

AN EMPIRICAL INVESTIGATION INTO TASK AVERSION

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THESIS

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ABSTRACT

Aversion is a complex phenomenon that arises over time through performance of cognitively demanding tasks and has been associated with the mechanisms of mental fatigue and compensatory control. However, little is known about this sensation to dissociate from the task at hand and the causation thereof. It is apparent that aversion is a negative state for the operator and could result in decreased performance and productivity. Through identification of factors that contribute to aversion when performing cognitively demanding tasks, recommendations to reduce design deficits may be employed to promote worker wellbeing and further advance performance and productivity.

The current study examined possible factors that may influence aversion experienced through execution of cognitive tasks. A subsequent aim of this study was to assess a possible cause of aversion. The cause of aversion was hypothesized to be related to efficiency, namely the perception of efficiency when performing tasks and actual efficiency calculated through performance of tasks in relation to the expenditure of effort.

Four investigations were undertaken with a non-repeated design between investigations and a repeated design within investigations. The first investigation was an analysis of the effect that stimulus cycling had on the aversion experienced. This consisted of a proof reading task with two conditions varying in the repetitiveness of the text, therefore, allowing an analysis as to how aversion is altered by the provision of a new stimulus to the participants. Investigation two investigated the effect that task difficulty imposed on aversion experienced. This comprised of two conditions with varied difficulty that were implemented through a driving simulator tracking task with difficulty altered by the width of the driving lane. The effect of performance feedback on the aversion experienced towards a task was the focus of the third investigation. The effect on aversion experienced was assessed through a driving simulator tracking task with a condition

providing feedback of performance to participants and a condition with no knowledge of performance. The final experiment evaluated the effect of task alternations on aversion. This experiment was conducted through alternations between a driving simulator tracking task and a choice reaction task. The choice reaction tasks required participants to identify critical and non-critical stimulus. Four conditions were required for this experiment and were made up of two conditions where there was provision of alternation that varied in frequencies between the two tasks (medium alternation condition and fast alternation condition) and two conditions where no alternations were instated (driving simulator task condition and choice reaction task condition).

Separations between all testing conditions were three or more days apart with sixty participants distributed between the investigations. Test duration of each condition was 30 minutes.

Subjective data was recorded throughout investigations for all conditions in the form of aversion, subjectively perceived efficiency and rate of perceived exertion. Objective data was collected in the form of physiological responses and performance of tasks for the analysis of objective efficiency.

For factors influencing aversion analysis, no differences in aversion experienced were found for the task difficulty and performance feedback investigations. Aversion was found to be less for the changes imposed through the task cycles and task alternation investigations. This concludes that aversion is aggravated through monotonous tasks and by a change of the stimulus or the structure of the cognitive tasks provided to operators; aversion can be alleviated.

The results for the cause of aversion analysis found no difference in objective efficiency over time, with a subsequent decrease in perceived efficiency associated with the increasing aversion. Inference from these findings suggest that aversion cannot be attributed to objective inefficiency of task performance, however it can further be assumed that perception of actual efficiency is inaccurate. Perception of efficiency however had a large influence on the sensation of aversion. Aversion is seen to be

more of a product of time on task, however whether this is mechanism of fatigue or compensatory control is still to be determined.

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TABLE OF CONTENT

1. INTRODUCTION	1
1.1. BACKGROUND TO THE STUDY	1
1.2. STATEMENT OF THE PROBLEM.....	2
2. REVIEW OF RELATED LITERATURE	5
2.1. WHAT IS AVERSION?.....	5
2.2. COMPENSATORY CONTROL AND AVERSION	6
2.3. MENTAL FATIGUE AND AVERSION	8
2.3.1. Mental fatigue and task performance	9
2.3.2. Mental fatigue: psychological experience and aversion.....	9
2.3.3. Mental fatigue and effort regulation	10
2.4. COGNITIVE EFFICIENCY	12
2.4.1. Likelihood Method	13
2.5. MEASURES OF MENTAL WORKLOAD FOR COGNITIVE EFFICIENCY	14
2.5.1. Performance	14
2.5.2. Subjective Measures	15
2.5.3. Physiological Measures.....	16
3. METHODOLOGY	22
3.1. CONCEPT FORMATION	22
3.1.1. Factors Influencing Aversion	22
3.1.2. Cause of Aversion	33
3.2. EXPERIMENTAL DESIGN.....	36
3.2.1. Investigation 1: Task Cycles.....	37

3.2.2.	Investigation 2: Task Difficulty	38
3.2.3.	Investigation 3: Performance Feedback	39
3.2.4.	Investigation 4: Task Alternation.....	40
3.2.5.	Protocol for the Study	43
3.3.	EXPERIMENTAL SET-UP	46
3.3.1.	Proof Reading Task.....	47
3.3.2.	Driving Simulator Task.....	48
3.3.3.	Choice Reaction Task.....	55
3.4.	DEPENDENT VARIABLES DATA COLLECTION.....	58
3.4.1.	Task Aversion.....	58
3.4.2.	Subjective Efficiency.....	60
3.4.3.	Subjective Input.....	60
3.4.4.	Objective Data collection	61
3.4.5.	Objective Input.....	61
3.4.6.	Objective Output – Performance Measures.....	66
3.5.	STATISTICAL HYPOTHESIS	67
3.5.1.	Factors Influencing Aversion	67
3.5.2.	Cause of Aversion	68
3.6.	PARTICIPANT CHARACTERISTICS.....	69
3.7.	ETHICAL CONSTRAINTS	69
3.8.	STATISTICAL ANALYSIS	70
4.	RESULTS.....	72
4.1.	INVESTIGATION 1 – TASK CYCLES.....	72
4.1.1.	Factors Influencing Aversion	73

4.1.2.	Cause of Aversion	83
4.1.3.	Response to Hypotheses.....	87
4.2.	INVESTIGATION 2 – TASK DIFFICULTY	89
4.2.1.	Factors Influencing Aversion	89
4.2.2.	Cause of Aversion	100
4.2.3.	Response to Hypothesis.....	103
4.4.	INVESTIGATION 3 – PERFORMANCE FEEDBACK	104
4.4.1.	Factors Influencing Aversion	104
4.4.2.	Cause of Aversion	119
4.4.3.	Response to Hypothesis.....	121
4.5.	INVESTIGATION 4 – TASK ALTERNATION	123
4.5.1.	Factors Influencing Aversion	123
4.5.2.	Cause of Aversion	144
4.5.3.	Response to Hypothesis.....	145
5.	DISCUSSION	147
5.1.	FACTORS INFLUENCING AVERSION	147
5.1.1.	Investigation 1: Task cycles.....	148
5.1.2.	Investigation 2: Task Difficulty	149
5.1.3.	Investigation 3: Performance Feedback	151
5.1.4.	Investigation 4: Task alternations	153
5.1.5.	Summary of Factors Influencing Aversion	155
5.2.	TASK EFFECTS	156
5.2.1.	Investigation 1: Task Cycles	156
5.2.2.	Investigation 2: Task Difficulty	159

5.2.3.	Investigation 3: Performance Feedback	162
5.2.4.	Investigation 4: Task Alternation.....	166
5.3.	CAUSE OF AVERSION	169
5.3.1.	Investigation 1: Task Cycles	170
5.3.2.	Investigation 2: Task Difficulty	171
5.3.3.	Investigation 3: Performance Feedback	173
5.3.4.	Investigation 4: Task Alternation.....	174
5.3.5.	Summary of Efficiency Considerations	174
5.4.	TIME EFFECTS	176
5.4.1.	Subjective Measures	177
5.4.2.	Physiological Measures	178
5.4.3.	Performance	182
5.5.	DISCUSSION OF PROCEDURE	184
6.	CONCLUSION.....	187
6.1.	SUMMARY OF PROCEDURE	187
6.2.	SUMMARY OF RESULTS	189
6.3.	CONCLUSION	191
6.4.	RECOMMENDATIONS	194
7.	REFERENCES	197
8.	APPENDIXES.....	206

LIST OF TABLES

Table I: Analysis of variance of aversion over task duration for a repetitive and non-repetitive condition of a proof reading task (*significance $p < 0.05$).	74
Table II: Analysis of variance of rate of perceived exertion over task duration for non-repetitive and repetitive conditions of a proof reading task (*significance $p < 0.05$).	75
Table III: Analysis of variance for subjective efficiency over task duration of a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).	76
Table IV: Analysis of variance of reading speed over task duration for a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).	78
Table V: Analysis of variance of heart rate from 10 minutes to 30 minutes of task duration of a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).	80
Table VI: Analysis of variance of heart rate variability SDNN over task duration for a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).	82
Table VII: Analysis of variance of low frequency heart rate variability (center frequency) over task duration of a repetitive and non-repetitive condition of a proof reading task (*significance $p < 0.05$).	83
Table VIII: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (repetitive and non-repetitive) and time (30 minutes) as factors (*significance $p < 0.05$).	85
Table IX: Analysis of variance for objective efficiency (reading speed over heart rate) for the non-repetitive condition over time (*significance $p < 0.05$).	87
Table X: Analysis of variance for objective efficiency (reading speed over heart rate) for the repetitive condition over time (*significance $p < 0.05$).	87
Table XI: Analysis of variance of aversion over task duration for an easy and a difficult condition of a driving simulator task (*significance $p < 0.05$).	90
Table XII: Analysis of variance for rate of perceived exertion over task duration for an easy and a difficult condition of a driving simulator task (*significance $P < 0.05$).	92

Table XIII: Analysis of variance of subjective efficiency over task duration for an easy and a difficult condition of a driving simulator task (*significance $p < 0.05$).	93
Table XIV: Analysis of variance of performance over task duration for an easy and a difficult condition of a driving simulator task (*significance $p < 0.05$).	95
Table XV: Analysis of variance of energy expenditure over task duration for an easy and a difficult condition for a driving simulator task (*significance $p < 0.05$).	97
Table XVI: Analysis of variance of high frequency band (center frequency) heart rate variability over task duration for an easy and a difficult condition for a driving simulator task (*significance $p < 0.05$).	99
Table XVII: Analysis of variance of heart rate variability LF power relative to (LF+HF) over task duration for an easy and a difficult condition for a driving simulator task (*significance ($p < 0.05$).	100
Table XVIII: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (easy and difficult) over time (30 minutes) as factors (*significance $p < 0.05$).	102
Table XIX: Analysis of variance of aversion over task duration for conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).	106
Table XX: Analysis of variance of rate of perceived exertion over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).	107
Table XXI: Analysis of variance of subjective efficiency over task duration for the conditions with no performance feedback and performance feedback of a driving simulator task (*significance $p < 0.05$).	108
Table XXII: Analysis of variance of performance over task duration for the conditions with no performance feedback and performance feedback of a driving simulator task (*significance $p < 0.05$).	110
Table XXIII: Analysis of variance of energy expenditure from 10 minutes to 30 minutes of task duration for the conditions with no performance feedback and performance feedback of a driving simulator task (*significance $p < 0.05$).	112

Table XXIV: Analysis of variance of heart rate variability SDNN over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).....	114
Table XXV: Analysis of variance of heart rate variability rMSSD over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).....	115
Table XXVI: Analysis of variance of high frequency band heart rate variability (center frequency) for the conditions with no performance feedback and performance feedback (*significance $p < 0.05$).....	116
Table XXVII: Analysis of variance of low frequency band heart rate variability (power) over task duration for conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).	117
Table XXVIII: Analysis of variance of heart rate variability LF power relative to (LF+HF) over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).	118
Table XXIX: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (no performance feedback and performance feedback) and time (30 minutes) as factors (*significance $p < 0.05$).	121
Table XXX: Analysis of variance for aversion over task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$).....	125
Table XXXI: Tukey post hoc analysis for aversion over task duration for the last time interval of all alternation conditions of the task alternation investigation (*significance $p < 0.05$).....	125
Table XXXII: Analysis of variance of rate of perceived exertion over task duration for all alternation conditions in the task alternation investigation (*significance $p < 0.05$).	126
Table XXXIII: Analysis of variance of subjective efficiency over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	127
Table XXXIV: Analysis of variance of relative performance over task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$).	129

Table XXXV: Analysis of variance of breathing frequency from 10 minutes to 30 minutes of task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$).....	131
Table XXXVI: Analysis of variance of SDNN heart rate variability over task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$). .	133
Table XXXVII: Tukey post hoc analysis of the last time interval for SDNN heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	133
Table XXXVIII: Analysis of variance for rMSSD heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).	135
Table XXXIX: Tukey post hoc analysis of the last time interval for rMSSD heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	135
Table XL: Analysis of variance of PNN50 heart rate variability over task duration for all alternation conditions of the task alteration investigation (*significance $p < 0.05$).	137
Table XLI: Analysis of variance of PNN30 heart rate variability over task duration for all alternation conditions in the task alternation investigation.....	138
Table XLII: Analysis of variance of low frequency band heart rate variability (center frequency) over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	139
Table XLIII: Analysis of variance of high frequency band heart rate variability (center frequency) over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	141
Table XLIV: Analysis of variance of high frequency band heart rate variability (power) over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	142
Table XLV: Analysis of variance of LF power relative to (LF+HF) heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).....	143

Table XLVI: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (choice reaction task, driving simulator task, medium alternation and fast alternation) and duration (30 minutes) as factors (*significance $p < 0.05$).	145
Table XLVII: Summary of condition effect and interaction effect for condition and time results for the task cycle investigation (X denotes a statistically significant difference where $p < 0.05$).	148
Table XLVIII: Summary of condition effects and interaction effects of condition and time results for the task difficulty investigation (X denotes a statistically significant difference where $p < 0.05$).	149
Table XLIX: Summary of condition effects and the interaction effects of condition and time results for the performance feedback investigation (X denotes a statistically significant difference where $p < 0.05$).	151
Table L: Summary of condition effects, interaction effect between condition and time and post hoc analysis effects for the task alternation investigation (X denotes a statistically significant difference where $p < 0.05$).	154
Table LI: Summary of time on task effects and interaction effect of condition and time results for the task cycle investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).	170
Table LII: Summary of time on task effects and interaction of condition and time results for the task difficulty investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).	171
Table LIII: Summary of time on task effects and interaction effects of condition and time results for the performance feedback investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).	173
Table LIV: Summary of time on task effects and interaction effects of condition and time results for the task alternation investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).	174
Table LV: Summary of time on task effect results for all investigations undertaken (arrows denote a statistically significant increase or decrease where $p < 0.05$).	177

LIST OF FIGURES

Figure 1: Assumed progression of task aversion.	24
Figure 2: Progression of aversion with changes to monotony.	25
Figure 3: Progression of aversion with changes to motivation.	26
Figure 4: Trend of expectation for task cycles investigation highlighting the two conditions and the anticipated effect these have on aversion.	28
Figure 5: Trend of expectation for the task difficulty investigation highlighting the two conditions and the anticipated effect these have on aversion.	29
Figure 6: Trend of expectation for the performance feedback investigation highlighting the two conditions and the anticipated effect these have on aversion.	30
Figure 7: Trend of expectation for the task alternation investigation highlighting the four alternation condition, and the anticipated effect these have on aversion.	32
Figure 8: Trend of expectation for subjective efficiency.....	35
Figure 9: Trend of expectation for objective data.	36
Figure 10: Experimental design of task cycles investigation.	38
Figure 11: Experimental design of task difficulty investigation.	39
Figure 12: Experimental design of performance feedback investigation.	40
Figure 13: Experimental design of task alternation experiment.	43
Figure 14: Podium with writing text.	47
Figure 15: Physical set-up of task alternation experiment displaying participant driving with ergospirometric equipment.	49

Figure 16: Screen-shot of driving parameters for easy condition of task difficulty experiment.	50
Figure 17: Screen-shot of driving parameters for difficult condition of task difficulty experiment.	51
Figure 18: Screen-shot of driving parameters for the performance feedback condition showing performance indicator.	52
Figure 19: Screen-shot showing visual display to participants indicating an improvement in performance for the performance feedback investigation.	53
Figure 20: Screen-shot showing visual display to participants indicating a decrease in performance for the performance feedback investigation.	53
Figure 21: Screen-shot of the driving simulator task for task alternation investigation. .	54
Figure 22: Apparatus for execution of the driving simulator and the choice reaction tasks.	56
Figure 23: Screen-shot of the software set-up for the choice reaction task.	57
Figure 24: Set-up of the ergospirometer (Quark b ²).	63
Figure 25: Set-up of the Polar T34 heart rate monitor.	64
Figure 26: Aversion over task duration for a non-repetitive and repetitive condition proof reading.	73
Figure 27: Rate of perceived exertion over task duration for a non-repetitive and a repetitive condition of a proof reading task.	74
Figure 28: Subjective efficiency over task duration for non-repetitive and repetitive condition of a proof reading task.	75
Figure 29: Reading speed over task duration for a repetitive and non-repetitive condition of a proof reading task.	77

Figure 30: Change in heart rate from 10 minutes to 30 minutes of task duration for a repetitive and a non-repetitive condition of a proof reading task. 79

Figure 31: Heart rate variability SDNN over task duration comparing a repetitive and a non-repetitive condition of a proof reading task..... 81

Figure 32: Low frequency band for heart rate variability over task duration for a repetitive and a non-repetitive condition of a proof reading task. 82

Figure 33: Subjective efficiency over task duration against aversion and rate of perceived exertion for all conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency)..... 84

Figure 34: Objective efficiency against aversion for task duration for a non-repetitive and repetitive condition showing performance (reading speed) over heart rate experienced (where OE: objective efficiency and AV: aversion)..... 86

Figure 35: Aversion experienced over task duration for an easy and a difficult condition of a driving simulator task..... 90

Figure 36: Rate of perceived exertion over task duration for an easy and a difficult condition of a driving simulator task. 91

Figure 37: Subjective efficiency over testing duration for easy and difficult conditions of a driving simulator task..... 92

Figure 38: Change in performance over testing duration for an easy and a difficult condition of a driving simulator task. 94

Figure 39: Energy expenditure from 10 minute to 30 minutes of testing duration for an easy and difficult condition of a driving simulator task..... 96

Figure 40: High frequency (center frequency) band heart rate variability over task duration for an easy and a difficult condition of a driving simulator task..... 98

Figure 41: LF power relative to (LF+Hf) heart rate variability over task duration for an easy and a difficult condition for a driving simulator task..... 99

Figure 42: Subjective efficiency over task duration against aversion and rate of perceived exertion for all conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency)..... 101

Figure 43: Change in aversion over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task. 105

Figure 44: Change in rate of perceived exertion over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task. 106

Figure 45: Change in subjective efficiency over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task. 107

Figure 46: Change in mean deviation for performance over test duration for the conditions with no performance feedback and performance feedback for a driving simulator task..... 109

Figure 47: Change in energy expenditure from 10 minutes to 30 minutes of task duration for the conditions with no performance feedback and performance feedback for a driving simulator task..... 111

Figure 48: Heart rate variability SDNN over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task. 113

Figure 49: Heart rate variability rMSSD over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task. 114

Figure 50: High frequency band heart rate variability (center frequency) over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task..... 115

Figure 51: Low frequency band heart rate variability (power) over task duration for conditions with no performance feedback and performance feedback for a driving simulator task.....	116
Figure 52: LF power relative to (LF+HF) heart rate variability over task duration for conditions with no performance feedback and performance feedback for a driving simulator task.....	118
Figure 53: Subjective efficiency over task duration against aversion and rate of perceived exertion for all conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency).....	120
Figure 54: Aversion over task duration for all conditions of the task alternation investigation.....	124
Figure 55: Rate of perceived exertion over task duration for all alternation conditions of the task alternation investigation.....	126
Figure 56: Subjective efficiency over task duration for all alternation conditions for the task alternation investigation.....	127
Figure 57: Relative performance over task duration for alternation conditions of the task alternation investigation.....	129
Figure 58: Breathing frequency from 10 minutes to 30 minutes of task duration for all alternation conditions of the task alternation condition.....	130
Figure 59: Heart rate variability SDNN over task duration for all alternation conditions for the task alternation investigation.....	132
Figure 60: Heart rate variability rMSSD over task duration for all alternation conditions in the task alteration investigation.....	134
Figure 61: Heart rate variability PNN50 over task duration for all alternation conditions of the task alternation investigation.....	136

Figure 62: Heart rate variability PNN30 over task duration for all alternation conditions in the task alternation investigation. 137

Figure 63: Low frequency band heart rate variability (center frequency) for all alternation conditions for the task alternation investigation. 138

Figure 64: High frequency band heart rate variability (center frequency) over task duration for all alternation conditions for the task alternation investigation..... 140

Figure 65: High frequency band heart rate variability (power) over task duration for all alternation conditions for the task alternation investigation. 141

Figure 66: LF power relative to (LF+HF) heart rate variability over task duration for all alternation conditions for the task alternation investigation. 142

Figure 67: Subjective efficiency over task duration against aversion and rate of perceived exertion for all alternation conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency). 144

CHAPTER I

1. INTRODUCTION

1.1. BACKGROUND TO THE STUDY

Through technological advancements as well as increased knowledge of work, work methods and equipment, there has been a shift from work that was physically demanding in nature to a new form of work that is reliant on cognitive ability and sustainability. Mechanization has increased the demand for operators to move away from physical work to work that is more cognitively demanding (Fredericks *et al.*, 2005). Although mentally demanding work has taken some emphasis off physical demands, this has provided new types of exertion for the worker.

Reports show that the stressors associated with an occupation are very serious, are an escalating problem in the workplace and are responsible for a multitude of costly outcomes (Fredericks *et al.*, 2005). Furthermore Goetsch (1999) states that job stress can be defined as the harmful physical and emotional responses that occur when the requirements of the job do not match the capabilities, resources or needs of the worker and can lead to poor health and even injury. Stress-related complaints have also been associated with computer use (Mackay, 1989). Some of the feelings associated with mental work and stress over long periods of time include tiredness or even exhaustion, a decrease in the level of commitment to the task at hand and aversion to continue with the present activity (Boksem and Tops, 2008). The manifestation of aversion to continue the present activity is often associated with mental fatigue. A notion put forward by Hockey (1997) states that central to mental fatigue is an aversion to continue the task at hand. Fatigue is often defined as subjectively experienced aversion to invest further effort in the task (Hulst *et al.*, 2001).

Not only is it important to assess the effects that mental fatigue has on the performance of the operator with regards to productivity, it is crucial that the psychological aspects of

work over periods of time are studied and understood, in order to obtain a holistic view. These sensations of tiredness, decrease in commitment and aversion are clearly negative states which workers should avoid in order to optimize production. Aversion especially becomes an important concern in “non-tasked” work systems where it might lead to a decrease in work pace and thus to decreased productivity. Specifically, if aversion is a consequence of mental fatigue, the factors that contribute to fatigue and thus the sensation of aversion should be identified. Lost productivity time from fatigued workers costs employers an excess of a hundred billion dollars annually in comparison to non-fatigued workers (Boksem and Tops, 2008). Further, looking at the social and personal aspects of mental fatigue, there was found to be intense negative impacts on the workers social and occupational life (Boksem and Tops, 2008). Not only is aversion a negative sensation for optimal work performance and productivity, the additional effects on social and personal lives can further cause problems towards reaching work objectives.

1.2. STATEMENT OF THE PROBLEM

As a specialist in human factors, not only is it important to look at the discrepancies between human abilities, work demands and performance, but also to look at all aspects affecting sound and smooth work execution. To gain a holistic approach, not only do the biomechanical and physiological aspects of work need to be assessed, but also psychological aspects need to be investigated. Aversion and the sensation to withdraw from cognitively demanding work is one such aspect. Aversion is a clear negative state for the operator which could ultimately impair performance and cause detrimental effects to the workers social and personal life. No studies are present on possible interventions to put in place to reduce the aversion to tasks. By identifying exacerbating task design deficits that contribute to aversion, this may be reduced and a resultant improvement of psychological perceptions to work can be achieved. The problem addressed in this study is to ascertain what factors contribute to or reduce this

sensation to discontinue work and an aversion to tasks and to identify a probable cause of this aversion.

Little is known about aversion and the cause there of; therefore this study not only hopes to uncover certain aspects that may have a detrimental effect on the sensation of aversion, but to also provide some understanding as to what causes aversion. This study hopes to gain a comprehensive understanding of task aversion and specific factors that either contribute to or reduce task aversion were assessed. The potential gain from identifying whether these factors contribute to or reduce aversion is to provide some knowledge and inference into design deficits of work tasks which could exacerbate negative psychological sensations towards work performance.

