46737 | .446 | -2.0825 | .5061 |
| | 2.0 | .0 | 2.72089* | .25859 | .000 | 2.0048 | 3.4370 |
| | | .5 | 2.38824* | .46737 | .000 | 1.0939 | 3.6825 |
| | | 1.0 | 1.98324* | .25792 | .000 | 1.2690 | 2.6975 |
| | | 1.5 | .78824 | .46737 | .446 | -.5061 | 2.0825 |
| LSD | .0 | .5 | -.33265 | .43129 | .442 | -1.1865 | .5212 |
| | | 1.0 | -.73765* | .18467 | .000 | -1.1033 | -.3721 |
| | | 1.5 | -1.93265* | .43129 | .000 | -2.7865 | -1.0788 |
| | | 2.0 | -2.72089* | .25859 | .000 | -3.2328 | -2.2089 |
| | .5 | .0 | .33265 | .43129 | .442 | -.5212 | 1.1865 |
| | | 1.0 | -.40500 | .43089 | .349 | -1.2581 | .4481 |
| | | 1.5 | -1.60000* | .58101 | .007 | -2.7503 | -.4497 |
| | | 2.0 | -2.38824* | .46737 | .000 | -3.3135 | -1.4630 |
| | 1.0 | .0 | .73765* | .18467 | .000 | .3721 | 1.1033 |
| | | .5 | .40500 | .43089 | .349 | -.4481 | 1.2581 |
| | | 1.5 | -1.19500* | .43089 | .006 | -2.0481 | -.3419 |
| | | 2.0 | -1.98324* | .25792 | .000 | -2.4939 | -1.4726 |
| | 1.5 | .0 | 1.93265* | .43129 | .000 | 1.0788 | 2.7865 |
| | | .5 | 1.60000* | .58101 | .007 | .4497 | 2.7503 |
| | | 1.0 | 1.19500* | .43089 | .006 | .3419 | 2.0481 |
| | | 2.0 | -.78824 | .46737 | .094 | -1.7135 | .1370 |
| | 2.0 | .0 | 2.72089* | .25859 | .000 | 2.2089 | 3.2328 |
| | | .5 | 2.38824* | .46737 | .000 | 1.4630 | 3.3135 |
| | | 1.0 | 1.98324* | .25792 | .000 | 1.4726 | 2.4939 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1.5 | .78824 | .46737 | .094 | -.1370 | 1.7135 |
| Dunnett t (2-sided)[a] | .0 | 2.0 | -2.72089* | .25859 | .000 | -3.3614 | -2.0803 |
| | .5 | 2.0 | -2.38824* | .46737 | .000 | -3.5460 | -1.2305 |
| | 1.0 | 2.0 | -1.98324* | .25792 | .000 | -2.6221 | -1.3443 |
| | 1.5 | 2.0 | -.78824 | .46737 | .277 | -1.9460 | .3695 |

*. The mean difference is significant at the 0.05 level.

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## J. Create Line Errors and Sleepiness (MF)

### Descriptives

CL_errors

| | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|
| .00 | 2 | .500 | .7071 | .5000 | -5.853 | 6.853 | 0.0 | 1.0 |
| 1.00 | 18 | .222 | .4278 | .1008 | .009 | .435 | 0.0 | 1.0 |
| 2.00 | 47 | .277 | .5398 | .0787 | .118 | .435 | 0.0 | 2.0 |
| 3.00 | 26 | .154 | .4641 | .0910 | -.034 | .341 | 0.0 | 2.0 |
| 4.00 | 21 | .095 | .3008 | .0656 | -.042 | .232 | 0.0 | 1.0 |
| 5.00 | 7 | .571 | .5345 | .2020 | .077 | 1.066 | 0.0 | 1.0 |
| 6.00 | 5 | 1.000 | .7071 | .3162 | .122 | 1.878 | 0.0 | 2.0 |
| Total | 126 | .262 | .5088 | .0453 | .172 | .352 | 0.0 | 2.0 |

### Test of Homogeneity of Variances

CL_errors

| Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|
| 2.125 | 6 | 119 | .055 |

### ANOVA

CL_errors

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 4.433 | 6 | .739 | 3.149 | .007 |
| Within Groups | 27.924 | 119 | .235 | | |
| Total | 32.357 | 125 | | | |

## Post Hoc Tests

**Multiple Comparisons**

Dependent Variable: CL_errors

| (I) Sleepiness (1-7) | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|
| Tukey HSD | .00 | 1.00 | .2778 | .3611 | .987 | -.805 | 1.361 |
| | | 2.00 | .2234 | .3497 | .995 | -.826 | 1.272 |
| | | 3.00 | .3462 | .3555 | .959 | -.720 | 1.412 |
| | | 4.00 | .4048 | .3585 | .918 | -.670 | 1.480 |
| | | 5.00 | -.0714 | .3884 | 1.000 | -1.236 | 1.094 |
| | | 6.00 | -.5000 | .4053 | .880 | -1.716 | .716 |
| | 1.00 | .00 | -.2778 | .3611 | .987 | -1.361 | .805 |
| | | 2.00 | -.0544 | .1343 | 1.000 | -.457 | .348 |
| | | 3.00 | .0684 | .1485 | .999 | -.377 | .514 |
| | | 4.00 | .1270 | .1556 | .983 | -.340 | .594 |
| | | 5.00 | -.3492 | .2158 | .671 | -.996 | .298 |
| | | 6.00 | -.7778* | .2449 | .030 | -1.512 | -.043 |
| | 2.00 | .00 | -.2234 | .3497 | .995 | -1.272 | .826 |
| | | 1.00 | .0544 | .1343 | 1.000 | -.348 | .457 |
| | | 3.00 | .1227 | .1184 | .944 | -.232 | .478 |
| | | 4.00 | .1814 | .1271 | .787 | -.200 | .563 |
| | | 5.00 | -.2948 | .1963 | .743 | -.883 | .294 |
| | | 6.00 | -.7234* | .2279 | .031 | -1.407 | -.040 |
| | 3.00 | .00 | -.3462 | .3555 | .959 | -1.412 | .720 |
| | | 1.00 | -.0684 | .1485 | .999 | -.514 | .377 |
| | | 2.00 | -.1227 | .1184 | .944 | -.478 | .232 |
| | | 4.00 | .0586 | .1421 | 1.000 | -.368 | .485 |
| | | 5.00 | -.4176 | .2063 | .405 | -1.036 | .201 |
| | | 6.00 | -.8462* | .2365 | .009 | -1.556 | -.137 |
| | 4.00 | .00 | -.4048 | .3585 | .918 | -1.480 | .670 |
| | | 1.00 | -.1270 | .1556 | .983 | -.594 | .340 |
| | | 2.00 | -.1814 | .1271 | .787 | -.563 | .200 |
| | | 3.00 | -.0586 | .1421 | 1.000 | -.485 | .368 |
| | | 5.00 | -.4762 | .2114 | .276 | -1.110 | .158 |
| | | 6.00 | -.9048* | .2410 | .005 | -1.628 | -.182 |
| | 5.00 | .00 | .0714 | .3884 | 1.000 | -1.094 | 1.236 |
| | | 1.00 | .3492 | .2158 | .671 | -.298 | .996 |
| | | 2.00 | .2948 | .1963 | .743 | -.294 | .883 |
| | | 3.00 | .4176 | .2063 | .405 | -.201 | 1.036 |
| | | 4.00 | .4762 | .2114 | .276 | -.158 | 1.110 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 6.00 | -.4286 | .2836 | .738 | -1.279 | .422 |
| | 6.00 | .00 | .5000 | .4053 | .880 | -.716 | 1.716 |
| | | 1.00 | .7778* | .2449 | .030 | .043 | 1.512 |
| | | 2.00 | .7234* | .2279 | .031 | .040 | 1.407 |
| | | 3.00 | .8462* | .2365 | .009 | .137 | 1.556 |
| | | 4.00 | .9048* | .2410 | .005 | .182 | 1.628 |
| | | 5.00 | .4286 | .2836 | .738 | -.422 | 1.279 |
| LSD | .00 | 1.00 | .2778 | .3611 | .443 | -.437 | .993 |
| | | 2.00 | .2234 | .3497 | .524 | -.469 | .916 |
| | | 3.00 | .3462 | .3555 | .332 | -.358 | 1.050 |
| | | 4.00 | .4048 | .3585 | .261 | -.305 | 1.115 |
| | | 5.00 | -.0714 | .3884 | .854 | -.840 | .698 |
| | | 6.00 | -.5000 | .4053 | .220 | -1.303 | .303 |
| | 1.00 | .00 | -.2778 | .3611 | .443 | -.993 | .437 |
| | | 2.00 | -.0544 | .1343 | .686 | -.320 | .211 |
| | | 3.00 | .0684 | .1485 | .646 | -.226 | .362 |
| | | 4.00 | .1270 | .1556 | .416 | -.181 | .435 |
| | | 5.00 | -.3492 | .2158 | .108 | -.776 | .078 |
| | | 6.00 | -.7778* | .2449 | .002 | -1.263 | -.293 |
| | 2.00 | .00 | -.2234 | .3497 | .524 | -.916 | .469 |
| | | 1.00 | .0544 | .1343 | .686 | -.211 | .320 |
| | | 3.00 | .1227 | .1184 | .302 | -.112 | .357 |
| | | 4.00 | .1814 | .1271 | .156 | -.070 | .433 |
| | | 5.00 | -.2948 | .1963 | .136 | -.683 | .094 |
| | | 6.00 | -.7234* | .2279 | .002 | -1.175 | -.272 |
| | 3.00 | .00 | -.3462 | .3555 | .332 | -1.050 | .358 |
| | | 1.00 | -.0684 | .1485 | .646 | -.362 | .226 |
| | | 2.00 | -.1227 | .1184 | .302 | -.357 | .112 |
| | | 4.00 | .0586 | .1421 | .681 | -.223 | .340 |
| | | 5.00 | -.4176* | .2063 | .045 | -.826 | -.009 |
| | | 6.00 | -.8462* | .2365 | .001 | -1.315 | -.378 |
| | 4.00 | .00 | -.4048 | .3585 | .261 | -1.115 | .305 |
| | | 1.00 | -.1270 | .1556 | .416 | -.435 | .181 |
| | | 2.00 | -.1814 | .1271 | .156 | -.433 | .070 |
| | | 3.00 | -.0586 | .1421 | .681 | -.340 | .223 |
| | | 5.00 | -.4762* | .2114 | .026 | -.895 | -.058 |
| | | 6.00 | -.9048* | .2410 | .000 | -1.382 | -.427 |
| | 5.00 | .00 | .0714 | .3884 | .854 | -.698 | .840 |
| | | 1.00 | .3492 | .2158 | .108 | -.078 | .776 |
| | | 2.00 | .2948 | .1963 | .136 | -.094 | .683 |
| | | 3.00 | .4176* | .2063 | .045 | .009 | .826 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4.00 | .4762* | .2114 | .026 | .058 | .895 |
| | | 6.00 | -.4286 | .2836 | .133 | -.990 | .133 |
| | 6.00 | .00 | .5000 | .4053 | .220 | -.303 | 1.303 |
| | | 1.00 | .7778* | .2449 | .002 | .293 | 1.263 |
| | | 2.00 | .7234* | .2279 | .002 | .272 | 1.175 |
| | | 3.00 | .8462* | .2365 | .001 | .378 | 1.315 |
| | | 4.00 | .9048* | .2410 | .000 | .427 | 1.382 |
| | | 5.00 | .4286 | .2836 | .133 | -.133 | .990 |
| Dunnett t (2-sided)[b] | .00 | 6.00 | -.5000 | .4053 | .552 | -1.516 | .516 |
| | 1.00 | 6.00 | -.7778* | .2449 | .008 | -1.392 | -.164 |
| | 2.00 | 6.00 | -.7234* | .2279 | .008 | -1.295 | -.152 |
| | 3.00 | 6.00 | -.8462* | .2365 | .002 | -1.439 | -.253 |
| | 4.00 | 6.00 | -.9048* | .2410 | .001 | -1.509 | -.300 |
| | 5.00 | 6.00 | -.4286 | .2836 | .373 | -1.140 | .283 |

*. The mean difference is significant at the 0.05 level.

b. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## K. Create Line and Read Text task by Session (MF)

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| CL_errors | 0 | 25 | .280 | .5416 | .1083 | .056 | .504 | 0.0 | 2.0 |
| | 1 | 25 | .320 | .5568 | .1114 | .090 | .550 | 0.0 | 2.0 |
| | 2 | 26 | .077 | .3922 | .0769 | -.082 | .235 | 0.0 | 2.0 |
| | 3 | 26 | .038 | .1961 | .0385 | -.041 | .118 | 0.0 | 1.0 |
| | 4 | 24 | .625 | .5758 | .1175 | .382 | .868 | 0.0 | 2.0 |
| | Total | 126 | .262 | .5088 | .0453 | .172 | .352 | 0.0 | 2.0 |
| RT_errors | 0 | 25 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 1 | 25 | .500 | .9014 | .1803 | .128 | .872 | 0.0 | 2.5 |
| | 2 | 26 | .404 | .6484 | .1272 | .142 | .666 | 0.0 | 2.5 |
| | 3 | 26 | 1.154 | 1.2472 | .2446 | .650 | 1.658 | 0.0 | 3.5 |
| | 4 | 24 | .583 | .8427 | .1720 | .227 | .939 | 0.0 | 3.0 |
| | Total | 126 | .532 | .9072 | .0808 | .372 | .692 | 0.0 | 3.5 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| CL_errors | 12.543 | 4 | 121 | .000 |
| RT_errors | 13.857 | 4 | 121 | .000 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| CL_errors | Between Groups | 5.444 | 4 | 1.361 | 6.120 | .000 |
| | Within Groups | 26.913 | 121 | .222 | | |
| | Total | 32.357 | 125 | | | |
| RT_errors | Between Groups | 17.645 | 4 | 4.411 | 6.263 | .000 |
| | Within Groups | 85.228 | 121 | .704 | | |
| | Total | 102.873 | 125 | | | |

## Post Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|---|
| CL_errors | Tukey HSD | 0 | 1 | -.0400 | .1334 | .998 | -.409 | .329 |
| | | | 2 | .2031 | .1321 | .540 | -.163 | .569 |
| | | | 3 | .2415 | .1321 | .362 | -.124 | .607 |
| | | | 4 | -.3450 | .1348 | .085 | -.718 | .028 |
| | | 1 | 0 | .0400 | .1334 | .998 | -.329 | .409 |
| | | | 2 | .2431 | .1321 | .356 | -.123 | .609 |
| | | | 3 | .2815 | .1321 | .214 | -.084 | .647 |
| | | | 4 | -.3050 | .1348 | .164 | -.678 | .068 |
| | | 2 | 0 | -.2031 | .1321 | .540 | -.569 | .163 |
| | | | 1 | -.2431 | .1321 | .356 | -.609 | .123 |
| | | | 3 | .0385 | .1308 | .998 | -.324 | .401 |
| | | | 4 | -.5481* | .1335 | .001 | -.918 | -.178 |
| | | 3 | 0 | -.2415 | .1321 | .362 | -.607 | .124 |
| | | | 1 | -.2815 | .1321 | .214 | -.647 | .084 |
| | | | 2 | -.0385 | .1308 | .998 | -.401 | .324 |
| | | | 4 | -.5865* | .1335 | .000 | -.956 | -.217 |
| | | 4 | 0 | .3450 | .1348 | .085 | -.028 | .718 |
| | | | 1 | .3050 | .1348 | .164 | -.068 | .678 |
| | | | 2 | .5481* | .1335 | .001 | .178 | .918 |
| | | | 3 | .5865* | .1335 | .000 | .217 | .956 |
| | LSD | 0 | 1 | -.0400 | .1334 | .765 | -.304 | .224 |
| | | | 2 | .2031 | .1321 | .127 | -.058 | .465 |
| | | | 3 | .2415 | .1321 | .070 | -.020 | .503 |
| | | | 4 | -.3450* | .1348 | .012 | -.612 | -.078 |
| | | 1 | 0 | .0400 | .1334 | .765 | -.224 | .304 |
| | | | 2 | .2431 | .1321 | .068 | -.018 | .505 |
| | | | 3 | .2815* | .1321 | .035 | .020 | .543 |
| | | | 4 | -.3050* | .1348 | .025 | -.572 | -.038 |
| | | 2 | 0 | -.2031 | .1321 | .127 | -.465 | .058 |
| | | | 1 | -.2431 | .1321 | .068 | -.505 | .018 |
| | | | 3 | .0385 | .1308 | .769 | -.220 | .297 |
| | | | 4 | -.5481* | .1335 | .000 | -.812 | -.284 |
| | | 3 | 0 | -.2415 | .1321 | .070 | -.503 | .020 |
| | | | 1 | -.2815* | .1321 | .035 | -.543 | -.020 |
| | | | 2 | -.0385 | .1308 | .769 | -.297 | .220 |
| | | | 4 | -.5865* | .1335 | .000 | -.851 | -.322 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 4 | 0 | .3450* | .1348 | .012 | .078 | .612 |
| | | | 1 | .3050* | .1348 | .025 | .038 | .572 |
| | | | 2 | .5481* | .1335 | .000 | .284 | .812 |
| | | | 3 | .5865* | .1335 | .000 | .322 | .851 |
| | Dunnett t (<control)[a] | 0 | 4 | -.3450* | .1348 | .020 | | -.051 |
| | | 1 | 4 | -.3050* | .1348 | .041 | | -.011 |
| | | 2 | 4 | -.5481* | .1335 | .000 | | -.257 |
| | | 3 | 4 | -.5865* | .1335 | .000 | | -.296 |
| RT_errors | Tukey HSD | 0 | 1 | -.5000 | .2374 | .224 | -1.157 | .157 |
| | | | 2 | -.4038 | .2351 | .427 | -1.055 | .247 |
| | | | 3 | -1.1538* | .2351 | .000 | -1.805 | -.503 |
| | | | 4 | -.5833 | .2398 | .114 | -1.248 | .081 |
| | | 1 | 0 | .5000 | .2374 | .224 | -.157 | 1.157 |
| | | | 2 | .0962 | .2351 | .994 | -.555 | .747 |
| | | | 3 | -.6538* | .2351 | .048 | -1.305 | -.003 |
| | | | 4 | -.0833 | .2398 | .997 | -.748 | .581 |
| | | 2 | 0 | .4038 | .2351 | .427 | -.247 | 1.055 |
| | | | 1 | -.0962 | .2351 | .994 | -.747 | .555 |
| | | | 3 | -.7500* | .2328 | .014 | -1.395 | -.105 |
| | | | 4 | -.1795 | .2376 | .943 | -.837 | .478 |
| | | 3 | 0 | 1.1538* | .2351 | .000 | .503 | 1.805 |
| | | | 1 | .6538* | .2351 | .048 | .003 | 1.305 |
| | | | 2 | .7500* | .2328 | .014 | .105 | 1.395 |
| | | | 4 | .5705 | .2376 | .122 | -.087 | 1.228 |
| | | 4 | 0 | .5833 | .2398 | .114 | -.081 | 1.248 |
| | | | 1 | .0833 | .2398 | .997 | -.581 | .748 |
| | | | 2 | .1795 | .2376 | .943 | -.478 | .837 |
| | | | 3 | -.5705 | .2376 | .122 | -1.228 | .087 |
| | LSD | 0 | 1 | -.5000* | .2374 | .037 | -.970 | -.030 |
| | | | 2 | -.4038 | .2351 | .088 | -.869 | .062 |
| | | | 3 | -1.1538* | .2351 | .000 | -1.619 | -.688 |
| | | | 4 | -.5833* | .2398 | .016 | -1.058 | -.109 |
| | | 1 | 0 | .5000* | .2374 | .037 | .030 | .970 |
| | | | 2 | .0962 | .2351 | .683 | -.369 | .562 |
| | | | 3 | -.6538* | .2351 | .006 | -1.119 | -.188 |
| | | | 4 | -.0833 | .2398 | .729 | -.558 | .391 |
| | | 2 | 0 | .4038 | .2351 | .088 | -.062 | .869 |
| | | | 1 | -.0962 | .2351 | .683 | -.562 | .369 |
| | | | 3 | -.7500* | .2328 | .002 | -1.211 | -.289 |
| | | | 4 | -.1795 | .2376 | .451 | -.650 | .291 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 0 | 1.1538* | .2351 | .000 | .688 | 1.619 |
| | | 1 | .6538* | .2351 | .006 | .188 | 1.119 |
| | | 2 | .7500* | .2328 | .002 | .289 | 1.211 |
| | | 4 | .5705* | .2376 | .018 | .100 | 1.041 |
| | 4 | 0 | .5833* | .2398 | .016 | .109 | 1.058 |
| | | 1 | .0833 | .2398 | .729 | -.391 | .558 |
| | | 2 | .1795 | .2376 | .451 | -.291 | .650 |
| | | 3 | -.5705* | .2376 | .018 | -1.041 | -.100 |
| Dunnett t (<control)[a] | 0 | 4 | -.5833* | .2398 | .028 | | -.061 |
| | 1 | 4 | -.0833 | .2398 | .663 | | .439 |
| | 2 | 4 | -.1795 | .2376 | .480 | | .338 |
| | 3 | 4 | .5705 | .2376 | 1.000 | | 1.088 |

*. The mean difference is significant at the 0.05 level.

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## L. Study Two tasks, Boring condition by Nausea, sleepiness and Fatigue (MF)

```
DATASET ACTIVATE DataSet12.

SAVE OUTFILE='F:\Motion Fatigue\MF_BMSetask_bor.sav'
  /COMPRESSED.
ONEWAY PZ_failed CU_failed CL_errors CT_errors RT_errors RU_errors BY
NAUSEA
  /PLOT MEANS
```

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| PZ_failed | Between Groups | .000 | 2 | .000 | .025 | .975 |
| | Within Groups | .243 | 37 | .007 | | |
| | Total | .244 | 39 | | | |
| CU_failed | Between Groups | 2.021 | 2 | 1.011 | 1.113 | .339 |
| | Within Groups | 33.579 | 37 | .908 | | |
| | Total | 35.600 | 39 | | | |
| CL_errors | Between Groups | .132 | 2 | .066 | .214 | .808 |
| | Within Groups | 11.368 | 37 | .307 | | |
| | Total | 11.500 | 39 | | | |
| CT_errors | Between Groups | .637 | 2 | .318 | .185 | .832 |
| | Within Groups | 63.763 | 37 | 1.723 | | |
| | Total | 64.400 | 39 | | | |
| RT_errors | Between Groups | 7.825 | 2 | 3.913 | 3.263 | .050 |
| | Within Groups | 44.368 | 37 | 1.199 | | |
| | Total | 52.194 | 39 | | | |
| RU_errors | Between Groups | .033 | 2 | .016 | .260 | .773 |
| | Within Groups | 2.342 | 37 | .063 | | |
| | Total | 2.375 | 39 | | | |

```
ONEWAY PZ_failed CU_failed CL_errors CT_errors RT_errors RU_errors BY
Sleepiness_rounded

  /PLOT MEANS
```

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| PZ_failed | Between Groups | .029 | 5 | .006 | .935 | .471 |
| | Within Groups | .214 | 34 | .006 | | |
| | Total | .244 | 39 | | | |
| CU_failed | Between Groups | 1.052 | 5 | .210 | .207 | .957 |
| | Within Groups | 34.548 | 34 | 1.016 | | |

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| | Total | 35.600 | 39 | | | |
| CL_errors | Between Groups | 3.016 | 5 | .603 | 2.417 | .056 |
| | Within Groups | 8.484 | 34 | .250 | | |
| | Total | 11.500 | 39 | | | |
| CT_errors | Between Groups | 10.251 | 5 | 2.050 | 1.287 | .292 |
| | Within Groups | 54.149 | 34 | 1.593 | | |
| | Total | 64.400 | 39 | | | |
| RT_errors | Between Groups | 3.876 | 5 | .775 | .546 | .740 |
| | Within Groups | 48.317 | 34 | 1.421 | | |
| | Total | 52.194 | 39 | | | |
| RU_errors | Between Groups | .304 | 5 | .061 | .997 | .435 |
| | Within Groups | 2.071 | 34 | .061 | | |
| | Total | 2.375 | 39 | | | |

```
ONEWAY PZ_failed CU_failed CL_errors CT_errors RT_errors RU_errors BY
fatigue_rounded
  /PLOT MEANS
```

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| PZ_failed | Between Groups | .010 | 2 | .005 | .826 | .446 |
| | Within Groups | .233 | 37 | .006 | | |
| | Total | .244 | 39 | | | |
| CU_failed | Between Groups | 1.825 | 2 | .913 | 1.000 | .378 |
| | Within Groups | 33.775 | 37 | .913 | | |
| | Total | 35.600 | 39 | | | |
| CL_errors | Between Groups | .635 | 2 | .318 | 1.082 | .349 |
| | Within Groups | 10.865 | 37 | .294 | | |
| | Total | 11.500 | 39 | | | |
| CT_errors | Between Groups | 6.683 | 2 | 3.342 | 2.142 | .132 |
| | Within Groups | 57.717 | 37 | 1.560 | | |
| | Total | 64.400 | 39 | | | |
| RT_errors | Between Groups | 4.350 | 2 | 2.175 | 1.682 | .200 |
| | Within Groups | 47.843 | 37 | 1.293 | | |
| | Total | 52.194 | 39 | | | |
| RU_errors | Between Groups | .018 | 2 | .009 | .138 | .871 |
| | Within Groups | 2.357 | 37 | .064 | | |
| | Total | 2.375 | 39 | | | |

## M. Mean HRV scores in Study Two (overall) (MF)

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| Mean RR (ms): | 0 | 23 | 891.81 | 448.43 | 93.51 | 697.90 | 1085.73 | 453.15 | 2103.40 |
| | 1 | 25 | 768.87 | 430.98 | 86.20 | 590.97 | 946.77 | 460.69 | 2705.25 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 25 | 764.98 | 309.60 | 61.92 | 637.19 | 892.78 | 375.59 | 1911.86 |
| | 3 | 25 | 792.11 | 194.73 | 38.95 | 711.73 | 872.49 | 506.37 | 1484.75 |
| | 4 | 25 | 793.21 | 162.59 | 32.52 | 726.10 | 860.32 | 560.51 | 1291.39 |
| | 5 | 25 | 789.51 | 130.84 | 26.17 | 735.50 | 843.51 | 581.23 | 1128.26 |
| | Total | 148 | 798.84 | 301.83 | 24.81 | 749.81 | 847.87 | 375.59 | 2705.25 |
| NN50 (count): | 0 | 23 | 69.13 | 127.81 | 26.65 | 13.86 | 124.40 | .00 | 566.00 |
| | 1 | 25 | 97.96 | 68.69 | 13.74 | 69.60 | 126.32 | .00 | 267.00 |
| | 2 | 25 | 607.64 | 754.77 | 150.95 | 296.09 | 919.19 | 12.00 | 2548.00 |
| | 3 | 25 | 78.08 | 91.79 | 18.36 | 40.19 | 115.97 | 1.00 | 406.00 |
| | 4 | 25 | 697.92 | 674.51 | 134.90 | 419.50 | 976.34 | 8.00 | 2719.00 |
| | 5 | 25 | 182.28 | 150.44 | 30.09 | 120.18 | 244.38 | 9.00 | 608.00 |
| | Total | 148 | 291.80 | 494.51 | 40.65 | 211.47 | 372.14 | .00 | 2719.00 |
| RMSSD (ms): | 0 | 23 | 1566.32 | 1152.80 | 240.37 | 1067.81 | 2064.82 | 8.91 | 5505.19 |
| | 1 | 25 | 869.35 | 1067.93 | 213.59 | 428.53 | 1310.17 | 12.41 | 4498.46 |
| | 2 | 25 | 408.80 | 726.10 | 145.22 | 109.09 | 708.52 | 17.58 | 3172.41 |
| | 3 | 25 | 285.84 | 472.04 | 94.41 | 90.99 | 480.69 | 15.16 | 1754.81 |
| | 4 | 25 | 267.04 | 413.23 | 82.65 | 96.47 | 437.61 | 17.92 | 1884.76 |
| | 5 | 25 | 219.79 | 333.93 | 66.79 | 81.95 | 357.63 | 19.48 | 1597.25 |
| | Total | 148 | 589.84 | 882.27 | 72.52 | 446.52 | 733.16 | 8.91 | 5505.19 |
| Peak Frequency, FFT spectrum, HF (Hz): | 0 | 23 | .18 | .06 | .01 | .15 | .20 | .15 | .35 |
| | 1 | 25 | .19 | .05 | .01 | .17 | .21 | .15 | .32 |
| | 2 | 25 | .20 | .05 | .01 | .18 | .22 | .15 | .36 |
| | 3 | 25 | .24 | .07 | .01 | .21 | .27 | .15 | .39 |
| | 4 | 25 | .19 | .05 | .01 | .17 | .21 | .15 | .37 |
| | 5 | 25 | .21 | .06 | .01 | .19 | .24 | .15 | .35 |
| | Total | 148 | .20 | .06 | .00 | .19 | .21 | .15 | .39 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| Mean RR (ms): | 4.209 | 5 | 142 | .001 |
| NN50 (count): | 23.961 | 5 | 142 | .000 |
| RMSSD (ms): | 4.341 | 5 | 142 | .001 |
| Peak Frequency, FFT spectrum, HF (Hz): | 2.529 | 5 | 142 | .032 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Mean RR (ms): | Between Groups | 254023.55 | 5 | 50804.710 | .549 | .739 |
| | Within Groups | 13137713.99 | 142 | 92519.113 | | |
| | Total | 13391737.54 | 147 | | | |
| NN50 (count): | Between Groups | 10138709.27 | 5 | 2027741.854 | 11.156 | .000 |
| | Within Groups | 25809342.05 | 142 | 181755.930 | | |
| | Total | 35948051.32 | 147 | | | |
| RMSSD (ms): | Between Groups | 33042039.10 | 5 | 6608407.819 | 11.531 | .000 |
| | Within Groups | 81383281.04 | 142 | 573121.697 | | |
| | Total | 114425320.13 | 147 | | | |
| Peak Frequency, FFT spectrum, HF (Hz): | Between Groups | 0.05 | 5 | .010 | 3.061 | .012 |
| | Within Groups | 0.48 | 142 | .003 | | |
| | Total | 0.53 | 147 | | | |

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| NN50 (count): | Tukey HSD | 0 | 1 | -28.830 | 123.177 | 1.000 | -384.69 | 327.03 |
| | | | 2 | -538.510* | 123.177 | .000 | -894.37 | -182.65 |
| | | | 3 | -8.950 | 123.177 | 1.000 | -364.81 | 346.91 |
| | | | 4 | -628.790* | 123.177 | .000 | -984.65 | -272.93 |
| | | | 5 | -113.150 | 123.177 | .941 | -469.01 | 242.71 |
| | | 1 | 0 | 28.830 | 123.177 | 1.000 | -327.03 | 384.69 |
| | | | 2 | -509.680* | 120.584 | .001 | -858.05 | -161.31 |
| | | | 3 | 19.880 | 120.584 | 1.000 | -328.49 | 368.25 |
| | | | 4 | -599.960* | 120.584 | .000 | -948.33 | -251.59 |
| | | | 5 | -84.320 | 120.584 | .982 | -432.69 | 264.05 |
| | | 2 | 0 | 538.510* | 123.177 | .000 | 182.65 | 894.37 |
| | | | 1 | 509.680* | 120.584 | .001 | 161.31 | 858.05 |
| | | | 3 | 529.560* | 120.584 | .000 | 181.19 | 877.93 |
| | | | 4 | -90.280 | 120.584 | .975 | -438.65 | 258.09 |
| | | | 5 | 425.360* | 120.584 | .007 | 76.99 | 773.73 |
| | | 3 | 0 | 8.950 | 123.177 | 1.000 | -346.91 | 364.81 |
| | | | 1 | -19.880 | 120.584 | 1.000 | -368.25 | 328.49 |
| | | | 2 | -529.560* | 120.584 | .000 | -877.93 | -181.19 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 4 | -619.840* | 120.584 | .000 | -968.21 | -271.47 |
| | | | 5 | -104.200 | 120.584 | .954 | -452.57 | 244.17 |
| | | 4 | 0 | 628.790* | 123.177 | .000 | 272.93 | 984.65 |
| | | | 1 | 599.960* | 120.584 | .000 | 251.59 | 948.33 |
| | | | 2 | 90.280 | 120.584 | .975 | -258.09 | 438.65 |
| | | | 3 | 619.840* | 120.584 | .000 | 271.47 | 968.21 |
| | | | 5 | 515.640* | 120.584 | .000 | 167.27 | 864.01 |
| | | 5 | 0 | 113.150 | 123.177 | .941 | -242.71 | 469.01 |
| | | | 1 | 84.320 | 120.584 | .982 | -264.05 | 432.69 |
| | | | 2 | -425.360* | 120.584 | .007 | -773.73 | -76.99 |
| | | | 3 | 104.200 | 120.584 | .954 | -244.17 | 452.57 |
| | | | 4 | -515.640* | 120.584 | .000 | -864.01 | -167.27 |
| RMSSD (ms): | Tukey HSD | 0 | 1 | 696.971* | 218.731 | .021 | 65.053 | 1328.889 |
| | | | 2 | 1157.514* | 218.731 | .000 | 525.596 | 1789.433 |
| | | | 3 | 1280.477* | 218.731 | .000 | 648.559 | 1912.395 |
| | | | 4 | 1299.279* | 218.731 | .000 | 667.361 | 1931.197 |
| | | | 5 | 1346.530* | 218.731 | .000 | 714.612 | 1978.449 |
| | | 1 | 0 | -696.971* | 218.731 | .021 | -1328.889 | -65.053 |
| | | | 2 | 460.543 | 214.126 | .268 | -158.070 | 1079.157 |
| | | | 3 | 583.506 | 214.126 | .077 | -35.107 | 1202.119 |
| | | | 4 | 602.308 | 214.126 | .061 | -16.305 | 1220.921 |
| | | | 5 | 649.560* | 214.126 | .034 | 30.946 | 1268.173 |
| | | 2 | 0 | -1157.514* | 218.731 | .000 | -1789.433 | -525.596 |
| | | | 1 | -460.543 | 214.126 | .268 | -1079.157 | 158.070 |
| | | | 3 | 122.963 | 214.126 | .993 | -495.651 | 741.576 |
| | | | 4 | 141.765 | 214.126 | .986 | -476.848 | 760.378 |
| | | | 5 | 189.016 | 214.126 | .950 | -429.597 | 807.630 |
| | | 3 | 0 | -1280.477* | 218.731 | .000 | -1912.395 | -648.559 |
| | | | 1 | -583.506 | 214.126 | .077 | -1202.119 | 35.107 |
| | | | 2 | -122.963 | 214.126 | .993 | -741.576 | 495.651 |
| | | | 4 | 18.802 | 214.126 | 1.000 | -599.811 | 637.415 |
| | | | 5 | 66.053 | 214.126 | 1.000 | -552.560 | 684.667 |
| | | 4 | 0 | -1299.279* | 218.731 | .000 | -1931.197 | -667.361 |
| | | | 1 | -602.308 | 214.126 | .061 | -1220.921 | 16.305 |
| | | | 2 | -141.765 | 214.126 | .986 | -760.378 | 476.848 |
| | | | 3 | -18.802 | 214.126 | 1.000 | -637.415 | 599.811 |
| | | | 5 | 47.251 | 214.126 | 1.000 | -571.362 | 665.865 |
| | | 5 | 0 | -1346.530* | 218.731 | .000 | -1978.449 | -714.612 |
| | | | 1 | -649.560* | 214.126 | .034 | -1268.173 | -30.946 |
| | | | 2 | -189.016 | 214.126 | .950 | -807.630 | 429.597 |
| | | | 3 | -66.053 | 214.126 | 1.000 | -684.667 | 552.560 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 4 | -47.251 | 214.126 | 1.000 | -665.865 | 571.362 |
| Peak Frequency, FFT spectrum, HF (Hz): | Tukey HSD | 0 | 1 | -.0163 | .0168 | .9268 | -.0649 | .0323 |
| | | | 2 | -.0251 | .0168 | .6714 | -.0737 | .0235 |
| | | | 3 | -.059* | .0168 | .0084 | -.1073 | -.0101 |
| | | | 4 | -.0133 | .0168 | .9683 | -.0619 | .0353 |
| | | | 5 | -.0376 | .0168 | .2295 | -.0862 | .0110 |
| | | 1 | 0 | .0163 | .0168 | .9268 | -.0323 | .0649 |
| | | | 2 | -.0088 | .0165 | .9948 | -.0563 | .0388 |
| | | | 3 | -.0423 | .0165 | .1113 | -.0899 | .0052 |
| | | | 4 | .0030 | .0165 | 1.0000 | -.0446 | .0505 |
| | | | 5 | -.0212 | .0165 | .7899 | -.0688 | .0263 |
| | | 2 | 0 | .0251 | .0168 | .6714 | -.0235 | .0737 |
| | | | 1 | .0088 | .0165 | .9948 | -.0388 | .0563 |
| | | | 3 | -.0336 | .0165 | .3253 | -.0812 | .0140 |
| | | | 4 | .0117 | .0165 | .9803 | -.0359 | .0593 |
| | | | 5 | -.0125 | .0165 | .9738 | -.0601 | .0351 |
| | | 3 | 0 | .059* | .0168 | .0084 | .0101 | .1073 |
| | | | 1 | .0423 | .0165 | .1113 | -.0052 | .0899 |
| | | | 2 | .0336 | .0165 | .3253 | -.0140 | .0812 |
| | | | 4 | .0453 | .0165 | .0717 | -.0023 | .0929 |
| | | | 5 | .0211 | .0165 | .7950 | -.0265 | .0687 |
| | | 4 | 0 | .0133 | .0168 | .9683 | -.0353 | .0619 |
| | | | 1 | -.0030 | .0165 | 1.0000 | -.0505 | .0446 |
| | | | 2 | -.0117 | .0165 | .9803 | -.0593 | .0359 |
| | | | 3 | -.0453 | .0165 | .0717 | -.0929 | .0023 |
| | | | 5 | -.0242 | .0165 | .6835 | -.0718 | .0234 |
| | | 5 | 0 | .0376 | .0168 | .2295 | -.0110 | .0862 |
| | | | 1 | .0212 | .0165 | .7899 | -.0263 | .0688 |
| | | | 2 | .0125 | .0165 | .9738 | -.0351 | .0601 |
| | | | 3 | -.0211 | .0165 | .7950 | -.0687 | .0265 |
| | | | 4 | .0242 | .0165 | .6835 | -.0234 | .0718 |

*. The mean difference is significant at the 0.05 level.

## N. Mean HRV scores in Study Two (Boredom Condition) (MF)

# Oneway

**Descriptives**

| | N | Mean | Std. | Std. Error | 95% Confidence | Minimum | Maximum |
|---|---|---|---|---|---|---|---|

| | | | | Deviation | | Interval for Mean | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| RMSSD (ms): | 0 | 11 | 1161.087 | 845.435 | 254.908 | 593.116 | 1729.058 | 8.908 | 2812.560 |
| | 1 | 12 | 820.022 | 1230.455 | 355.202 | 38.228 | 1601.816 | 12.413 | 4498.457 |
| | 2 | 12 | 439.204 | 894.076 | 258.097 | -128.865 | 1007.273 | 17.584 | 3172.406 |
| | 3 | 12 | 364.077 | 606.544 | 175.094 | -21.302 | 749.456 | 15.161 | 1754.813 |
| | 4 | 12 | 250.366 | 270.691 | 78.142 | 78.377 | 422.355 | 17.921 | 793.298 |
| | 5 | 12 | 193.788 | 201.604 | 58.198 | 65.696 | 321.881 | 19.481 | 685.618 |
| | Total | 71 | 529.316 | 810.725 | 96.215 | 337.421 | 721.212 | 8.908 | 4498.457 |
| NN50 (count): | 0 | 11 | 115.545 | 174.636 | 52.655 | -1.777 | 232.868 | 0.000 | 566.000 |
| | 1 | 12 | 99.917 | 85.439 | 24.664 | 45.631 | 154.202 | 0.000 | 267.000 |
| | 2 | 12 | 535.250 | 704.013 | 203.231 | 87.941 | 982.559 | 12.000 | 2360.000 |
| | 3 | 12 | 74.333 | 72.420 | 20.906 | 28.320 | 120.347 | 1.000 | 240.000 |
| | 4 | 12 | 603.417 | 524.867 | 151.516 | 269.932 | 936.901 | 35.000 | 1622.000 |
| | 5 | 12 | 150.000 | 117.187 | 33.829 | 75.543 | 224.457 | 9.000 | 421.000 |
| | Total | 71 | 265.155 | 422.489 | 50.140 | 165.154 | 365.156 | 0.000 | 2360.000 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| RMSSD (ms): | 2.100 | 5 | 65 | .077 |
| NN50 (count): | 9.805 | 5 | 65 | .000 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| RMSSD (ms): | Between Groups | 8114396.01 | 5 | 1622879.20 | 2.784 | .024 |
| | Within Groups | 37894851.62 | 65 | 582997.72 | | |
| | Total | 46009247.64 | 70 | | | |
| NN50 (count): | Between Groups | 3418407.82 | 5 | 683681.56 | 4.896 | .001 |
| | Within Groups | 9076349.48 | 65 | 139636.15 | | |
| | Total | 12494757.30 | 70 | | | |