In order to assess as many aspects of task aversion in this study and gain a comprehensive understanding of it, three varying task objectives were decided on to be analyzed. Firstly, the cycling of information of a task was assessed through a reading task. Secondly, task specific variables namely, task difficulty and performance feedback, were assessed. Lastly the structure of the task in the form of task alternations between two tasks (driving simulator and choice reaction) was studied. By changing the tasks through these different objectives a conclusion may be drawn on the impact that monotonous work, difficulty of work, an affirmation of performance and a possibility of alternating between tasks has on the sensation of aversion.

As stated, aversion is central to the concept of mental fatigue (Hockey, 1997), however mental fatigue is often accompanied by a decrease in performance (Hulst *et al.*, 2001; Meijman 1997; Boksem *et al.*, 2006). Often during work, performance is still maintained although aversion to continue the work is clearly and decidedly present. This caused indecision as to whether aversion is truly a central component of mental fatigue. An additional aim of this study was to attempt to identify a probable cause of aversion. The theory for this investigation is that aversion is a byproduct of inefficiency. Actual inefficiency due to the disparity between the amounts of output, through performance of

a task, versus the amount of input invested, in the form of cognitive effort, or the subjective sensation of inefficiency may be the possible cause of aversion.

CHAPTER II

2. REVIEW OF RELATED LITERATURE

In a world that is continuously striving for optimization and efficiency of performance, often little attention is given to the psychological state of a worker while performing cognitively demanding tasks. Subjective consequences to performing cognitively demanding work over periods of time are usually manifested in a decreased willingness, or an aversion to further continue the task at hand.

This chapter looks at the literature relating to the study performed. This review hopes to establish some of the theories behind the presence of aversion during the performance of cognitive tasks. The two theories analyzed are: Compensatory Control and Mental Fatigue. Further, it looks at cognitive efficiency as another possible theory of aversion in cognitive tasks. Subjective and objective methods of workload for cognitive efficiency are finally assessed.

2.1. WHAT IS AVERSION?

Through ergonomic practices a large emphasis has typically been put on physiological capabilities and identification of discrepancies between workers and cognitively demanding tasks. Recently, additional attention has been given to the effects of mental fatigue (Bültmann *et al.*, 2002). It is clear that mental fatigue has a debilitating and, over prolonged periods of time, a deleterious effect on the worker that is not easily reversed. Furthermore, focus on mental fatigue has been on productivity through performance decrements strongly associated with mental fatigue (Hulst *et al.*, 2001); however little is known about the subjective aspects of mental fatigue, or the subjective consequences of working on mentally demanding tasks. Prior to the appearance of mental fatigue, through performance decrements or a strategic shift in effort to maintain the task performance (Hulst *et al.*, 2001), is the appearance of subjective symptoms through

performance of cognitively demanding work. One of the greatest subjective consequences of working on cognitively demanding tasks is the appearance of aversion to the task at hand (Craig *et al.*, 2006).

There is a dearth in the literature on this subjective phenomenon of aversion. Aversion according to the literature is only inferred to be present during mental fatigue (Boksem *et al.*, 2005; Hockey, 1997; Linden *et al.*, 2003) and that it may be the psychological representation of mental fatigue (Craig *et al.*, 2006). Furthermore, aversion has been seen in the literature to exist through sustaining an effortful state (Hockey, 1997) or further investment of effort. O'Hanlon (1981, p. 74) state that "effort seemingly has a negative affective component that alone may cause pervasive attitudes of dissatisfaction and lead to aversion to the entire working environment". However, the underlying cause or purpose of aversion while performing mentally demanding tasks is not apparent and further no investigation has been done into possible tasks, task variables and task structures that may aggravate the aversion to continue with the present activity.

In order to gain a comprehensive understanding of whether aversion is a possible component of mental fatigue, or caused by an increase in effort investment, the definition, components and characterization of mental fatigue and compensatory control need to be discussed.

2.2. COMPENSATORY CONTROL AND AVERSION

Human performance is understood as either the effectiveness of specific skills in meeting cognitive goals or the underlying mental operations associated with such behaviours (Hockey, 1997). It was Thorndike (1990) who formulated the theory on the compensatory character of effort in task performance (Meijman, 1997). In order to understand performance and latent decrements in performance it is important to

understand the compensatory control mechanism explained by energetical analyses of performance (Hockey, 1997).

Primary tasks performance is considered generally stable under stress and high demands, and in order to have effective performance under stress there is typically an accompanied high level of physiological activation and subjective strain (Hockey, 1997). According to the energetical-control framework of Hockey (1997), the maintenance and stability of performance under demanding conditions is an active process under the control of the individual, requiring the management of cognitive resources through mobilization of mental effort. Resources can be understood as the one or more general-purpose processing units, capable of performing elementary operations across a range of tasks, however these resources are limited in capacity (Kahneman, 1973). Kahneman (1973) identified effort as an increase in the overall resources to meet the prevailing demand and that it attracted costs in terms of sympathetic activation. The cognitive-energetical approach assumes that energetic resources may be allocated, controlled and subject to strategic resource-management decisions (Hockey, 1997). Therefore, in order to maintain and have effective performance, effort is employed in the form of resource utilization, which can be felt through physiological responses. The activation and control of these resources can further be strategically controlled in order to meet the demands imposed by the task. This regulatory-control model was proposed to account for the effects of stress on performance (Hockey, 1997). In situations where there are disturbances in performance from stressors, an effort-based compensatory control mechanism may be needed not only for maintaining tasks but for preventing the loss of task goals under circumstances of increased processing demands (Hockey, 1997).

With this regulatory activity, and thus compensatory control, costs may be attracted to emotional and physiological sub-systems, particularly in situations of agitation from stress and environmental load (Hockey, 1997). Costs may be interpreted as an expenditure of mental resources and experienced subjectively as mental effort and high levels of subjective strain and accompanied by increased levels of sympathetic

dominance and displayed through physiological changes (Kahneman, 1973). From this, it can be understood that when performing demanding mental tasks, conflicts may arise as cognitive tasks are taken at the expense of other kinds of behaviour (Hockey, 1997). Cognitive performance requires sustaining an effortful state, or increases in an effortful state in order to sustain this performance which is often difficult. As stated previously, not only is there a cost imposed on the physiological sub-systems there is an emotional cost which is established as subjectively aversive (Kahneman, 1973). O'Hanlon's (1981) work on boredom, reiterates that aversion has a presence in the investment of further effort into a task. Effort is required to not only cope with the challenge of task performance, but further to stave off boredom in monotonous work (Brown, 1994).

From the above literature it can be seen that with compensatory control and the regulation of cognitive-energetical resources, an increased effort, displayed through physiological responses, is needed in the maintenance of performance. When stressors imposed by changes to the tasks arise, effort-based compensatory control is needed to cope with the increased demands of the tasks. By maintaining an effortful state, this is often difficult and results in emotional costs generally seen as aversive to the task at hand (Hockey, 1997). Therefore, this provides some clear evidence that the need to maintain performance through effort and compensatory regulation has an effect on the willingness to continue a task, and thus has an impact on aversion experienced towards cognitive tasks.

2.3. MENTAL FATIGUE AND AVERSION

Fatigue is a complex phenomenon and is generally known as a self-recognized state in which an individual experiences an overwhelming sustained sense of exhaustion and decreased capacity for physical and mental work (Shen *et al.*, 2006). In order to maintain normal functioning fatigue needs to be avoided as it interferes with an individual's ability to function at their normal capacity. Furthermore, fatigue is seen as a protective function of the body with stress, exercise and rest as the alleviating factors of

fatigue (Shen *et al.*, 2006). Mental fatigue is a component of fatigue that is the manifestation of prolonged periods of cognitive activity (Boksem and Tops, 2008), however, there is contention as to the definition and concept of the nature of fatigue (Hulst *et al.*, 2001).

2.3.1. Mental fatigue: task performance and time on task

As already stated, it is understood that mental fatigue is the resultant outcome of cognitive activity over prolonged periods of time (Boksem and Tops, 2008). According to Boksem and Tops (2008) mental fatigue has been associated with impaired cognitive and behavioural performance impacting on task performance. Meijman (1997) further reiterates this by stating that mental fatigue can be defined as the degradation of the ability to sustain adequate performance in mental tasks due to the exertion of mental activities. Mental fatigue therefore leads to sub-optimal functioning and human error with deterioration in cognitive functioning (Lorist *et al.*, 2005; Boksem *et al.*, 2008). Consequently it can be understood that fatigue is a change in performance, normally a decrement in performance over task time (Boksem and Tops, 2008). Although according to this literature, it is apparent that many take the view that mental fatigue is seen through a decrease in the performance of a task, fatigue is a complex concept which cannot be measured through a single indicator (Meijman, 1997). It has been established that fatigue comprises of physiological and psychological experiences (Craig *et al.*, 2006).

2.3.2. Mental fatigue: psychological experience and aversion

It was found through the early research of Bartley and Chute (1947) that the measurable pattern of deterioration associated with fatigue may not have a clear representation in subjective experienced fatigue, such that an individual may have stable performance, though subjectively experienced fatigue is high and vice versa (Craig *et al.*, 2006). Brown (1994) described fatigue as a subjectively experienced disinclination to continue performing the task at hand. Mental fatigue has additionally been described by Boksem *et al.* (2006) as a decrease in the level of commitment to the

task at hand as well as an aversion to continue with the present activity. However, through the study of Hulst *et al.* (2001) on maintaining task-set under fatigue, it was found that with increases of subjective fatigue (feelings of tiredness and reduced alertness associated with drowsiness), there were associations with increases in aversion to continue driving and deterioration of performance. The literature provides conflicting evidence as to the purpose of aversion in studies of mental fatigue as some theories state that aversion is central to mental fatigue (Hockey, 1997), and thus a representation of subjective fatigue, where other literature implies that aversion is a characteristic that is affected by mental fatigue (Hulst *et al.*, 2001).

2.3.3. Mental fatigue and effort regulation

As already discussed the maintenance of performance in cognitively demanding tasks requires continuous self-regulation and effort mobilization through voluntary control over resource allocation. The works of Matthew and Desmond (2002) found that with fatigue however, both resources and effort may be implicated. The effort regulation theory of fatigue as described by Matthews and Desmond (2002) in de Grey Birch (2012), finds that an operator's ability to meet the level of effort required by task demands has a greater impact than the actual resource availability. Through the appearance of fatigue, the difficulty of continuous performance and the maintenance of performance are increased. The operator needs to compensate for this increased difficulty by increasing the effort exerted (Kahneman, 1973). According to this compensatory character of effort, it is highly implausible for mental fatigue to show up as performance impairment as long as the subject is willing to compensate by investing more effort (Meijman, 1997). Mental fatigue in the form of performance decrements will therefore only deteriorate when the total effort required to maintain performance of tasks exceeds an individual's information processing system (de Grey Birch, 2012; Jorna, 1992) The extra energy (in the form of mental effort) allocated to maintain performance can only be maintained for a short period, as physiological and psychological costs are high and will induce cognitive strain and mental fatigue (Gaillard, 1993; 2001). Negative changes of the

willingness to expend mental capacity in order to sustain adequate performance have also been associated with mental fatigue (Meijman, 1997).

Human behaviour is an adaptive behaviour, such that Jorna (1992) notes that operators seek to maintain an acceptable level of performance at a comfortable level of effort (de Grey Birch, 2012). However, with fatigue there is reduced ability to match one's effort to the demands of a task and fatigue produces strategies for effort regulation. Hockey (1997) states, that if performance maintenance is associated with accumulative effort cost, operators may have an adaptive role, such that there is shifting behaviour towards a strategy that demands less effort (Hulst *et al.*, 2001). This type of strategy shift can be understood as an economizing of effort through maintaining adequate performance and protecting task priorities, known as passive coping (Hulst *et al.*, 2001). A trade-off is normally assumed however, by either adapting to strategies that require less effort from the operator or lowering the acceptable performance.

From the literature it is noted that in order to obtain a comprehensive understanding of aversion, not only must mental fatigue be understood, but the components behind mental fatigue as well, such as effort compensation for performance sustainability. Thorndike (1900) proposed an efficiency paradigm in the study of mental fatigue such that performance in mental tasks can always be related to some parameter of the costs involved in the realization of that performance (Meijman, 1997). Brown (1994) further reiterated that fatigue causes a disinclination to continue performing the task and that it involves a diminishing human efficiency when work continues after the person has become aware of their fatigued state (Lal and Craig, 2001). This provides an interesting notion into the analysis of aversion. It provides questions as to whether or not cognitive efficiency plays a part in the formation of aversion and mental fatigue.

2.4. COGNITIVE EFFICIENCY

Cognitive efficiency is known as the increases in the rate, amount and conceptual clarity of knowledge versus costs, such as the cognitive effort needed to attain the knowledge (Hoffman, 2012). Great contention has arisen from the conceptual and measurement properties of cognitive efficiency and how individuals optimize mental resources to achieve gains in learning, problem-solving and cognitive performance (Hoffman, 2012). Cognitive or mental efficiency is comprised of three primary constructs of efficiency: neurological, validated by the location and degree of brain activity during learning; instructional, expressed as the relative effectiveness of pedagogical methods or instructional material as measured by learning outcomes; and finally performance efficiency (van Gog and Pass, 2008). Performance efficiency is the type of efficiency that provides the main focus for this investigation. It is determined by regulation of effort during the learning process and looking at the measurable changes in the amount, rate, frequency or complexity of knowledge structures (Hoffman, 2012). Costs involved in this efficiency are measured by factors such as time taken, effort invested and error rates incurred (Hoffman, 2012). An individual is seen as cognitively efficient if acquisition is high in relation to lower expenditure of effort, time, or working memory during the learning process (Hoffman, 2012). Mental effort is a core concept of cognitive efficiency and is seen as the depletion of human interval resources to accomplish the work (Xie and Salvendy, 2000). Although knowledge acquisition is not the primary objective of this investigation, poorly designed material will inhibit cognitive efficiency regardless of expertise, while optimally designed tasks should differentially affect perceptions of effort as a function of expertise (Beckmann, 2010).

Cognitive efficiency is seen as the measurement of optimal cognitive processing (Hoffman, 2012). Cognitive processing is regulated depending on motivation, affect and reflective judgment and involves the use of metacognitive and regulatory strategies in order to have accurate monitoring, analytical reasoning and reflection of attainment of problem-solving goals. These all relate to cognitive efficiency as performance is dependent on existing knowledge but also through the regulation of effort factors such

as how operators evaluate task difficulty (van Gog and Pass, 2008). Cognitive efficiency is determined by speed and accuracy of task performance and by the ability to retrieve past knowledge from memory, typically, long-term memory, but also the extent to which available resources can be invested towards higher-order thinking processes needed to advance (Beckmann, 2010). Reinforced by the works of Galy *et al.* (2012), it was noted that a subject's performance is considered more efficient if the performance is better when the mental effort expended is lower than expected.

Cognitive efficiency is measured through two main approaches; the Likelihood method and the Deviation method. Both methods are proposed to measure overall cognitive load associated with problem-solving tasks to determine which facets of the load are attributed instructional design considerations and which are limited by cognitive architecture restrictions such as working memory capacity (Hoffman, 2012). The deviation method was initially developed to determine relative efficiency of instructional conditions although it has been used to describe measurements of individual efficiency as well (Hoffman, 2012). However for the purpose of this investigation the likelihood method was chosen as the deviation method focusses its calculations on the standardized difference between performance and effort (Hoffman, 2012).

2.4.1. Likelihood Method

The likelihood method is a mathematical ratio calculation that provides a measure of efficiency consistent with the definition of the ratio of work output to work input. Output can be defined as learning or performance and input as work, time or effort (Smith and Street, 2005). According to Hoffman (2012) the likelihood method has been used to test the superiority of different modalities in conjunction with pre- and post-task effort to investigate the cognitive efficiency of reading, efficiency of performance in mathematics with increasing complexity or restricted learning and during strategy selection problem solving. The likelihood method denotes efficiency $E = P/R$, that shows the ratio between raw score for the test performance P , divided by a raw score for effort denoted as R , where R can be any self-report or an objective measure based on time or cognitive

resources expended (Hoffman, 2012). The likelihood formula provides an efficiency score that represents raw scores on the same scale and not converted to standard normal scores, “where E provides a measure of where P and R lie in relation to each other or an index of relative gain” (Hoffman, 2012, p. 136). The likelihood method scores are most useful for determining the degree of progress or rate of change between two dissimilar scores on different scales (Hoffman, 2012).

2.5. MEASURES OF MENTAL WORKLOAD FOR COGNITIVE EFFICIENCY

With the theory of aversion being apparent as a possible resultant effect of inefficiency, the next section of this review will move away from the concept of aversion and cognitive efficiency and look into the chosen measurement techniques of mental workload that were chosen to assist in the identification of cognitive efficiency. The measures of mental workload chosen and discussed will be: performance; subjective measures; and physiological measures namely, energy expenditure and breathing frequency, heart rate and heart rate variability.

2.5.1. Performance

According to Cain (2004) task performance measures are vital for the hypothesis of predictive models on the operator’s state and can be evaluated in constructive simulations with numerous repetitions. Performance measures assess the operator’s capacity and provide an index into the variation of cognitive working load across a variety of information processing functions. Performance, as a concept of cognitive load, provides the investigator with an insight into the cognitive capacity that is actually allocated to accommodate the demands imposed by the task (Pass *et al.*, 2003). Thus, performance measures directly measure the intensity of effort being expended by the participant, which is a reliable estimate of cognitive load. Performance measures provide a reference to the effectiveness of specific skills in meeting cognitive goals and the underlying mental processes (Hockey, 1997). The purpose of studying performance

is so that tasks are designed as indicators of the functional level of underlying processes or mental operations. If the process is operating less efficiently, the task is assumed to result and reflect this by deteriorated levels of overt performance (Hockey, 1997).

2.5.2. Subjective Measures

Subjective measures provide crucial analysis into human understanding of mental workload and the requirements for task performance. "Rating scale techniques are based on the assumption that people are able to introspect on their cognitive processes and to report the amount of mental effort expended." (Paas *et al.*, 2003, p. 66). Subjective measures have been found to be a more sensitive and valid indicator of mental workload than other measurement techniques as the person concerned has a more accurate judgment with respect to the load experienced (de Grey Birch, 2012). Most subjective measures are multidimensional in that they assess groups of associated variables such as mental effort, fatigue and frustration which have been found to be highly correlated (Paas *et al.*, 2003). However, unidimensional scales have been shown to produce reliable measures (Pass *et al.*, 2003). Most importantly, it is known and has been demonstrated that such scales (multidimensional and unidimensional) are reliable, valid, non-intrusive and are sensitive to relatively small differences in cognitive load (Paas *et al.*, 2003).

Subjective measurement techniques rely on an individual's personal feelings and perceptions however, according to Fredericks *et al.* (2005) these are typically considered less reliable (Fredericks *et al.*, 2005). Paas *et al.* (2003) however refute this by stating that although self-rating may appear questionable, it has been established that people are quite capable of giving numerical indications of their perceived mental burden.

2.5.3. Physiological Measures

Physiological techniques are based on the postulation that changes in the cognitive execution of tasks are reflected by physiological responses (Pass *et al.*, 2003). The changes in various bodily processes and states have been reported with changes in mental workload (Galy *et al.*, 2012). Since performance measures are often insensitive to mental effort if a participant's total information processing resources are not exceeded, physiological measures of mental effort are needed as an objective and nonintrusive indices of mental workload (Backs and Seljos, 1994). Due to the protective compensatory effect of increased effort, it is clear that measuring performance is not sufficient to assess the state of the operator. The level of performance does not provide information about the costs involved in the adaptive response to stress (Cain, 2004). The sensitivity of physiological responses to cognitive demands is regarded as neurophysiological changes and further as a shift to catabolic activity within the autonomic nervous system (Fairclough *et al.*, 2005). These changes in neurophysiology have been associated with energy mobilization and the investment of mental effort (Fairclough *et al.*, 2005). Physiological techniques can provide information about the cost involved when performing cognitively demanding work (Cain, 2004). Physiological measurements are frequently used to index the level of cognitive demand associated with a task (Hancock and Verwey, 1997). Furthermore, the major advantage of physiological measures is the continuous availability of bodily data. This allows for mental effort to be measured at a high rate and with a high degree of sensitivity (Galy *et al.*, 2012)

The concept of active coping has been dominant in the physiological studies on solving mental tasks. Solving mental tasks effects many physiological variables in particular the variables, regarded as being the most sensitive indices of activation (Sosnowski *et al.*, 2010). Some of the physiological techniques that provide inference to mental effort include: heart rate, heart rate variability, eye movement and activity, and energy expenditure (Pass *et al.*, 2003). It is important however to note that physiological measures can also be influenced by a number of variables. These variables may not

reflect the cognitive or mental workload imposed by the tasks, therefore it is important to assess a combination of physiological variables in order to get a reliable understanding of mental effort (de Grey Birch, 2011; Eggemeier *et al.*, 1991).

Energy Expenditure and Breathing Frequency

The measures of metabolic activity and energy expenditure are not solely limited to physically demanding tasks (Backs and Seljos, 1994). It is important to clarify the relationship between mental effort and metabolic activity during information processing to determine the validity of metabolically adjusted mental workload measures. Mental effort investment has been described as energy mobilization in the service of cognitive goals (Gaillard, 1993; 2001; Fairclough and Houston, 2004). Increased respiration and heart rate are broadly representative of energy mobilization or mental effort to meet increased task demands (Fairclough *et al.*, 2005).

According to studies done by Carrol *et al.* (1986a; 1986b), it was found that energy expenditure as measured by oxygen consumption and carbon dioxide production is greater during task performance than during resting baseline. However these authors state that this greater energy expenditure is not evidence that information processing has its own metabolic cost, but should rather be associated with the somatic task demands. They did demonstrate however that mental effort clearly affects metabolic activity, specifically energy expenditure through the performance of tasks varying in difficulty, with no changes in the somatic demands to the task (Carrol *et al.*, 1986a; 1986b). “Recent evidence indicates that central processing has a small, but significant, effect on energy expenditure that increases with the mental effort devoted to the task” (Backs and Seljos, 1994, p. 58). Upon studying the energy expenditure and respiration rate associated with a memory task, Backs and Seljos (1994) found that from base-line to task data, physiological activity increased during the task performance.

This provided evidence to further look at the effects of the metabolic cost of cognitively demanding tasks. It is important to discover whether varying tasks or the nature of tasks provided enough changes in metabolic activity to distinguish whether energy

expenditure and breathing frequency could be used as physiological measures of cognitive effort.

Heart Rate and Heart Rate Variability

Heart Rate

It has been found that the measures of heart rate (HR) and heart rate variability (HRV) are relatively easy to employ unobtrusively both in laboratory and field settings (Cain, 2004). For many years heart rate and the measurement thereof has provided an indication of task involvement, anxiety and a guide for arousal. More recently, heart rate measures have been assessed as a measure of mental load and effort (Jorna, 1992). Heart rate has been reported to vary as a function of the mental load imposed by the task, such that it will increase with increasing cognitive demands placed on the operator (de Gray Birch, 2011; Brookings *et al.*, 1996). Therefore it is a well-known concept that solving mental tasks elicits tonic increases in cardiovascular activity (Sosnowski *et al.*, 2010). Studies have shown (Fairclough and Roberts, 2011; Sosnowski *et al.*, 2010) through performance of cognitively demanding tasks that the cardiovascular system responds by increasing the heart rate in the number of beats per minute.

The explanation most accepted for the activity of the cardiovascular system during mental task performance is that of active coping with stress. According to Obrist (1978) cardiovascular reactions to stress are greater when a person actively copes with stress and is not dependent on the stressor itself. Cardiovascular changes during coping with mental tasks reflects complex patterns of autonomic activation (Sosnowski *et al.*, 2010).

Furthermore, Sosnowski *et al.* (2010) went on to note that cardiovascular changes can be treated as an index of motivational arousal represent through the total amount of effort needed to satisfy a motive; however, Fredricks *et al.* (2005) state that heart rate is a useful indicator of the attentional aspects of mental load.