**Post Hoc Tests**

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|---|---|
| RMSSD (ms): | Tukey HSD | 0 | 1 | 341.065 | 318.721 | 0.891 | -594.837 | 1276.967 |
| | | | 2 | 721.883 | 318.721 | 0.223 | -214.019 | 1657.785 |
| | | | 3 | 797.010 | 318.721 | 0.139 | -138.892 | 1732.912 |
| | | | 4 | 910.721 | 318.721 | 0.061 | -25.180 | 1846.623 |
| | | | 5 | 967.299* | 318.721 | 0.039 | 31.397 | 1903.201 |
| | | 1 | 0 | -341.065 | 318.721 | 0.891 | -1276.967 | 594.837 |
| | | | 2 | 380.818 | 311.715 | 0.825 | -534.512 | 1296.148 |
| | | | 3 | 455.945 | 311.715 | 0.689 | -459.385 | 1371.275 |
| | | | 4 | 569.656 | 311.715 | 0.456 | -345.674 | 1484.986 |
| | | | 5 | 626.233 | 311.715 | 0.349 | -289.097 | 1541.564 |
| | | 2 | 0 | -721.883 | 318.721 | 0.223 | -1657.785 | 214.019 |
| | | | 1 | -380.818 | 311.715 | 0.825 | -1296.148 | 534.512 |
| | | | 3 | 75.127 | 311.715 | 1.000 | -840.203 | 990.457 |
| | | | 4 | 188.838 | 311.715 | 0.990 | -726.492 | 1104.168 |
| | | | 5 | 245.416 | 311.715 | 0.969 | -669.915 | 1160.746 |
| | | 3 | 0 | -797.010 | 318.721 | 0.139 | -1732.912 | 138.892 |
| | | | 1 | -455.945 | 311.715 | 0.689 | -1371.275 | 459.385 |
| | | | 2 | -75.127 | 311.715 | 1.000 | -990.457 | 840.203 |
| | | | 4 | 113.711 | 311.715 | 0.999 | -801.619 | 1029.041 |
| | | | 5 | 170.289 | 311.715 | 0.994 | -745.041 | 1085.619 |
| | | 4 | 0 | -910.721 | 318.721 | 0.061 | -1846.623 | 25.180 |
| | | | 1 | -569.656 | 311.715 | 0.456 | -1484.986 | 345.674 |
| | | | 2 | -188.838 | 311.715 | 0.990 | -1104.168 | 726.492 |
| | | | 3 | -113.711 | 311.715 | 0.999 | -1029.041 | 801.619 |
| | | | 5 | 56.577 | 311.715 | 1.000 | -858.753 | 971.907 |
| | | 5 | 0 | -967.299 | 318.721 | 0.039 | -1903.201 | -31.397 |
| | | | 1 | -626.233 | 311.715 | 0.349 | -1541.564 | 289.097 |
| | | | 2 | -245.416 | 311.715 | 0.969 | -1160.746 | 669.915 |
| | | | 3 | -170.289 | 311.715 | 0.994 | -1085.619 | 745.041 |
| | | | 4 | -56.577 | 311.715 | 1.000 | -971.907 | 858.753 |
| NN50 (count): | Tukey HSD | 0 | 1 | 15.629 | 155.983 | 1.000 | -442.40 | 473.66 |
| | | | 2 | -419.705 | 155.983 | .091 | -877.74 | 38.33 |
| | | | 3 | 41.212 | 155.983 | 1.000 | -416.82 | 499.24 |
| | | | 4 | -487.871* | 155.983 | .030 | -945.90 | -29.84 |
| | | | 5 | -34.455 | 155.983 | 1.000 | -492.49 | 423.58 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 0 | -15.629 | 155.983 | 1.000 | -473.66 | 442.40 |
| | | 2 | -435.333 | 152.554 | .062 | -883.30 | 12.63 |
| | | 3 | 25.583 | 152.554 | 1.000 | -422.38 | 473.55 |
| | | 4 | -503.500* | 152.554 | .019 | -951.46 | -55.54 |
| | | 5 | -50.083 | 152.554 | .999 | -498.05 | 397.88 |
| | 2 | 0 | 419.705 | 155.983 | .091 | -38.33 | 877.74 |
| | | 1 | 435.333 | 152.554 | .062 | -12.63 | 883.30 |
| | | 3 | 460.917* | 152.554 | .040 | 12.95 | 908.88 |
| | | 4 | -68.167 | 152.554 | .998 | -516.13 | 379.80 |
| | | 5 | 385.250 | 152.554 | .132 | -62.71 | 833.21 |
| | 3 | 0 | -41.212 | 155.983 | 1.000 | -499.24 | 416.82 |
| | | 1 | -25.583 | 152.554 | 1.000 | -473.55 | 422.38 |
| | | 2 | -460.917* | 152.554 | .040 | -908.88 | -12.95 |
| | | 4 | -529.083* | 152.554 | .012 | -977.05 | -81.12 |
| | | 5 | -75.667 | 152.554 | .996 | -523.63 | 372.30 |
| | 4 | 0 | 487.871* | 155.983 | .030 | 29.84 | 945.90 |
| | | 1 | 503.500* | 152.554 | .019 | 55.54 | 951.46 |
| | | 2 | 68.167 | 152.554 | .998 | -379.80 | 516.13 |
| | | 3 | 529.083* | 152.554 | .012 | 81.12 | 977.05 |
| | | 5 | 453.417* | 152.554 | .046 | 5.45 | 901.38 |
| | 5 | 0 | 34.455 | 155.983 | 1.000 | -423.58 | 492.49 |
| | | 1 | 50.083 | 152.554 | .999 | -397.88 | 498.05 |
| | | 2 | -385.250 | 152.554 | .132 | -833.21 | 62.71 |
| | | 3 | 75.667 | 152.554 | .996 | -372.30 | 523.63 |
| | | 4 | -453.417* | 152.554 | .046 | -901.38 | -5.45 |

*. The mean difference is significant at the 0.05 level.

## O. Mean HRV scores in Study Two (Motion Condition) (MF)

### Oneway

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| RMSSD (ms): | 0 | 12 | 1937.780 | 1301.289 | 375.650 | 1110.980 | 2764.579 | 688.224 | 5505.187 |
| | 1 | 13 | 914.878 | 942.559 | 261.419 | 345.295 | 1484.461 | 101.413 | 3855.138 |
| | 2 | 13 | 380.742 | 565.594 | 156.868 | 38.957 | 722.527 | 21.648 | 2052.605 |
| | 3 | 13 | 213.623 | 310.861 | 86.217 | 25.772 | 401.474 | 19.608 | 1071.499 |
| | 4 | 13 | 282.430 | 523.267 | 145.128 | -33.778 | 598.637 | 24.917 | 1884.761 |
| | 5 | 13 | 243.787 | 429.493 | 119.120 | -15.753 | 503.327 | 27.081 | 1597.251 |
| | Total | 77 | 645.641 | 945.323 | 107.729 | 431.079 | 860.203 | 19.608 | 5505.187 |
| NN50 (count): | 0 | 12 | 26.583 | 28.526 | 8.235 | 8.459 | 44.708 | 3.000 | 89.000 |
| | 1 | 13 | 96.154 | 52.332 | 14.514 | 64.530 | 127.778 | 5.000 | 205.000 |
| | 2 | 13 | 674.462 | 821.552 | 227.858 | 178.002 | 1170.921 | 35.000 | 2548.000 |
| | 3 | 13 | 81.538 | 109.622 | 30.404 | 15.295 | 147.782 | 1.000 | 406.000 |
| | 4 | 13 | 785.154 | 800.136 | 221.918 | 301.636 | 1268.671 | 8.000 | 2719.000 |
| | 5 | 13 | 212.077 | 175.137 | 48.574 | 106.243 | 317.911 | 50.000 | 608.000 |
| | Total | 77 | 316.377 | 554.365 | 63.176 | 190.551 | 442.202 | 1.000 | 2719.000 |

**Test of Homogeneity of Variances**

| | Levene Statistic | df1 | df2 | Sig. |
|---|---|---|---|---|
| RMSSD (ms): | 2.522 | 5 | 71 | .037 |
| NN50 (count): | 16.775 | 5 | 71 | .000 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| RMSSD (ms): | Between Groups | 28130677.65 | 5.00 | 5626135.53 | 10.04 | 0.00 |
| | Within Groups | 39785556.08 | 71.00 | 560359.94 | | |
| | Total | 67916233.73 | 76.00 | | | |
| NN50 (count): | Between Groups | 7020292.39 | 5.00 | 1404058.48 | 6.10 | 0.00 |
| | Within Groups | 16336085.69 | 71.00 | 230085.71 | | |
| | Total | 23356378.08 | 76.00 | | | |

## Post Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|---|
| RMSSD (ms): | Tukey HSD | 0 | 1 | 1022.901* | 299.669 | .013 | 145.177 | 1900.626 |
| | | | 2 | 1557.037* | 299.669 | .000 | 679.313 | 2434.762 |
| | | | 3 | 1724.156* | 299.669 | .000 | 846.432 | 2601.881 |
| | | | 4 | 1655.350* | 299.669 | .000 | 777.626 | 2533.074 |
| | | | 5 | 1693.993* | 299.669 | .000 | 816.269 | 2571.717 |
| | | 1 | 0 | -1022.901* | 299.669 | .013 | -1900.626 | -145.177 |
| | | | 2 | 534.136 | 293.614 | .460 | -325.855 | 1394.127 |
| | | | 3 | 701.255 | 293.614 | .174 | -158.736 | 1561.245 |
| | | | 4 | 632.448 | 293.614 | .272 | -227.542 | 1492.439 |
| | | | 5 | 671.091 | 293.614 | .214 | -188.899 | 1531.082 |
| | | 2 | 0 | -1557.037* | 299.669 | .000 | -2434.762 | -679.313 |
| | | | 1 | -534.136 | 293.614 | .460 | -1394.127 | 325.855 |
| | | | 3 | 167.119 | 293.614 | .993 | -692.872 | 1027.110 |
| | | | 4 | 98.312 | 293.614 | .999 | -761.678 | 958.303 |
| | | | 5 | 136.955 | 293.614 | .997 | -723.035 | 996.946 |
| | | 3 | 0 | -1724.156* | 299.669 | .000 | -2601.881 | -846.432 |
| | | | 1 | -701.255 | 293.614 | .174 | -1561.245 | 158.736 |
| | | | 2 | -167.119 | 293.614 | .993 | -1027.110 | 692.872 |
| | | | 4 | -68.806 | 293.614 | 1.000 | -928.797 | 791.184 |
| | | | 5 | -30.164 | 293.614 | 1.000 | -890.154 | 829.827 |
| | | 4 | 0 | -1655.350* | 299.669 | .000 | -2533.074 | -777.626 |
| | | | 1 | -632.448 | 293.614 | .272 | -1492.439 | 227.542 |
| | | | 2 | -98.312 | 293.614 | .999 | -958.303 | 761.678 |
| | | | 3 | 68.806 | 293.614 | 1.000 | -791.184 | 928.797 |
| | | | 5 | 38.643 | 293.614 | 1.000 | -821.348 | 898.634 |
| | | 5 | 0 | -1693.993* | 299.669 | .000 | -2571.717 | -816.269 |
| | | | 1 | -671.091 | 293.614 | .214 | -1531.082 | 188.899 |
| | | | 2 | -136.955 | 293.614 | .997 | -996.946 | 723.035 |
| | | | 3 | 30.164 | 293.614 | 1.000 | -829.827 | 890.154 |
| | | | 4 | -38.643 | 293.614 | 1.000 | -898.634 | 821.348 |
| | LSD | 0 | 1 | 1022.901* | 299.669 | .001 | 425.379 | 1620.424 |
| | | | 2 | 1557.037* | 299.669 | .000 | 959.515 | 2154.560 |
| | | | 3 | 1724.156* | 299.669 | .000 | 1126.634 | 2321.679 |
| | | | 4 | 1655.350* | 299.669 | .000 | 1057.828 | 2252.872 |
| | | | 5 | 1693.993* | 299.669 | .000 | 1096.471 | 2291.515 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 1 | 0 | -1022.901* | 299.669 | .001 | -1620.424 | -425.379 |
| | | | 2 | 534.136 | 293.614 | .073 | -51.314 | 1119.586 |
| | | | 3 | 701.255* | 293.614 | .020 | 115.805 | 1286.705 |
| | | | 4 | 632.449* | 293.614 | .035 | 46.999 | 1217.898 |
| | | | 5 | 671.091* | 293.614 | .025 | 85.641 | 1256.541 |
| | | 2 | 0 | -1557.037* | 299.669 | .000 | -2154.560 | -959.515 |
| | | | 1 | -534.136 | 293.614 | .073 | -1119.586 | 51.314 |
| | | | 3 | 167.119 | 293.614 | .571 | -418.331 | 752.569 |
| | | | 4 | 98.312 | 293.614 | .739 | -487.137 | 683.762 |
| | | | 5 | 136.955 | 293.614 | .642 | -448.494 | 722.405 |
| | | 3 | 0 | -1724.156* | 299.669 | .000 | -2321.679 | -1126.634 |
| | | | 1 | -701.255* | 293.614 | .020 | -1286.705 | -115.805 |
| | | | 2 | -167.119 | 293.614 | .571 | -752.569 | 418.331 |
| | | | 4 | -68.806 | 293.614 | .815 | -654.256 | 516.643 |
| | | | 5 | -30.164 | 293.614 | .918 | -615.613 | 555.286 |
| | | 4 | 0 | -1655.350* | 299.669 | .000 | -2252.872 | -1057.828 |
| | | | 1 | -632.449* | 293.614 | .035 | -1217.898 | -46.999 |
| | | | 2 | -98.312 | 293.614 | .739 | -683.762 | 487.137 |
| | | | 3 | 68.806 | 293.614 | .815 | -516.643 | 654.256 |
| | | | 5 | 38.643 | 293.614 | .896 | -546.807 | 624.093 |
| | | 5 | 0 | -1693.993* | 299.669 | .000 | -2291.515 | -1096.471 |
| | | | 1 | -671.091* | 293.614 | .025 | -1256.541 | -85.641 |
| | | | 2 | -136.955 | 293.614 | .642 | -722.405 | 448.494 |
| | | | 3 | 30.164 | 293.614 | .918 | -555.286 | 615.613 |
| | | | 4 | -38.643 | 293.614 | .896 | -624.093 | 546.807 |
| NN50 (count): | Tukey HSD | 0 | 1 | -69.571 | 192.023 | .999 | -632.00 | 492.86 |
| | | | 2 | -647.878* | 192.023 | .015 | -1210.31 | -85.45 |
| | | | 3 | -54.955 | 192.023 | 1.000 | -617.39 | 507.48 |
| | | | 4 | -758.571* | 192.023 | .002 | -1321.00 | -196.14 |
| | | | 5 | -185.494 | 192.023 | .927 | -747.92 | 376.94 |
| | | 1 | 0 | 69.571 | 192.023 | .999 | -492.86 | 632.00 |
| | | | 2 | -578.308* | 188.143 | .034 | -1129.38 | -27.24 |
| | | | 3 | 14.615 | 188.143 | 1.000 | -536.45 | 565.68 |
| | | | 4 | -689.000* | 188.143 | .006 | -1240.07 | -137.93 |
| | | | 5 | -115.923 | 188.143 | .990 | -666.99 | 435.14 |
| | | 2 | 0 | 647.878* | 192.023 | .015 | 85.45 | 1210.31 |
| | | | 1 | 578.308* | 188.143 | .034 | 27.24 | 1129.38 |
| | | | 3 | 592.923* | 188.143 | .028 | 41.86 | 1143.99 |
| | | | 4 | -110.692 | 188.143 | .992 | -661.76 | 440.38 |
| | | | 5 | 462.385 | 188.143 | .151 | -88.68 | 1013.45 |
| | | 3 | 0 | 54.955 | 192.023 | 1.000 | -507.48 | 617.39 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1 | -14.615 | 188.143 | 1.000 | -565.68 | 536.45 |
| | | 2 | -592.923* | 188.143 | .028 | -1143.99 | -41.86 |
| | | 4 | -703.615* | 188.143 | .005 | -1254.68 | -152.55 |
| | | 5 | -130.538 | 188.143 | .982 | -681.61 | 420.53 |
| | 4 | 0 | 758.571* | 192.023 | .002 | 196.14 | 1321.00 |
| | | 1 | 689.000* | 188.143 | .006 | 137.93 | 1240.07 |
| | | 2 | 110.692 | 188.143 | .992 | -440.38 | 661.76 |
| | | 3 | 703.615* | 188.143 | .005 | 152.55 | 1254.68 |
| | | 5 | 573.077* | 188.143 | .037 | 22.01 | 1124.14 |
| | 5 | 0 | 185.494 | 192.023 | .927 | -376.94 | 747.92 |
| | | 1 | 115.923 | 188.143 | .990 | -435.14 | 666.99 |
| | | 2 | -462.385 | 188.143 | .151 | -1013.45 | 88.68 |
| | | 3 | 130.538 | 188.143 | .982 | -420.53 | 681.61 |
| | | 4 | -573.077* | 188.143 | .037 | -1124.14 | -22.01 |
| LSD | 0 | 1 | -69.571 | 192.023 | .718 | -452.45 | 313.31 |
| | | 2 | -647.878* | 192.023 | .001 | -1030.76 | -265.00 |
| | | 3 | -54.955 | 192.023 | .776 | -437.84 | 327.93 |
| | | 4 | -758.571* | 192.023 | .000 | -1141.45 | -375.69 |
| | | 5 | -185.494 | 192.023 | .337 | -568.38 | 197.39 |
| | 1 | 0 | 69.571 | 192.023 | .718 | -313.31 | 452.45 |
| | | 2 | -578.308* | 188.143 | .003 | -953.45 | -203.16 |
| | | 3 | 14.615 | 188.143 | .938 | -360.53 | 389.76 |
| | | 4 | -689.000* | 188.143 | .000 | -1064.15 | -313.85 |
| | | 5 | -115.923 | 188.143 | .540 | -491.07 | 259.22 |
| | 2 | 0 | 647.878* | 192.023 | .001 | 265.00 | 1030.76 |
| | | 1 | 578.308* | 188.143 | .003 | 203.16 | 953.45 |
| | | 3 | 592.923* | 188.143 | .002 | 217.78 | 968.07 |
| | | 4 | -110.692 | 188.143 | .558 | -485.84 | 264.45 |
| | | 5 | 462.385* | 188.143 | .016 | 87.24 | 837.53 |
| | 3 | 0 | 54.955 | 192.023 | .776 | -327.93 | 437.84 |
| | | 1 | -14.615 | 188.143 | .938 | -389.76 | 360.53 |
| | | 2 | -592.923* | 188.143 | .002 | -968.07 | -217.78 |
| | | 4 | -703.615* | 188.143 | .000 | -1078.76 | -328.47 |
| | | 5 | -130.538 | 188.143 | .490 | -505.69 | 244.61 |
| | 4 | 0 | 758.571* | 192.023 | .000 | 375.69 | 1141.45 |
| | | 1 | 689.000* | 188.143 | .000 | 313.85 | 1064.15 |
| | | 2 | 110.692 | 188.143 | .558 | -264.45 | 485.84 |
| | | 3 | 703.615* | 188.143 | .000 | 328.47 | 1078.76 |
| | | 5 | 573.077* | 188.143 | .003 | 197.93 | 948.22 |
| | 5 | 0 | 185.494 | 192.023 | .337 | -197.39 | 568.38 |
| | | 1 | 115.923 | 188.143 | .540 | -259.22 | 491.07 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 2 | -462.385* | 188.143 | .016 | -837.53 | -87.24 |
| | 3 | 130.538 | 188.143 | .490 | -244.61 | 505.69 |
| | 4 | -573.077* | 188.143 | .003 | -948.22 | -197.93 |

*. The mean difference is significant at the 0.05 level.

## P. Mean errors in Create Text task (MP)

### General Linear Model

**Within-Subjects Factors**

Measure: MEASURE_1

| Intensity | | Dependent Variable |
|---|---|---|
| 1 | 1 | Low_Roll |
| | 2 | Low_Pitch |
| | 3 | Low_Yaw |
| | 4 | Low_X |
| | 5 | Low_Y |
| | 6 | Low_Z |
| 2 | 1 | Med_Roll |
| | 2 | Med_Pitch |
| | 3 | Med_Yaw |
| | 4 | Med_X |
| | 5 | Med_Y |
| | 6 | Med_Z |
| 3 | 1 | High_Roll |
| | 2 | High_Pitch |
| | 3 | High_Yaw |
| | 4 | High_X |
| | 5 | High_Y |
| | 6 | High_Z |

**Multivariate Tests[a]**

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Intensity | Pillai's Trace | .008 | .112[b] | 2.000 | 27.000 | .895 |
| | Wilks' Lambda | .992 | .112[b] | 2.000 | 27.000 | .895 |
| | Hotelling's Trace | .008 | .112[b] | 2.000 | 27.000 | .895 |
| | Roy's Largest Root | .008 | .112[b] | 2.000 | 27.000 | .895 |
| Motion | Pillai's Trace | .241 | 1.526[b] | 5.000 | 24.000 | .219 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Wilks' Lambda | .759 | 1.526[b] | 5.000 | 24.000 | .219 |
| | Hotelling's Trace | .318 | 1.526[b] | 5.000 | 24.000 | .219 |
| | Roy's Largest Root | .318 | 1.526[b] | 5.000 | 24.000 | .219 |
| Intensity * Motion | Pillai's Trace | .485 | 1.790[b] | 10.000 | 19.000 | .132 |
| | Wilks' Lambda | .515 | 1.790[b] | 10.000 | 19.000 | .132 |
| | Hotelling's Trace | .942 | 1.790[b] | 10.000 | 19.000 | .132 |
| | Roy's Largest Root | .942 | 1.790[b] | 10.000 | 19.000 | .132 |

a. Design: Intercept
Within Subjects Design: Intensity + Motion + Intensity * Motion
b. Exact statistic

**Mauchly's Test of Sphericity[a]**

Measure: MEASURE_1

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[b] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Intensity | .974 | .703 | 2 | .704 | .975 | 1.000 | .500 |
| Motion | .431 | 21.951 | 14 | .081 | .737 | .863 | .200 |
| Intensity * Motion | .046 | 75.102 | 54 | .035 | .644 | .857 | .100 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept
Within Subjects Design: Intensity + Motion + Intensity * Motion
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Intensity | Sphericity Assumed | .287 | 2 | .144 | .101 | .904 |
| | Greenhouse-Geisser | .287 | 1.950 | .147 | .101 | .899 |
| | Huynh-Feldt | .287 | 2.000 | .144 | .101 | .904 |
| | Lower-bound | .287 | 1.000 | .287 | .101 | .753 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Error(Intensity) | Sphericity Assumed | 79.379 | 56 | 1.417 | | |
| | Greenhouse-Geisser | 79.379 | 54.596 | 1.454 | | |
| | Huynh-Feldt | 79.379 | 56.000 | 1.417 | | |
| | Lower-bound | 79.379 | 28.000 | 2.835 | | |
| Motion | Sphericity Assumed | 7.374 | 5 | 1.475 | 1.700 | .139 |
| | Greenhouse-Geisser | 7.374 | 3.685 | 2.001 | 1.700 | .161 |
| | Huynh-Feldt | 7.374 | 4.313 | 1.710 | 1.700 | .150 |
| | Lower-bound | 7.374 | 1.000 | 7.374 | 1.700 | .203 |
| Error(Motion) | Sphericity Assumed | 121.460 | 140 | .868 | | |
| | Greenhouse-Geisser | 121.460 | 103.184 | 1.177 | | |
| | Huynh-Feldt | 121.460 | 120.763 | 1.006 | | |
| | Lower-bound | 121.460 | 28.000 | 4.338 | | |
| Intensity * Motion | Sphericity Assumed | 23.667 | 10 | 2.367 | 2.623 | .005 |
| | Greenhouse-Geisser | 23.667 | 6.443 | 3.673 | 2.623 | .016 |
| | Huynh-Feldt | 23.667 | 8.575 | 2.760 | 2.623 | .008 |
| | Lower-bound | 23.667 | 1.000 | 23.667 | 2.623 | .117 |
| Error(Intensity*Motion) | Sphericity Assumed | 252.667 | 280 | .902 | | |
| | Greenhouse-Geisser | 252.667 | 180.403 | 1.401 | | |
| | Huynh-Feldt | 252.667 | 240.093 | 1.052 | | |
| | Lower-bound | 252.667 | 28.000 | 9.024 | | |

**Tests of Within-Subjects Contrasts**

Measure: MEASURE_1

| Source | | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| Intensity | Linear | | .072 | 1 | .072 | .053 | .820 |
| | Quadratic | | .216 | 1 | .216 | .146 | .705 |
| Error(Intensity) | Linear | | 38.011 | 28 | 1.358 | | |
| | Quadratic | | 41.368 | 28 | 1.477 | | |
| Motion | | Linear | 2.733 | 1 | 2.733 | 3.061 | .091 |
| | | Quadratic | .709 | 1 | .709 | .700 | .410 |
| | | Cubic | 2.657 | 1 | 2.657 | 3.723 | .064 |
| | | Order 4 | .164 | 1 | .164 | .181 | .674 |
| | | Order 5 | 1.110 | 1 | 1.110 | 1.370 | .252 |
| Error(Motion) | | Linear | 24.996 | 28 | .893 | | |
| | | Quadratic | 28.386 | 28 | 1.014 | | |
| | | Cubic | 19.987 | 28 | .714 | | |
| | | Order 4 | 25.407 | 28 | .907 | | |
| | | Order 5 | 22.684 | 28 | .810 | | |
| Intensity * Motion | Linear | Linear | 2.040 | 1 | 2.040 | 2.150 | .154 |
| | | Quadratic | 6.799 | 1 | 6.799 | 7.579 | .010 |
| | | Cubic | .002 | 1 | .002 | .003 | .960 |
| | | Order 4 | 7.724 | 1 | 7.724 | 10.800 | .003 |
| | | Order 5 | 1.623 | 1 | 1.623 | 1.418 | .244 |
| | Quadratic | Linear | 3.938 | 1 | 3.938 | 3.859 | .059 |
| | | Quadratic | .121 | 1 | .121 | .184 | .671 |
| | | Cubic | .662 | 1 | .662 | .633 | .433 |
| | | Order 4 | .161 | 1 | .161 | .130 | .721 |
| | | Order 5 | .599 | 1 | .599 | .779 | .385 |
| Error(Intensity*Motion) | Linear | Linear | 26.567 | 28 | .949 | | |
| | | Quadratic | 25.118 | 28 | .897 | | |
| | | Cubic | 16.471 | 28 | .588 | | |
| | | Order 4 | 20.026 | 28 | .715 | | |
| | | Order 5 | 32.048 | 28 | 1.145 | | |
| | Quadratic | Linear | 28.569 | 28 | 1.020 | | |
| | | Quadratic | 18.320 | 28 | .654 | | |
| | | Cubic | 29.299 | 28 | 1.046 | | |
| | | Order 4 | 34.732 | 28 | 1.240 | | |
| | | Order 5 | 21.517 | 28 | .768 | | |

**Tests of Within-Subjects Contrasts**

Measure: MEASURE_1

| Source | | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| Intensity | Level 1 vs. Level 3 | | .024 | 1 | .024 | .053 | .820 |
| | Level 2 vs. Level 3 | | .024 | 1 | .024 | .044 | .836 |
| Error(Intensity) | Level 1 vs. Level 3 | | 12.670 | 28 | .453 | | |
| | Level 2 vs. Level 3 | | 15.282 | 28 | .546 | | |
| Motion | | Level 2 vs. Level 1 | 3.222 | 1 | 3.222 | 3.500 | .072 |
| | | Level 3 vs. Level 1 | 1.383 | 1 | 1.383 | 1.810 | .189 |
| | | Level 4 vs. Level 1 | 2.590 | 1 | 2.590 | 3.736 | .063 |
| | | Level 5 vs. Level 1 | 1.241 | 1 | 1.241 | 1.138 | .295 |
| | | Level 6 vs. Level 1 | 3.682 | 1 | 3.682 | 5.804 | .023 |
| Error(Motion) | | Level 2 vs. Level 1 | 25.778 | 28 | .921 | | |
| | | Level 3 vs. Level 1 | 21.395 | 28 | .764 | | |
| | | Level 4 vs. Level 1 | 19.410 | 28 | .693 | | |
| | | Level 5 vs. Level 1 | 30.536 | 28 | 1.091 | | |
| | | Level 6 vs. Level 1 | 17.762 | 28 | .634 | | |
| Intensity * Motion | Level 1 vs. Level 3 | Level 2 vs. Level 1 | 42.241 | 1 | 42.241 | 11.290 | .002 |
| | | Level 3 vs. Level 1 | 7.759 | 1 | 7.759 | 2.490 | .126 |
| | | Level 4 vs. Level 1 | 31.034 | 1 | 31.034 | 5.756 | .023 |
| | | Level 5 vs. Level 1 | 47.207 | 1 | 47.207 | 10.853 | .003 |
| | | Level 6 vs. Level 1 | 6.759 | 1 | 6.759 | 1.671 | .207 |
| | Level 2 vs. Level 3 | Level 2 vs. Level 1 | 25.138 | 1 | 25.138 | 5.683 | .024 |
| | | Level 3 vs. Level 1 | 16.690 | 1 | 16.690 | 5.747 | .023 |
| | | Level 4 vs. Level 1 | 18.241 | 1 | 18.241 | 3.388 | .076 |
| | | Level 5 vs. Level 1 | 42.241 | 1 | 42.241 | 11.976 | .002 |
| | | Level 6 vs. Level 1 | 23.310 | 1 | 23.310 | 6.482 | .017 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Error(Intensity*Motion) | Level 1 vs. Level 3 | Level 2 vs. Level 1 | 104.759 | 28 | 3.741 | | |
| | | Level 3 vs. Level 1 | 87.241 | 28 | 3.116 | | |
| | | Level 4 vs. Level 1 | 150.966 | 28 | 5.392 | | |
| | | Level 5 vs. Level 1 | 121.793 | 28 | 4.350 | | |
| | | Level 6 vs. Level 1 | 113.241 | 28 | 4.044 | | |
| | Level 2 vs. Level 3 | Level 2 vs. Level 1 | 123.862 | 28 | 4.424 | | |
| | | Level 3 vs. Level 1 | 81.310 | 28 | 2.904 | | |
| | | Level 4 vs. Level 1 | 150.759 | 28 | 5.384 | | |
| | | Level 5 vs. Level 1 | 98.759 | 28 | 3.527 | | |
| | | Level 6 vs. Level 1 | 100.690 | 28 | 3.596 | | |

## Q. Combined Errors by Axis only (MP)

```
ONEWAY PZ_errors CU_errors CL_errors CT_errors
RT_errors RU_errors BY Axiscode
```

# Oneway

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| PZ_errors | Between Groups | .010 | 5 | .002 | .504 | .773 |
| | Within Groups | 1.960 | 516 | .004 | | |
| | Total | 1.969 | 521 | | | |
| CU_errors | Between Groups | .061 | 5 | .012 | .093 | .993 |
| | Within Groups | 67.678 | 516 | .131 | | |
| | Total | 67.739 | 521 | | | |
| CL_errors | Between Groups | 2.414 | 5 | .483 | .892 | .486 |
| | Within Groups | 279.172 | 516 | .541 | | |
| | Total | 281.586 | 521 | | | |
| CT_errors | Between Groups | 7.374 | 5 | 1.475 | 1.445 | .207 |
| | Within Groups | 526.782 | 516 | 1.021 | | |
| | Total | 534.155 | 521 | | | |
| RT_errors | Between Groups | .492 | 5 | .098 | .478 | .793 |
| | Within Groups | 106.299 | 516 | .206 | | |
| | Total | 106.791 | 521 | | | |
| RU_errors | Between Groups | .130 | 5 | .026 | .629 | .678 |
| | Within Groups | 21.379 | 516 | .041 | | |
| | Total | 21.510 | 521 | | | |

## R. Combined Errors and Time by Intensity only (MP)

```
ONEWAY Errors Time BY IntensityCode
```

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Errors | Between Groups | .802 | 2 | .401 | 1.148 | .318 |
| | Within Groups | 1091.841 | 3123 | .350 | | |
| | Total | 1092.644 | 3125 | | | |
| Time | Between Groups | 108851780.985 | 2 | 54425890.493 | 1.169 | .311 |
| | Within Groups | 145423838584.357 | 3123 | 46565430.222 | | |
| | Total | 145532690365.343 | 3125 | | | |

## S. Combined Errors and Time by Axis only (MP)

```
ONEWAY Errors Time BY Axiscode
```

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Errors | Between Groups | 2.616 | 5 | .523 | 1.498 | .187 |
| | Within Groups | 1090.027 | 3120 | .349 | | |
| | Total | 1092.644 | 3125 | | | |
| Time | Between Groups | 42403206.056 | 5 | 8480641.211 | .182 | .970 |
| | Within Groups | 145490287159.287 | 3120 | 46631502.295 | | |
| | Total | 145532690365.343 | 3125 | | | |

# T. Practice Effects on Errors and Time (MP)

**Oneway**

```
GET
  FILE='F:\Motion Perception\MP_overviewNEW_30_09_14.sav'.
DATASET NAME DataSet1 WINDOW=FRONT.
ONEWAY PZ_time CU_time CL_time CT_time RT_time RU_time PZ_errors CU_errors CL_errors CT_errors
RT_errors RU_errors BY Task
```

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| PZ_time | Between Groups | 96594639.688 | 17 | 5682037.629 | 3.885 | .000 |
| | Within Groups | 737143512.690 | 504 | 1462586.335 | | |
| | Total | 833738152.377 | 521 | | | |
| CU_time | Between Groups | 1142183839.259 | 17 | 67187284.662 | 6.121 | .000 |
| | Within Groups | 5532201416.759 | 504 | 10976590.113 | | |
| | Total | 6674385256.017 | 521 | | | |
| CL_time | Between Groups | 2721463887.711 | 17 | 160086111.042 | 3.586 | .000 |
| | Within Groups | 22502232018.759 | 504 | 44647285.752 | | |
| | Total | 25223695906.469 | 521 | | | |
| CT_time | Between Groups | 1347277961.533 | 17 | 79251644.796 | 3.308 | .000 |
| | Within Groups | 12074004649.035 | 504 | 23956358.431 | | |
| | Total | 13421282610.567 | 521 | | | |
| RT_time | Between Groups | 267376880.845 | 17 | 15728051.814 | 4.663 | .000 |
| | Within Groups | 1699998657.172 | 504 | 3373013.209 | | |
| | Total | 1967375538.017 | 521 | | | |
| RU_time | Between Groups | 1181020243.757 | 17 | 69471779.045 | 17.436 | .000 |
| | Within Groups | 2008188182.345 | 504 | 3984500.362 | | |
| | Total | 3189208426.102 | 521 | | | |
| PZ_errors | Between Groups | .073 | 17 | .004 | 1.138 | .314 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Within Groups | 1.897 | 504 | .004 | | |
| | Total | 1.969 | 521 | | | |
| CU_errors | Between Groups | .360 | 17 | .021 | .158 | 1.000 |
| | Within Groups | 67.379 | 504 | .134 | | |
| | Total | 67.739 | 521 | | | |
| CL_errors | Between Groups | 18.621 | 17 | 1.095 | 2.099 | .006 |
| | Within Groups | 262.966 | 504 | .522 | | |
| | Total | 281.586 | 521 | | | |
| CT_errors | Between Groups | 25.672 | 17 | 1.510 | 1.497 | .091 |
| | Within Groups | 508.483 | 504 | 1.009 | | |
| | Total | 534.155 | 521 | | | |
| RT_errors | Between Groups | 3.481 | 17 | .205 | .999 | .458 |
| | Within Groups | 103.310 | 504 | .205 | | |
| | Total | 106.791 | 521 | | | |
| RU_errors | Between Groups | 1.027 | 17 | .060 | 1.486 | .094 |
| | Within Groups | 20.483 | 504 | .041 | | |
| | Total | 21.510 | 521 | | | |

```
ONEWAY PZ_time CU_time CL_time CT_time RT_time RU_time CL_errors BY Task
  /STATISTICS DESCRIPTIVES HOMOGENEITY
  /PLOT MEANS
  /MISSING ANALYSIS
  /POSTHOC=TUKEY DUNNETTL (1) ALPHA(0.05).
```