Heart Rate Variability – Time Domain Analysis

Heart rate variability is known as the mean hear rate or inter-beat interval (IBI) as the average time duration of heart beats in that period (Brookhuis and De Waard, 2010). “Heartbeats have variable time durations with different oscillation patterns, leading to time series with source characteristic patterns and frequency contents.” (Brookhuis and de Waard, 2010, p. 900). Both branches of the autonomic nervous system, the sympathetic and parasympathetic processes influence the heart’s inter-beat-interval. The power spectrum density calculation of heart period time series has been shown to provide insight into the respective activation of the sympathetic and parasympathetic branches (Pattyn *et al.*, 2008). Pattyn *et al.* (2008) went further to state that recordings of heart activity and the results from the derived computation of respective parasympathetic and sympathetic nervous system activation have been applied to infer workload variations with given tasks.

Much attention has been given in the past decade to the measure of heart rate variability as a measure for cardiovascular reactivity. Through the work of Porges and Raskin (1969) it was found that with increased attention there was a direct fluctuation in the interbeat-interval between normal heartbeats, producing a significantly reduced heart rate variability during sustained attention tasks. Heart rate variability has been demonstrated to show systematic and reliable relationships with task demands (Galy *et al.*, 2012). And has also been related to more recent studies on memory performance, mental workload and attention (Hansen *et al.*, 2003). Backs and Seljos (1994) found through the use of a continuous memory task, that by increasing memory load, good performers had a smaller heart rate period variability decrease and poor performers had a large heart period variability decrease. Therefore, heart rate variability increases as a function of time-on-task, and decreases as task complexity increases (de Grey Birch, 2012). Time domain analysis may however be insensitive to variance influencing heart rate variability and therefore further investigation into the spectral analysis techniques should be undertaken.

Typically two types of time domain variables are assessed, explicitly a measure calculated from the intervals between normal heart beats (N-N) and from differences between intervals of successive normal heart beats (Huysamen, 2011). SDNN is the variable measure through the calculation of the intervals between normal heart beats measured. This measure is defined as the standard deviation of all the N-N intervals and reflects total heart rate variability for a period of interest (Huysamen, 2011). Analysis of the differences between intervals of successive normal heart beats results in two measurements used for assessment of short term heart rate variability and are considered reflective of parasympathetic control of the heart, namely pNN50 and rMSSD (Huysamen, 2011). rMSSD calculates the average change in intervals between any two normal heart beats or the square root of the mean of the squared differences between successive N-N intervals in milliseconds (Huysamen, 2011). Additionally the pNN50 calculates the percentage difference between successive N-N intervals that are greater than 50ms (Huysamen, 2011).

Heart Rate Variability - Spectral Analysis

Frequency analysis or spectral analysis has been shown to denote heart rate variability into three frequency domains, specifically very low frequency (0-0.04 Hz), low frequency (0.04-0.15 Hz) and high frequency (0.15-0.4 Hz) (Redondo *et al.*, 1992). The high frequency band (0.15-0.4Hz) or the respiratory sinus arrhythmia band is known to reflect both parasympathetic activity and respiration (Redondo *et al.*, 1992; Berntson *et al.*, 1997). This high frequency band functioning as an indicator of parasympathetic or vagal tone has been found to decrease when task demands are high (Fairclough *et al.*, 2005). The low frequency band measured at frequencies between 0.04-0.15Hz is commonly understood to reflect complex processes of blood pressure regulation, mediated by baroreflex from the interplay between sympathetic and parasympathetic influence (Berntson *et al.*, 1997). The low frequency band is most commonly suggested to be an indicator of parasympathetic and sympathetic activity, though this is contentious, and it has been suggested as an indicator of sympathetic activity.

A decrease in the low frequency band component is often found in conditions of increased cognitive demand (Berntson *et al.*, 1997). For each frequency band there are two parameters calculated: power and center frequency. Power frequency is defined as the total power within the respective frequency band (ms^2) while center frequency is the frequency splitting the power spectrum of the respective frequency band into two portions of equal power (Hz) (Huysamen, 2011). The power calculation provides for inference to oscillatory effects if frequency does change (Huysamen, 2011).

While authors suggest that a low frequency band should be used to indicate increases in mental demand, the low frequency/high frequency ratio may reflect mental workload activity and reflect sympathetic modulations (de Grey Birch, 2012). A decrease in this LF-HF ratio can either indicate an increase in parasympathetic activity or an increase in sympathetic activity as this ratio is commonly used to indicate the balance between the two (Berntson *et al.*, 1997).

CHAPTER III

3. METHODOLOGY

This study intends to look into varying aspects that could contribute to or alleviate aversion experienced while performing a cognitive task. The following chapter goes extensively through the formation of the concept to assess these aspects of cognitively demanding tasks. These aspects that reduce or aggravate task aversion will be assessed through the performance of tasks based on cognitive resources; and additional analysis will be performed to ascertain whether this sensation of aversion is a manifestation of inefficiency.

This chapter encapsulates the hypotheses proposed to study task aversion and aversion as a manifestation of inefficiency, and by what means the tasks were chosen in order to assess this. It highlights the tasks as well as the objective and subjective variables chosen in order to attain a quantitative evaluation of efficiency.

Additionally the methodologies of the investigations undertaken will be discussed, specifically highlighting the experimental design, the variables of interest, the collection of data and analysis decided upon, and differences between the investigations in the form of experimental set-up. Variations within the investigations will be divided into subheadings for easier understanding.

3.1. CONCEPT FORMATION

3.1.1. Factors Influencing Aversion

As can be seen from the literature, little is known about the causes of aversion. Task aversion as a phenomenon is poorly understood and it has only been speculated as to what its purpose is in the performance of cognitive tasks. Initially this study started off as an investigation into design deficits that contribute to or reduce task aversion.

Through pilot testing it was found that although aversion to the task is seen at the early stages of task execution, performance was only slightly inhibited by this unwillingness to continue. Thus, even though people experience a desire to stop performing the task, the performance was still adequate. Aversion is clearly a negative psychological state for the operator and with this state there could, over long periods of time, be detrimental effects to performance and productivity of the task. It is therefore important to identify which task factors, such as task structure, task difficulty and more, reduce this strong aversion to cognitive tasks. By highlighting what increases or decreases aversion, tasks can be structured in such a way as to reduce the negative psychological effects of aversion.

It was hypothesized that through providing changes to cognitive tasks in varying forms, aversion would be alleviated to a certain degree and further slow the increasing trend experienced with time on tasks. Many factors such as task monotony, time feedback systems, task complexity and difficulty, dual task performance and feedback of performance were discussed as possible factors that could affect the aversion experienced by the operator when performing cognitive tasks.

Through discussion of the formation of this study it was assumed that there was a progression of aversion with monotony and the possible interaction of this with operator motivation and perceived inefficiency which was proposed to cause aversion. During task situation, if a task provided a monotonous state, participants would be unmotivated and unwilling to continue attributed to no immediate benefit to the performance of the task with additional effort to maintain performance affecting inefficiency. This inefficiency would cause a high task aversion (Figure 1). The factors elected therefore provided the criteria to assess this progression of aversion. Four different aspects of cognitive tasks were chosen; the cycling of information, task difficulty, performance feedback and the alternation between two cognitively demanding tasks. The reason for selecting these four aspects will be discussed further.

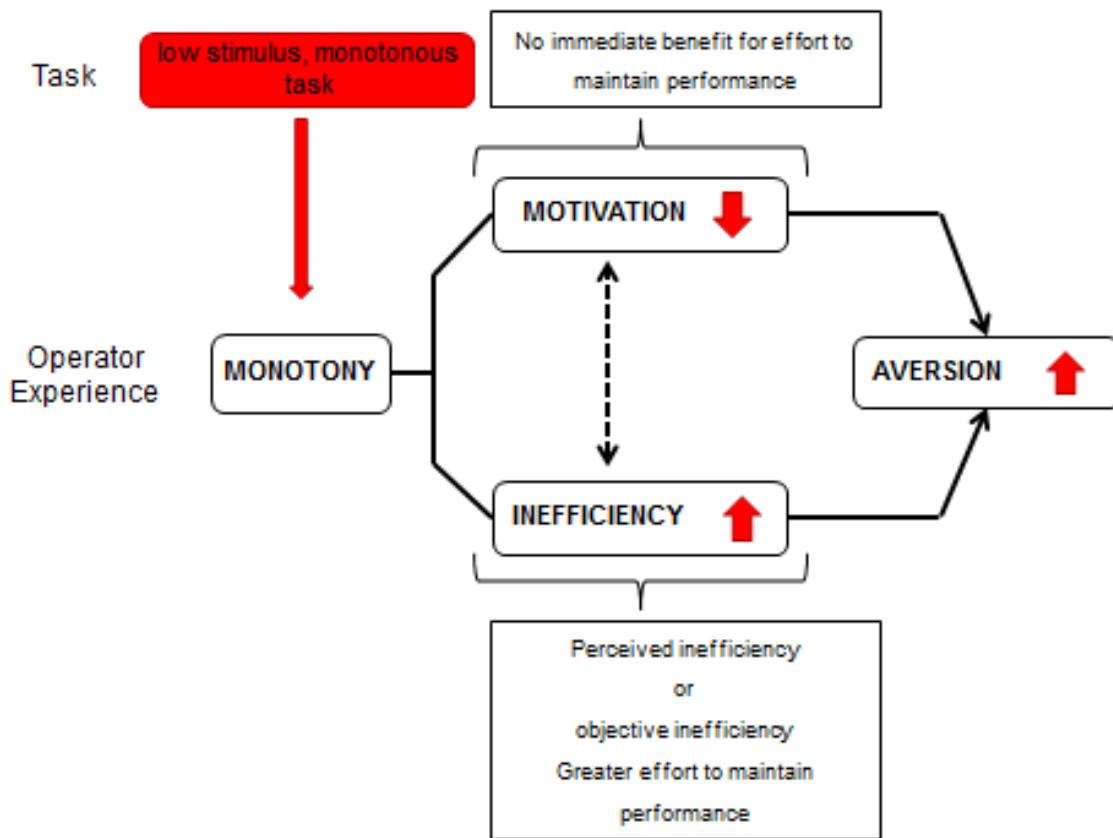


Figure 1: Assumed progression of task aversion.

It was hypothesized that aversion progressed, from a perceived monotonous state of the operator which is attributed to a decreased motivation and an increased inefficiency. Additionally, it was assumed that the decreased motivation may additionally interact with the perceived inefficiency. It was anticipated that by changing an aspect of the progression of aversion that this would ultimately result in decreased task aversion. It was proposed to assess aspects of tasks that corresponded to changes in monotony and aspects that provided changes to motivation, thus the purpose for electing the four specific factors that affect task aversion. Therefore, the task and task alternation investigations would change the monotonous aspect of the process. Task cycles attempted to change the monotonous aspect within a task, while task alternations attempted to change monotony by task structure, thus imposing alternations between two tasks. The elective of task cycles and task alternations provided two varying

degrees of changes to monotonous environments by the within task design of the task cycles investigation, and the between task design of task alternation. Each of these factors was additionally chosen due to the ease of producing a change in monotony (Figure 2).

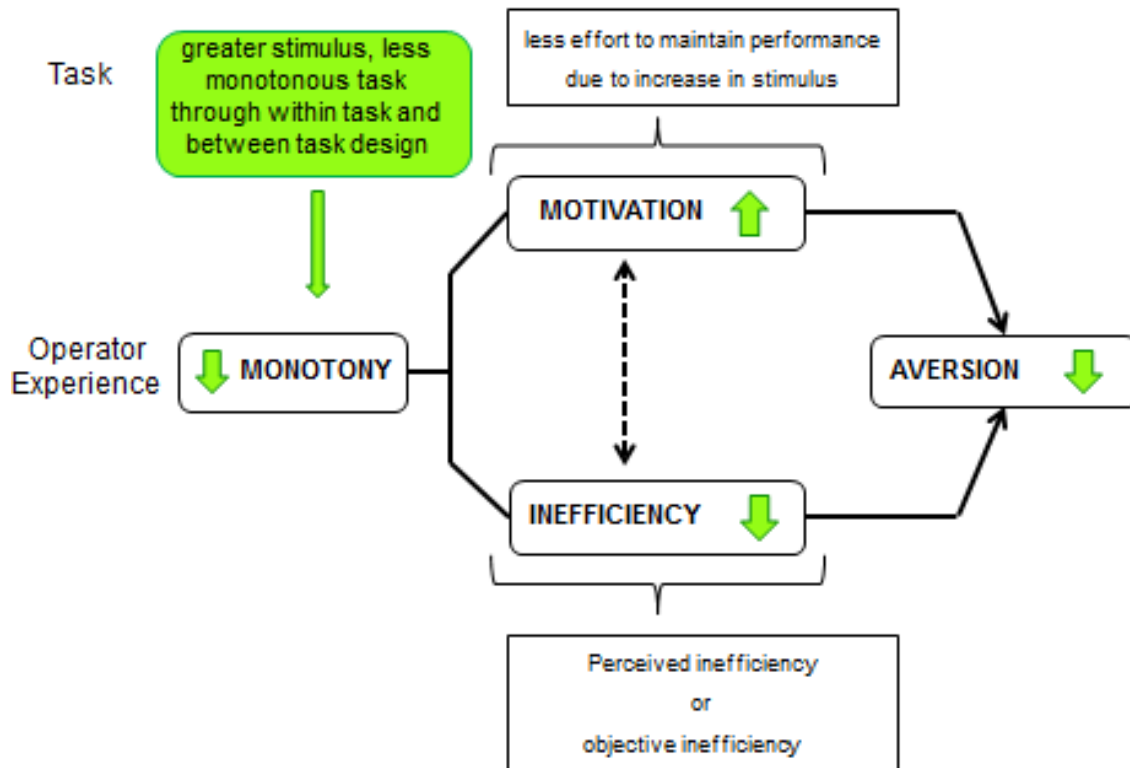


Figure 2: Progression of aversion with changes to monotony.

Similarly, task difficulty and performance feedback were proposed to change the motivation aspect of the progression of task aversion. By changing the difficulty and through provision of a performance feedback modulator, this would change the motivation experienced through task performance, with the hope that it would improve motivation improve inefficiency and cause a result in a decreased aversion to the performance of the task (Figure 3). The choice of change in difficulty and providing

participants with a performance feedback modulator provided an easy means for this change in motivation towards the task.

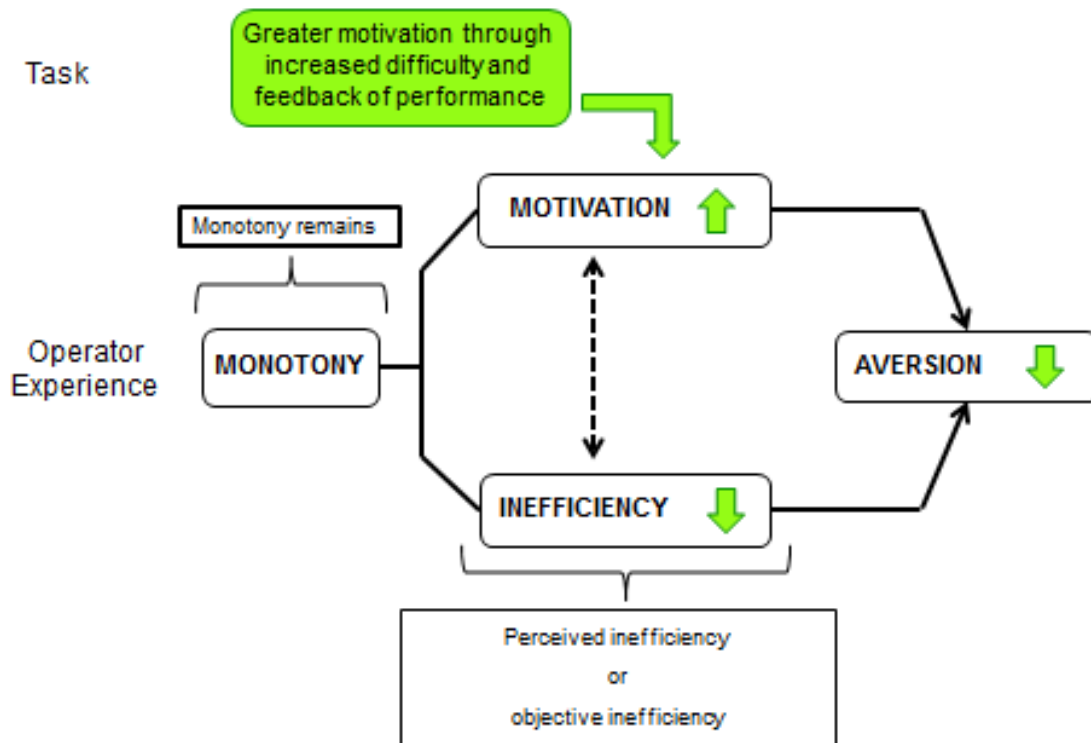


Figure 3: Progression of aversion with changes to motivation.

For the purpose of this investigation the following aspects were excluded: time feedback mechanism, task complexity and dual task performance. Time feedback mechanism was excluded from the analysis due to the fact that knowledge of time would have a predictable outcome for aversion experienced. It is understood and anticipated that workers would have improved performance and greater positive subjective sensations towards tasks upon nearing the end of a task shift. Task complexity was excluded due to the irregular and unpredictable nature of complex tasks. With this, it would be problematic to anticipate a trend for aversion over time. Additionally task complexity may have resulted in an early onset of fatigue, and for the purpose of this investigation there was an attempt to eliminate the incidence of fatigue in order to ascertain whether

aversion can be present without the fatiguing mechanism having taken place. Dual task analysis in the context of aversion analysis was excluded according to the overload theory. It was anticipated that through the addition of a secondary task, this could have resulted in an overload situation for the participants and thus aversion to the task as a whole would have been low. Additionally due to the time constraints of testing, these criteria had to be excluded; however, all of the listed excluded criteria still provide valid factors of cognitive tasks to consider in future analysis of task aversion.

This therefore forms the project, consisting of four parts, namely the four different aspects of cognitive tasks chosen to assess: 1: task cycles; 2: task difficulty; 3: performance feedback; and 4: task alternations.

Investigation 1 – Task Cycles

The cycling of information was based on the concept of boredom, such that a task that was constantly providing new and updated information would result in a change from monotony which would directly affect the psychological feelings towards the task. The task looked at the comparison of a constant cycling of information to the user, as opposed to a standard length of information repeated for the duration of the task. This was achieved through the use of one task, with two varying conditions. Therefore, there was a repetitive condition where the information was not changed and was recycled for the entirety of the experiment. The repetitive condition provided a monotonous state such that the stimulus that was presented to the participants remained the same throughout the condition. Additionally there was a non-repetitive condition, where the information was constantly changing for the duration of the test, such that there was a consistent change of stimulus to the operator. Task cycles aimed to test the monotony effect within a task by the changes imposed by the varying stimuli (repetitive or non-repetitive). It was theorized that the conditions that had new information being cycled to the operator would elicit a lower rate of aversion.

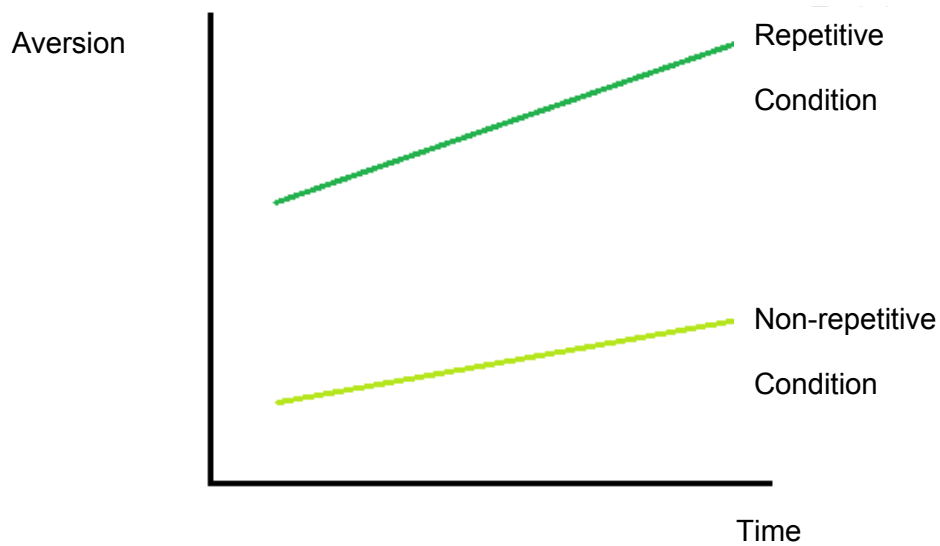


Figure 4: Trend of expectation for task cycles investigation highlighting the two conditions and the anticipated effect these have on aversion.

From the above figure the difference anticipated for the task cycle investigation are made apparent. It was anticipated that the repetitive (no change in stimuli to participant) condition would result in an exacerbated aversion rating that would show a steep increasing trend over the task time. The opposing non-repetitive condition (continuously changing stimulus) was expected to result in a lower starting aversion measure with a slower rate of increase over the task time.

Investigation 2 – Task Difficulty

For task difficulty, the investigation was based on the difficulty law of motivation proposed by Ach (1910) in Venables and Fairclough (2009). The difficulty law of motivation provides an explanation of performance similar to the inverted U theory of arousal proposed by Yerkes and Dodson (1908) in de Grey Birch (2012). When in an “underload” situation, such that a task is too easy, it was anticipated that individuals would not want to try hard or invest more resources into performance therefore producing a high degree of aversion. Similarly a task that was too difficult, producing an “overload” effect, would correspondingly result in a decreased motivation to try and

similarly, a high level of aversion. Therefore it was important to assess what the aversion effects would be with regards to difficulty. It was anticipated that a difficult condition would result in a lower aversion experienced due to the increased arousal associated with a more difficult task. Task difficulty comprised of an easy condition (1) and a difficult condition (2).

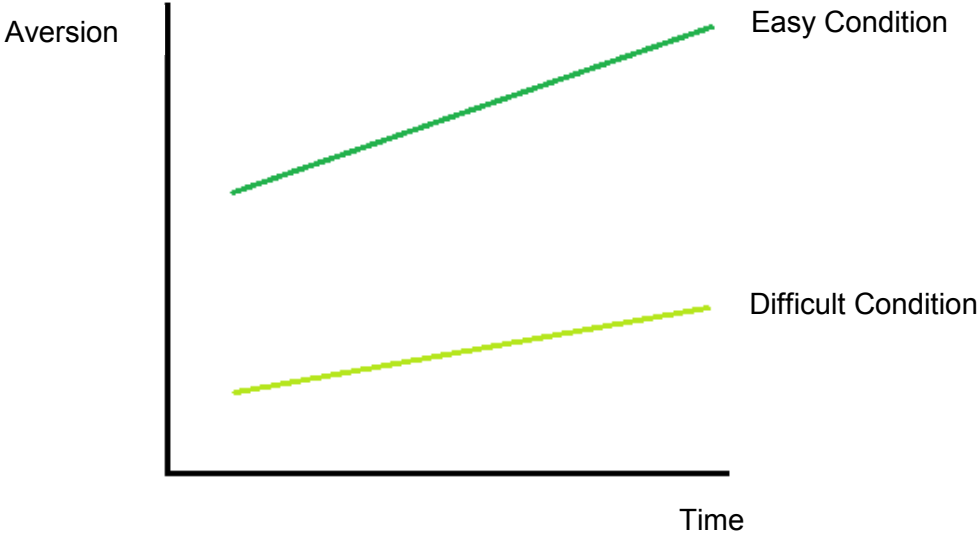


Figure 5: Trend of expectation for the task difficulty investigation highlighting the two conditions and the anticipated effect these have on aversion.

Figure 5 provides a visual display of the anticipated effects of difficulty to task aversion. From the figure it can be seen that the easier condition would result in a heightened starting aversion measure with a greater increasing trend over the task time. In comparison, the difficult condition would have a decreased starting aversion and a more gradual increase in aversion over the duration of the task.

Investigation 3 – Performance Feedback

The investigation of performance feedback was carried out through the observation of subjective feelings of individuals when executing computer and video games. It was found that individuals who played computer games for extended periods of time had

very little resultant aversion towards the game. By comparison, through performance of a driving simulator condition, which in its execution could relate to driving video games; the resultant aversion experienced was greatly exaggerated, providing some questions as to why this occurs. It was theorized that the absence of aversion could be due to a continuous performance feedback throughout the game, providing motivation to continue. Therefore performance feedback of a task became a concept to investigate in the elimination, or at least the reduction in aversion. Fu *et al.* (2011) state that feedback of performance institutes a crucial role in motivation as it provides information to the user on how well they are performing and how individual performance compares to goals set (Fu *et al.*, 2011). It was theorized that this motivation would influence the willingness to continue the task.