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| PZ_time | 1.0 | 29 | 4018.793 | 966.0383 | 179.3888 | 3651.332 | 4386.254 | 2188.0 | 6093.0 |
| | 2.0 | 29 | 4346.966 | 2470.4728 | 458.7553 | 3407.248 | 5286.683 | 2360.0 | 16031.0 |
| | 3.0 | 29 | 3819.379 | 993.5262 | 184.4932 | 3441.462 | 4197.296 | 2047.0 | 5672.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4.0 | 29 | 4277.448 | 1330.4695 | 247.0620 | 3771.365 | 4783.532 | 2625.0 | 8359.0 |
| | 5.0 | 29 | 4315.690 | 1534.4852 | 284.9467 | 3732.003 | 4899.377 | 2234.0 | 9046.0 |
| | 6.0 | 29 | 3622.241 | 887.7471 | 164.8505 | 3284.560 | 3959.922 | 2281.0 | 6172.0 |
| | 7.0 | 29 | 3332.448 | 1084.6310 | 201.4109 | 2919.877 | 3745.020 | 1860.0 | 5813.0 |
| | 8.0 | 29 | 3525.276 | 707.2400 | 131.3312 | 3256.256 | 3794.296 | 2172.0 | 5235.0 |
| | 9.0 | 29 | 3870.621 | 1501.9393 | 278.9031 | 3299.314 | 4441.928 | 1328.0 | 9235.0 |
| | 10.0 | 29 | 3665.000 | 1289.3597 | 239.4281 | 3174.554 | 4155.446 | 1844.0 | 8125.0 |
| | 11.0 | 29 | 3270.517 | 923.3326 | 171.4586 | 2919.300 | 3621.734 | 1391.0 | 4875.0 |
| | 12.0 | 29 | 3574.931 | 1344.5859 | 249.6833 | 3063.478 | 4086.384 | 2188.0 | 8937.0 |
| | 13.0 | 29 | 3407.862 | 1124.6127 | 208.8353 | 2980.082 | 3835.642 | 1421.0 | 6562.0 |
| | 14.0 | 29 | 3603.517 | 1112.7037 | 206.6239 | 3180.267 | 4026.767 | 2328.0 | 7203.0 |
| | 15.0 | 29 | 3293.690 | 910.2003 | 169.0200 | 2947.468 | 3639.911 | 2063.0 | 5593.0 |
| | 16.0 | 29 | 2976.931 | 749.0399 | 139.0932 | 2692.011 | 3261.851 | 1625.0 | 5203.0 |
| | 17.0 | 29 | 2931.034 | 897.1351 | 166.5938 | 2589.783 | 3272.286 | 1219.0 | 5719.0 |
| | 18.0 | 29 | 3010.379 | 661.4590 | 122.8299 | 2758.774 | 3261.985 | 2110.0 | 5016.0 |
| | Total | 522 | 3603.485 | 1265.0159 | 55.3682 | 3494.712 | 3712.257 | 1219.0 | 16031.0 |
| CU_time | 1.0 | 29 | 16917.483 | 4161.1028 | 772.6974 | 15334.684 | 18500.282 | 12235.0 | 33421.0 |
| | 2.0 | 29 | 14741.310 | 4406.7009 | 818.3038 | 13065.091 | 16417.530 | 8922.0 | 32532.0 |
| | 3.0 | 29 | 13114.690 | 2607.0141 | 484.1104 | 12123.035 | 14106.345 | 8969.0 | 20562.0 |
| | 4.0 | 29 | 13505.414 | 2309.2963 | 428.8256 | 12627.004 | 14383.823 | 7375.0 | 18984.0 |
| | 5.0 | 29 | 14618.931 | 3948.2312 | 733.1681 | 13117.104 | 16120.758 | 8734.0 | 27984.0 |
| | 6.0 | 29 | 12636.759 | 2804.2412 | 520.7345 | 11570.082 | 13703.435 | 9093.0 | 21375.0 |
| | 7.0 | 29 | 13063.069 | 3994.1528 | 741.6956 | 11543.774 | 14582.363 | 8766.0 | 28110.0 |
| | 8.0 | 29 | 11966.586 | 2390.7717 | 443.9552 | 11057.185 | 12875.987 | 8438.0 | 17906.0 |
| | 9.0 | 29 | 11912.690 | 3459.9049 | 642.4882 | 10596.612 | 13228.767 | 6359.0 | 22047.0 |
| | 10.0 | 29 | 11974.724 | 2195.6199 | 407.7164 | 11139.555 | 12809.893 | 8078.0 | 17156.0 |
| | 11.0 | 29 | 11344.897 | 2208.6627 | 410.1384 | 10504.766 | 12185.027 | 7079.0 | 15828.0 |
| | 12.0 | 29 | 12100.690 | 3879.2577 | 720.3601 | 10625.099 | 13576.280 | 7125.0 | 26703.0 |
| | 13.0 | 29 | 11784.414 | 2631.5073 | 488.6586 | 10783.442 | 12785.386 | 7656.0 | 18781.0 |
| | 14.0 | 29 | 12956.690 | 4465.1181 | 829.1516 | 11258.250 | 14655.130 | 8109.0 | 27828.0 |
| | 15.0 | 29 | 10299.069 | 2608.9112 | 484.4626 | 9306.692 | 11291.446 | 6406.0 | 16609.0 |
| | 16.0 | 29 | 11640.069 | 2758.7359 | 512.2844 | 10590.702 | 12689.436 | 8360.0 | 17734.0 |
| | 17.0 | 29 | 12270.897 | 4092.3515 | 759.9306 | 10714.249 | 13827.544 | 2359.0 | 24547.0 |
| | 18.0 | 29 | 11731.862 | 2974.7444 | 552.3962 | 10600.330 | 12863.394 | 7437.0 | 19594.0 |
| | Total | 522 | 12698.902 | 3579.2067 | 156.6576 | 12391.144 | 13006.661 | 2359.0 | 33421.0 |
| CL_time | 1.0 | 29 | 24663.897 | 6996.7616 | 1299.2660 | 22002.471 | 27325.322 | 12890.0 | 43235.0 |
| | 2.0 | 29 | 22966.586 | 5584.9676 | 1037.1025 | 20842.178 | 25090.994 | 15875.0 | 37109.0 |
| | 3.0 | 29 | 21735.931 | 5521.0608 | 1025.2353 | 19635.832 | 23836.030 | 11687.0 | 32234.0 |
| | 4.0 | 29 | 21414.931 | 6636.9754 | 1232.4554 | 18890.361 | 23939.501 | 11406.0 | 45110.0 |
| | 5.0 | 29 | 21969.897 | 6772.1342 | 1257.5538 | 19393.914 | 24545.879 | 10719.0 | 39032.0 |
| | 6.0 | 29 | 23892.172 | 8817.1592 | 1637.3054 | 20538.304 | 27246.040 | 10718.0 | 59828.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 7.0 | 29 | 19079.621 | 5989.6749 | 1112.2547 | 16801.270 | 21357.971 | 2922.0 | 37141.0 |
| | 8.0 | 29 | 19637.379 | 5991.9978 | 1112.6861 | 17358.145 | 21916.613 | 9656.0 | 37328.0 |
| | 9.0 | 29 | 19851.793 | 6420.2943 | 1192.2187 | 17409.644 | 22293.942 | 8375.0 | 32984.0 |
| | 10.0 | 29 | 20299.655 | 7433.7340 | 1380.4097 | 17472.014 | 23127.296 | 9735.0 | 43547.0 |
| | 11.0 | 29 | 20125.483 | 7379.6043 | 1370.3581 | 17318.431 | 22932.534 | 9485.0 | 44031.0 |
| | 12.0 | 29 | 19648.759 | 7226.0665 | 1341.8469 | 16900.110 | 22397.407 | 9813.0 | 46422.0 |
| | 13.0 | 29 | 19587.793 | 6043.5424 | 1122.2576 | 17288.953 | 21886.634 | 10766.0 | 39063.0 |
| | 14.0 | 29 | 17648.828 | 5655.0609 | 1050.1184 | 15497.757 | 19799.898 | 9734.0 | 37250.0 |
| | 15.0 | 29 | 18174.517 | 6954.6590 | 1291.4477 | 15529.106 | 20819.928 | 8265.0 | 44985.0 |
| | 16.0 | 29 | 17070.069 | 8945.5500 | 1661.1469 | 13667.364 | 20472.774 | 531.0 | 52704.0 |
| | 17.0 | 29 | 15876.172 | 5751.9121 | 1068.1033 | 13688.262 | 18064.083 | 828.0 | 28719.0 |
| | 18.0 | 29 | 18111.379 | 4522.6960 | 839.8436 | 16391.038 | 19831.721 | 11031.0 | 28453.0 |
| | Total | 522 | 20097.492 | 6958.0172 | 304.5441 | 19499.207 | 20695.778 | 531.0 | 59828.0 |
| CT_time | 1.0 | 29 | 19975.759 | 5296.2460 | 983.4882 | 17961.174 | 21990.343 | 12953.0 | 35047.0 |
| | 2.0 | 29 | 20147.138 | 5942.5786 | 1103.5091 | 17886.702 | 22407.574 | 11594.0 | 37063.0 |
| | 3.0 | 29 | 17661.724 | 5335.4296 | 990.7644 | 15632.235 | 19691.213 | 7016.0 | 31140.0 |
| | 4.0 | 29 | 16162.759 | 4922.5558 | 914.0957 | 14290.319 | 18035.199 | 4719.0 | 24796.0 |
| | 5.0 | 29 | 16868.517 | 4457.6946 | 827.7731 | 15172.901 | 18564.134 | 10000.0 | 24781.0 |
| | 6.0 | 29 | 17288.690 | 6394.6592 | 1187.4584 | 14856.291 | 19721.088 | 8719.0 | 44094.0 |
| | 7.0 | 29 | 17483.241 | 5133.5468 | 953.2757 | 15530.545 | 19435.938 | 8110.0 | 30281.0 |
| | 8.0 | 29 | 18271.414 | 4877.2485 | 905.6823 | 16416.208 | 20126.620 | 11141.0 | 29000.0 |
| | 9.0 | 29 | 16093.690 | 4299.8291 | 798.4582 | 14458.122 | 17729.257 | 8468.0 | 24516.0 |
| | 10.0 | 29 | 19651.310 | 4394.4155 | 816.0225 | 17979.764 | 21322.857 | 12328.0 | 29250.0 |
| | 11.0 | 29 | 15015.069 | 3638.2806 | 675.6117 | 13631.141 | 16398.997 | 9032.0 | 21859.0 |
| | 12.0 | 29 | 17100.862 | 5798.5112 | 1076.7565 | 14895.226 | 19306.498 | 7203.0 | 31000.0 |
| | 13.0 | 29 | 18643.345 | 3868.0594 | 718.2806 | 17172.014 | 20114.676 | 12063.0 | 27812.0 |
| | 14.0 | 29 | 15094.931 | 4920.2585 | 913.6691 | 13223.365 | 16966.497 | 6875.0 | 31016.0 |
| | 15.0 | 29 | 15362.586 | 5222.5161 | 969.7969 | 13376.047 | 17349.125 | 6750.0 | 25140.0 |
| | 16.0 | 29 | 15761.862 | 4382.1811 | 813.7506 | 14094.970 | 17428.755 | 6953.0 | 23406.0 |
| | 17.0 | 29 | 15448.793 | 4335.7226 | 805.1235 | 13799.572 | 17098.014 | 9703.0 | 25578.0 |
| | 18.0 | 29 | 16529.000 | 3891.1853 | 722.5750 | 15048.872 | 18009.128 | 10516.0 | 26609.0 |
| | Total | 522 | 17142.261 | 5075.4920 | 222.1483 | 16705.844 | 17578.677 | 4719.0 | 44094.0 |
| RT_time | 1.0 | 29 | 10929.586 | 2175.4935 | 403.9790 | 10102.073 | 11757.100 | 7391.0 | 16344.0 |
| | 2.0 | 29 | 10846.379 | 2057.3074 | 382.0324 | 10063.821 | 11628.937 | 7453.0 | 15516.0 |
| | 3.0 | 29 | 9961.138 | 1690.6928 | 313.9538 | 9318.033 | 10604.243 | 7515.0 | 13953.0 |
| | 4.0 | 29 | 9438.966 | 2321.5254 | 431.0965 | 8555.904 | 10322.027 | 6265.0 | 18328.0 |
| | 5.0 | 29 | 10150.828 | 2087.6028 | 387.6581 | 9356.746 | 10944.909 | 6844.0 | 15265.0 |
| | 6.0 | 29 | 9840.517 | 1472.6094 | 273.4567 | 9280.367 | 10400.668 | 6610.0 | 12875.0 |
| | 7.0 | 29 | 9851.207 | 2162.1742 | 401.5057 | 9028.760 | 10673.654 | 6782.0 | 16156.0 |
| | 8.0 | 29 | 9615.793 | 1847.5562 | 343.0826 | 8913.020 | 10318.566 | 7344.0 | 14250.0 |
| | 9.0 | 29 | 9681.517 | 1395.7948 | 259.1926 | 9150.585 | 10212.449 | 6922.0 | 12359.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 10.0 | 29 | 9422.483 | 1762.9608 | 327.3736 | 8751.888 | 10093.077 | 6093.0 | 14891.0 |
| | 11.0 | 29 | 9262.862 | 1661.7159 | 308.5729 | 8630.779 | 9894.945 | 5968.0 | 12547.0 |
| | 12.0 | 29 | 9231.103 | 1564.2232 | 290.4690 | 8636.105 | 9826.102 | 6422.0 | 11984.0 |
| | 13.0 | 29 | 9571.690 | 2138.5996 | 397.1280 | 8758.210 | 10385.169 | 7078.0 | 18218.0 |
| | 14.0 | 29 | 8996.862 | 2054.5673 | 381.5236 | 8215.346 | 9778.378 | 5953.0 | 13937.0 |
| | 15.0 | 29 | 8866.379 | 1705.6325 | 316.7280 | 8217.591 | 9515.167 | 6843.0 | 14437.0 |
| | 16.0 | 29 | 8761.862 | 1497.6704 | 278.1104 | 8192.179 | 9331.545 | 5938.0 | 12547.0 |
| | 17.0 | 29 | 8552.828 | 1491.6268 | 276.9881 | 7985.443 | 9120.212 | 6188.0 | 12188.0 |
| | 18.0 | 29 | 8016.241 | 1565.0982 | 290.6314 | 7420.910 | 8611.573 | 5797.0 | 11485.0 |
| | Total | 522 | 9499.902 | 1943.2325 | 85.0530 | 9332.813 | 9666.991 | 5797.0 | 18328.0 |
| RU_time | 1.0 | 29 | 12196.207 | 2517.1551 | 467.4240 | 11238.732 | 13153.681 | 7031.0 | 17516.0 |
| | 2.0 | 29 | 11228.448 | 2371.6121 | 440.3973 | 10326.335 | 12130.561 | 7172.0 | 18500.0 |
| | 3.0 | 29 | 10284.483 | 2212.7977 | 410.9062 | 9442.780 | 11126.186 | 6500.0 | 15953.0 |
| | 4.0 | 29 | 9064.759 | 1544.9111 | 286.8828 | 8477.106 | 9652.411 | 5516.0 | 11844.0 |
| | 5.0 | 29 | 9295.345 | 2632.2241 | 488.7918 | 8294.100 | 10296.589 | 47.0 | 14141.0 |
| | 6.0 | 29 | 9189.034 | 1686.3442 | 313.1463 | 8547.583 | 9830.486 | 5812.0 | 12719.0 |
| | 7.0 | 29 | 8933.793 | 1813.0845 | 336.6813 | 8244.133 | 9623.454 | 5734.0 | 12719.0 |
| | 8.0 | 29 | 8572.690 | 2009.1954 | 373.0982 | 7808.433 | 9336.947 | 5188.0 | 12516.0 |
| | 9.0 | 29 | 9356.690 | 2359.0539 | 438.0653 | 8459.354 | 10254.026 | 5297.0 | 15438.0 |
| | 10.0 | 29 | 8262.828 | 1587.6003 | 294.8100 | 7658.937 | 8866.718 | 5391.0 | 12093.0 |
| | 11.0 | 29 | 7859.448 | 1561.2367 | 289.9144 | 7265.586 | 8453.311 | 4547.0 | 10703.0 |
| | 12.0 | 29 | 6912.690 | 1607.4297 | 298.4922 | 6301.256 | 7524.123 | 4015.0 | 10468.0 |
| | 13.0 | 29 | 6841.621 | 2482.1248 | 460.9190 | 5897.471 | 7785.770 | 3891.0 | 17032.0 |
| | 14.0 | 29 | 8256.931 | 1858.6427 | 345.1413 | 7549.941 | 8963.921 | 5109.0 | 14563.0 |
| | 15.0 | 29 | 7357.862 | 2283.4065 | 424.0179 | 6489.301 | 8226.423 | 3906.0 | 14766.0 |
| | 16.0 | 29 | 6934.241 | 1812.4584 | 336.5651 | 6244.819 | 7623.664 | 4468.0 | 12875.0 |
| | 17.0 | 29 | 6499.517 | 1537.8266 | 285.5672 | 5914.559 | 7084.475 | 3688.0 | 10015.0 |
| | 18.0 | 29 | 7669.034 | 1339.5554 | 248.7492 | 7159.495 | 8178.574 | 5203.0 | 10156.0 |
| | Total | 522 | 8595.312 | 2474.1304 | 108.2897 | 8382.574 | 8808.050 | 47.0 | 18500.0 |
| CL_errors | 1.0 | 29 | .690 | .7608 | .1413 | .400 | .979 | 0.0 | 2.0 |
| | 2.0 | 29 | .414 | .6823 | .1267 | .154 | .673 | 0.0 | 2.0 |
| | 3.0 | 29 | .379 | .8625 | .1602 | .051 | .707 | 0.0 | 3.0 |
| | 4.0 | 29 | .310 | .6603 | .1226 | .059 | .561 | 0.0 | 2.0 |
| | 5.0 | 29 | .310 | .8064 | .1497 | .004 | .617 | 0.0 | 3.0 |
| | 6.0 | 29 | .448 | .8275 | .1537 | .134 | .763 | 0.0 | 4.0 |
| | 7.0 | 29 | .345 | .6139 | .1140 | .111 | .578 | 0.0 | 2.0 |
| | 8.0 | 29 | .310 | .7123 | .1323 | .039 | .581 | 0.0 | 3.0 |
| | 9.0 | 29 | .276 | .6490 | .1205 | .029 | .523 | 0.0 | 2.0 |
| | 10.0 | 29 | .241 | .7863 | .1460 | -.058 | .540 | 0.0 | 4.0 |
| | 11.0 | 29 | .483 | .7847 | .1457 | .184 | .781 | 0.0 | 3.0 |
| | 12.0 | 29 | .414 | .9070 | .1684 | .069 | .759 | 0.0 | 3.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 13.0 | 29 | .448 | .6317 | .1173 | .208 | .689 | 0.0 | 2.0 |
| 14.0 | 29 | .414 | .7328 | .1361 | .135 | .693 | 0.0 | 2.0 |
| 15.0 | 29 | .345 | .6139 | .1140 | .111 | .578 | 0.0 | 2.0 |
| 16.0 | 29 | .517 | .7847 | .1457 | .219 | .816 | 0.0 | 3.0 |
| 17.0 | 29 | 1.069 | .4576 | .0850 | .895 | 1.243 | 0.0 | 3.0 |
| 18.0 | 29 | .241 | .5766 | .1071 | .022 | .461 | 0.0 | 2.0 |
| Total | 522 | .425 | .7352 | .0322 | .362 | .489 | 0.0 | 4.0 |

**See SPSS Output on CD for Post-Hoc Results.**

## U. NASA Task Load Index

### NASA Task Load Index

ID

Drive completed: Easy

Task performed: Spatial Stroop

Mental Demand - How mentally demanding was the task?

| Very Low | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Very High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Physical Demand - How physically demanding was the task?

| Very Low | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Very High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Temporal Demand - How hurried or rushed was the pace of the task?

| Very Low | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Very High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Performance - How successful were you in accomplishing what you were asked to?

| Perfect | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Failure |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Effort- How hard did you have to work to accomplish your level of performance?

| Very Low | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Very High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Frustration - How insecure, discouraged, irritated, stressed, and annoyed were you?

| Very Low | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | Very High |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ |

Submit

## V. Stroop task results by weighted measure of Performance (MW)

```
ONEWAY S_difIC S_difIN S_difNC S_meanI s_meanC S_meanN
S_errI S_errC S_errN S_lapseI S_lapseC S_lapseN BY
Performance_w2
  /STATISTICS DESCRIPTIVES
  /PLOT MEANS
  /MISSING ANALYSIS
  /POSTHOC=TUKEY ALPHA(0.05).
```

## Oneway

**Notes**

| | | |
|---|---|---|
| Output Created | | 17-NOV-2014 09:29:48 |
| Comments | | |
| Input | Data | G:\Mental Workload\MW_Stroop_w2.sav |
| | Active Dataset | DataSet3 |
| | Filter | <none> |
| | Weight | <none> |
| | Split File | <none> |
| | N of Rows in Working Data File | 60 |
| Missing Value Handling | Definition of Missing | User-defined missing values are treated as missing. |
| | Cases Used | Statistics for each analysis are based on cases with no missing data for any variable in the analysis. |
| Syntax | | ONEWAY S_difIC S_difIN S_difNC S_meanI s_meanC S_meanN S_errI S_errC S_errN S_lapseI S_lapseC S_lapseN BY Performance_w2 /STATISTICS DESCRIPTIVES /PLOT MEANS /MISSING ANALYSIS /POSTHOC=TUKEY ALPHA(0.05). |
| Resources | Processor Time | 00:00:01.25 |
| | Elapsed Time | 00:00:01.24 |

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| S_difIC | 1 | 29 | 63.830 | 73.179 | 13.589 | 35.994 | 91.666 | -42.100 | 281.344 |
| | 2 | 13 | 41.665 | 76.359 | 21.178 | -4.478 | 87.809 | -87.433 | 175.365 |
| | 3 | 16 | 13.844 | 240.220 | 60.055 | -114.160 | 141.848 | -802.750 | 307.111 |
| | 4 | 1 | 35.000 | | | | | 35.000 | 35.000 |
| | Total | 59 | 44.902 | 138.437 | 18.023 | 8.825 | 80.979 | -802.750 | 307.111 |
| S_difIN | 1 | 29 | 54.635 | 79.005 | 14.671 | 24.583 | 84.687 | -81.000 | 296.500 |
| | 2 | 13 | 45.168 | 83.105 | 23.049 | -5.051 | 95.388 | -157.044 | 141.500 |
| | 3 | 16 | 4.136 | 230.836 | 57.709 | -118.868 | 127.141 | -735.400 | 417.500 |
| | 4 | 1 | 49.700 | | | | | 49.700 | 49.700 |
| | Total | 59 | 38.771 | 136.715 | 17.799 | 3.143 | 74.399 | -735.400 | 417.500 |
| S_difN | 1 | 29 | 9.195 | 58.509 | 10.865 | -13.061 | 31.450 | -110.600 | 169.100 |
| C | 2 | 13 | -3.503 | 79.959 | 22.177 | -51.822 | 44.815 | -127.800 | 159.389 |
| | 3 | 16 | 9.707 | 126.801 | 31.700 | -57.860 | 77.275 | -129.978 | 389.143 |
| | 4 | 1 | -14.700 | | | | | -14.700 | -14.700 |
| | Total | 59 | 6.131 | 84.677 | 11.024 | -15.936 | 28.198 | -129.978 | 389.143 |
| S_mea | 1 | 29 | 552.460 | 85.839 | 15.940 | 519.809 | 585.112 | 432.800 | 796.900 |
| nI | 2 | 13 | 508.569 | 92.847 | 25.751 | 452.462 | 564.676 | 404.833 | 705.143 |
| | 3 | 16 | 487.474 | 211.945 | 52.986 | 374.536 | 600.412 | 0.000 | 974.000 |
| | 4 | 1 | 433.300 | | | | | 433.300 | 433.300 |
| | Total | 59 | 523.146 | 133.887 | 17.431 | 488.255 | 558.038 | 0.000 | 974.000 |
| s_mean | 1 | 29 | 488.631 | 54.992 | 10.212 | 467.713 | 509.548 | 367.600 | 595.900 |
| C | 2 | 13 | 466.904 | 84.595 | 23.462 | 415.784 | 518.025 | 350.000 | 605.000 |
| | 3 | 16 | 473.630 | 131.431 | 32.858 | 403.596 | 543.665 | 336.625 | 802.750 |
| | 4 | 1 | 398.300 | | | | | 398.300 | 398.300 |
| | Total | 59 | 478.245 | 87.217 | 11.355 | 455.516 | 500.973 | 336.625 | 802.750 |
| S_mea | 1 | 29 | 497.825 | 71.722 | 13.318 | 470.544 | 525.107 | 381.900 | 687.100 |
| nN | 2 | 13 | 463.401 | 125.900 | 34.918 | 387.320 | 539.482 | 349.000 | 699.500 |
| | 3 | 16 | 483.338 | 161.433 | 40.358 | 397.316 | 569.359 | 353.600 | 950.286 |
| | 4 | 1 | 383.600 | | | | | 383.600 | 383.600 |
| | Total | 59 | 484.375 | 113.433 | 14.768 | 454.815 | 513.936 | 349.000 | 950.286 |
| S_errI | 1 | 29 | 0.483 | 0.574 | 0.107 | 0.264 | 0.701 | 0.000 | 2.000 |
| | 2 | 13 | 1.846 | 1.573 | 0.436 | 0.896 | 2.797 | 0.000 | 4.000 |
| | 3 | 16 | 1.500 | 2.191 | 0.548 | 0.333 | 2.667 | 0.000 | 8.000 |
| | 4 | 1 | 0.000 | | | | | 0.000 | 0.000 |
| | Total | 59 | 1.051 | 1.513 | 0.197 | 0.656 | 1.445 | 0.000 | 8.000 |
| S_errC | 1 | 29 | 0.103 | 0.310 | 0.058 | -0.014 | 0.221 | 0.000 | 1.000 |
| | 2 | 13 | 0.538 | 0.877 | 0.243 | 0.008 | 1.068 | 0.000 | 3.000 |
| | 3 | 16 | 0.563 | 0.964 | 0.241 | 0.049 | 1.076 | 0.000 | 3.000 |
| | 4 | 1 | 0.000 | | | | | 0.000 | 0.000 |
| | Total | 59 | 0.322 | 0.706 | 0.092 | 0.138 | 0.506 | 0.000 | 3.000 |
| S_errN | 1 | 29 | 0.103 | 0.310 | 0.058 | -0.014 | 0.221 | 0.000 | 1.000 |
| | 2 | 13 | 0.231 | 0.439 | 0.122 | -0.034 | 0.496 | 0.000 | 1.000 |
| | 3 | 16 | 0.750 | 1.125 | 0.281 | 0.150 | 1.350 | 0.000 | 3.000 |
| | 4 | 1 | 0.000 | | | | | 0.000 | 0.000 |
| | Total | 59 | 0.305 | 0.701 | 0.091 | 0.122 | 0.488 | 0.000 | 3.000 |
| S_lapse | 1 | 29 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| I | 2 | 13 | 0.077 | 0.277 | 0.077 | -0.091 | 0.245 | 0.000 | 1.000 |
| | 3 | 16 | 0.125 | 0.500 | 0.125 | -0.141 | 0.391 | 0.000 | 2.000 |
| | 4 | 1 | 0.000 | | | | | 0.000 | 0.000 |
| | Total | 59 | 0.051 | 0.289 | 0.038 | -0.024 | 0.126 | 0.000 | 2.000 |
| S_lapse | 1 | 29 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| C | 2 | 13 | 0.077 | 0.277 | 0.077 | -0.091 | 0.245 | 0.000 | 1.000 |
| | 3 | 16 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 4 | 1 | 0.000 | | | | | 0.000 | 0.000 |
| | Total | 59 | 0.017 | 0.130 | 0.017 | -0.017 | 0.051 | 0.000 | 1.000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| S_lapseN | 1 | 29 | 0.034 | 0.186 | 0.034 | -0.036 | 0.105 | 0.000 | 1.000 |
| | 2 | 13 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | 3 | 16 | 0.125 | 0.500 | 0.125 | -0.141 | 0.391 | 0.000 | 2.000 |
| | 4 | 1 | 0.000 | | | | | 0.000 | 0.000 |
| | Total | 59 | 0.051 | 0.289 | 0.038 | -0.024 | 0.126 | 0.000 | 2.000 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| S_difIC | Between Groups | 26057.576 | 3 | 8685.859 | .440 | .725 |
| | Within Groups | 1085495.185 | 55 | 19736.276 | | |
| | Total | 1111552.762 | 58 | | | |
| S_difIN | Between Groups | 27142.767 | 3 | 9047.589 | .471 | .704 |
| | Within Groups | 1056929.288 | 55 | 19216.896 | | |
| | Total | 1084072.056 | 58 | | | |
| S_difNC | Between Groups | 2117.453 | 3 | 705.818 | .094 | .963 |
| | Within Groups | 413750.955 | 55 | 7522.745 | | |
| | Total | 415868.408 | 58 | | | |
| S_meanI | Between Groups | 56115.009 | 3 | 18705.003 | 1.046 | .380 |
| | Within Groups | 983572.662 | 55 | 17883.139 | | |
| | Total | 1039687.671 | 58 | | | |
| s_meanC | Between Groups | 11531.881 | 3 | 3843.960 | .492 | .689 |
| | Within Groups | 429662.375 | 55 | 7812.043 | | |
| | Total | 441194.256 | 58 | | | |
| S_meanN | Between Groups | 21138.107 | 3 | 7046.036 | .534 | .661 |
| | Within Groups | 725151.892 | 55 | 13184.580 | | |
| | Total | 746289.998 | 58 | | | |
| S_errI | Between Groups | 21.914 | 3 | 7.305 | 3.622 | .019 |
| | Within Groups | 110.934 | 55 | 2.017 | | |
| | Total | 132.847 | 58 | | | |
| S_errC | Between Groups | 3.023 | 3 | 1.008 | 2.144 | .105 |
| | Within Groups | 25.858 | 55 | .470 | | |
| | Total | 28.881 | 58 | | | |
| S_errN | Between Groups | 4.511 | 3 | 1.504 | 3.446 | .023 |
| | Within Groups | 23.997 | 55 | .436 | | |
| | Total | 28.508 | 58 | | | |
| S_lapseI | Between Groups | .174 | 3 | .058 | .684 | .566 |
| | Within Groups | 4.673 | 55 | .085 | | |
| | Total | 4.847 | 58 | | | |
| S_lapseC | Between Groups | .060 | 3 | .020 | 1.191 | .322 |
| | Within Groups | .923 | 55 | .017 | | |
| | Total | .983 | 58 | | | |
| S_lapseN | Between Groups | .132 | 3 | .044 | .513 | .675 |
| | Within Groups | 4.716 | 55 | .086 | | |
| | Total | 4.847 | 58 | | | |