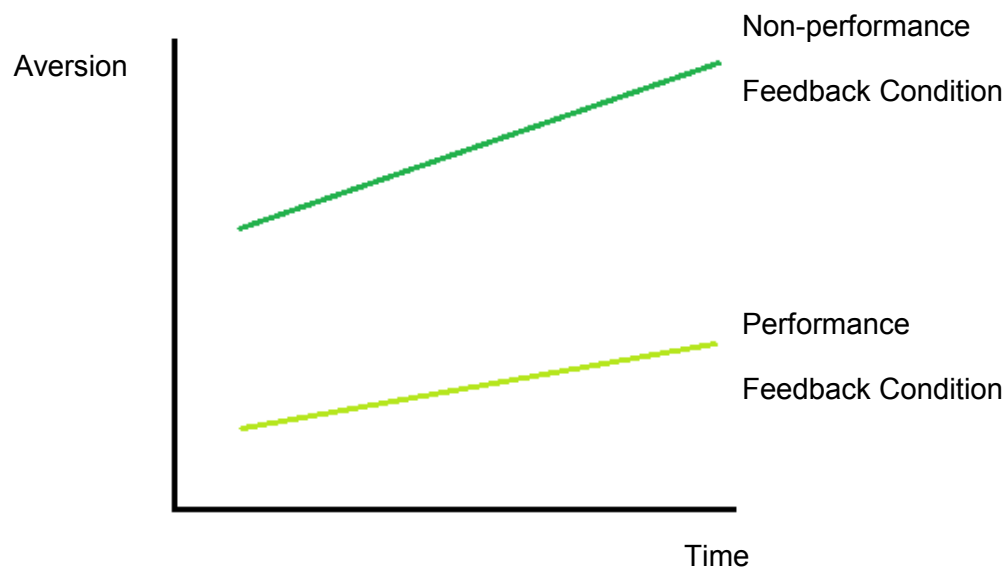


Figure 6: Trend of expectation for the performance feedback investigation highlighting the two conditions and the anticipated effect these have on aversion.

Similar to the previous investigations, this figure represents the expected difference over the duration of task execution for the performance feedback investigation into task aversion. It can be inferred from figure 6 that the condition with the performance feedback modulator would result in a reduced starting aversion rating in comparison to

the condition with no direct feedback of performance. Additionally the condition with no performance feedback would have a steeper incline in the increase of aversion over time with the condition with the modulator of performance having a gradual increase in task aversion over the task time.

Investigation 4 – Task Alternations

Finally, the task alternations investigation intended to look at the concept of a set alternation design between two tasks and the effect on aversion. This investigation, like the task cycles investigation, hoped to further assess the concept of monotony. Unlike the task cycles investigation that provided a change in monotony within the task through the stimulus to the operator, this investigation was proposed to change monotony in the structure of task execution; therefore a change in monotony by the alternation to a differing task focusing on differing cognitive resources to the preceding task. Therefore, the task cycles investigated the alleviation of monotony through change of stimuli within the task and task alternation investigated the alleviation of monotony through changes between two tasks thus the structuring of a task. The structure of the task was changed through the employment of alternations and by the frequency of task alternation.

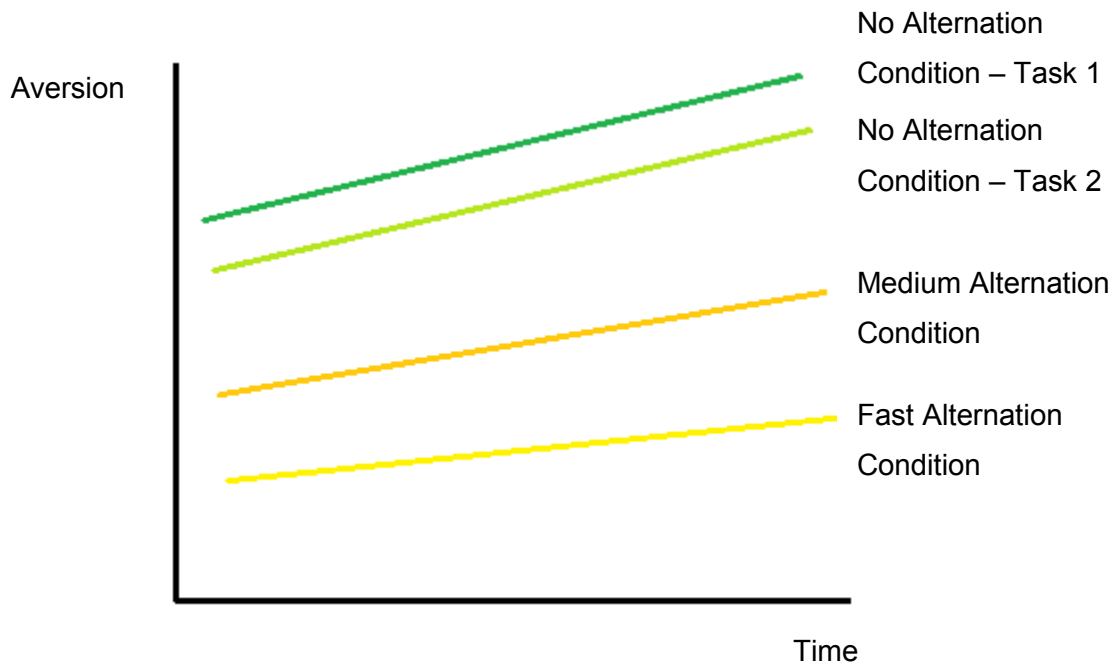


Figure 7: Trend of expectation for the task alternation investigation highlighting the four alternation condition, and the anticipated effect these have on aversion.

The anticipated difference for task alternation can be seen in figure 7. According to the figure it was anticipated that the two conditions without alternations (slow choice reaction task condition and slow driving simulator task condition) would result in a greater aversion experienced in comparison to the conditions (medium and fast) with alternations between the two tasks. Additionally, it was anticipated that the conditions without alternations would result in a greater increasing trend of aversion over time compared to the alternation conditions, which would have a more gradual increase in aversion over time. Furthermore, it was anticipated that frequency of alternations would have a resultant effect on aversion, such that the medium condition would have a higher aversion and a greater increasing trend over time in comparison to the lower aversion measure of the fast alternation condition with a slower increasing rate over task time.

These four investigations therefore encompassed the first hypothesis of this study, such that task aversion would be affected and reduced by the change employed by these four factors; namely task cycles, task alternation, task difficulty and performance feedback.

3.1.2. Cause of Aversion

Having elected to investigate the factors that add to or diminish aversion, it was further proposed to look into a possible cause of aversion. The cause of aversion is unknown, though a few theories have been speculated on. The most common theory for task aversion is that aversion is central to mental fatigue (Hockey, 1997). However, according to the concept of mental fatigue, though there is a presence of this subjective sensation to discontinue the task at hand, fatigue is generally accompanied by a decrease in performance or an increase in effort (Hulst *et al.*, 2001; Meijman 1997; Boksem *et al.*, 2006). According to the pilot studies undertaken on aversion, no effect on performance was seen, therefore, though aversion to continue was high, performance remained constant, and even increased in some instances. This provided some speculation as to whether aversion could be due to mental fatigue.

The theory of the manifestation of aversion proposed for this study was that of cognitive efficiency. Cognitive efficiency is defined according to Hoffman (2012) as the qualitative increase in knowledge or skills in relation to the time and effort invested to acquire them. Therefore it is the increases in the rate and amount of knowledge/skill or conceptual clarity, versus the cost such as cognitive effort needed to attain this knowledge or skill (Hoffman, 2012). It was speculated that aversion occurred due to a decrease in efficiency over the task time. A feeling of inefficiency or actual inefficiency would lead to a decreased motivation to invest effort and time into a task, which was theorized to lead to an increased aversion to continue the task at hand. If the task was perceived as not worthwhile such that it was unlikely to achieve a tangible motive, effort would be withdrawn (Venables and Fairclough, 2009). This made up the second hypothesis for the investigation – aversion would increase over task time followed by a

statistically significant decrease in efficiency (subjective and objective). As established in the literature, the likelihood method was chosen to work out efficiency for this investigation and is calculated by the formula:

$$Efficiency = \frac{Performance}{Resources}$$
$$\therefore E = \frac{P}{R}$$

Each of the four investigations undertaken (task cycles, task difficulty, performance feedback and task alternations) further had efficiency assessed throughout the task time. Therefore, additional to the investigation of whether changes imposed a variation in aversion, each condition was further assessed to see if there was an objective and subjective change in efficiency over task time. Furthermore it was anticipated that the changes imposed by the varying conditions of the tasks, may produce a slowing of the rate of increase for aversion and a slowing of the decreasing rate of efficiency (subjective and objective) over the time on task. However the prominent supporting factor of the cause of aversion hypothesis was that a subjective decrease in efficiency would be accompanied by an objective decrease in efficiency over time.

For the investigation into efficiency, variables of interest were divided into two parts, namely into subjective and objective measures. Objective measures were used to calculate the efficiency of the performance of the task whilst subjective efficiency was representative of the perceived efficiency to the task. Each variable will be discussed in detail further in the chapter. A subjective efficiency scale was utilized to assess the perceived efficiency of participants, while objective efficiency was calculated using the likelihood formula, such that performance was assessed over the resources employed to continue performance, in the form of physiological measures of mental effort.

Trend of Expectation for Cause of Aversion Hypothesis

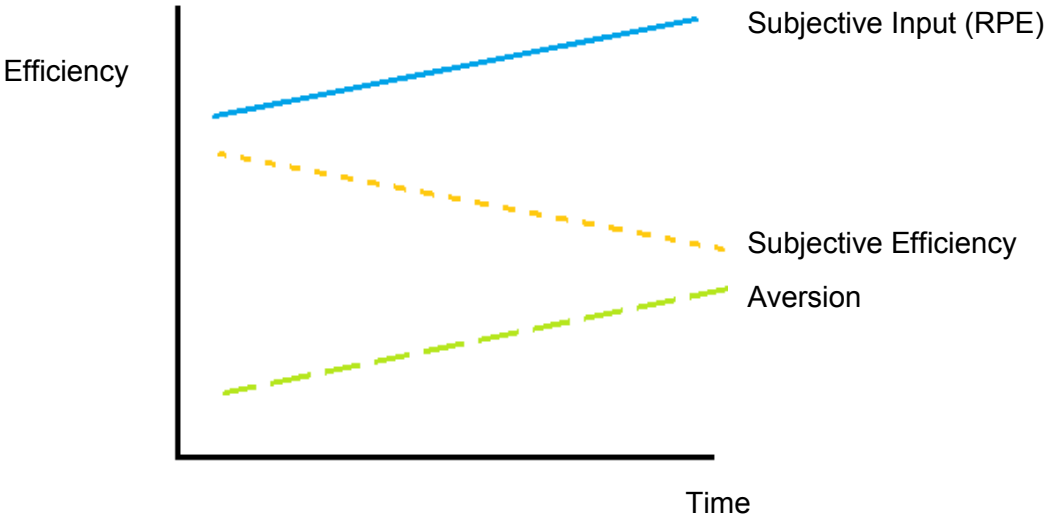


Figure 8: Trend of expectation for subjective efficiency.

The trend for subjective efficiency over time can be seen in figure 8. Each variable in the figure below is different and based on a different scaling system; the y-axis was labeled as efficiency to rather emphasize the difference over time than an actual quantitative change. The figure shows that with increasing aversion of task over time, there is a subsequent decrease in subjective efficiency perceived over time. Additionally it was anticipated that with the aversion increasing over task time, there would be an increase in subjective input (subjective effort) over the task time.

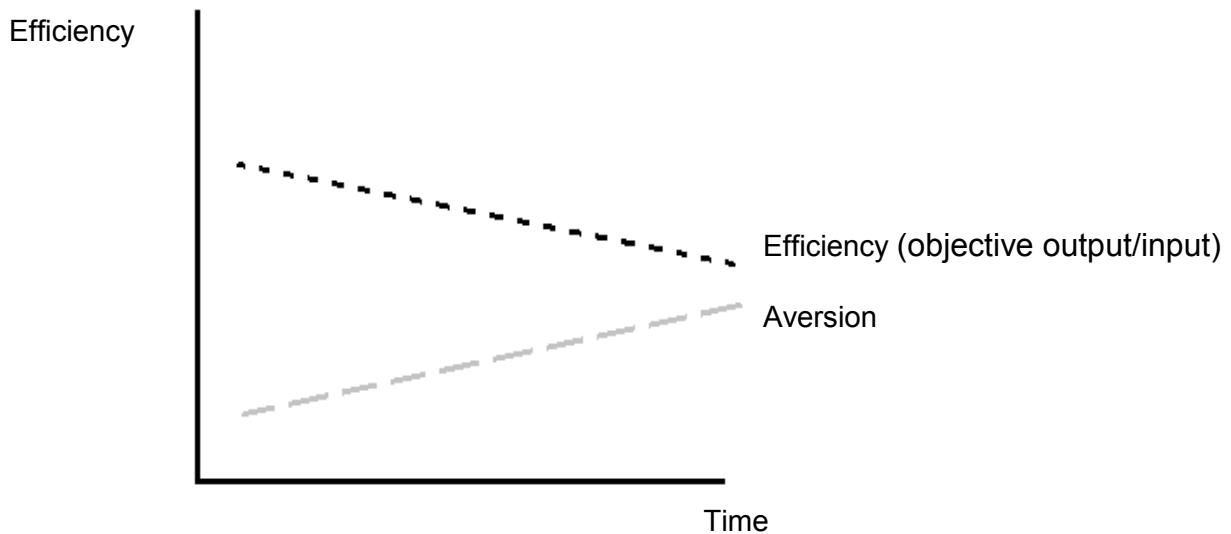


Figure 9: Trend of expectation for objective data.

Similar to the subjective trend of expectation for the efficiency hypothesis, the objective efficiency would follow the same trends. Again the figure above the y-axis is denoted as efficiency as it was the aim to show trends, not quantitative measures. With the increasing aversion over time found for tasks there would be a decreasing objective efficiency experienced over time.

3.2. EXPERIMENTAL DESIGN

The preliminary purpose of this study was to analyze factors that are specific to cognitive tasks, which contribute to the sensation of aversion experienced by the user while performing these tasks. These factors were broken down into factors specific to the task such as task structure by alternations between two tasks (no alternations versus alternations), and within task design by the cycling of stimulus to the operator (repetitive cycling and non-repetitive cycling), difficulty (easy versus difficult) and the provision of performance feedback (no feedback of performance versus a continuous

performance feedback). All investigations followed a repeated measures design with conditions being permuted.

The subsequent purpose of this study was to explore a possible mechanism behind aversion experienced by a user when performing cognitive tasks. Thus it was decided to look at a possible cause of aversion in the form of efficiency monitoring.

3.2.1. Investigation 1: Task Cycles

The purpose of this investigation was to understand whether a constant cycling of information and therefore a changing stimulus to the user, changed the level of aversion to a task in comparison to a task where there was no new information cycled and thus a stagnant stimulus throughout. It was essential that the task employed provided easy manipulation of the information cycled to the user and further minimized interferences imposed by recordings of subjective measure. Additionally, it was crucial that the task further fulfilled the criteria for assessment of subjective efficiency as it could provide the operator with an innate sense of performance through execution of the task. This was all achieved through the election of a proof reading task where participants had to identify and mark double letter errors. Thus the stimulus was cycled through the reading content within the task and upon measurement of the subjective ratings, participants could return to the text without there being a deleterious effect to performance. Additionally, the innate sense of performance was achieved through the number of paragraphs or pages read in an allocated amount of time.

Two conditions were thus designed; condition 1 was a repeated cycling of text (repetitive condition) and condition 2 where new information and therefore stimulus to the operator was constantly changing (non-repetitive condition). The repetitive condition was achieved by use of a single paragraph of text that was repeated throughout the task time. The non-repetitive condition was defined by new reading material being presented to the operator throughout the duration of the task. This structure of varying reading text for the non-repetitive condition provided new information and varying stimulus throughout task execution.

Task cycles were further investigated to see whether there would be performance, physiological or subjective differences to the concept of recycling information as opposed to the constant cycling of new information. The conditions were performed on separate occasions with three or more days of recovery in between testing. The conditions were further tested for the duration of 30 minutes. This was established in order to reduce the incidence of fatigue occurring, as fatigue occurs over time on task (Boksem *et al.*, 2005), with Hulst (2001) stating that fatigue symptoms can occur after the first 30 minutes of task execution. The purpose to reduce the incidence of fatigue was to allow for insight into whether aversion can occur without the presence of fatigue, as aversion has been previously attributed to the mechanism of fatigue.

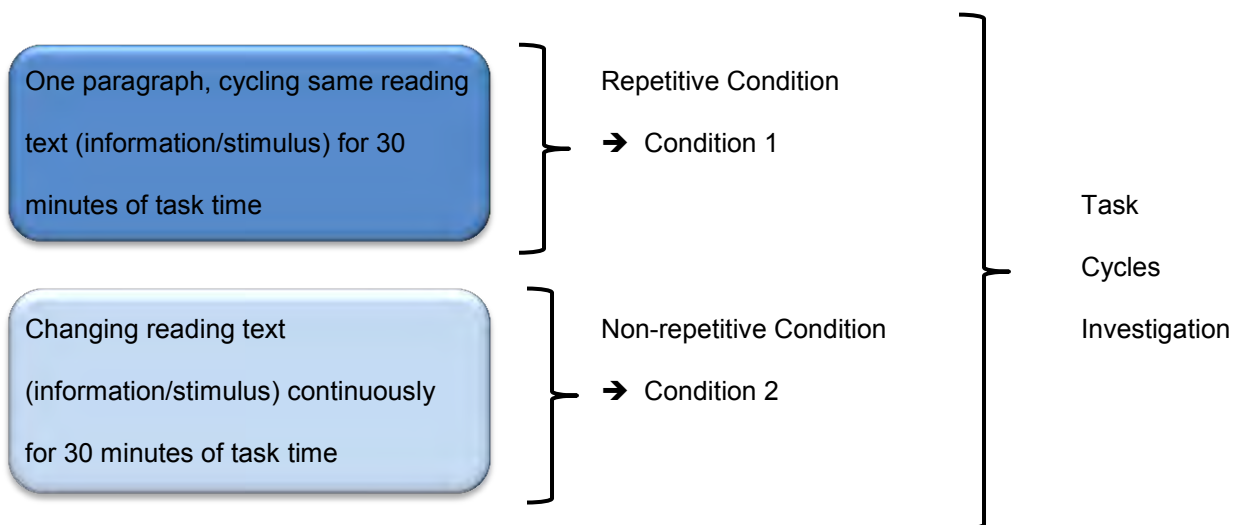


Figure 10: Experimental design of task cycles investigation.

3.2.2. Investigation 2: Task Difficulty

Task difficulty was assessed in order to ascertain whether a change in the difficulty of a task resulted in a change of aversion experienced towards the task. It was hypothesized, that an increase in the degree of difficulty would result in less aversion experienced towards the task. This was achieved through performance of a driving simulator task for 30 minutes with two conditions presented on separate testing days and with three or more days separating testing days. In order to critically assess

difficulty a need for a repetitive task situation that accentuated change by varying degrees of difficulty was proposed. Additionally, in order to assess subjective efficiency, similar to the task cycles investigation; the task needed an innate sense of how well the participant was performing. These criteria were fulfilled by a driving simulator task, namely a tracking task by keeping the car within the confines of a lane. Additionally the driving simulator provided for an assessment of subjective efficiency such that participants were able to assess performance due to the innate feedback produced by the visual deviations from the road lane. Condition 1 was an easy condition and condition 2 a difficult condition with difficulty varying in the lane width of the road. Differences between tasks in the form of subjective and objective measures were additionally analyzed in order to prove that a difference in difficulty did exist.

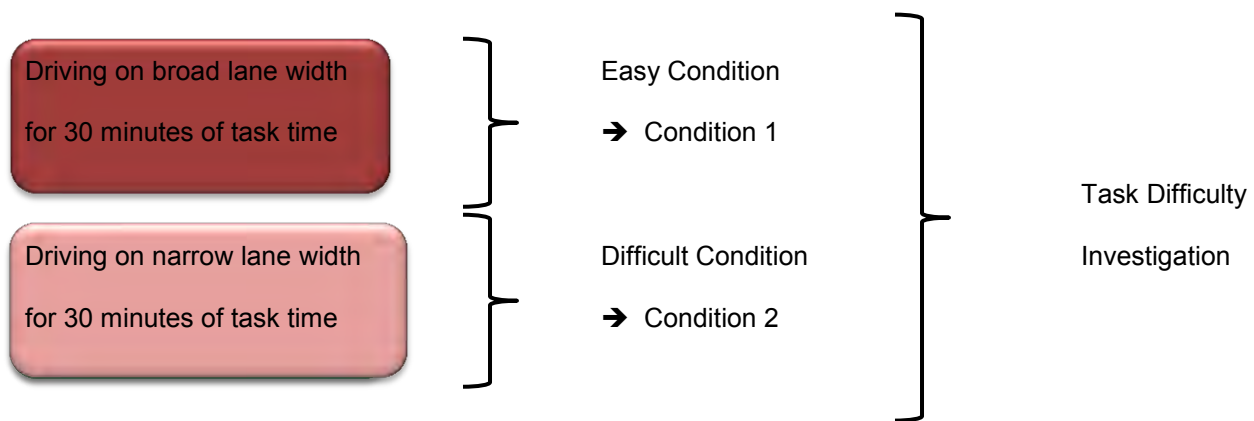


Figure 11: Experimental design of task difficulty investigation.

3.2.3. Investigation 3: Performance Feedback

The aim of the experiment was to ascertain whether the knowledge of performance provided to the participants constantly throughout testing, thereby producing a change in task, would result in a lower level of aversion experienced. To create a condition where performance feedback could be easily instituted and the effects there of highlighted a repetitive task situation was required. Additionally, a task with an innate presentation of performance for subjective analysis of efficiency was essential. This was achieved through analysis of a driving simulator tracking task, similar to task difficulty,

where participants were required to remain in the confines of a lane on a simulated road. Two conditions were employed: a condition with no performance feedback (condition 1 – no performance feedback, which was tested through the easy condition in the task difficulty investigation) and a condition where performance was constantly updated to the participant (condition 2 – performance feedback). Conditions remained identical, except for the indicator of performance. In order to analyze that a difference between conditions existed, performance, physiological and subjective measures were again recorded as for the task difficulty experiment. Conditions were again performed for 30 minutes with dependent variables measured throughout. Conditions were performed on separate days with three or more days separating a condition.

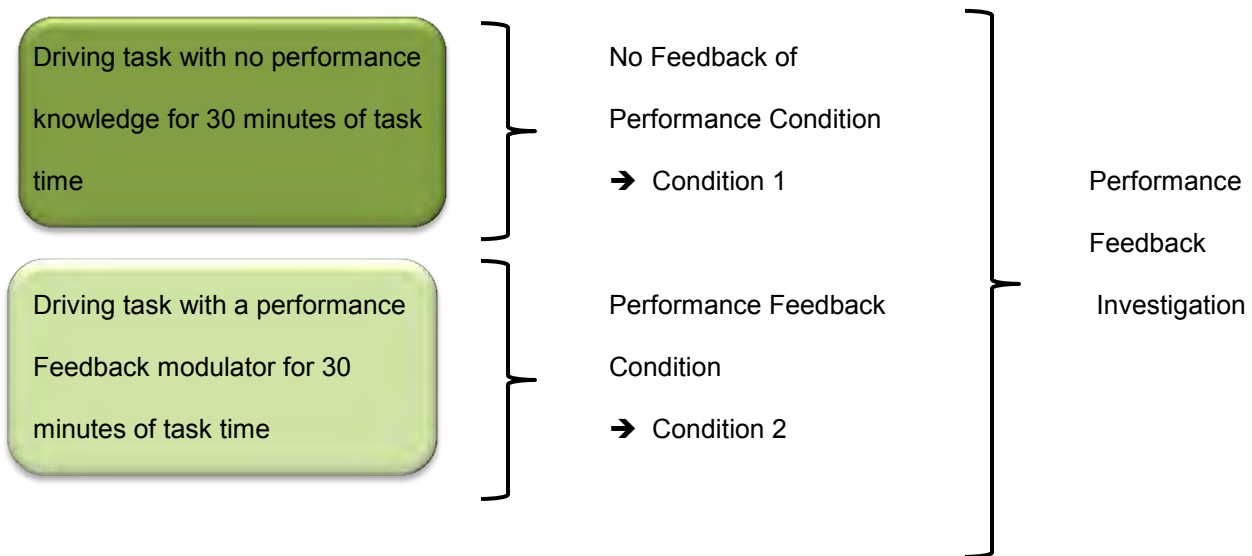


Figure 12: Experimental design of performance feedback investigation.