## W. Number Switching task results by weighted measure of Effort (MW)

# Oneway

**Notes**

| | | |
|---|---|---|
| Output Created | | 17-NOV-2014 11:42:29 |
| Comments | | |
| Input | Data | G:\Mental Workload\MW_numberswitch_w2.sav |
| | Active Dataset | DataSet11 |
| | Filter | <none> |
| | Weight | <none> |
| | Split File | <none> |
| | N of Rows in Working Data File | 61 |
| Missing Value Handling | Definition of Missing | User-defined missing values are treated as missing. |
| | Cases Used | Statistics for each analysis are based on cases with no missing data for any variable in the analysis. |
| Syntax | | ONEWAY N_difSR N_meanS N_meanR N_errS N_errR N_lapseS N_lapseR BY Effort_w2<br>/STATISTICS DESCRIPTIVES<br>/PLOT MEANS<br>/MISSING ANALYSIS<br>/POSTHOC=TUKEY DUNNETT ALPHA(0.05). |
| Resources | Processor Time | 00:00:01.89 |
| | Elapsed Time | 00:00:01.92 |

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| N_difSR | 1.0 | 16 | 314.536 | 226.595 | 56.649 | 193.792 | 435.281 | -97.776 | 661.154 |
| | 2.0 | 22 | 238.817 | 181.379 | 38.670 | 158.398 | 319.235 | -110.094 | 642.826 |
| | 3.0 | 17 | 230.787 | 175.022 | 42.449 | 140.799 | 320.775 | -32.137 | 583.399 |
| | 4.0 | 3 | 312.328 | 115.964 | 66.952 | 24.256 | 600.399 | 209.055 | 437.780 |
| | Total | 58 | 261.154 | 190.022 | 24.951 | 211.190 | 311.117 | -110.094 | 661.154 |
| N_meanS | 1.0 | 16 | 1138.466 | 176.880 | 44.220 | 1044.213 | 1232.719 | 799.913 | 1425.294 |
| | 2.0 | 22 | 1089.357 | 182.966 | 39.008 | 1008.234 | 1170.479 | 795.957 | 1503.250 |
| | 3.0 | 17 | 1143.329 | 297.270 | 72.098 | 990.487 | 1296.171 | 705.200 | 1971.571 |
| | 4.0 | 3 | 1352.888 | 188.596 | 108.886 | 884.390 | 1821.387 | 1221.095 | 1568.923 |
| | Total | 58 | 1132.354 | 223.472 | 29.343 | 1073.595 | 1191.114 | 705.200 | 1971.571 |
| N_meanR | 1.0 | 16 | 823.929 | 252.165 | 63.041 | 689.560 | 958.299 | 589.077 | 1407.263 |
| | 2.0 | 22 | 850.540 | 196.440 | 41.881 | 763.443 | 937.637 | 599.360 | 1221.615 |
| | 3.0 | 17 | 912.542 | 320.325 | 77.690 | 747.846 | 1077.238 | 563.375 | 1851.700 |
| | 4.0 | 3 | 1040.561 | 80.219 | 46.314 | 841.287 | 1239.835 | 978.500 | 1131.143 |
| | Total | 58 | 871.201 | 250.579 | 32.903 | 805.315 | 937.087 | 563.375 | 1851.700 |
| N_errS | 1.0 | 16 | 1.813 | 1.7212 | .4303 | .895 | 2.730 | 0.0 | 5.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2.0 | 22 | 1.864 | 1.5211 | .3243 | 1.189 | 2.538 | 0.0 | 6.0 |
| | 3.0 | 17 | 1.647 | 2.0899 | .5069 | .573 | 2.722 | 0.0 | 8.0 |
| | 4.0 | 3 | 4.000 | 1.0000 | .5774 | 1.516 | 6.484 | 3.0 | 5.0 |
| | Total | 58 | 1.897 | 1.7740 | .2329 | 1.430 | 2.363 | 0.0 | 8.0 |
| N_errR | 1.0 | 16 | .563 | 1.2633 | .3158 | -.111 | 1.236 | 0.0 | 5.0 |
| | 2.0 | 22 | 1.000 | 1.3093 | .2791 | .419 | 1.581 | 0.0 | 5.0 |
| | 3.0 | 17 | 1.235 | 1.7150 | .4159 | .354 | 2.117 | 0.0 | 7.0 |
| | 4.0 | 3 | 3.333 | 3.2146 | 1.8559 | -4.652 | 11.319 | 1.0 | 7.0 |
| | Total | 58 | 1.069 | 1.6099 | .2114 | .646 | 1.492 | 0.0 | 7.0 |
| N_lapseS | 1.0 | 16 | .875 | 1.4549 | .3637 | .100 | 1.650 | 0.0 | 5.0 |
| | 2.0 | 22 | 1.091 | 1.3770 | .2936 | .480 | 1.701 | 0.0 | 6.0 |
| | 3.0 | 17 | 1.765 | 3.3825 | .8204 | .026 | 3.504 | 0.0 | 14.0 |
| | 4.0 | 3 | 5.333 | 5.1316 | 2.9627 | -7.414 | 18.081 | 1.0 | 11.0 |
| | Total | 58 | 1.448 | 2.5213 | .3311 | .785 | 2.111 | 0.0 | 14.0 |
| N_lapseR | 1.0 | 16 | .375 | .8851 | .2213 | -.097 | .847 | 0.0 | 3.0 |
| | 2.0 | 22 | .318 | 1.0861 | .2316 | -.163 | .800 | 0.0 | 5.0 |
| | 3.0 | 17 | 1.059 | 3.1319 | .7596 | -.551 | 2.669 | 0.0 | 13.0 |
| | 4.0 | 3 | 3.000 | 3.6056 | 2.0817 | -5.957 | 11.957 | 0.0 | 7.0 |
| | Total | 58 | .690 | 2.0622 | .2708 | .147 | 1.232 | 0.0 | 13.0 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| N_difSR | Between Groups | 80105.116 | 3 | 26701.705 | .729 | .539 |
| | Within Groups | 1978061.438 | 54 | 36630.767 | | |
| | Total | 2058166.554 | 57 | | | |
| N_meanS | Between Groups | 189224.657 | 3 | 63074.886 | 1.282 | .290 |
| | Within Groups | 2657352.038 | 54 | 49210.223 | | |
| | Total | 2846576.695 | 57 | | | |
| N_meanR | Between Groups | 160248.020 | 3 | 53416.007 | .844 | .476 |
| | Within Groups | 3418770.196 | 54 | 63310.559 | | |
| | Total | 3579018.217 | 57 | | | |
| N_errS | Between Groups | 14.469 | 3 | 4.823 | 1.579 | .205 |
| | Within Groups | 164.911 | 54 | 3.054 | | |
| | Total | 179.379 | 57 | | | |
| N_errR | Between Groups | 20.061 | 3 | 6.687 | 2.829 | .047 |
| | Within Groups | 127.663 | 54 | 2.364 | | |
| | Total | 147.724 | 57 | | | |
| N_lapseS | Between Groups | 55.051 | 3 | 18.350 | 3.225 | .030 |
| | Within Groups | 307.294 | 54 | 5.691 | | |
| | Total | 362.345 | 57 | | | |
| N_lapseR | Between Groups | 22.950 | 3 | 7.650 | 1.882 | .144 |
| | Within Groups | 219.464 | 54 | 4.064 | | |
| | Total | 242.414 | 57 | | | |

## Post Hoc Tests

**Multiple Comparisons**

| Dependent Variable | | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|---|
| N_difSR | Tukey HSD | 1.0 | 2.0 | 75.720 | 62.884 | 0.627 | -90.979 | 242.419 |
| | | | 3.0 | 83.750 | 66.665 | 0.594 | -92.970 | 260.469 |
| | | | 4.0 | 2.209 | 120.415 | 1.000 | -316.995 | 321.413 |
| | | 2.0 | 1.0 | -75.720 | 62.884 | 0.627 | -242.419 | 90.979 |
| | | | 3.0 | 8.030 | 61.804 | 0.999 | -155.806 | 171.866 |
| | | | 4.0 | -73.511 | 117.793 | 0.924 | -385.767 | 238.745 |
| | | 3.0 | 1.0 | -83.750 | 66.665 | 0.594 | -260.469 | 92.970 |
| | | | 2.0 | -8.030 | 61.804 | 0.999 | -171.866 | 155.806 |
| | | | 4.0 | -81.541 | 119.854 | 0.904 | -399.259 | 236.178 |
| | | 4.0 | 1.0 | -2.209 | 120.415 | 1.000 | -321.413 | 316.995 |
| | | | 2.0 | 73.511 | 117.793 | 0.924 | -238.745 | 385.767 |
| | | | 3.0 | 81.541 | 119.854 | 0.904 | -236.178 | 399.259 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | 2.209 | 120.415 | 1.000 | -271.987 | 276.405 |
| | | 2.0 | 4.0 | -73.511 | 117.793 | 0.750 | -341.738 | 194.717 |
| | | 3.0 | 4.0 | -81.541 | 119.854 | 0.709 | -354.461 | 191.379 |
| N_meanS | Tukey HSD | 1.0 | 2.0 | 49.109 | 72.887 | 0.907 | -144.104 | 242.323 |
| | | | 3.0 | -4.863 | 77.268 | 1.000 | -209.691 | 199.965 |
| | | | 4.0 | -214.423 | 139.567 | 0.423 | -584.398 | 155.553 |
| | | 2.0 | 1.0 | -49.109 | 72.887 | 0.907 | -242.323 | 144.104 |
| | | | 3.0 | -53.972 | 71.635 | 0.875 | -243.867 | 135.923 |
| | | | 4.0 | -263.532 | 136.529 | 0.228 | -625.454 | 98.390 |
| | | 3.0 | 1.0 | 4.863 | 77.268 | 1.000 | -199.965 | 209.691 |
| | | | 2.0 | 53.972 | 71.635 | 0.875 | -135.923 | 243.867 |
| | | | 4.0 | -209.559 | 138.918 | 0.440 | -577.813 | 158.694 |
| | | 4.0 | 1.0 | 214.423 | 139.567 | 0.423 | -155.553 | 584.398 |
| | | | 2.0 | 263.532 | 136.529 | 0.228 | -98.390 | 625.454 |
| | | | 3.0 | 209.559 | 138.918 | 0.440 | -158.694 | 577.813 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | -214.423 | 139.567 | 0.217 | -532.231 | 103.386 |
| | | 2.0 | 4.0 | -263.532 | 136.529 | 0.104 | -574.423 | 47.359 |
| | | 3.0 | 4.0 | -209.559 | 138.918 | 0.227 | -525.889 | 106.770 |
| N_meanR | Tukey HSD | 1.0 | 2.0 | -26.611 | 82.672 | 0.988 | -245.764 | 192.543 |
| | | | 3.0 | -88.613 | 87.642 | 0.744 | -320.940 | 143.714 |
| | | | 4.0 | -216.632 | 158.305 | 0.524 | -636.278 | 203.015 |
| | | 2.0 | 1.0 | 26.611 | 82.672 | 0.988 | -192.543 | 245.764 |
| | | | 3.0 | -62.002 | 81.252 | 0.871 | -277.391 | 153.387 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 4.0 | -190.021 | 154.859 | 0.613 | -600.533 | 220.491 |
| | | 3.0 | 1.0 | 88.613 | 87.642 | 0.744 | -143.714 | 320.940 |
| | | | 2.0 | 62.002 | 81.252 | 0.871 | -153.387 | 277.391 |
| | | | 4.0 | -128.019 | 157.568 | 0.848 | -545.712 | 289.674 |
| | | 4.0 | 1.0 | 216.632 | 158.305 | 0.524 | -203.015 | 636.278 |
| | | | 2.0 | 190.021 | 154.859 | 0.613 | -220.491 | 600.533 |
| | | | 3.0 | 128.019 | 157.568 | 0.848 | -289.674 | 545.712 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | -216.632 | 158.305 | 0.286 | -577.108 | 143.845 |
| | | 2.0 | 4.0 | -190.021 | 154.859 | 0.355 | -542.650 | 162.608 |
| | | 3.0 | 4.0 | -128.019 | 157.568 | 0.613 | -486.817 | 230.779 |
| N_errS | Tukey HSD | 1.0 | 2.0 | -.0511 | .5742 | 1.000 | -1.573 | 1.471 |
| | | | 3.0 | .1654 | .6087 | .993 | -1.448 | 1.779 |
| | | | 4.0 | -2.1875 | 1.0995 | .205 | -5.102 | .727 |
| | | 2.0 | 1.0 | .0511 | .5742 | 1.000 | -1.471 | 1.573 |
| | | | 3.0 | .2166 | .5643 | .981 | -1.279 | 1.713 |
| | | | 4.0 | -2.1364 | 1.0755 | .206 | -4.987 | .715 |
| | | 3.0 | 1.0 | -.1654 | .6087 | .993 | -1.779 | 1.448 |
| | | | 2.0 | -.2166 | .5643 | .981 | -1.713 | 1.279 |
| | | | 4.0 | -2.3529 | 1.0944 | .151 | -5.254 | .548 |
| | | 4.0 | 1.0 | 2.1875 | 1.0995 | .205 | -.727 | 5.102 |
| | | | 2.0 | 2.1364 | 1.0755 | .206 | -.715 | 4.987 |
| | | | 3.0 | 2.3529 | 1.0944 | .151 | -.548 | 5.254 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | -2.1875 | 1.0995 | .093 | -4.691 | .316 |
| | | 2.0 | 4.0 | -2.1364 | 1.0755 | .093 | -4.585 | .313 |
| | | 3.0 | 4.0 | -2.3529 | 1.0944 | .066 | -4.845 | .139 |
| N_errR | Tukey HSD | 1.0 | 2.0 | -.4375 | .5052 | .822 | -1.777 | .902 |
| | | | 3.0 | -.6728 | .5356 | .594 | -2.092 | .747 |
| | | | 4.0 | -2.7708* | .9674 | .029 | -5.335 | -.206 |
| | | 2.0 | 1.0 | .4375 | .5052 | .822 | -.902 | 1.777 |
| | | | 3.0 | -.2353 | .4965 | .965 | -1.551 | 1.081 |
| | | | 4.0 | -2.3333 | .9463 | .077 | -4.842 | .175 |
| | | 3.0 | 1.0 | .6728 | .5356 | .594 | -.747 | 2.092 |
| | | | 2.0 | .2353 | .4965 | .965 | -1.081 | 1.551 |
| | | | 4.0 | -2.0980 | .9629 | .142 | -4.650 | .454 |
| | | 4.0 | 1.0 | 2.7708* | .9674 | .029 | .206 | 5.335 |
| | | | 2.0 | 2.3333 | .9463 | .077 | -.175 | 4.842 |
| | | | 3.0 | 2.0980 | .9629 | .142 | -.454 | 4.650 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | -2.7708* | .9674 | .012 | -4.974 | -.568 |
| | | 2.0 | 4.0 | -2.3333* | .9463 | .032 | -4.488 | -.178 |
| | | 3.0 | 4.0 | -2.0980 | .9629 | .062 | -4.291 | .095 |
| N_lapseS | Tukey | 1.0 | 2.0 | -.2159 | .7838 | .993 | -2.294 | 1.862 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HSD | | 3.0 | -.8897 | .8309 | .709 | -3.092 | 1.313 |
| | | | 4.0 | -4.4583* | 1.5008 | .022 | -8.437 | -.480 |
| | | 2.0 | 1.0 | .2159 | .7838 | .993 | -1.862 | 2.294 |
| | | | 3.0 | -.6738 | .7703 | .818 | -2.716 | 1.368 |
| | | | 4.0 | -4.2424* | 1.4682 | .028 | -8.134 | -.350 |
| | | 3.0 | 1.0 | .8897 | .8309 | .709 | -1.313 | 3.092 |
| | | | 2.0 | .6738 | .7703 | .818 | -1.368 | 2.716 |
| | | | 4.0 | -3.5686 | 1.4939 | .091 | -7.529 | .391 |
| | | 4.0 | 1.0 | 4.4583* | 1.5008 | .022 | .480 | 8.437 |
| | | | 2.0 | 4.2424* | 1.4682 | .028 | .350 | 8.134 |
| | | | 3.0 | 3.5686 | 1.4939 | .091 | -.391 | 7.529 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | -4.4583* | 1.5008 | .009 | -7.876 | -1.041 |
| | | 2.0 | 4.0 | -4.2424* | 1.4682 | .011 | -7.586 | -.899 |
| | | 3.0 | 4.0 | -3.5686* | 1.4939 | .039 | -6.970 | -.167 |
| N_lapseR | Tukey HSD | 1.0 | 2.0 | .0568 | .6624 | 1.000 | -1.699 | 1.813 |
| | | | 3.0 | -.6838 | .7022 | .765 | -2.545 | 1.178 |
| | | | 4.0 | -2.6250 | 1.2684 | .176 | -5.987 | .737 |
| | | 2.0 | 1.0 | -.0568 | .6624 | 1.000 | -1.813 | 1.699 |
| | | | 3.0 | -.7406 | .6510 | .668 | -2.466 | .985 |
| | | | 4.0 | -2.6818 | 1.2407 | .147 | -5.971 | .607 |
| | | 3.0 | 1.0 | .6838 | .7022 | .765 | -1.178 | 2.545 |
| | | | 2.0 | .7406 | .6510 | .668 | -.985 | 2.466 |
| | | | 4.0 | -1.9412 | 1.2625 | .423 | -5.288 | 1.405 |
| | | 4.0 | 1.0 | 2.6250 | 1.2684 | .176 | -.737 | 5.987 |
| | | | 2.0 | 2.6818 | 1.2407 | .147 | -.607 | 5.971 |
| | | | 3.0 | 1.9412 | 1.2625 | .423 | -1.405 | 5.288 |
| | Dunnett t (2-sided)[a] | 1.0 | 4.0 | -2.6250 | 1.2684 | .078 | -5.513 | .263 |
| | | 2.0 | 4.0 | -2.6818 | 1.2407 | .065 | -5.507 | .143 |
| | | 3.0 | 4.0 | -1.9412 | 1.2625 | .216 | -4.816 | .934 |

*. The mean difference is significant at the 0.05 level.

a. Dunnett t-tests treat one group as a control, and compare all other groups against it.