3.2.4. Investigation 4: Task Alternation

The purpose of this experiment was to further identify design deficits of specific tasks and the way tasks are structured in the investigation into task aversion. Task alternations is an investigation into the structuring of tasks mainly performance of two tasks for long durations with no changes between tasks, as opposed to quick and

frequent alternations of the tasks identifying any effects on aversion experienced. All sessions with and without the alternations were tested for 30 minutes of task time as previously explained in the purpose of investigation 1.

To critically assess the effect that task alternations have on aversion, it was essential that the two tasks chosen utilized similar information processing resources. Similarly to all the investigations prior to this, the task required an innate sense of performance to be instated in the task, such that participants could assess how well they were performing so as to judge efficiency. Thus in order to fulfill these criteria for the task alternation investigation, a driving simulator tracking task and a choice reaction task were chosen. The driving simulator tracking task required the participants to steer the cursor (car) along the center line of a road providing an innate sense of performance to the operator in the form of visual deviation. The choice reaction task comprised of rules, critical response stimuli to identify, being verbally provided to participants. Upon identification of the rules/critical stimuli, participants were required to produce a critical response such that a critical response button was to be pushed. Other stimuli that did not fit the criteria of the rules provided required a non-critical response button to be pushed. The visual display of the stimulus allowed operators to approximate how long it took to respond to the stimulus presented. Furthermore, by having critical and non-critical responses and by having the participants commit the critical stimuli to memory prior to the testing, participants were reasonably aware whether a correct or incorrect response was given.

The driving simulator task and the choice reaction task were based on the utilization of information processing resources. Performance of both tasks utilize the same cognitive processes such that the tasks comprise a motor program component, a reaction component, continuous attentional demand, memory element and decision making to maintain performance. Although the two varying tasks operate the same cognitive processes, there are slight variations between the tasks, such that each task focusses on certain aspects of cognitive processes in comparison to the latter task. The driving task has a greater motor programming aspect and attentional demand in comparison to

the choice reaction task. Similarly, the choice reaction task requires greater reaction responses, memory and decision making. By utilizing these two tasks, the general processes would be the same, but inference could be made on whether aversion is dependent on the greater central processing (memory and decision making) associated with the choice reaction task or with the larger attentional demand attributed to the driving simulator task.

The alternations chosen were slow, medium and fast. With these three chosen alternations, there were four testing sessions. The first two sessions were slow alternations for each the choice reaction task and the driving simulator tested. The slow sessions comprised of each task being performed for 30 minutes with no alternation. The medium session (third session) encompassed alternations between the driving and the choice reaction task, alternating every 10 minutes for the 30 minute task duration. Finally the fast session, similarly to the medium session, had alternations between the choice reaction task and the driving simulator occurring every 3 minutes and 20 seconds for 30 minutes. In addition, all objective and subjective measures were recorded to identify whether there was a subjective, physiological or performance difference between the different alternations.

The following figure shows a visual display of the experimental design for the task alternation investigation.

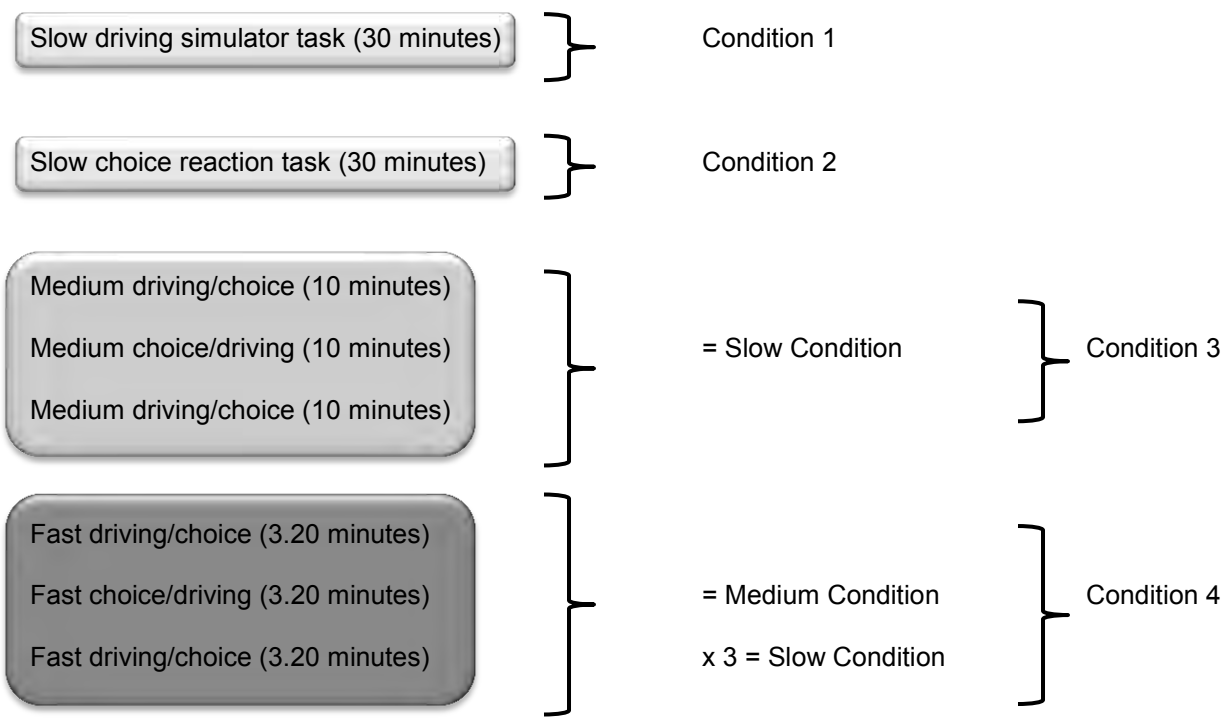


Figure 13: Experimental design of task alternation experiment.

3.2.5. Protocol for the Study

For all investigations the following protocol was used. Prior to the execution of the first session, any risks associated with participation, and any benefits that would be achieved by performing the study were explained to participants. Participants were required to fill out informed consent forms. Participants were made familiar with the subjective rating scales (RPE, Efficiency and Aversion scale). Rate of perceived exertion, though used primarily for physical activity was used as a measure of the rate of perceived mental exertion to the task, providing a sense of subjective input to performance of the task. It was defined verbally to the subjects as a quantifiable measure of mental effort required when performing the task. It was emphasized that this did not relate to how tired or sleepy they felt, but how much mental input was required of them to sustain performance of the task. Efficiency was defined as the ratio of input into the task versus the level of subjective output, thus how well the participant felt they were

performing the task in comparison to the amount of effort invested. This was consistent with Hoffman's (2012) definition of efficiency, as the ratio of work output to work input. Finally aversion was defined according to the works of Hockey (1997) and Holding (1980) as the willingness to continue the task, with participants required to actively provide a quantitative measure of this. Participants were required throughout testing to verbally relay subjective ratings. This occurred at 5 minute intervals which were not made apparent to the participants.

After being briefed about the subjective rating scales, participants were fitted with a heart rate monitor that transmitted to a laptop. The laptop ran the program which was used to assess heart rate and heart rate variability. Participants were also fitted with a mask and head piece for an ergospirometer. This was used to record energy expenditure and breathing frequency throughout the testing protocol. The participants were placed at the work station and were required to sit silently for 5 minutes before execution of the task in order to get baseline measures for heart rate, heart rate variability, breathing frequency energy expenditure as well as 5 minutes post testing to attain recovery measures.

Investigation 1: Task Cycles

Participation in the study required two separate testing sessions in order to test each condition (repetitive and non-repetitive), spaced approximately three or more days apart. This was to ensure that participants did not carry over any residual aversion experienced from the last testing session. Conditions were randomly assigned. Participants were required to come into the Human Kinetics and Ergonomics Department for these separate sessions and were informed on arrival, at the first session, what would be required of them. The tasks were verbally explained to the participants, emphasizing the importance to read actively and not to skim read. Instructions defined that reading had to be done in silent and at a pace the reader was comfortable with in order to follow the text. Errors were also explained to the participants (for details refer to experimental set-up: proof reading task) and participants

were told to call out errors to the experimenter. The task was to be performed for 30 minutes and participants were told that at certain intervals (5 minutes) they would be required to mark the text and to call out subjective ratings. Time intervals were not made apparent to the participant.

Investigation 2: Task Difficulty

Participants were required to come into the testing venue on two separate occasions, as previously stated, with three or more days separating a test. The testing sessions were composed of the two testing conditions and each condition was tested for 30 minutes. Conditions 1 and 2 were tests for the task difficulty experiment, with condition 1 being the easy difficulty and condition 2 the difficult difficulty driving simulator condition. Conditions were randomly permuted and all participants were familiar with the driving task prior to testing. Driving was performed in a lane, and task difficulty was achieved through the change in the width of the driving lane. Upon arrival, the task was verbally relayed to participants and participants were told to stay in the middle of the left lane, and avoid any deviation out of the lane for both task difficulty conditions. Additionally participants were informed that at certain time intervals they would be asked to relay subjective measures.

Investigation 3: Performance Feedback

Similar to the previous investigations, participants were required on two separate occasions to report to the testing venue for the analysis of the performance feedback investigation. Testing sessions were spaced three or more days apart and each session assessed a condition of the performance feedback investigation. Conditions were defined by the provision of performance feedback, such that condition 1 had no feedback of performance and condition 2 where participants were continuously informed of performance. The condition with no feedback of performance was a shared condition with task difficulty, such that the easy condition provided the condition with no performance feedback to this investigation. Each condition was tested for the duration of 30 minutes Task instructions were verbally relayed to participants such that the

participants had to drive in the confines of the left lane and avoid deviation out of the lane and across to the adjacent lane. Similar to previous investigations, participants were informed that subjective data would be recorded at certain time intervals.

Investigation 4: Task Alternations

Participants were required to perform four testing sessions in order to complete the task alternation investigation. Sessions were as follows: slow driving task, slow choice reaction task, medium alternation and fast alternation. Sessions were spaced three or more days apart in order to limit the residual carry-over of aversion from the previous testing session. Sessions were randomly permuted between the participants. Half of the 20 participants started the medium session and fast session with the driving task and the remainder started the medium and fast session with the choice reaction task.

Upon arrival at the first session, subjects were verbally relayed the instructions of the tasks. Participants were instructed to manipulate the steering wheel, such that the arrow remained on the center line of the road while driving. With regards to the choice reaction task, participants were verbally informed that they were required to identify critical and non-critical stimuli, using buttons that had been mounted onto the steering wheel. Participants were made familiar with the different sessions, explaining that they would be alternating between the two tasks at fast, medium alternations; or a perform condition with no alternations with each condition tested for 30 minutes.

3.3. EXPERIMENTAL SET-UP

Participants for all of the investigations were placed in a room, well lit with artificial lighting. There was little to no distracting noises present during the testing times, limiting errors to data collection. Participants were seated at a desk, with an adjustable seat to allow for the comfort of the participant.

3.3.1. Proof Reading Task

The reading text was placed on an inclined podium in front of the participant in order to limit neck and eye strain. Participants were told that they could read the text in which ever manor they preferred allowing for optimal reading speed and to reduce fatigue to the eyes.



Figure 14: Podium with writing text.

For the proof reading task, text was chosen from the Time online magazine website. This was chosen as the appropriate reading material, as subjects were required to remain alert and interested in the task without the incidence of fatigue occurring due to boredom. As subjects were chosen at random, they had to fully understand the text, thus magazine articles had to provide writing that was not too scientific or difficult to read. Articles were chosen out of the health and wellness section at random, thus having an appeal to the readers as it was something that was easy to understand and applies to daily life.

The articles were placed into a word document for alterations to the text. The word document followed the protocol of Chaplin (2010), with a format of Times New Roman font, size eleven, one line spacing and fully justified. Obvious errors were placed in the text in the form of double letter errors for example: book was spelt bookk. This was to analyze performance of the task. Participants were required to identify these errors out loud in order to assess that they were actively reading the task. Any missed double letter was considered an error. Furthermore, participants were required to mark the text every 5 minutes to highlight the number of words read per minute therefore providing the second performance measure. The task for both conditions was 30 minutes.

For the non-repetitive condition, numerous articles were chosen to comprise the text, ensuring that there was a constant cycle of new information to the reader. The articles varied in length, but were never more than two pages long, with each page having approximately 3000 characters. The text was twelve pages long, ensuring enough reading material for the duration of the test. For the repetitive condition, one short article of approximately 805 characters was used. This article was replicated for the entirety of the task therefore enforcing the repetitiveness and thus no cycling of new information to the users. The repetitive article was made up of 19 pages, ensuring that there was enough material to read for the whole test. Though participants were told not to skim read, the 19 pages provided more reading than the twelve page non-repetitive task in the likelihood that this would occur and finish the task before the testing period was completed.

3.3.2. Driving Simulator Task

Hardware Set-up

The workstation had been set up at the same desk as the reading task in task cycles. A (48cm) monitor was placed in front of the participants at a distance of approximately 60cm. The monitor was used to display the driving simulator programme, in essence, the road simulated for driving. A steering wheel was build using an old steering wheel, still attached to the pre-existing shaft.

This steering wheel was mounted to the desk at a 45 degree angle, in order to imitate a real car set-up. This set-up can be seen in figure 15. A computer mouse was attached upside down directly parallel to the steering shaft, with tape spun around the shaft in order to provide a contact point for the mouse to detect movement of the steering wheel. This was put in place in order to eliminate large motor movements and motor fatigue in the arms of the participants, and to reduce any resistance formed by a normal steering wheel that relies on force of movement for steering. Large motor movements and exerted pressure to move the steering wheel could result in exaggerated energy expenditure detected by the breath by breath pulmonary gas exchange of the ergospirometer. Therefore, the mouse provided compensation for this effect.



Figure 15: Physical set-up of task alternation experiment displaying participant driving with ergospirometric equipment.

Software Set-up

All testing done through the driving simulator task was performed on the Driving Simulator 7.6-0.2. The driving simulator consists of a road, with a white line that separates the road into two lanes. Settings for driving were based on pilot studies prior

to execution of the experiment. Road parameters remained the same for the easy, difficult, performance feedback condition, and the driving simulator task for the task alternation investigation, with a curve radius of between 20 – 60 degrees, a set driving speed of 5 km/h and a steering sensitivity of 0.3.

Difficulty Investigation

For the purpose of the task difficulty and performance feedback investigation a square car bonnet appeared in the left hand lane of the simulated road, providing a visual indication of movement of the car within the lane. Figure 16 shows representation of the display to participants. As road width comprised the degree of difficulty, the easy condition had a road width of 1.2 m

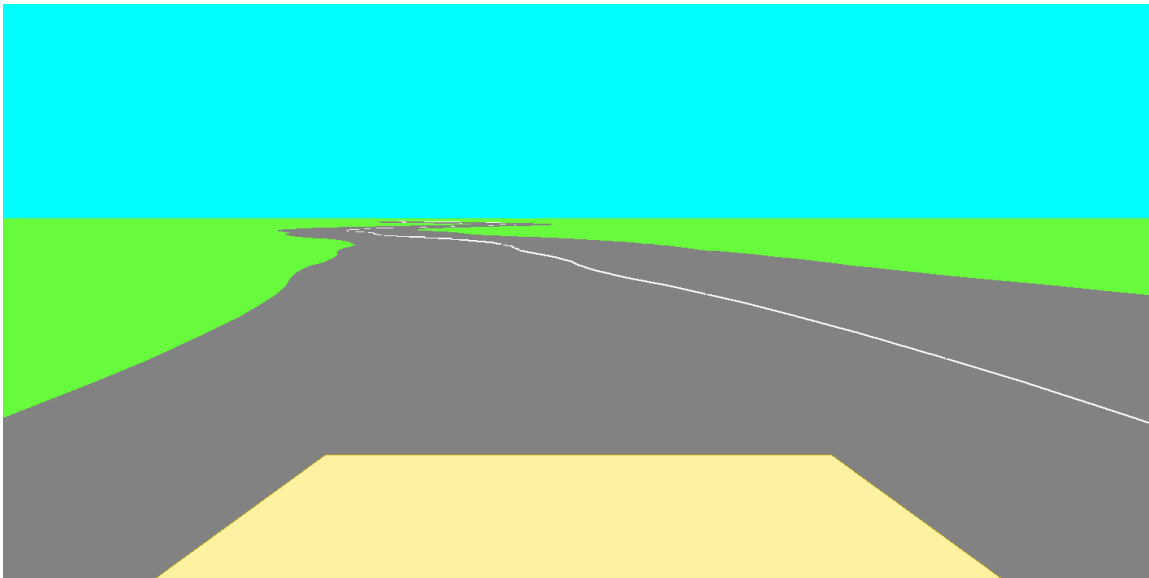


Figure 16: Screen-shot of driving parameters for easy condition of task difficulty experiment.

For the difficult condition, the street width was programmed at 0.6 m to provide a difference between easy and difficult. Figure 17 shows representation of the street width for the difficult condition for the task difficulty experiment.

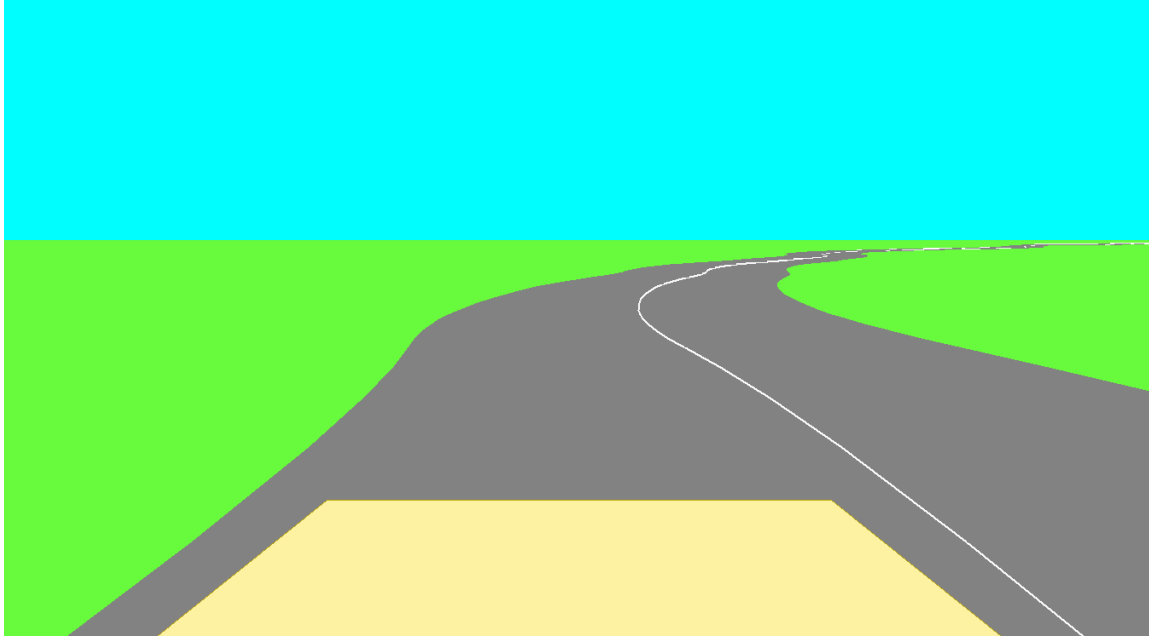


Figure 17: Screen-shot of driving parameters for difficult condition of task difficulty experiment.

Performance Feedback Investigation

For the performance feedback condition, the road parameters remained similar to the easy condition for the task difficulty investigation as this was the shared condition and ultimately provided the condition with no feedback of performance to participants. Thus the road width was set at 1.2 m. This remained constant for the performance feedback condition in order to highlight the effect of feedback of performance on dependent variables measured.

Specific to the performance feedback condition, participants were briefed prior to the execution of the task on how performance would be relayed. Present throughout testing, a purple circle would appear on the bonnet of the car with a red line representing a gauge for performance as deviation. At two minutes into the testing protocol, a reference of driving would be taken for 30 seconds as an average representation of performance. The line would appear after the 30 seconds reference, pointing directly

upright, as if representing 12 o'clock on a watch for average performance (the 30 second reference of driving).



Figure 18: Screen-shot of driving parameters for the performance feedback condition showing performance indicator.

The movement of the line would indicate to the participant whether performance was above or below average performance. Movement of the line right of 12 o'clock would indicate an improvement of performance above average and respectively, a movement left of 12 o'clock would indicate a decrease in performance below the 30 second reference. An improvement in performance would indicate a decrease in mean deviation from the center of the lane, with a decrease in performance indicating a greater mean deviation from the center of the lane.



Figure 19: Screen-shot showing visual display to participants indicating an improvement in performance for the performance feedback investigation.



Figure 20: Screen-shot showing visual display to participants indicating a decrease in performance for the performance feedback investigation.

Reference was taken at two minutes into the driving task as this provided participants with enough time to become accustomed to the driving and also to provide enough time to assess rate of perceived exertion, aversion and subjective efficiency prior to the first recording at 5 minutes of the subjective measures.

Alternation Investigation

The driving simulator task varied for the alternation investigation as opposed to the task difficulty and performance feedback investigation as driving was performed through tracking of the center line with an arrow. Participants were required to keep the arrow on the line throughout the task. This can be seen in figure 21, which was displayed to the participants. Arrow width was set at 0.2 m; with a street line width of 2mm. Street width was set at 1.2 m. Figure 21 shows a display to the participant of the driving simulator.

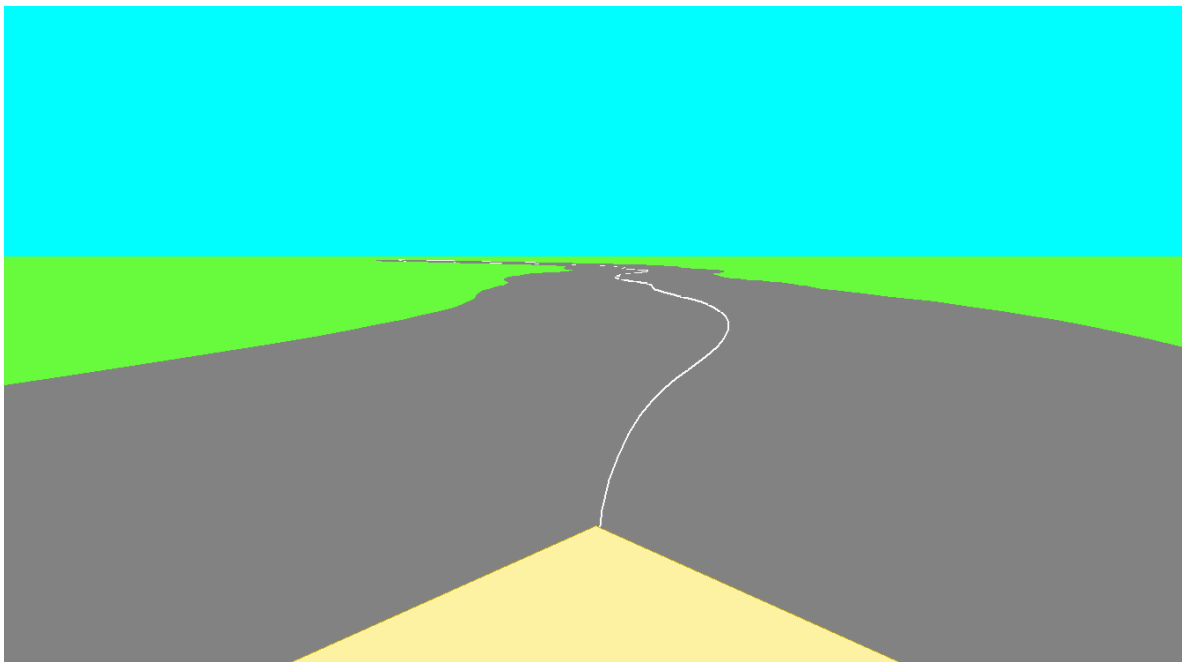


Figure 21: Screen-shot of the driving simulator task for task alternation investigation.