## X. Stroop Task results by weighted measure of Frustration (MW)

# Oneway

**Notes**

| | | |
|---|---|---|
| Output Created | | 17-NOV-2014 09:36:02 |
| Comments | | |
| Input | Data | G:\Mental Workload\MW_Stroop_w2.sav |
| | Active Dataset | DataSet3 |
| | Filter | <none> |
| | Weight | <none> |
| | Split File | <none> |
| | N of Rows in Working Data File | 60 |
| Missing Value Handling | Definition of Missing | User-defined missing values are treated as missing. |
| | Cases Used | Statistics for each analysis are based on cases with no missing data for any variable in the analysis. |
| Syntax | | ONEWAY S_difIC S_difIN S_difNC S_meanI s_meanC S_meanN S_errI S_errC S_errN S_lapseI S_lapseC S_lapseN BY Frustration_w2 /STATISTICS DESCRIPTIVES /PLOT MEANS /MISSING ANALYSIS /POSTHOC=TUKEY ALPHA(0.05). |
| Resources | Processor Time | 00:00:01.31 |
| | Elapsed Time | 00:00:01.32 |

**Descriptives**

| | | | | | | 95% Confidence Interval for Mean | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N | Mean | Std. Deviation | Std. Error | Lower Bound | Upper Bound | Minimum | Maximum |
| S_difIC | 1 | 47 | 49.434 | 73.655 | 10.744 | 27.808 | 71.060 | -144.378 | 281.344 |
| | 2 | 7 | 88.959 | 122.005 | 46.113 | -23.877 | 201.794 | -87.433 | 307.111 |
| | 3 | 5 | -59.384 | 419.451 | 187.584 | -580.201 | 461.434 | -802.750 | 179.667 |
| | Total | 59 | 44.902 | 138.437 | 18.023 | 8.825 | 80.979 | -802.750 | 307.111 |
| S_difIN | 1 | 47 | 46.424 | 78.387 | 11.434 | 23.409 | 69.439 | -143.452 | 296.500 |
| | 2 | 7 | 97.187 | 167.979 | 63.490 | -58.168 | 252.542 | -157.044 | 417.500 |
| | 3 | 5 | -114.951 | 349.046 | 156.098 | -548.349 | 318.446 | -735.400 | 99.476 |
| | Total | 59 | 38.771 | 136.715 | 17.799 | 3.143 | 74.399 | -735.400 | 417.500 |
| S_difNC | 1 | 47 | 3.010 | 86.928 | 12.680 | -22.513 | 28.533 | -129.978 | 389.143 |
| | 2 | 7 | -8.229 | 65.139 | 24.620 | -68.472 | 52.015 | -110.389 | 69.611 |
| | 3 | 5 | 55.568 | 84.687 | 37.873 | -49.585 | 160.720 | -67.350 | 169.100 |
| | Total | 59 | 6.131 | 84.677 | 11.024 | -15.936 | 28.198 | -129.978 | 389.143 |
| S_meanI | 1 | 47 | 517.811 | 98.863 | 14.421 | 488.783 | 546.838 | 376.800 | 806.833 |
| | 2 | 7 | 595.805 | 184.622 | 69.781 | 425.058 | 766.552 | 411.000 | 974.000 |
| | 3 | 5 | 471.582 | 288.959 | 129.227 | 112.791 | 830.372 | 0.000 | 705.143 |
| | Total | 59 | 523.146 | 133.887 | 17.431 | 488.255 | 558.038 | 0.000 | 974.000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| s_meanC | 1 | 47 | 468.376 | 69.724 | 10.170 | 447.904 | 488.848 | 336.625 | 605.000 |
| | 2 | 7 | 506.846 | 119.356 | 45.113 | 396.460 | 617.232 | 350.000 | 666.889 |
| | 3 | 5 | 530.966 | 164.233 | 73.447 | 327.044 | 734.887 | 383.900 | 802.750 |
| | Total | 59 | 478.245 | 87.217 | 11.355 | 455.516 | 500.973 | 336.625 | 802.750 |
| S_meanN | 1 | 47 | 471.386 | 108.195 | 15.782 | 439.619 | 503.154 | 349.000 | 950.286 |
| | 2 | 7 | 498.617 | 112.496 | 42.519 | 394.576 | 602.659 | 353.600 | 668.444 |
| | 3 | 5 | 586.533 | 132.615 | 59.307 | 421.870 | 751.196 | 423.600 | 735.400 |
| | Total | 59 | 484.375 | 113.433 | 14.768 | 454.815 | 513.936 | 349.000 | 950.286 |
| S_errI | 1 | 47 | .830 | 1.1096 | .1619 | .504 | 1.156 | 0.0 | 4.0 |
| | 2 | 7 | 1.571 | 1.7182 | .6494 | -.018 | 3.161 | 0.0 | 4.0 |
| | 3 | 5 | 2.400 | 3.3615 | 1.5033 | -1.774 | 6.574 | 0.0 | 8.0 |
| | Total | 59 | 1.051 | 1.5134 | .1970 | .656 | 1.445 | 0.0 | 8.0 |
| S_errC | 1 | 47 | .255 | .6068 | .0885 | .077 | .433 | 0.0 | 3.0 |
| | 2 | 7 | .571 | 1.1339 | .4286 | -.477 | 1.620 | 0.0 | 3.0 |
| | 3 | 5 | .600 | .8944 | .4000 | -.511 | 1.711 | 0.0 | 2.0 |
| | Total | 59 | .322 | .7057 | .0919 | .138 | .506 | 0.0 | 3.0 |
| S_errN | 1 | 47 | .213 | .5874 | .0857 | .040 | .385 | 0.0 | 3.0 |
| | 2 | 7 | .571 | .7868 | .2974 | -.156 | 1.299 | 0.0 | 2.0 |
| | 3 | 5 | .800 | 1.3038 | .5831 | -.819 | 2.419 | 0.0 | 3.0 |
| | Total | 59 | .305 | .7011 | .0913 | .122 | .488 | 0.0 | 3.0 |
| S_lapseI | 1 | 47 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 2 | 7 | .143 | .3780 | .1429 | -.207 | .492 | 0.0 | 1.0 |
| | 3 | 5 | .400 | .8944 | .4000 | -.711 | 1.511 | 0.0 | 2.0 |
| | Total | 59 | .051 | .2891 | .0376 | -.024 | .126 | 0.0 | 2.0 |
| S_lapseC | 1 | 47 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 2 | 7 | .143 | .3780 | .1429 | -.207 | .492 | 0.0 | 1.0 |
| | 3 | 5 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | Total | 59 | .017 | .1302 | .0169 | -.017 | .051 | 0.0 | 1.0 |
| S_lapseN | 1 | 47 | .021 | .1459 | .0213 | -.022 | .064 | 0.0 | 1.0 |
| | 2 | 7 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 3 | 5 | .400 | .8944 | .4000 | -.711 | 1.511 | 0.0 | 2.0 |
| | Total | 59 | .051 | .2891 | .0376 | -.024 | .126 | 0.0 | 2.0 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| S_difIC | Between Groups | 68929.971 | 2 | 34464.985 | 1.851 | .167 |
| | Within Groups | 1042622.791 | 56 | 18618.264 | | |
| | Total | 1111552.762 | 58 | | | |
| S_difIN | Between Groups | 144793.063 | 2 | 72396.532 | 4.316 | .018 |
| | Within Groups | 939278.992 | 56 | 16772.839 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Total | 1084072.056 | 58 | | | |
| S_difNC | Between Groups | 14121.110 | 2 | 7060.555 | .984 | .380 |
| | Within Groups | 401747.298 | 56 | 7174.059 | | |
| | Total | 415868.408 | 58 | | | |
| S_meanI | Between Groups | 51587.285 | 2 | 25793.642 | 1.462 | .241 |
| | Within Groups | 988100.386 | 56 | 17644.650 | | |
| | Total | 1039687.671 | 58 | | | |
| s_meanC | Between Groups | 24200.947 | 2 | 12100.474 | 1.625 | .206 |
| | Within Groups | 416993.309 | 56 | 7446.309 | | |
| | Total | 441194.256 | 58 | | | |
| S_meanN | Between Groups | 61530.709 | 2 | 30765.354 | 2.516 | .090 |
| | Within Groups | 684759.290 | 56 | 12227.844 | | |
| | Total | 746289.998 | 58 | | | |
| S_errI | Between Groups | 13.295 | 2 | 6.647 | 3.114 | .052 |
| | Within Groups | 119.553 | 56 | 2.135 | | |
| | Total | 132.847 | 58 | | | |
| S_errC | Between Groups | 1.031 | 2 | .515 | 1.036 | .361 |
| | Within Groups | 27.850 | 56 | .497 | | |
| | Total | 28.881 | 58 | | | |
| S_errN | Between Groups | 2.122 | 2 | 1.061 | 2.252 | .115 |
| | Within Groups | 26.387 | 56 | .471 | | |
| | Total | 28.508 | 58 | | | |
| S_lapseI | Between Groups | .790 | 2 | .395 | 5.454 | .007 |
| | Within Groups | 4.057 | 56 | .072 | | |
| | Total | 4.847 | 58 | | | |
| S_lapseC | Between Groups | .126 | 2 | .063 | 4.113 | .022 |
| | Within Groups | .857 | 56 | .015 | | |
| | Total | .983 | 58 | | | |
| S_lapseN | Between Groups | .669 | 2 | .334 | 4.481 | .016 |
| | Within Groups | 4.179 | 56 | .075 | | |
| | Total | 4.847 | 58 | | | |

# Post Hoc Tests

**Multiple Comparisons**

Tukey HSD

| Dependent Variable | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| S_difIC | 1 | 2 | -39.524 | 55.280 | 0.756 | -172.615 | 93.566 |
| | | 3 | 108.818 | 64.186 | 0.216 | -45.713 | 263.349 |
| | 2 | 1 | 39.524 | 55.280 | 0.756 | -93.566 | 172.615 |
| | | 3 | 148.342 | 79.896 | 0.161 | -44.013 | 340.698 |
| | 3 | 1 | -108.818 | 64.186 | 0.216 | -263.349 | 45.713 |
| | | 2 | -148.342 | 79.896 | 0.161 | -340.698 | 44.013 |
| S_difIN | 1 | 2 | -50.763 | 52.469 | 0.600 | -177.085 | 75.559 |
| | | 3 | 161.376* | 60.922 | 0.028 | 14.703 | 308.048 |
| | 2 | 1 | 50.763 | 52.469 | 0.600 | -75.559 | 177.085 |
| | | 3 | 212.139* | 75.833 | 0.019 | 29.565 | 394.712 |
| | 3 | 1 | -161.376* | 60.922 | 0.028 | -308.048 | -14.703 |
| | | 2 | -212.139* | 75.833 | 0.019 | -394.712 | -29.565 |
| S_difNC | 1 | 2 | 11.239 | 34.315 | 0.943 | -71.376 | 93.854 |
| | | 3 | -52.558 | 39.843 | 0.391 | -148.482 | 43.367 |
| | 2 | 1 | -11.239 | 34.315 | 0.943 | -93.854 | 71.376 |
| | | 3 | -63.796 | 49.595 | 0.409 | -183.200 | 55.607 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 1 | 52.558 | 39.843 | 0.391 | -43.367 | 148.482 |
| | | 2 | 63.796 | 49.595 | 0.409 | -55.607 | 183.200 |
| S_meanI | 1 | 2 | -77.994 | 53.815 | 0.323 | -207.558 | 51.569 |
| | | 3 | 46.229 | 62.485 | 0.741 | -104.207 | 196.665 |
| | 2 | 1 | 77.994 | 53.815 | 0.323 | -51.569 | 207.558 |
| | | 3 | 124.223 | 77.779 | 0.255 | -63.035 | 311.481 |
| | 3 | 1 | -46.229 | 62.485 | 0.741 | -196.665 | 104.207 |
| | | 2 | -124.223 | 77.779 | 0.255 | -311.481 | 63.035 |
| s_meanC | 1 | 2 | -38.470 | 34.960 | 0.518 | -122.638 | 45.698 |
| | | 3 | -62.589 | 40.592 | 0.279 | -160.317 | 35.138 |
| | 2 | 1 | 38.470 | 34.960 | 0.518 | -45.698 | 122.638 |
| | | 3 | -24.120 | 50.527 | 0.882 | -145.767 | 97.528 |
| | 3 | 1 | 62.589 | 40.592 | 0.279 | -35.138 | 160.317 |
| | | 2 | 24.120 | 50.527 | 0.882 | -97.528 | 145.767 |
| S_meanN | 1 | 2 | -27.231 | 44.800 | 0.816 | -135.089 | 80.627 |
| | | 3 | -115.147 | 52.017 | 0.078 | -240.380 | 10.086 |
| | 2 | 1 | 27.231 | 44.800 | 0.816 | -80.627 | 135.089 |
| | | 3 | -87.916 | 64.749 | 0.370 | -243.803 | 67.971 |
| | 3 | 1 | 115.147 | 52.017 | 0.078 | -10.086 | 240.380 |
| | | 2 | 87.916 | 64.749 | 0.370 | -67.971 | 243.803 |
| S_errI | 1 | 2 | -0.742 | 0.592 | 0.428 | -2.167 | 0.684 |
| | | 3 | -1.570 | 0.687 | 0.066 | -3.225 | 0.085 |
| | 2 | 1 | 0.742 | 0.592 | 0.428 | -0.684 | 2.167 |
| | | 3 | -0.829 | 0.856 | 0.600 | -2.888 | 1.231 |
| | 3 | 1 | 1.570 | 0.687 | 0.066 | -0.085 | 3.225 |
| | | 2 | 0.829 | 0.856 | 0.600 | -1.231 | 2.888 |
| S_errC | 1 | 2 | -0.316 | 0.286 | 0.514 | -1.004 | 0.372 |
| | | 3 | -0.345 | 0.332 | 0.556 | -1.143 | 0.454 |
| | 2 | 1 | 0.316 | 0.286 | 0.514 | -0.372 | 1.004 |
| | | 3 | -0.029 | 0.413 | 0.997 | -1.023 | 0.966 |
| | 3 | 1 | 0.345 | 0.332 | 0.556 | -0.454 | 1.143 |
| | | 2 | 0.029 | 0.413 | 0.997 | -0.966 | 1.023 |
| S_errN | 1 | 2 | -0.359 | 0.278 | 0.407 | -1.028 | 0.311 |
| | | 3 | -0.587 | 0.323 | 0.173 | -1.365 | 0.190 |
| | 2 | 1 | 0.359 | 0.278 | 0.407 | -0.311 | 1.028 |
| | | 3 | -0.229 | 0.402 | 0.837 | -1.196 | 0.739 |
| | 3 | 1 | 0.587 | 0.323 | 0.173 | -0.190 | 1.365 |
| | | 2 | 0.229 | 0.402 | 0.837 | -0.739 | 1.196 |
| S_lapseI | 1 | 2 | -0.143 | 0.109 | 0.396 | -0.405 | 0.120 |
| | | 3 | -.4000* | 0.127 | 0.007 | -0.705 | -0.095 |
| | 2 | 1 | 0.143 | 0.109 | 0.396 | -0.120 | 0.405 |
| | | 3 | -0.257 | 0.158 | 0.241 | -0.637 | 0.122 |
| | 3 | 1 | .4000* | 0.127 | 0.007 | 0.095 | 0.705 |
| | | 2 | 0.257 | 0.158 | 0.241 | -0.122 | 0.637 |
| S_lapseC | 1 | 2 | -.1429* | 0.050 | 0.017 | -0.264 | -0.022 |
| | | 3 | 0.000 | 0.058 | 1.000 | -0.140 | 0.140 |
| | 2 | 1 | .1429* | 0.050 | 0.017 | 0.022 | 0.264 |
| | | 3 | 0.143 | 0.072 | 0.129 | -0.032 | 0.317 |
| | 3 | 1 | 0.000 | 0.058 | 1.000 | -0.140 | 0.140 |
| | | 2 | -0.143 | 0.072 | 0.129 | -0.317 | 0.032 |
| S_lapseN | 1 | 2 | 0.021 | 0.111 | 0.980 | -0.245 | 0.288 |
| | | 3 | -.3787* | 0.128 | 0.013 | -0.688 | -0.069 |
| | 2 | 1 | -0.021 | 0.111 | 0.980 | -0.288 | 0.245 |
| | | 3 | -.4000* | 0.160 | 0.040 | -0.785 | -0.015 |
| | 3 | 1 | .3787* | 0.128 | 0.013 | 0.069 | 0.688 |
| | | 2 | .4000* | 0.160 | 0.040 | 0.015 | 0.785 |

*. The mean difference is significant at the 0.05 level.

## Y. Number Switching task results by weighted measure of Frustration (MW)

```
ONEWAY N_difSR N_meanS N_meanR N_errS N_errR N_lapseS N_lapseR BY
Frustration_w2
  /STATISTICS DESCRIPTIVES
  /PLOT MEANS
  /MISSING ANALYSIS
  /POSTHOC=TUKEY DUNNETT ALPHA(0.05).
```

# Oneway

**Notes**

| | | |
|---|---|---|
| Output Created | | 17-NOV-2014 11:43:25 |
| Comments | | |
| Input | Data | G:\Mental Workload\MW_numberswitch_w2.sav |
| | Active Dataset | DataSet11 |
| | Filter | <none> |
| | Weight | <none> |
| | Split File | <none> |
| | N of Rows in Working Data File | 61 |
| Missing Value Handling | Definition of Missing | User-defined missing values are treated as missing. |
| | Cases Used | Statistics for each analysis are based on cases with no missing data for any variable in the analysis. |
| Syntax | | ONEWAY N_difSR N_meanS N_meanR N_errS N_errR N_lapseS N_lapseR BY Frustration_w2 /STATISTICS DESCRIPTIVES /PLOT MEANS /MISSING ANALYSIS /POSTHOC=TUKEY DUNNETT ALPHA(0.05). |
| Resources | Processor Time | 00:00:01.92 |
| | Elapsed Time | 00:00:01.87 |

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound | | |
| S_difIC | 1 | 47 | 49.434 | 73.655 | 10.744 | 27.808 | 71.060 | -144.378 | 281.344 |
| | 2 | 7 | 88.959 | 122.005 | 46.113 | -23.877 | 201.794 | -87.433 | 307.111 |
| | 3 | 5 | -59.384 | 419.451 | 187.584 | -580.201 | 461.434 | -802.750 | 179.667 |
| | Total | 59 | 44.902 | 138.437 | 18.023 | 8.825 | 80.979 | -802.750 | 307.111 |
| S_difIN | 1 | 47 | 46.424 | 78.387 | 11.434 | 23.409 | 69.439 | -143.452 | 296.500 |
| | 2 | 7 | 97.187 | 167.979 | 63.490 | -58.168 | 252.542 | -157.044 | 417.500 |
| | 3 | 5 | -114.951 | 349.046 | 156.098 | -548.349 | 318.446 | -735.400 | 99.476 |
| | Total | 59 | 38.771 | 136.715 | 17.799 | 3.143 | 74.399 | -735.400 | 417.500 |
| S_difNC | 1 | 47 | 3.010 | 86.928 | 12.680 | -22.513 | 28.533 | -129.978 | 389.143 |
| | 2 | 7 | -8.229 | 65.139 | 24.620 | -68.472 | 52.015 | -110.389 | 69.611 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 3 | 5 | 55.568 | 84.687 | 37.873 | -49.585 | 160.720 | -67.350 | 169.100 |
| | Total | 59 | 6.131 | 84.677 | 11.024 | -15.936 | 28.198 | -129.978 | 389.143 |
| S_meanI | 1 | 47 | 517.811 | 98.863 | 14.421 | 488.783 | 546.838 | 376.800 | 806.833 |
| | 2 | 7 | 595.805 | 184.622 | 69.781 | 425.058 | 766.552 | 411.000 | 974.000 |
| | 3 | 5 | 471.582 | 288.959 | 129.227 | 112.791 | 830.372 | 0.000 | 705.143 |
| | Total | 59 | 523.146 | 133.887 | 17.431 | 488.255 | 558.038 | 0.000 | 974.000 |
| s_meanC | 1 | 47 | 468.376 | 69.724 | 10.170 | 447.904 | 488.848 | 336.625 | 605.000 |
| | 2 | 7 | 506.846 | 119.356 | 45.113 | 396.460 | 617.232 | 350.000 | 666.889 |
| | 3 | 5 | 530.966 | 164.233 | 73.447 | 327.044 | 734.887 | 383.900 | 802.750 |
| | Total | 59 | 478.245 | 87.217 | 11.355 | 455.516 | 500.973 | 336.625 | 802.750 |
| S_meanN | 1 | 47 | 471.386 | 108.195 | 15.782 | 439.619 | 503.154 | 349.000 | 950.286 |
| | 2 | 7 | 498.617 | 112.496 | 42.519 | 394.576 | 602.659 | 353.600 | 668.444 |
| | 3 | 5 | 586.533 | 132.615 | 59.307 | 421.870 | 751.196 | 423.600 | 735.400 |
| | Total | 59 | 484.375 | 113.433 | 14.768 | 454.815 | 513.936 | 349.000 | 950.286 |
| S_errI | 1 | 47 | .830 | 1.1096 | .1619 | .504 | 1.156 | 0.0 | 4.0 |
| | 2 | 7 | 1.571 | 1.7182 | .6494 | -.018 | 3.161 | 0.0 | 4.0 |
| | 3 | 5 | 2.400 | 3.3615 | 1.5033 | -1.774 | 6.574 | 0.0 | 8.0 |
| | Total | 59 | 1.051 | 1.5134 | .1970 | .656 | 1.445 | 0.0 | 8.0 |
| S_errC | 1 | 47 | .255 | .6068 | .0885 | .077 | .433 | 0.0 | 3.0 |
| | 2 | 7 | .571 | 1.1339 | .4286 | -.477 | 1.620 | 0.0 | 3.0 |
| | 3 | 5 | .600 | .8944 | .4000 | -.511 | 1.711 | 0.0 | 2.0 |
| | Total | 59 | .322 | .7057 | .0919 | .138 | .506 | 0.0 | 3.0 |
| S_errN | 1 | 47 | .213 | .5874 | .0857 | .040 | .385 | 0.0 | 3.0 |
| | 2 | 7 | .571 | .7868 | .2974 | -.156 | 1.299 | 0.0 | 2.0 |
| | 3 | 5 | .800 | 1.3038 | .5831 | -.819 | 2.419 | 0.0 | 3.0 |
| | Total | 59 | .305 | .7011 | .0913 | .122 | .488 | 0.0 | 3.0 |
| S_lapseI | 1 | 47 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 2 | 7 | .143 | .3780 | .1429 | -.207 | .492 | 0.0 | 1.0 |
| | 3 | 5 | .400 | .8944 | .4000 | -.711 | 1.511 | 0.0 | 2.0 |
| | Total | 59 | .051 | .2891 | .0376 | -.024 | .126 | 0.0 | 2.0 |
| S_lapseC | 1 | 47 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 2 | 7 | .143 | .3780 | .1429 | -.207 | .492 | 0.0 | 1.0 |
| | 3 | 5 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | Total | 59 | .017 | .1302 | .0169 | -.017 | .051 | 0.0 | 1.0 |
| S_lapseN | 1 | 47 | .021 | .1459 | .0213 | -.022 | .064 | 0.0 | 1.0 |
| | 2 | 7 | 0.000 | 0.0000 | 0.0000 | 0.000 | 0.000 | 0.0 | 0.0 |
| | 3 | 5 | .400 | .8944 | .4000 | -.711 | 1.511 | 0.0 | 2.0 |
| | Total | 59 | .051 | .2891 | .0376 | -.024 | .126 | 0.0 | 2.0 |