3.3.3. Choice Reaction Task

Stimuli

The choice reaction task was based on a study performed by Sunshine (2010) and followed a similar set-up. For the choice reaction task, participants were verbally given rules in the form of critical stimuli to be identified. The stimuli were in the form of randomly permuted shapes (square, circle) in differing colours (blue, red). Critical stimuli for the task were a blue square and a red circle. These critical stimuli, when identified, required a right button response from the participant while the alternate red square and blue circle stimuli were seen as non-critical stimuli, and a left button response was required of them.

Hardware Set-up

The workstation remained the same as for the task difficulty and performance feedback investigation with the steering wheel directly in front of the participants and a 48cm monitor placed at a distance of approximately 60cm. The monitor was used to display the two tasks – the choice reaction task and the driving simulator program (Figure 15).

For this investigation buttons were mounted onto the steering wheel to provide the critical and non-critical responses for the choice reaction task. These buttons were linked to the mouse directly beneath the shaft and were wired such that a critical response (right button) corresponded with a right mouse button response and vice versa for the non-critical response (left button was non-critical, corresponded to left mouse button). Figure 22 below shows the physical set-up of the steering wheel displaying the critical and non-critical response buttons.

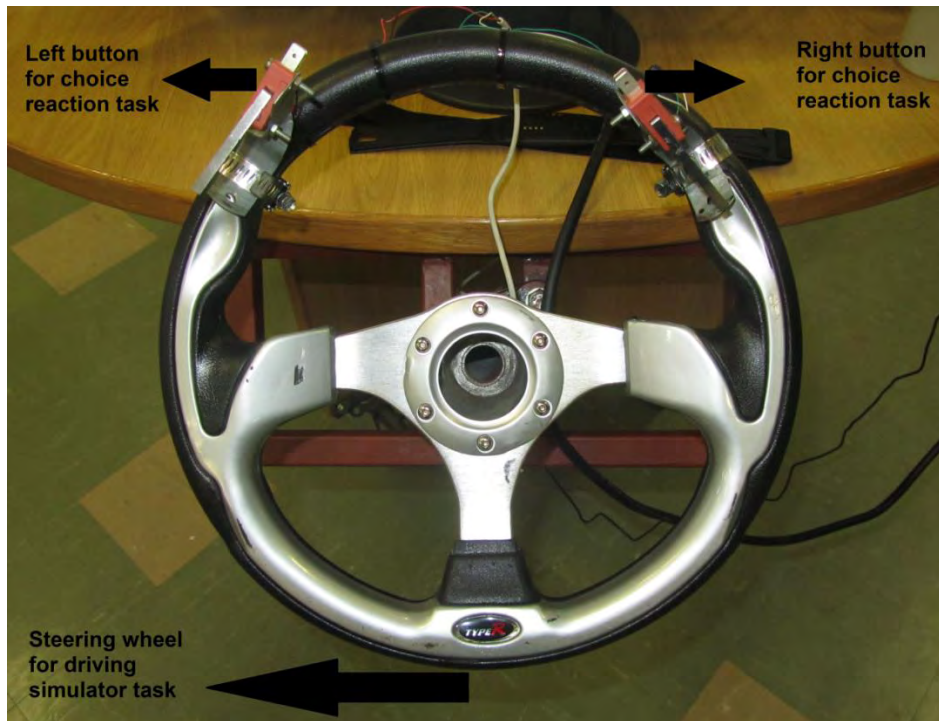


Figure 22: Apparatus for execution of the driving simulator and the choice reaction tasks.

Software Set-up

The choice reaction task is run off a computer programme known as the Stimulus Response Test version 2.4, adapted by. The stimulus response test is based on the Fitts task proposed by Fitts (1954). For the choice reaction task, all four stimuli, critical and non-critical were programmed. The blue square and the red circle were programmed such that they required a right button response. The remaining two stimuli (red square and blue circle) were alternatively programmed to respond to a left button response. If a response to a critical stimuli (a right button response) was incorrect such that the participant responded with a left button response, this was considered an error.

The size of the stimuli were set at 25mm with the stimulus appearing in a location of 100 mm left, right, above and below the center of the screen. This was chosen so that the stimuli appeared in full range of the screen and the participant's visual field, as the screen size was set at 360 mm (horizontal). The stimuli appeared between 200 and 400

(ms) after the previous response had been given, allowing for randomization and unpredictability of stimuli appearance. This provided a greater attention demand and vigilance for the testing protocol. Stimuli remained visible on the screen until the participant provided a response, with an object refresh rate set at 20Hz.

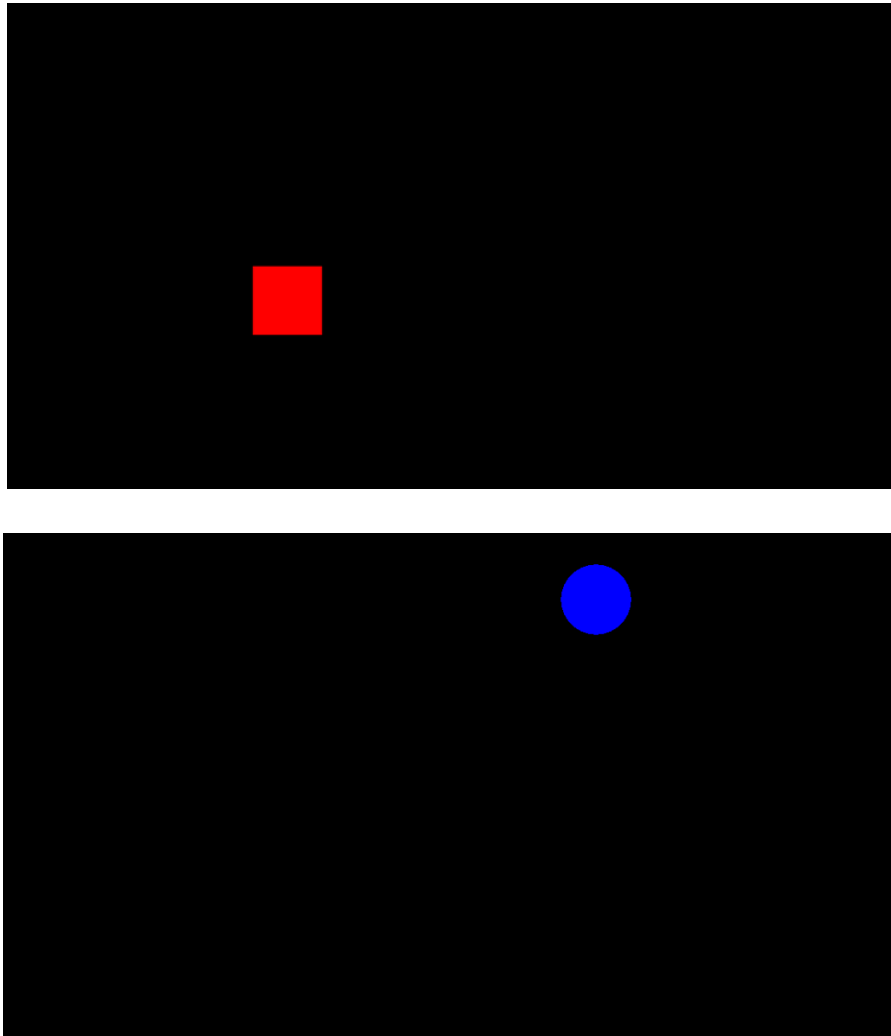


Figure 23: Screen-shot of the software set-up for the choice reaction task.

3.4. DEPENDENT VARIABLES DATA COLLECTION

For all four of the protocols, the method of data collection remained the same. Data collected was assessed over the duration of the task and between tasks. According to the aversion hypothesis where a change in task reduces the level of aversion and thus the improvement in the willingness to continue, all data (subjective and objective) was analyzed to assess whether there was a substantial change between the task conditions. Whether it was the cycling of information of the task, the task difficulty, whether performance is known or unknown, or how frequently tasks are alternated, objective and subjective data was hypothesized to provide an indication that these changes did in fact occur.

As this study was based on the speculation that task aversion is a manifestation of inefficiency, so objective data collected was based on input and output of the task performed. Furthermore, subjective data was recorded in order to differentiate whether task aversion was due to actual objective inefficiency or a subjective sensation of inefficiency. The purpose of attaining subjective data was further justified, as aversion is a subjective sensation, it was important to distinguish whether this was influenced by other subjective data.

As the literature has already highlighted the purpose for using the dependent measures decided upon, this section looks at how those measures were collected and analyzed to prove or disprove the hypotheses. All dependent measures, whether subjective or objective will be discussed in this section, further dividing objective measures into either objective input – effort response to performing tasks (physiological measures) or objective output – measurement of performance.

3.4.1. Task Aversion

As aversion is a subjective sensation that arises from working on cognitively demanding tasks, it was decided that the most appropriate way of quantitatively assessing aversion was through the use of a rating scale. Rating scales are the most widely used

measuring instruments for psychological assessment (Preston and Colman, 2000). According to studies by Preston and Colman (2000) which looked at the optimal response categories on a rating scale the optimal number of response categories in rating scales is still unresolved. Preston and Colman (2000) assessed scales of varying length to 149 participants using real situations and found that rating scales that yielded the least reliable score were scales with the lowest response categories. It was found that scales of 7 – 10 categories were seen to be the most reliable, had the greatest indices of validity, the most interval consistency and were easy to use and most preferred. This was further reinstated by Miller's (1956) theoretical analysis of human information processing capacity and short-term memory, and Simon's (1974) classification of information "chunks".

Therefore, for this investigation, a seven point Likert scale was chosen as the most appropriate measure of subjective analysis of aversion. Throughout the 30 minutes of testing for each protocol, (task alternation, task specific variables, and task cycles) task aversion was measured on this seven point Likert scale (Appendix B2). Prior to testing, subjects were familiarized with the concept of aversion and task aversion was explained as "an unreasoning desire to avoid that which displeases, annoys or offends" (Dictionary.com). It was furthermore described as the willingness to continue the task, as described by the works of Hockey (1997) and Holding (1980).

The seven point Likert scale ranged from one being the lowest measure of aversion to task experienced; to seven, being a great desire to stop performing the task (high aversion, maximal). With each task, at 5 minute intervals of the testing, participants were required to verbally relay the level of aversion they were experiencing. The 5 minute interval of retrieval of all the subjective measures were decided upon, as any more frequent subjective measures would result in a performance disturbance of the operator. This aversion scale was based on the study by Lorist *et al.*, (2000) where mental fatigue and task control, with a subjective measure of aversion, was looked at with regards to planning and preparation.

3.4.2. Subjective Efficiency

A subjective efficiency scale was created using the same methodology as the aversion scale in order to get quantitative data. A seven point Likert scale was used as a method of rating the subjective efficiency (Appendix B3). In order for participants to be able to assess how subjectively efficient they were at performing the task, the choice of task had to have an innate performance feedback. By having this feedback mechanism, participants were able to judge efficiency based on the amount of effort that was being put into performing the task, according to Borg's rate of perceived exertion scale, against how well they felt they were performing it. This provided subjects with a subjective sense of efficiency. Subjects were told that efficiency was based on the ratio of mental input/effort against the performance. This was according to the Likelihood Model proposed by Smith and Street (2005). "The likelihood method provides a measure of efficiency consistent with the definition of the ratio of work output to work input" (Hoffman, 2012). Output can be defined as performance, whereas input can be defined as work or effort (Hoffman, 2012). Participants relayed rating to the experimenter at 5 minute intervals throughout the testing time.

3.4.3. Subjective Input

Subjective input was assessed in the form of Borg's Rate of Perceived Exertion scale. Though this scale is predominantly used for physical activity, it provides a quantifiable measure of operator's perceived effort when performing cognitive work. This is a popular scale for ratings of effort as it is easy to use and understand (Borg, 1970). Borg's rate of perceived exertion scale is a 15 point scale with verbal queues, ranging from 6 – 20, with 6 being "no exertion at all" to 20 being "maximal exertion". Subjective scales are often questioned for their reliability, as subjective implies that there is a level of uncertainty in the response. With the perception of exertion however, there is an innate sense of exertion, it is easy to describe (Borg, 1970) and the reliability of the scale has been found to be high in many instances.

Though many participants were already familiar with the rate of perceived exertion scale, participants were informed that the rate of perceived exertion scale was a measure of subjective input. It was further defined to them as a measure of the rate of perceived mental exertion, and thus a subjective measure of the level of mental effort that was required of them to perform the task. Again measures were recorded at 5 minute intervals throughout testing, and were verbally relayed to the experimenter.

3.4.4. Objective Data collection

As described in the literature, and previously in the chapter, objective data was collected in order to substantiate the basis of change between the conditions of the tasks; furthermore it was used to analyze efficiency throughout the conditions. Objective data was similarly used to authenticate subjective data of the tasks. To reiterate further, for the purpose of the analysis of efficiency, objective data was divided into objective input and objective output. Objective input was in the form of physiological measures providing measures of mental effort for performance of the tasks. Objective output was used in order to assess how well participants were executing the tasks; assessment of this was through performance measures specific to the tasks. Efficiency was calculated as the performance experienced (objective output) over the degree of effort put in to maintain this performance (objective input). All objective data for all of the investigations were assessed and analyzed at 5 minute intervals except for the task alternation investigation which processed objective measures according to the alteration frequencies of the fast alternation condition (3 minute and 20 seconds).

3.4.5. Objective Input

Objective input was thus measured based on physiological measure in order to provide a measure of the amount of mental effort expended on the task (Fairclough *et al.*, 2005). The objective input measures chosen were: energy expenditure and breathing frequency (measured by ergospirometry), heart rate and heart rate variability.

Energy Expenditure and Breathing Frequency

The measures of metabolic activity and energy expenditure are not solely limited to physically demanding tasks (Backs and Seljos, 1994). It is important to clarify the relationship between mental effort and metabolic activity during information processing to determine the validity of metabolically adjusted mental workload measures (Backs and Seljos, 1994). Common sense would dictate that in order to maintain appropriate performance, energy expenditure and breathing frequency would change in order to compensate for the increased mental workload. It is widely known that cardiovascular changes occur when cognitively demanding work is undertaken; subsequently this should have a direct effect on the respiratory system.

In order to assess energy expenditure and breathing frequency the Cosmed Quark b² ergospirometer was used. The Quark b² is an indirect calorimetry system based on open-circuit spirometry. Direct calorimetry is impractical for studies of human energy expenditure, therefore indirect methods are used. The open-circuit method allows individuals to inhale ambient air that has a constant composition of 20.93 % oxygen, 0.03 % carbon dioxide and 79.04 % nitrogen. During energy yielding reactions oxygen is utilized and carbon dioxide is produced. The exhaled air contains less oxygen and more carbon dioxide than the inhaled air allowing for an analysis of the difference in composition between the exhaled air and the ambient air, reflecting the body's constant release of energy. The Quark b² employs a breath-by-breath gas exchange measurement system, with O₂ and CO₂ analyzers that are thermostated and compensated for variations in barometric pressure, temperature and humidity. Sampling rate and pressure sensors are also continuously monitored. Flow and volume are measured by a turbine that ensures a great accuracy with a wide flow range of up to 20L.sec⁻¹ and which is able to cope with a wide ventilation range. Quark b² provides measures of pulmonary gas exchange (breathing frequency) as well as indirect calorimetry (energy expenditure)

Calibration occurs regularly to ensure accurate measurements. The Quark b² calibration consists of three parts: room air calibration, a reference gas calibration and flowmeter calibration. Room air calibration is done to ensure that the baseline of CO₂ analyzer and the gain of O₂ analyzer are updated to match that of the room air concentrations. Reference gas calibration ensures a calibration of zero, appropriate gain and alignments of the gas sensors – this is done through a gas mixture of known concentrations of O₂ = 16 %, CO₂ = 5 % and N₂ = balance. Finally flowmeter calibration calibrates the turbine flowmeter and a 3 liter calibration syringe is used for this process.

For collection, a harness is placed around the participants head and the mask with the flowmeter attached to the face. The face mask is positioned over the nose and mouth ensuring a tight fit to avoid air escaping through the sides of the mask.



Figure 24: Set-up of the ergospirometer (Quark b²).

Reduction of energy expenditure and breathing frequency data was performed using the Data Analysis Tool version 3.4-03. This tool provided mean and median measure for energy expenditure and breathing frequency according to the time intervals for each test.

Heart Rate and Heart Rate Variability

It is a well-known fact that when placed in stressful situations, the body reacts and copes producing physiological responses. Heart rate and Heart rate variability are two of these responses and are the easiest and most reliable measures of physiological demand. To assess both these measures the Biometric Datalogg program was utilized. The Biometric Datalogg software allows for constant measurement of heart rate and heart rate variability throughout testing by recording the data via Bluetooth from a Polar heart rate sensor positioned on or near the participants picking up continuous cardiac activity from the Polar T34 heart rate monitor attached to participants. For the Polar T34 heart rate monitor, the electrode straps were positioned around the mid-chest, in line with the apex of the left ventricle, at the inferior border of the pectoralis major muscle. Conductive gel was placed on the electrode sensors prior to fitting of the monitor. This was done to ensure connectivity, eliminating the loss of signal due to a lack of moisture or friction between the electrode and skin.



Figure 25: Set-up of the Polar T34 heart rate monitor.

For heart rate analysis the Data Analysis Tool version 3.4-03 was again used and a minimum heart rate of 50 beats per minute and a maximum heart rate of 120 beats per

minute were accepted for analysis, furthermore a maximum variation between beats of 33 % was accepted. The Biometric Datalogg provides heart rate information fed in via heart rate pulses in time rows. This provides data to be analyzed for heart rate variability which was assessed through two domains: time domain analysis and frequency domain analysis.

Time Domain Analysis

The time domain analysis variables considered for this study were SDNN, rMSSD, PNN50 and PNN30. Interval lengths were set at 30 seconds for analysis. SDNN is defined as the mean difference between adjacent beat-to-beat intervals for the set analysis interval. rMSSD is calculated as the square root of the mean of the sum of the squares of differences between adjacent beat-to-beat intervals for the set analysis interval. PNN50 appraises the percentage of adjacent beat-to-beat intervals differing by more than 50 ms compared to all beat-to-beat intervals in the set analysis interval. Furthermore, PNN30 is analogous to PNN50, in that it is the percentage of adjacent beat-to-beat intervals but with 30 ms as a differentiation criterion. The PNN30 parameter allows for improved identification of phases with low variability.

Frequency Domain Analysis

The examination of frequency domain analysis of heart rate variability separates the heart rate variability signal into differing frequency ranges, with the most widely used for mental workload being high frequency (HF) (0.15-0.4 Hz) and low frequency (LF) (0.04-0.15 Hz). According to Berntson *et al.* (1997), the high frequency component is highly affected by vagal activity but a disagreement exists with respect to the low frequency component, in that some studies suggest that LF, when expressed in normalized units, is a quantitative marker of sympathetic modulation, while other studies view LF as reflecting both sympathetic and vagal activity. Low frequency and high frequency were assessed for this study, through a FFT transformation, with both power and center frequency investigated. Power is defined as the total power within the respective

frequency band (ms^2) and center frequency being the frequency splitting the power spectrum of the respective frequency band into two portions of equal power (Hz).

Consequently, the LF/HF ratio is considered by some investigators to mirror sympathovagal balance or to reflect the sympathetic modulations (Berntson *et al.*, 1997) and thus was also a factor for analysis throughout the investigation.

3.4.6. Objective Output – Performance Measures

Performance, as a concept of cognitive load, provides the investigator with insight into the cognitive capacity that is actually allocated to accommodate the demands imposed by the task (Pass *et al.*, 2003). Performance provides some insight into how effectively cognitive resources are being utilized in order to maintain appropriate execution of the task. Furthermore, performance and deviations in performance help assess what effects variables of interest have on the human ability to maintain performance in demanding and changing environments. With performance being the objective output for each task, each method of data collection and analysis will be described.

Objective Output for Investigation 1: Task Cycles

Task cycle's performance was assessed through two measures – reading speed and number of spelling errors missed. As described in the protocol, while participants were reading, at 5 minute intervals throughout the task, the participant was instructed by the investigator to mark on the text the last words read. Reading speed was thus calculated as the number of word read over the 5 minute reading period (words per minute). Participants were required to read out loud words that had been incorrectly spelt throughout the reading text.

Objective Output for Investigation 2 and 3: Task Difficulty and Performance Feedback

The driving simulator task provides performance in the form of mean deviation (m), which results from movements from the target line, in this instance the center of the lane.

Objective Output for Investigation 4: Task Alternation

For the choice reaction task, participants were required to provide either critical or non-critical responses according to the stimuli presented. The performance measure for the choice reaction task was response time. Response time was defined as the time taken from the first appearance of the stimuli up until the time that the participant responded by pushing the response button. Response time was given in milliseconds.

For the driving simulator task, performance was measured according to the deviation from the target, which was in the form of tracking (following the line). Deviation was provided by the driving simulator as a mean deviation in meters.

3.5. STATISTICAL HYPOTHESIS

3.5.1. Factors Influencing Aversion

Statistical Hypothesis Investigation 1: Task Cycles

Statistical Hypothesis for Aversion Measures

Null Hypothesis: $H_0: \mu_{\text{non-repetitive}} = \mu_{\text{repetitive}}$

Alternative Hypothesis: $H_A: \mu_{\text{non-repetitive}} \neq \mu_{\text{repetitive}}$

Where repetitive: repetitive reading task; non-repetitive: non-repetitive reading task

Statistical Hypothesis Investigation 2: Task Difficulty

Statistical Hypothesis for Aversion Measures

Null Hypothesis: $H_0: \mu_{\text{easy}} = \mu_{\text{difficult}}$

Alternative Hypothesis: $H_A: \mu_{\text{easy}} \neq \mu_{\text{difficult}}$

Where easy: easy condition; difficult: difficult condition

Statistical Hypothesis Investigation 3: Performance Feedback

Statistical Hypothesis for Aversion Measures

Null Hypothesis: $H_0: \mu_{\text{No Performance Feedback}} = \mu_{\text{Performance Feedback}}$

Alternative Hypothesis: $H_A: \mu_{\text{No Performance Feedback}} \neq \mu_{\text{Performance Feedback}}$

Where no Performance Feedback: condition providing no performance feedback;
Performance Feedback: performance feedback condition.

Statistical Hypothesis Investigation 4: Task Alternation

Statistical Hypothesis for Aversion Measures

Null Hypothesis: $H_0: \mu_{\text{slow drive}} = \mu_{\text{slow choice}} = \mu_{\text{medium alternation}} = \mu_{\text{fast alternation}}$

Alternate Hypothesis: $H_A: \mu_{\text{slow drive}} \neq \mu_{\text{slow choice}} \neq \mu_{\text{medium alternation}} \neq \mu_{\text{fast alternation}}$

Where slow drive: slow driving simulator task condition; slow choice: slow choice reaction task condition; medium alternation: medium alternation condition; fast alternation: fast alternation condition

3.5.2. Cause of Aversion

Null Hypothesis: $H_0: \mu_{\text{Eff T1}} = \mu_{\text{Eff T2}} = \mu_{\text{Eff T3}} = \dots \mu_{\text{Eff Tn}}$

Alternate Hypothesis: $H_A: \mu_{\text{Eff T1}} \neq \mu_{\text{Eff T2}} \neq \mu_{\text{Eff T3}} \neq \dots \mu_{\text{Eff Tn}}$

Where Eff: efficiency (perceived or objectively measured) and T1, T2 T3... Tn: time intervals

This statistical hypothesis remained the same throughout all the four investigations undertaken.

3.6. PARTICIPANT CHARACTERISTICS

Participants for this study were chosen out of the Rhodes University student population. For each of the methodologies, 10 male and 10 female participants were chosen to execute the investigation. Therefore 20 participants for task cycles and 20 participants for task alternations were required. As the task difficulty and performance feedback investigation shared a condition, only 20 participants in total were required to assess both investigations, therefore a total of 60 participants were required for this study.

Participants were seen as fit to partake in the study provided that they met the following requirements. They had to have no memory problems, such as short term memory recall and those that had any visual problems such as, myopia or hyperopia, were required to wear corrective glasses throughout the testing sessions. If participants suffered from tunnel vision, colour blindness or a colour deficiency they were not permitted to take part in the study. Furthermore, participants were not accepted for testing should they suffer from attention disorders such as, Attention Deficit Disorder or Attention Deficit Hyperactivity Disorder.

3.7. ETHICAL CONSTRAINTS

Ethical clearance was obtained from the departmental ethics committee. A letter of information (Appendix A1 (i), A1 (ii), A1 (iii)) was provided to each participant prior to any testing having taken place. The letter of information provided the participant with information on the purpose of the study, any risks that may occur due to or during testing, and the benefits that would be incurred by the participant performing the study. In addition, the letter of information provided the participants with a list of activities that were to be avoided both 24 hours and two hours prior to the testing session. Ingestion of alcohol or medication that was not necessary or prescription medication, was prohibited. Furthermore, participants were instructed not to partake in any strenuous physical activity or any arduous mental activities such as driving great distances prior to

testing. In the two hours leading up to the testing, participants were again instructed not to consume any stimulants, take any medication that could cause drowsiness and were asked to eat a good meal.

In order to ensure that there was voluntary participation and no coercion in the study participants were required to sign an informed consent form (Appendix A2). Data that was collected from the participants in the study were assigned codes which were kept separately from any participant names and, data collected and were in no way present throughout processing of the data to ensure that no direct correlation could be made to participants and the data obtained. To enforce anonymity and privacy, on completion of the data processing, and printing of the thesis, thus completing the study, data was destroyed, further making it impossible to correlate data with participants

3.8. STATISTICAL ANALYSIS

Descriptive statistics (mean and standard deviation) were performed on all data obtained in order to summarize and graphically display the data. The Statistica programme (version 10) was used to analyze the data obtained. The level of probability used was $p < 0.05$ throughout the statistical analysis in order to test the statistical significance. Statistical analysis for each investigation will be discussed in the results sections to follow.

Two-way analysis of variance was performed for the objective and subjective data. Subjective efficiency was measured against aversion and rate of perceived exertion. For the objective data, a ratio was obtained (errors, reading speed, breathing frequency, energy expenditure and heart rate) in all possible combinations. All objective output measures (errors and reading speed) were divided by objective input measures (energy expenditure, breathing frequency and heart rate and heart rate variability) in order to attain a measure of efficiency. This was achieved through a two-way analysis of

variance in order to prove whether there would be a statistically significant difference over time for efficiency over aversion.

CHAPTER IV

4. RESULTS

The following chapter will look into the results obtained from the four investigations undertaken. The results section for each of the four investigations will first assess the factors influencing aversion, with subjective measures of aversion between the conditions for each investigation represented and analyzed initially. Following this, additional subjective measures (rate of perceived exertion, and subjective efficiency) and objective measures (performance measures and physiological measures) will be assessed to discover whether the conditions differed statistically significantly for the dependent variables.

Subsequently, the cause of aversion analysis will be represented and analyzed for both subjective and objective measures. Objective efficiency will be assessed in accordance with the likelihood method, such that efficiency is denoted by performance over resources in the form of objective input.

4.1. INVESTIGATION 1 – TASK CYCLES

To reinstate, the purpose of this investigation was to assess whether two proof reading conditions, varying in the repetitiveness of the stimulus presented to the operator, would affect the degree of aversion experienced. As stated, two conditions were put forth, a repetitive condition such that the stimulus was repeated throughout the testing duration, and a non-repetitive condition where the stimulus was consistently changing throughout the task duration. Analysis of variance was performed for aversion over time, for the two conditions over time to clarify whether a difference did exist between a repetitive and a non-repetitive condition. In addition, analysis of variance was performed on all subjective and objective variables for each condition over time, to ascertain whether a difference was in fact apparent between a repetitive and a non-repetitive condition over

the task duration. Finally, analysis was done for efficiency over time for both subjective measures and objective measures.

4.1.1. Factors Influencing Aversion

Subjective Measures

As subjective data was recorded at 5 minute intervals throughout the testing duration, data for all of the subjective measures will be displayed and assessed according to these intervals.

Aversion

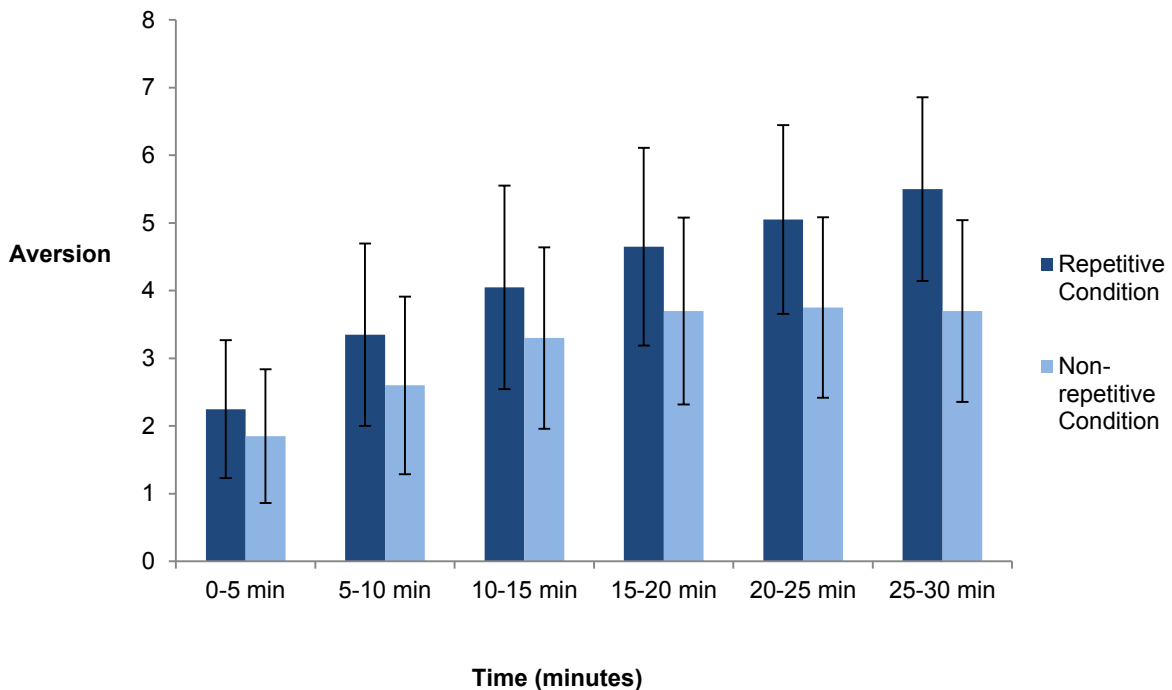


Figure 26: Aversion over task duration for a non-repetitive and repetitive condition proof reading.

Aversion increased statistically significantly over time for both the repetitive and the non-repetitive condition (Figure 26, Table I). The increase in aversion for the repetitive condition was found to be higher than the non-repetitive condition. Change over time

was found to be statistically significant ($p < 0.01$). Thus a greater aversion was experienced throughout the repetitive condition and found to have a greater increase for the testing period.

Table I: Analysis of variance of aversion over task duration for a repetitive and non-repetitive condition of a proof reading task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	10.45	<0.01*
TIMES	5, 95	64.77	<0.01*
CONDITIONS*TIMES	5, 95	7.91	<0.01*

Rate of Perceived Exertion

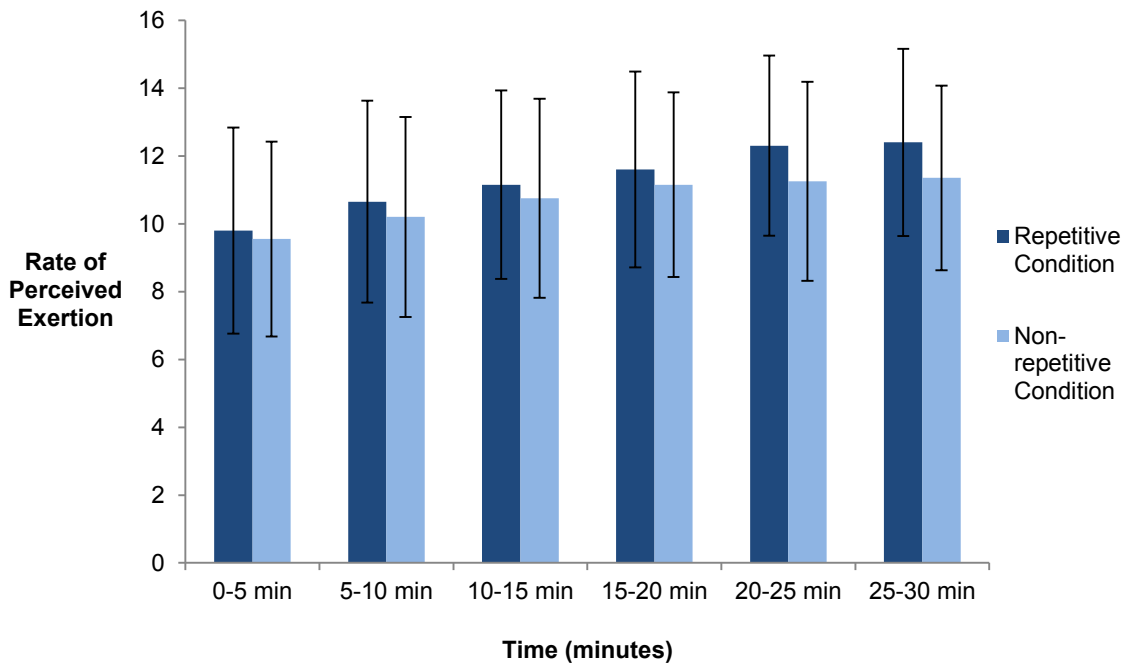


Figure 27: Rate of perceived exertion over task duration for a non-repetitive and a repetitive condition of a proof reading task.

The analysis of variance shows a significance difference over time ($p < 0.01$), indicating that over time an increasing trend for rate of perceived exertion was found. Statistical significance was further found for the interaction effect of condition over time ($p < 0.01$), showing a statistically significant difference for each condition over the testing period in rate of perceived exertion.

Table II: Analysis of variance of rate of perceived exertion over task duration for non-repetitive and repetitive conditions of a proof reading task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITION	1, 19	2.50	0.13
TIME	5, 95	19.38	<0.01*
CONDITION*TIME	5, 95	3.68	<0.01*

Subjective Efficiency

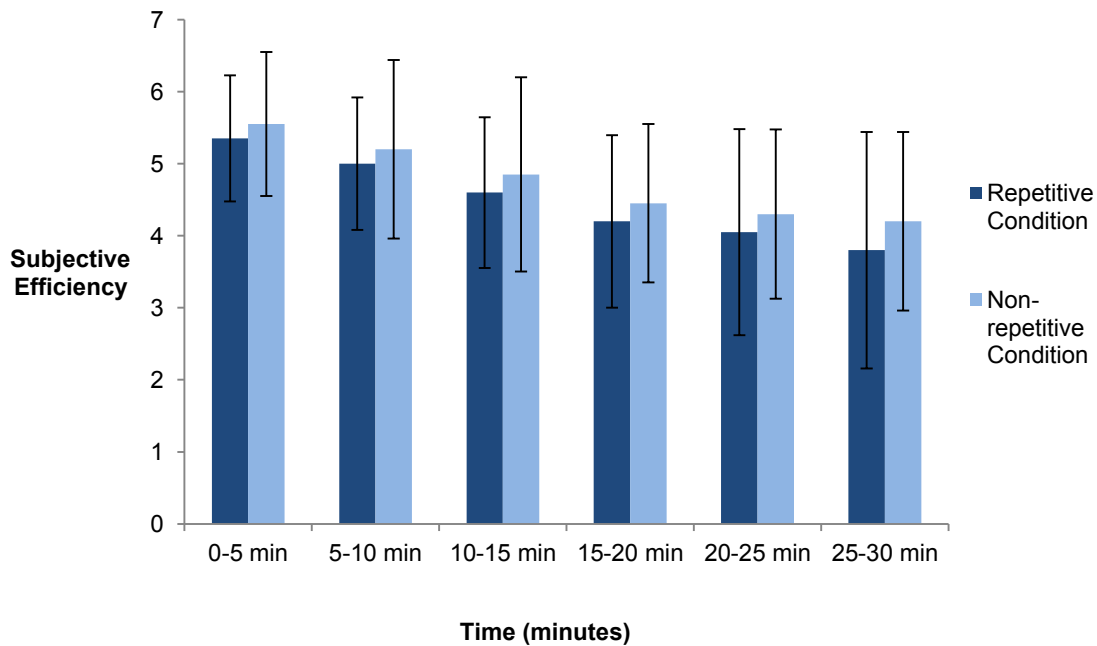


Figure 28: Subjective efficiency over task duration for non-repetitive and repetitive condition of a proof reading task.

Analysis of variance for subjective efficiency was found to produce a statistically significant difference over time ($p < 0.01$), highlighting the decreasing trend for perceived efficiency.

Table III: Analysis of variance for subjective efficiency over task duration of a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).

	Degrees of - Freedom	F	p
CONDITIONS	1, 19	1.22	0.28
TIME	5, 95	17.01	<0.01*
CONDITIONS*TIME	5, 95	0.14	0.98

Objective Output

Performance

Objective output was assessed through reading speed of the proof reading task and errors. As participants were required to mark the text at 5 minute intervals throughout the testing duration, the reading speed was assessed as the number of words read over 5 minutes and errors were defined as the number of unidentified incorrectly spelt words in the same 5 minute period.

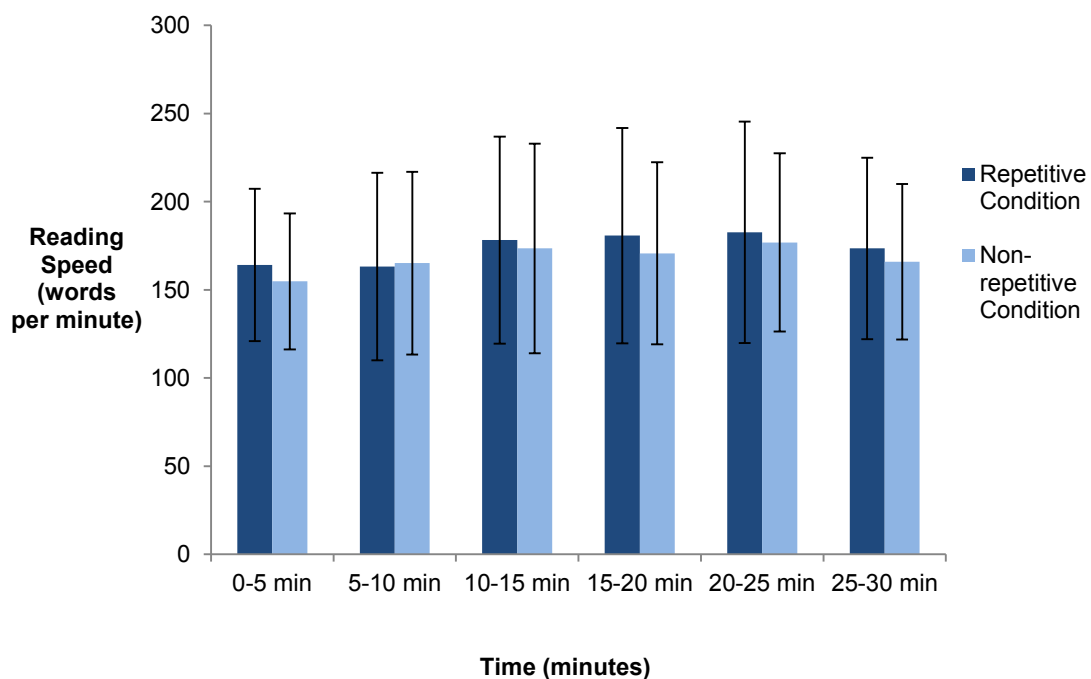


Figure 29: Reading speed over task duration for a repetitive and non-repetitive condition of a proof reading task.

Analysis of variance shows that there is a statistically significant increase ($p < 0.01$) in reading speed over time (Table IV.)

Table IV: Analysis of variance of reading speed over task duration for a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.35	0.56
TIMES	5, 95	4.63	<0.01*
CONDITIONS*TIMES	5, 95	0.27	0.93

With regards to error performance, no significance was found. This reiterates that there is no difference between the conditions in respect to reading speed or errors identified (see Appendix C1).

Objective Input

The objective input analysis of variance is comprised of the measures of mental effort, thus, breathing frequency, energy expenditure, heart rate and heart rate variability. Heart rate variability is further analyzed according to time domain analysis and spectral frequency analysis. For all objective input measures, excluding heart rate variability, the first time interval is excluded from analysis, so that analysis can be performed on data once the participant has obtained a physiological steady state. With the recording of subjective measures at 5 minute intervals throughout the testing duration and objective output assessed according to this, this provided the assessment times for objective input data, and data will be displayed in 5 minute intervals.

Heart Rate

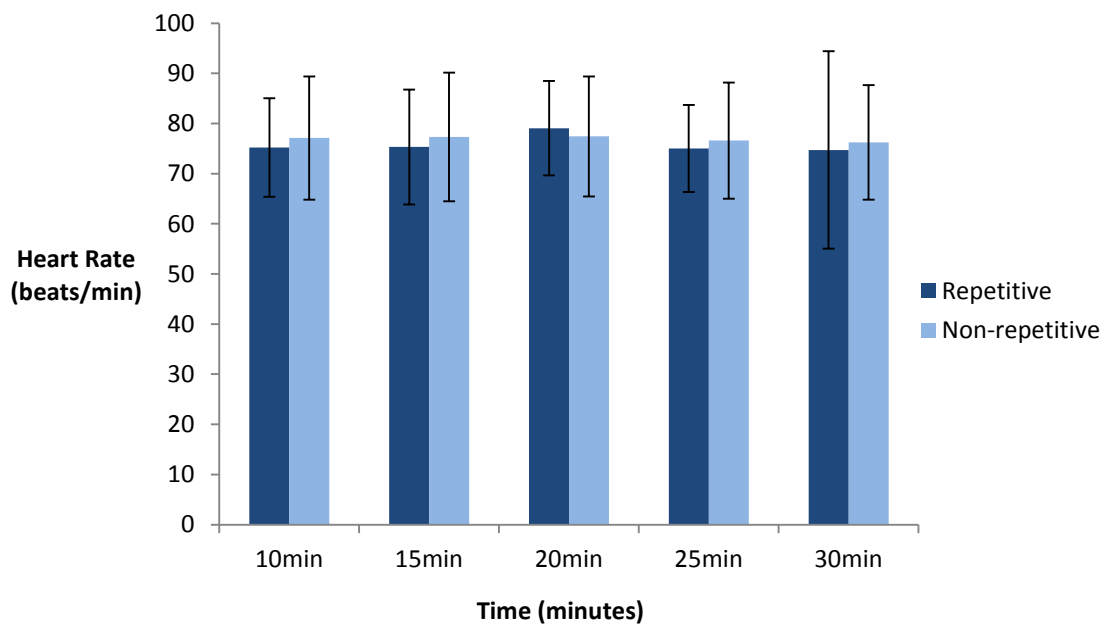


Figure 30: Change in heart rate from 10 minutes to 30 minutes of task duration for a repetitive and a non-repetitive condition of a proof reading task.

Breathing frequency, energy expenditure and heart rate followed the same tendencies for this investigation. Statistical analysis showed that there is no difference in heart rate,

and similarly for breathing frequency and energy expenditure, between the repetitive and the non-repetitive conditions; nor any change over time (Table V).

Table V: Analysis of variance of heart rate from 10 minutes to 30 minutes of task duration of a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.21	0.65
TIMES	4, 76	1.05	0.39
CONDITIONS*TIMES	4, 76	0.58	0.68

Heart Rate Variability

As stated, heart rate variability was assessed through time domain analysis and spectral frequency analysis in order to ascertain the effects the two conditions imposed on heart rate variability.

Time Domain Analysis

SDNN

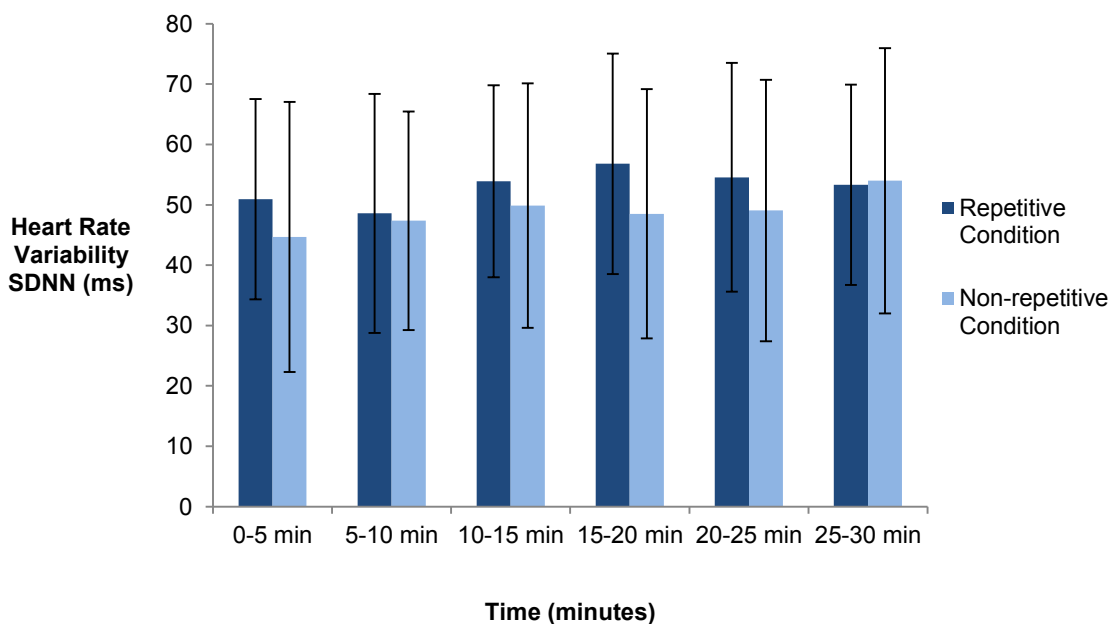


Figure 31: Heart rate variability SDNN over task duration comparing a repetitive and a non-repetitive condition of a proof reading task.

Analysis of variance proves that for the heart rate variability SDNN, there is a statistically significant ($p=0.02$) increase over the testing duration. No statistical significance was found between the two conditions. Additionally, no statistically significant difference was found for any of the remaining time domain analysis variables (see Appendix C1)

Table VI: Analysis of variance of heart rate variability SDNN over task duration for a repetitive and a non-repetitive condition of a proof reading task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	1.43	0.25
TIMES	5, 95	2.62	0.03*
CONDITIONS*TIMES	5, 95	2.11	0.07

Spectral Frequency Analysis

Spectral frequency analysis was performed in order to determine whether variations occurred in the parasympathetic and sympathetic nervous system associated with the change in repetitiveness of conditions.