**Descriptives**

| | | N | Mean | Std. Deviation | Std. Error | 95% Confidence Interval for Mean Lower Bound | 95% Confidence Interval for Mean Upper Bound | Minimum | Maximum |
|---|---|---|---|---|---|---|---|---|---|
| N_difSR | 1.0 | 34 | 323.339 | 199.582 | 34.228 | 253.702 | 392.976 | -97.776 | 661.154 |
| | 2.0 | 9 | 141.660 | 117.727 | 39.242 | 51.167 | 232.153 | -32.137 | 333.875 |
| | 3.0 | 12 | 161.788 | 141.287 | 40.786 | 72.019 | 251.558 | -110.094 | 399.750 |
| | 4.0 | 3 | 312.328 | 115.964 | 66.952 | 24.256 | 600.399 | 209.055 | 437.780 |
| | Total | 58 | 261.154 | 190.022 | 24.951 | 211.190 | 311.117 | -110.094 | 661.154 |
| N_meanS | 1.0 | 34 | 1147.605 | 185.255 | 31.771 | 1082.966 | 1212.243 | 795.957 | 1503.250 |
| | 2.0 | 9 | 1079.983 | 348.148 | 116.049 | 812.373 | 1347.593 | 799.913 | 1971.571 |
| | 3.0 | 12 | 1073.290 | 202.907 | 58.574 | 944.369 | 1202.212 | 705.200 | 1333.950 |
| | 4.0 | 3 | 1352.888 | 188.596 | 108.886 | 884.390 | 1821.387 | 1221.095 | 1568.923 |
| | Total | 58 | 1132.354 | 223.472 | 29.343 | 1073.595 | 1191.114 | 705.200 | 1971.571 |
| N_meanR | 1.0 | 34 | 824.266 | 221.371 | 37.965 | 747.026 | 901.506 | 599.360 | 1407.263 |
| | 2.0 | 9 | 938.323 | 391.161 | 130.387 | 637.650 | 1238.996 | 563.375 | 1851.700 |
| | 3.0 | 12 | 911.502 | 214.038 | 61.788 | 775.509 | 1047.496 | 602.692 | 1227.955 |
| | 4.0 | 3 | 1040.561 | 80.219 | 46.314 | 841.287 | 1239.835 | 978.500 | 1131.143 |
| | Total | 58 | 871.201 | 250.579 | 32.903 | 805.315 | 937.087 | 563.375 | 1851.700 |
| N_errS | 1.0 | 34 | 1.618 | 1.5573 | .2671 | 1.074 | 2.161 | 0.0 | 5.0 |
| | 2.0 | 9 | 2.889 | 2.2608 | .7536 | 1.151 | 4.627 | 1.0 | 8.0 |
| | 3.0 | 12 | 1.417 | 1.6214 | .4680 | .387 | 2.447 | 0.0 | 6.0 |
| | 4.0 | 3 | 4.000 | 1.0000 | .5774 | 1.516 | 6.484 | 3.0 | 5.0 |
| | Total | 58 | 1.897 | 1.7740 | .2329 | 1.430 | 2.363 | 0.0 | 8.0 |
| N_errR | 1.0 | 34 | .765 | 1.0462 | .1794 | .400 | 1.130 | 0.0 | 5.0 |
| | 2.0 | 9 | 1.778 | 2.2236 | .7412 | .069 | 3.487 | 0.0 | 7.0 |
| | 3.0 | 12 | .833 | 1.5859 | .4578 | -.174 | 1.841 | 0.0 | 5.0 |
| | 4.0 | 3 | 3.333 | 3.2146 | 1.8559 | -4.652 | 11.319 | 1.0 | 7.0 |
| | Total | 58 | 1.069 | 1.6099 | .2114 | .646 | 1.492 | 0.0 | 7.0 |
| N_lapseS | 1.0 | 34 | 1.059 | 1.3013 | .2232 | .605 | 1.513 | 0.0 | 5.0 |
| | 2.0 | 9 | 2.000 | 4.5552 | 1.5184 | -1.501 | 5.501 | 0.0 | 14.0 |
| | 3.0 | 12 | 1.167 | 1.7495 | .5050 | .055 | 2.278 | 0.0 | 6.0 |
| | 4.0 | 3 | 5.333 | 5.1316 | 2.9627 | -7.414 | 18.081 | 1.0 | 11.0 |
| | Total | 58 | 1.448 | 2.5213 | .3311 | .785 | 2.111 | 0.0 | 14.0 |
| N_lapseR | 1.0 | 34 | .324 | .7270 | .1247 | .070 | .577 | 0.0 | 3.0 |
| | 2.0 | 9 | 1.556 | 4.3044 | 1.4348 | -1.753 | 4.864 | 0.0 | 13.0 |
| | 3.0 | 12 | .500 | 1.4460 | .4174 | -.419 | 1.419 | 0.0 | 5.0 |
| | 4.0 | 3 | 3.000 | 3.6056 | 2.0817 | -5.957 | 11.957 | 0.0 | 7.0 |
| | Total | 58 | .690 | 2.0622 | .2708 | .147 | 1.232 | 0.0 | 13.0 |

**ANOVA**

| | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| N_difSR | Between Groups | 386324.41 | 3 | 128774.80 | 4.159 | .010 |
| | Within Groups | 1671842.14 | 54 | 30960.04 | | |
| | Total | 2058166.55 | 57 | | | |
| N_meanS | Between Groups | 220360.90 | 3 | 73453.63 | 1.510 | .222 |
| | Within Groups | 2626215.79 | 54 | 48633.63 | | |
| | Total | 2846576.69 | 57 | | | |
| N_meanR | Between Groups | 220985.38 | 3 | 73661.79 | 1.185 | .324 |
| | Within Groups | 3358032.84 | 54 | 62185.79 | | |
| | Total | 3579018.22 | 57 | | | |
| N_errS | Between Groups | 27.54 | 3 | 9.18 | 3.265 | .028 |
| | Within Groups | 151.83 | 54 | 2.81 | | |
| | Total | 179.38 | 57 | | | |
| N_errR | Between Groups | 23.72 | 3 | 7.91 | 3.443 | .023 |
| | Within Groups | 124.01 | 54 | 2.30 | | |
| | Total | 147.72 | 57 | | | |
| N_lapseS | Between Groups | 54.13 | 3 | 18.04 | 3.161 | .032 |
| | Within Groups | 308.22 | 54 | 5.71 | | |
| | Total | 362.34 | 57 | | | |
| N_lapseR | Between Groups | 27.75 | 3 | 9.25 | 2.327 | .085 |
| | Within Groups | 214.66 | 54 | 3.98 | | |
| | Total | 242.414 | 57 | | | |

# Post Hoc Tests

**Multiple Comparisons - Dunnett t (2-sided**

| Dependent Variable | | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| N_errS | 1.0 | 4.0 | -2.3824* | 1.0099 | .044 | -4.705 | -.060 |
| | 2.0 | 4.0 | -1.1111 | 1.1179 | .511 | -3.682 | 1.460 |
| | 3.0 | 4.0 | -2.5833* | 1.0824 | .041 | -5.073 | -.094 |
| N_errR | 1.0 | 4.0 | -2.5686* | .9127 | .014 | -4.668 | -.470 |
| | 2.0 | 4.0 | -1.5556 | 1.0103 | .226 | -3.879 | .768 |
| | 3.0 | 4.0 | -2.5000* | .9782 | .027 | -4.750 | -.250 |
| N_lapseS | 1.0 | 4.0 | -4.2745* | 1.4389 | .010 | -7.584 | -.965 |
| | 2.0 | 4.0 | -3.3333 | 1.5927 | .079 | -6.996 | .330 |
| | 3.0 | 4.0 | -4.1667* | 1.5421 | .019 | -7.713 | -.620 |
| N_lapseR | 1.0 | 4.0 | -2.6765 | 1.2008 | .059 | -5.438 | .085 |
| | 2.0 | 4.0 | -1.4444 | 1.3292 | .452 | -4.501 | 1.613 |
| | 3.0 | 4.0 | -2.5000 | 1.2870 | .107 | -5.460 | .460 |

*. The mean difference is significant at the 0.05 level.

## Z. Biomeasures by Drive, Task and Drive*Task (MW)

Note: Only Statistically Significant measures are listed here. For all data, please refer to CD.

### a. Respiratory Rate

```
DATASET ACTIVATE DataSet6.
GET DATA /TYPE=XLSX
  /FILE='F:\Mental Workload\MW_bioharness.xlsx'
  /SHEET=name 'biodata_RM_RR'
  /CELLRANGE=full
  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet11 WINDOW=FRONT.

SAVE OUTFILE='F:\Mental Workload\MW_RR_RM format.sav'
  /COMPRESSED.
GLM RR0_1 RR0_2 RR0_3 RR0_0 RR1_1 RR1_2 RR1_3 RR1_5 RR2_1 RR2_2 RR2_3 RR2_5 RR3_1 RR3_2 RR3_3
RR3_5
  /WSFACTOR=Drive 4 Polynomial Task 4 Polynomial
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(Drive*Task Task*Drive)
  /EMMEANS=TABLES(OVERALL)
  /PRINT=DESCRIPTIVE HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Drive Task Drive*Task.
```

**Multivariate Tests[a]**

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Drive | Pillai's Trace | .732 | 10.943[b] | 3.000 | 12.000 | .001 |
| | Wilks' Lambda | .268 | 10.943[b] | 3.000 | 12.000 | .001 |
| | Hotelling's Trace | 2.736 | 10.943[b] | 3.000 | 12.000 | .001 |
| | Roy's Largest Root | 2.736 | 10.943[b] | 3.000 | 12.000 | .001 |
| Task | Pillai's Trace | .447 | 3.230[b] | 3.000 | 12.000 | .061 |
| | Wilks' Lambda | .553 | 3.230[b] | 3.000 | 12.000 | .061 |
| | Hotelling's Trace | .808 | 3.230[b] | 3.000 | 12.000 | .061 |
| | Roy's Largest Root | .808 | 3.230[b] | 3.000 | 12.000 | .061 |
| Drive * Task | Pillai's Trace | .865 | 4.273[b] | 9.000 | 6.000 | .046 |
| | Wilks' Lambda | .135 | 4.273[b] | 9.000 | 6.000 | .046 |
| | Hotelling's Trace | 6.409 | 4.273[b] | 9.000 | 6.000 | .046 |
| | Roy's Largest Root | 6.409 | 4.273[b] | 9.000 | 6.000 | .046 |

a. Design: Intercept
Within Subjects Design: Drive + Task + Drive * Task
b. Exact statistic

**Mauchly's Test of Sphericity[a]**

Measure: MEASURE_1

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[b] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Drive | .267 | 16.809 | 5 | .005 | .535 | .593 | .333 |
| Task | .738 | 3.870 | 5 | .569 | .832 | 1.000 | .333 |
| Drive * Task | .024 | 40.247 | 44 | .698 | .530 | .837 | .111 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept
Within Subjects Design: Drive + Task + Drive * Task
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Drive | Sphericity Assumed | 207.712 | 3 | 69.237 | 6.033 | .002 |
| | Greenhouse-Geisser | 207.712 | 1.604 | 129.457 | 6.033 | .012 |
| | Huynh-Feldt | 207.712 | 1.780 | 116.675 | 6.033 | .009 |
| | Lower-bound | 207.712 | 1.000 | 207.712 | 6.033 | .028 |
| Error(Drive) | Sphericity Assumed | 482.035 | 42 | 11.477 | | |
| | Greenhouse-Geisser | 482.035 | 22.463 | 21.459 | | |
| | Huynh-Feldt | 482.035 | 24.924 | 19.340 | | |
| | Lower-bound | 482.035 | 14.000 | 34.431 | | |
| Task | Sphericity Assumed | 73.067 | 3 | 24.356 | 4.179 | .011 |
| | Greenhouse-Geisser | 73.067 | 2.496 | 29.277 | 4.179 | .017 |
| | Huynh-Feldt | 73.067 | 3.000 | 24.356 | 4.179 | .011 |
| | Lower-bound | 73.067 | 1.000 | 73.067 | 4.179 | .060 |
| Error(Task) | Sphericity Assumed | 244.778 | 42 | 5.828 | | |
| | Greenhouse-Geisser | 244.778 | 34.940 | 7.006 | | |
| | Huynh-Feldt | 244.778 | 42.000 | 5.828 | | |
| | Lower-bound | 244.778 | 14.000 | 17.484 | | |
| Drive * Task | Sphericity Assumed | 223.969 | 9 | 24.885 | 6.818 | .000 |
| | Greenhouse-Geisser | 223.969 | 4.768 | 46.978 | 6.818 | .000 |
| | Huynh-Feldt | 223.969 | 7.529 | 29.747 | 6.818 | .000 |
| | Lower-bound | 223.969 | 1.000 | 223.969 | 6.818 | .021 |
| Error(Drive*Task) | Sphericity Assumed | 459.913 | 126 | 3.650 | | |
| | Greenhouse-Geisser | 459.913 | 66.745 | 6.891 | | |
| | Huynh-Feldt | 459.913 | 105.408 | 4.363 | | |
| | Lower-bound | 459.913 | 14.000 | 32.851 | | |

## b. Pupil Diameter

```
GET DATA /TYPE=XLSX
  /FILE='F:\Mental Workload\MW_pupil_diameter.xlsx'
  /SHEET=name 'Pupildia_repeatedmeasures'
  /CELLRANGE=full
  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet8 WINDOW=FRONT.

SAVE OUTFILE='F:\Mental Workload\MW_pupil_diameter_RM format.sav'
  /COMPRESSED.
GLM Dia0_1 Dia0_2 Dia0_3 Dia0_0 Dia1_1 Dia1_2 Dia1_3 Dia1_5 Dia2_1 Dia2_2 Dia2_3 Dia2_5 Dia3_1
Dia3_2 Dia3_3 Dia3_5
  /WSFACTOR=Drive 4 Polynomial Task 4 Polynomial
  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Drive Task Drive*Task.
```

**Multivariate Tests[a]**

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Drive | Pillai's Trace | .606 | 5.641[b] | 3.000 | 11.000 | .014 |
| | Wilks' Lambda | .394 | 5.641[b] | 3.000 | 11.000 | .014 |
| | Hotelling's Trace | 1.538 | 5.641[b] | 3.000 | 11.000 | .014 |
| | Roy's Largest Root | 1.538 | 5.641[b] | 3.000 | 11.000 | .014 |
| Task | Pillai's Trace | .771 | 12.332[b] | 3.000 | 11.000 | .001 |
| | Wilks' Lambda | .229 | 12.332[b] | 3.000 | 11.000 | .001 |
| | Hotelling's Trace | 3.363 | 12.332[b] | 3.000 | 11.000 | .001 |
| | Roy's Largest Root | 3.363 | 12.332[b] | 3.000 | 11.000 | .001 |
| Drive * Task | Pillai's Trace | .829 | 2.700[b] | 9.000 | 5.000 | .143 |
| | Wilks' Lambda | .171 | 2.700[b] | 9.000 | 5.000 | .143 |
| | Hotelling's Trace | 4.860 | 2.700[b] | 9.000 | 5.000 | .143 |
| | Roy's Largest Root | 4.860 | 2.700[b] | 9.000 | 5.000 | .143 |

a. Design: Intercept
Within Subjects Design: Drive + Task + Drive * Task
b. Exact statistic

**Mauchly's Test of Sphericity[a]**

Measure: MEASURE_1

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[b] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Drive | .382 | 11.268 | 5 | .047 | .664 | .784 | .333 |
| Task | .661 | 4.848 | 5 | .436 | .792 | .982 | .333 |
| Drive * Task | .000 | 85.358 | 44 | .000 | .384 | .541 | .111 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept
Within Subjects Design: Drive + Task + Drive * Task
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Drive | Sphericity Assumed | 82409.685 | 3 | 27469.895 | 7.664 | .000 |
| | Greenhouse-Geisser | 82409.685 | 1.992 | 41369.045 | 7.664 | .002 |
| | Huynh-Feldt | 82409.685 | 2.352 | 35040.580 | 7.664 | .001 |
| | Lower-bound | 82409.685 | 1.000 | 82409.685 | 7.664 | .016 |
| Error(Drive) | Sphericity Assumed | 139784.737 | 39 | 3584.224 | | |
| | Greenhouse-Geisser | 139784.737 | 25.897 | 5397.761 | | |
| | Huynh-Feldt | 139784.737 | 30.574 | 4572.034 | | |
| | Lower-bound | 139784.737 | 13.000 | 10752.672 | | |
| Task | Sphericity Assumed | 92465.357 | 3 | 30821.786 | 16.135 | .000 |
| | Greenhouse-Geisser | 92465.357 | 2.377 | 38897.124 | 16.135 | .000 |
| | Huynh-Feldt | 92465.357 | 2.945 | 31401.150 | 16.135 | .000 |
| | Lower-bound | 92465.357 | 1.000 | 92465.357 | 16.135 | .001 |
| Error(Task) | Sphericity Assumed | 74498.915 | 39 | 1910.229 | | |
| | Greenhouse-Geisser | 74498.915 | 30.903 | 2410.710 | | |
| | Huynh-Feldt | 74498.915 | 38.280 | 1946.136 | | |
| | Lower-bound | 74498.915 | 13.000 | 5730.686 | | |
| Drive * Task | Sphericity Assumed | 15807.576 | 9 | 1756.397 | 1.843 | .068 |
| | Greenhouse-Geisser | 15807.576 | 3.460 | 4568.457 | 1.843 | .145 |
| | Huynh-Feldt | 15807.576 | 4.868 | 3247.087 | 1.843 | .119 |
| | Lower-bound | 15807.576 | 1.000 | 15807.576 | 1.843 | .198 |
| Error(Drive*Task) | Sphericity Assumed | 111509.838 | 117 | 953.076 | | |
| | Greenhouse-Geisser | 111509.838 | 44.982 | 2478.986 | | |
| | Huynh-Feldt | 111509.838 | 63.287 | 1761.970 | | |
| | Lower-bound | 111509.838 | 13.000 | 8577.680 | | |

### c. HRV

```
GET DATA /TYPE=XLSX
  /FILE='F:\Mental Workload\MW_ HRV readings.xlsx'
  /SHEET=name 'NN50'
  /CELLRANGE=full
  /READNAMES=on
  /ASSUMEDSTRWIDTH=32767.
EXECUTE.
DATASET NAME DataSet3 WINDOW=FRONT.

SAVE OUTFILE='F:\Mental Workload\MW_NN50_HRV_RM.sav'
  /COMPRESSED.
GLM NN0_1 NN0_2 NN0_3 NN0_0 NN1_1 NN1_2 NN1_3 NN1_5 NN2_1 NN2_2 NN2_3 NN2_5 NN3_1 NN3_2 NN3_3
NN3_5
  /WSFACTOR=Drive 4 Polynomial Task 4 Polynomial
  /METHOD=SSTYPE(3)
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=Drive Task Drive*Task.
```

**Multivariate Tests[a]**

| Effect | | Value | F | Hypothesis df | Error df | Sig. |
|---|---|---|---|---|---|---|
| Drive | Pillai's Trace | .426 | 2.723[b] | 3.000 | 11.000 | .095 |
| | Wilks' Lambda | .574 | 2.723[b] | 3.000 | 11.000 | .095 |
| | Hotelling's Trace | .743 | 2.723[b] | 3.000 | 11.000 | .095 |
| | Roy's Largest Root | .743 | 2.723[b] | 3.000 | 11.000 | .095 |
| Task | Pillai's Trace | .505 | 3.744[b] | 3.000 | 11.000 | .045 |
| | Wilks' Lambda | .495 | 3.744[b] | 3.000 | 11.000 | .045 |
| | Hotelling's Trace | 1.021 | 3.744[b] | 3.000 | 11.000 | .045 |
| | Roy's Largest Root | 1.021 | 3.744[b] | 3.000 | 11.000 | .045 |
| Drive * Task | Pillai's Trace | .597 | .825[b] | 9.000 | 5.000 | .623 |
| | Wilks' Lambda | .403 | .825[b] | 9.000 | 5.000 | .623 |
| | Hotelling's Trace | 1.484 | .825[b] | 9.000 | 5.000 | .623 |
| | Roy's Largest Root | 1.484 | .825[b] | 9.000 | 5.000 | .623 |

a. Design: Intercept
Within Subjects Design: Drive + Task + Drive * Task
b. Exact statistic

**Mauchly's Test of Sphericity[a]**

Measure: MEASURE_1

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[b] Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
|---|---|---|---|---|---|---|---|
| Drive | .180 | 20.112 | 5 | .001 | .538 | .603 | .333 |
| Task | .020 | 45.616 | 5 | .000 | .379 | .391 | .333 |
| Drive * Task | .000 | 261.896 | 44 | .000 | .171 | .190 | .111 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept
Within Subjects Design: Drive + Task + Drive * Task
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Drive | Sphericity Assumed | 294175.821 | 3 | 98058.607 | 1.541 | .219 |
| | Greenhouse-Geisser | 294175.821 | 1.614 | 182228.500 | 1.541 | .237 |
| | Huynh-Feldt | 294175.821 | 1.809 | 162587.560 | 1.541 | .235 |
| | Lower-bound | 294175.821 | 1.000 | 294175.821 | 1.541 | .236 |
| Error(Drive) | Sphericity Assumed | 2481952.179 | 39 | 63639.799 | | |
| | Greenhouse-Geisser | 2481952.179 | 20.986 | 118265.857 | | |
| | Huynh-Feldt | 2481952.179 | 23.521 | 105518.934 | | |
| | Lower-bound | 2481952.179 | 13.000 | 190919.398 | | |
| Task | Sphericity Assumed | 2105329.036 | 3 | 701776.345 | 10.912 | .000 |
| | Greenhouse-Geisser | 2105329.036 | 1.136 | 1852692.901 | 10.912 | .004 |
| | Huynh-Feldt | 2105329.036 | 1.172 | 1795725.849 | 10.912 | .004 |
| | Lower-bound | 2105329.036 | 1.000 | 2105329.036 | 10.912 | .006 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Error(Task) | Sphericity Assumed | 2508280.464 | 39 | 64314.884 | | |
| | Greenhouse-Geisser | 2508280.464 | 14.773 | 169791.600 | | |
| | Huynh-Feldt | 2508280.464 | 15.241 | 164570.806 | | |
| | Lower-bound | 2508280.464 | 13.000 | 192944.651 | | |
| Drive * Task | Sphericity Assumed | 929079.143 | 9 | 103231.016 | 2.237 | .024 |
| | Greenhouse-Geisser | 929079.143 | 1.539 | 603666.402 | 2.237 | .142 |
| | Huynh-Feldt | 929079.143 | 1.706 | 544748.697 | 2.237 | .136 |
| | Lower-bound | 929079.143 | 1.000 | 929079.143 | 2.237 | .159 |
| Error(Drive*Task) | Sphericity Assumed | 5399955.357 | 117 | 46153.465 | | |
| | Greenhouse-Geisser | 5399955.357 | 20.008 | 269892.684 | | |
| | Huynh-Feldt | 5399955.357 | 22.172 | 243551.219 | | |
| | Lower-bound | 5399955.357 | 13.000 | 415381.181 | | |