Low Frequency– Center Frequency

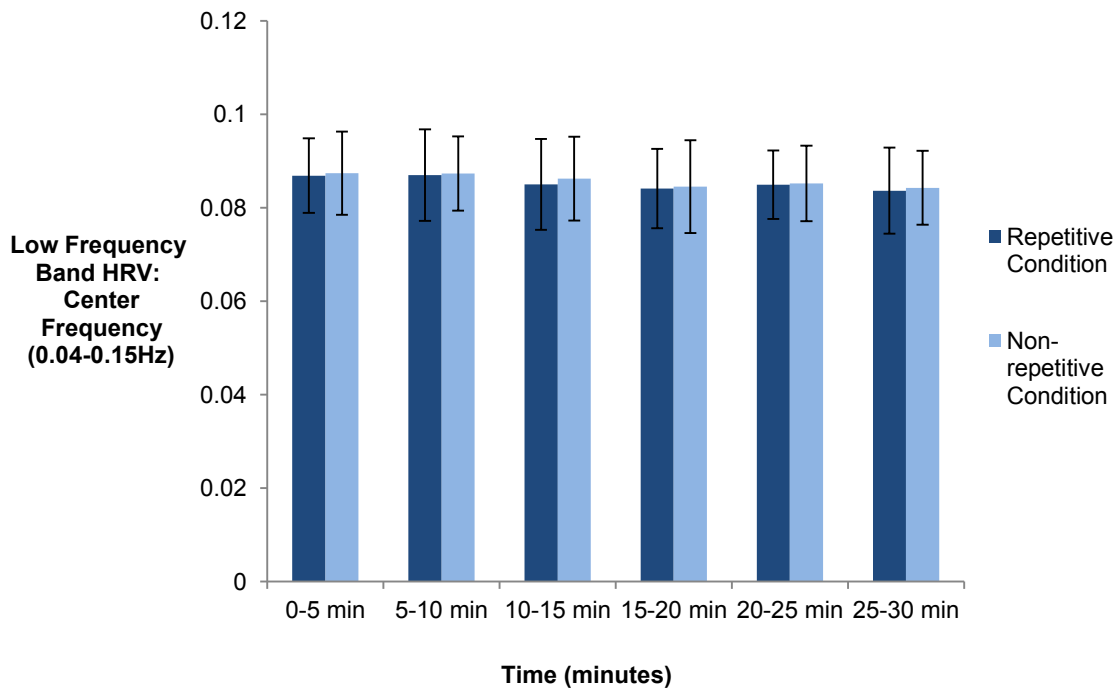


Figure 32: Low frequency band for heart rate variability over task duration for a repetitive and a non-repetitive condition of a proof reading task.

Out of all the heart rate variability spectral frequency analysis measures, only low frequency band heart rate variability was found to have significance decrease over time ($p= 0.017$) (Figure 32 and Table VII). (see Appendix C1)

Table VII: Analysis of variance of low frequency heart rate variability (center frequency) over task duration of a repetitive and non-repetitive condition of a proof reading task (*significance $p<0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.12	0.74
TIMES	5, 95	2.91	0.02*
CONDITIONS*TIMES	5, 95	0.05	0.99

4.1.2. Cause of Aversion

The cause of aversion was the subsidiary investigation into a possible explanation for the manifestation of the perceived unwillingness to continue the task. This section will examine the cause of aversion through the multivariate analysis of subjective efficiency, aversion and rate of perceived exertion over the task duration for both of the task conditions. Additionally an analysis of variance will be discussed of the objective efficiency experienced over task duration for the two conditions.

Subjective Efficiency

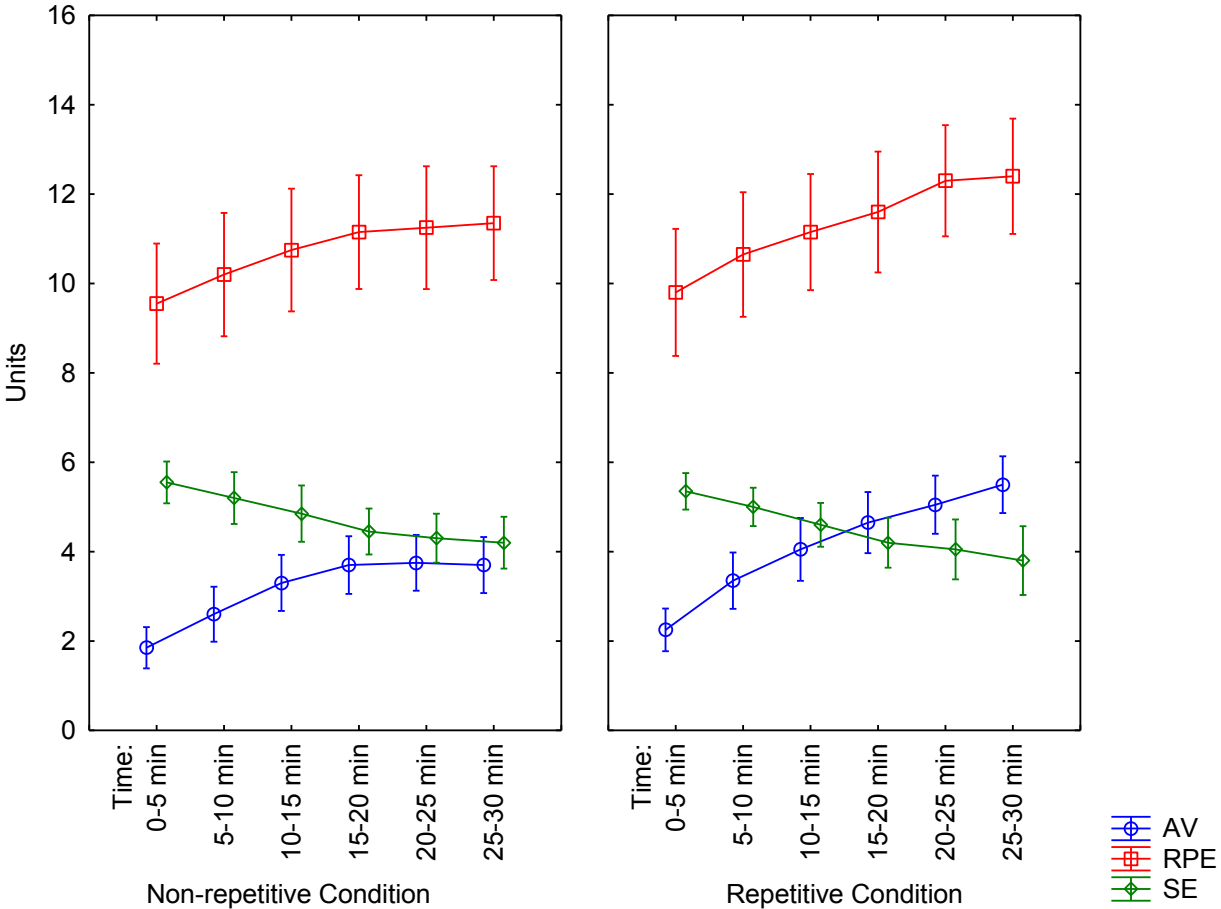


Figure 33: Subjective efficiency over task duration against aversion and rate of perceived exertion for all conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency).

For the assessment of efficiency, as all subjective measures had varying units, the y-axis was titled as units. From the graph it can be seen, for both conditions, that with an increase in the subjective input (RPE), there is a decrease in the amount of subjective efficiency. Aversion follows the trend of subjective input, such that it increases over the testing period.

It is further apparent that the effects for the repetitive condition are at a greater scale to that of the non-repetitive condition with subjective input and aversion showing a greater increase and subjective efficiency showing a greater decrease over time.

A multivariate analysis of variance for both conditions over time showed statistically significant difference for condition ($p=0.007$), time ($p<0.01$) and conditions over time ($p<0.01$).

Table VIII: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (repetitive and non-repetitive) and time (30 minutes) as factors (*significance $p<0.05$).

	Degrees of Freedom	F	p
VARIABLE	1, 19	164.77	<0.01*
CONDITIONS	1, 19	8.88	<0.01*
TIMES	5, 95	42.95	<0.01*
VARIABLE*CONDITIONS	1, 19	0.75	0.40
VARIABLE*TIMES	5, 95	0.90	0.49
CONDITIONS*TIMES	5, 95	8.98	<0.01*
VARIABLE*CONDITIONS*TIMES	5, 95	0.88	0.50

Objective Efficiency

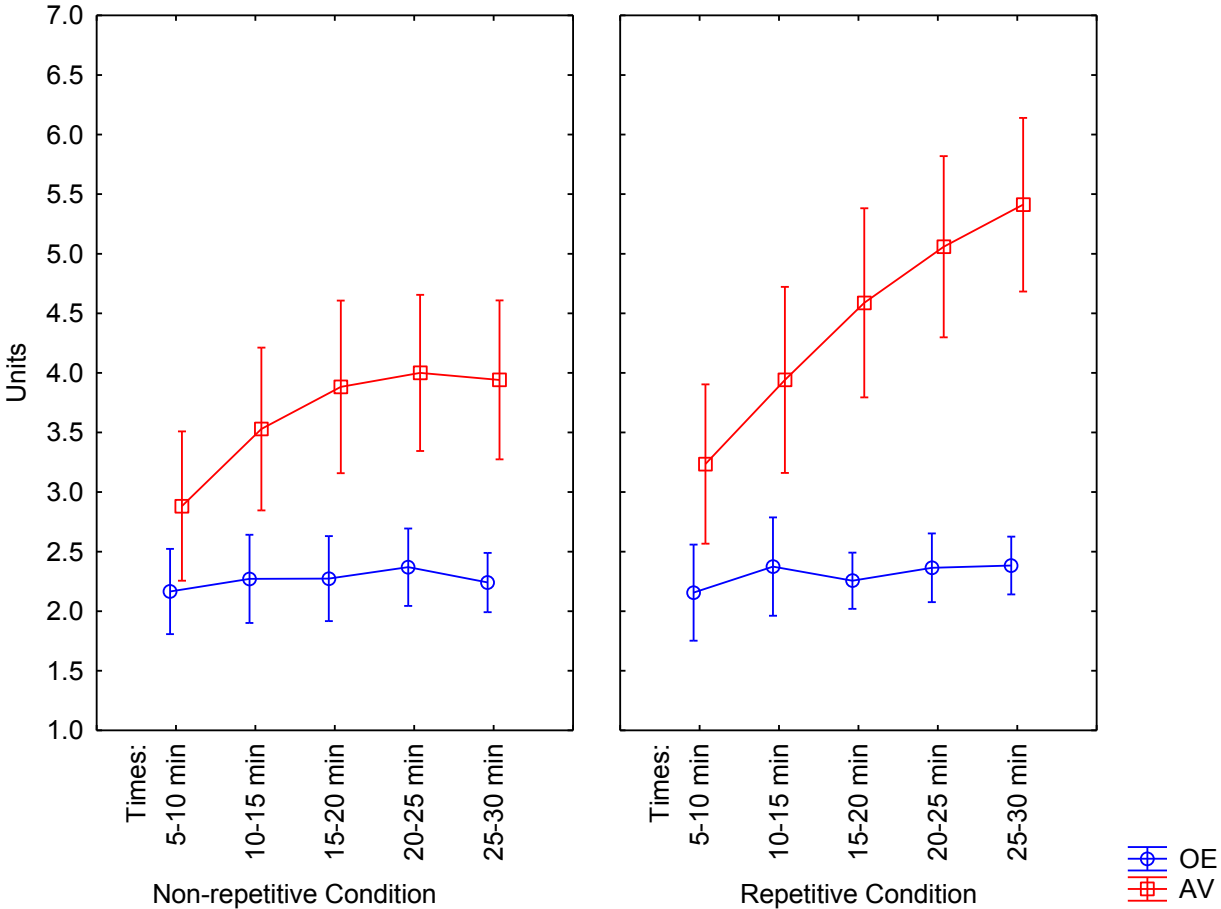


Figure 34: Objective efficiency against aversion for task duration for a non-repetitive and repetitive condition showing performance (reading speed) over heart rate experienced (where OE: objective efficiency and AV: aversion).

As the units for aversion and the efficiency, worked out by objective output (reading speed) over input (heart rate), are not similar, the y-axis has been denoted as units. Furthermore, similar to the analysis of factors influencing aversion, the first time interval was excluded from analysis. It can be seen that the trend for aversion for both conditions increases over the 30 minute testing duration, with the repetitive condition having a higher starting and ending measure of aversion experienced in comparison to the non-repetitive condition. The trend of the resultant efficiency, for both the repetitive

and the non-repetitive condition, show a similar, constant maintenance throughout the testing duration. Analyses of variance further showed no statistical difference in efficiency over time for both the repetitive and the non-repetitive condition. Furthermore, no significance was found for any of the objective efficiency measures through all possible combinations of performance (reading speed and errors) and effort (breathing frequency, energy expenditure and heart rate variability) (see Appendix C1).

Table IX: Analysis of variance for objective efficiency (reading speed over heart rate) for the non-repetitive condition over time (*significance $p < 0.05$).

	Degrees of Freedom	F	p
TIMES	4, 76	1.12	0.35

Table X: Analysis of variance for objective efficiency (reading speed over heart rate) for the repetitive condition over time (*significance $p < 0.05$).

	Degrees of Freedom	F	p
TIMES	4, 76	0.79	0.54

4.1.3. Response to Hypotheses

The null hypothesis for the task cycle investigation stated that a change in task imposed through the repetitiveness of the cycling of stimulus to an operator would result in no overt changes in aversion experienced. According to the results obtained for the task cycles investigation it can be observed that the change in the stimulus cycled to the participants, through the non-repetitive condition, changes the aversion experienced. Aversion was seen to be less with the non-repetitive condition (Figure 26 and Table I). The alternate hypothesis for this investigation is tentatively accepted.

With regards to the cause of aversion hypothesis, the null hypothesis stated that there would be no difference in objective and subjective efficiency experienced over time on task. It can be observed that although there is a decreased in the perceived efficiency

(Figure 33 and Table VIII), there is no change in the objective efficiency (Figure 34, Table IX and X). Thus the alternate hypothesis is rejected for the cause of aversion for objectively measured efficiency and tentatively accepted for perceived efficiency.

4.2. INVESTIGATION 2 – TASK DIFFICULTY

The purpose of the task difficulty investigation was to establish whether changes imposed by difficulty would alter the aversion experienced when performing a driving simulation task. In order to assess this, two conditions were instated, an easy condition and a difficulty condition. Analysis of variance for aversion over time was performed on the two conditions to support the notion that a change in difficulty would alter aversion experienced. Additionally, analysis of variance for each variable, subjective and objective, was performed over time for the two conditions to further discover whether the change in difficulty imposed resulted in a difference between the subjective and objective variables of interest. Finally the cause of aversion was assessed through the analysis of subjective efficiency and objective efficiency.

4.2.1. Factors Influencing Aversion

As stated, the factors influencing aversion was performed to assess whether changes according to task difficulty would result in a statistically significant difference to task aversion. For this section, aversion analysis will firstly be performed, with analysis of the remaining subjective measures to follow. Finally objective variables in the form of objective output (performance) and objective input (breathing frequency, energy expenditure) will be assessed.

Similar to the task cycles investigation, all subjective measures were recorded at 5 minute intervals throughout the task duration thus providing the intervals of analysis for all subjective and objective measures.

Subjective Measures

Aversion

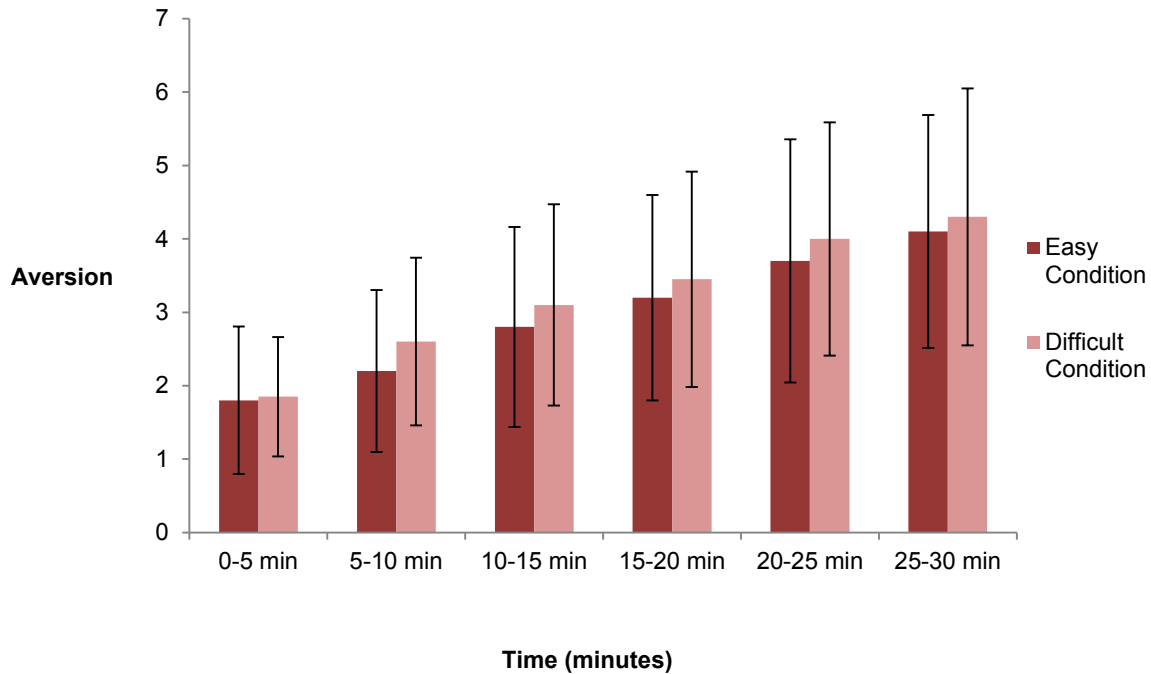


Figure 35: Aversion experienced over task duration for an easy and a difficult condition of a driving simulator task.

Analysis of variance of aversion over time showed a statistically significant increase ($p < 0.01$) (Table XI, Figure 35). From figure 35 and table XI it can be seen however that no statistically significant difference was found between aversion of the easy and the difficult condition ($p = 0.3$).

Table XI: Analysis of variance of aversion over task duration for an easy and a difficult condition of a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.94	0.35
TIMES	5, 95	66.80	<0.01*
CONDITIONS*TIMES	5, 95	0.47	0.80

Rate of Perceived Exertion

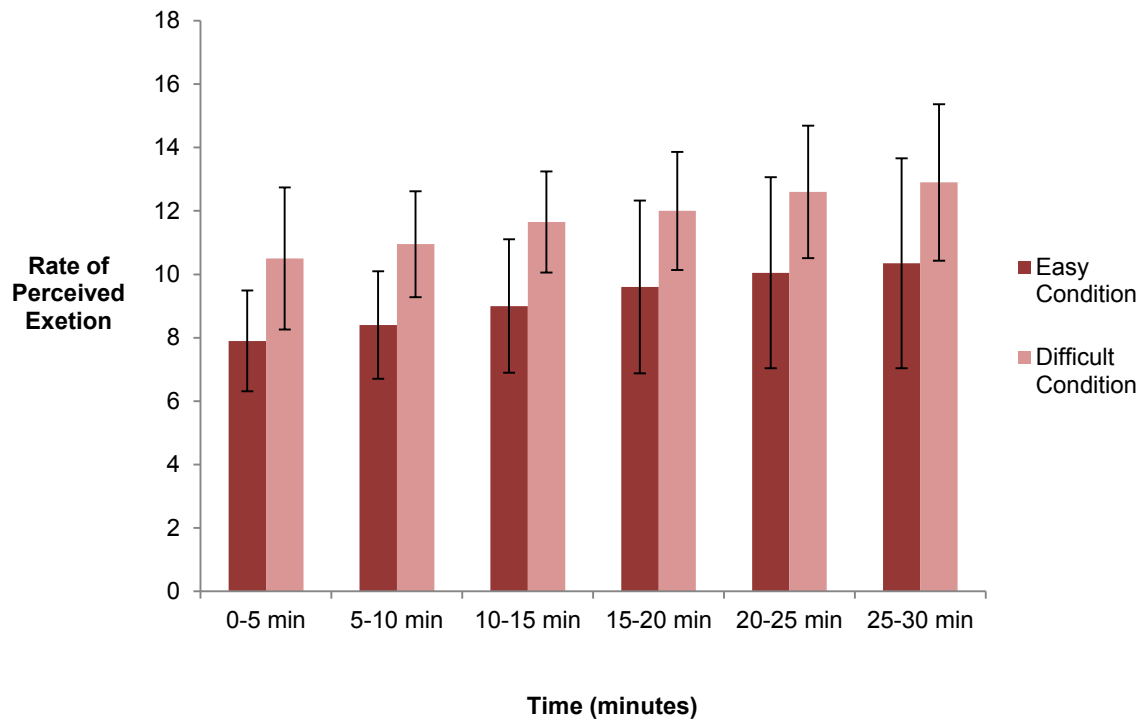


Figure 36: Rate of perceived exertion over task duration for an easy and a difficult condition of a driving simulator task.

Figure 36 shows the rate of perceived exertion between the easy condition and the difficult condition for the task difficulty investigation. The rate of perceived exertion for the easy condition was statistically significantly less than the rate of perceived exertion for the difficult condition throughout the 30 minutes of task time ($p < 0.01$). Furthermore, a statistically significant increasing trend over time was found (Table XII).

Table XII: Analysis of variance for rate of perceived exertion over task duration for an easy and a difficult condition of a driving simulator task (*significance $P < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	20.11	<0.01*
TIMES	5, 95	16.78	<0.01*
CONDITIONS*TIMES	5, 95	0.08	0.99

Subjective Efficiency

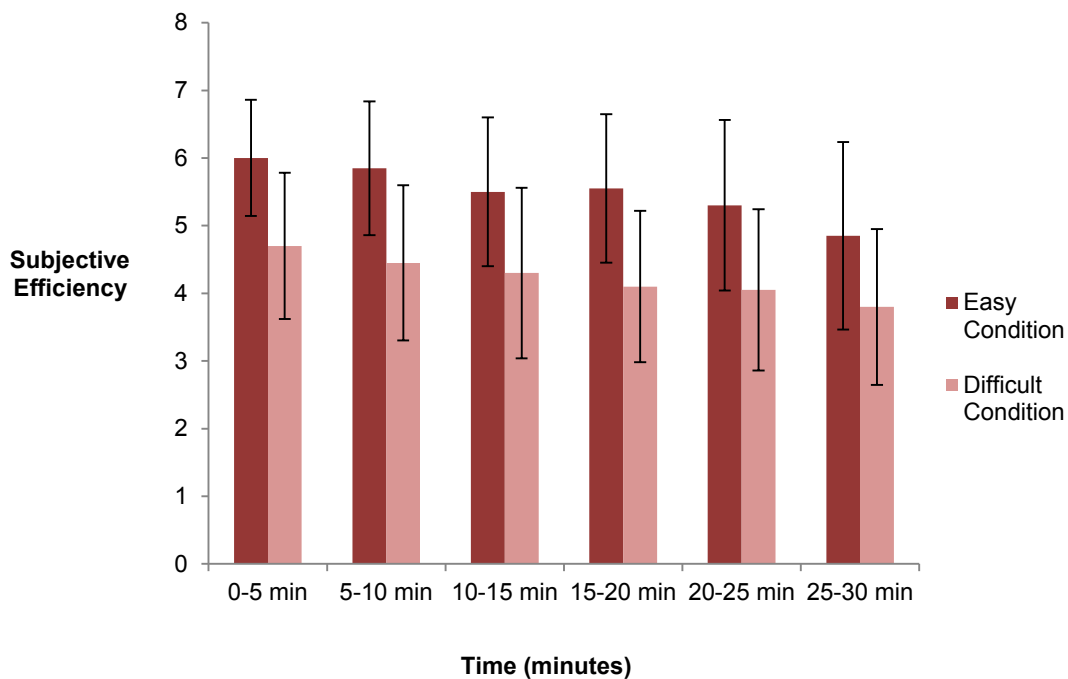


Figure 37: Subjective efficiency over testing duration for easy and difficult conditions of a driving simulator task.

Figure 37 shows subjective efficiency was higher throughout the task duration for the easy condition. The difficult condition produced a statistically significantly ($p < 0.01$) lower subjective efficiency rating in comparison to the easy condition. Analysis over time shows a statistically significant ($p < 0.01$) decreasing trend, however, no significance found for the interactional effect between condition and time ($p = 0.4$).

Table XIII: Analysis of variance of subjective efficiency over task duration for an easy and a difficult condition of a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	35.05	<0.01*
TIMES	5, 95	13.70	<0.01*
CONDITIONS*TIMES	5, 95	0.89	0.49

Objective Output

Performance

Initial output sample interval was set to 5 second to produce one output sample every 5 second to avoid strong variations due to changes in the curvature of the street. For performance it was anticipated that the difficult condition would result in an improved performance in comparison to the easy condition. The greater road width associated with the easy condition would allow for a greater deviation off the center line of the driving lane as the confines of the road would be larger. Similarly it is was expected that the more difficulty condition, with the narrow road width, would result in improved performance as the narrow road provided for a smaller confinement for probability of deviation off the center line of the driving lane.

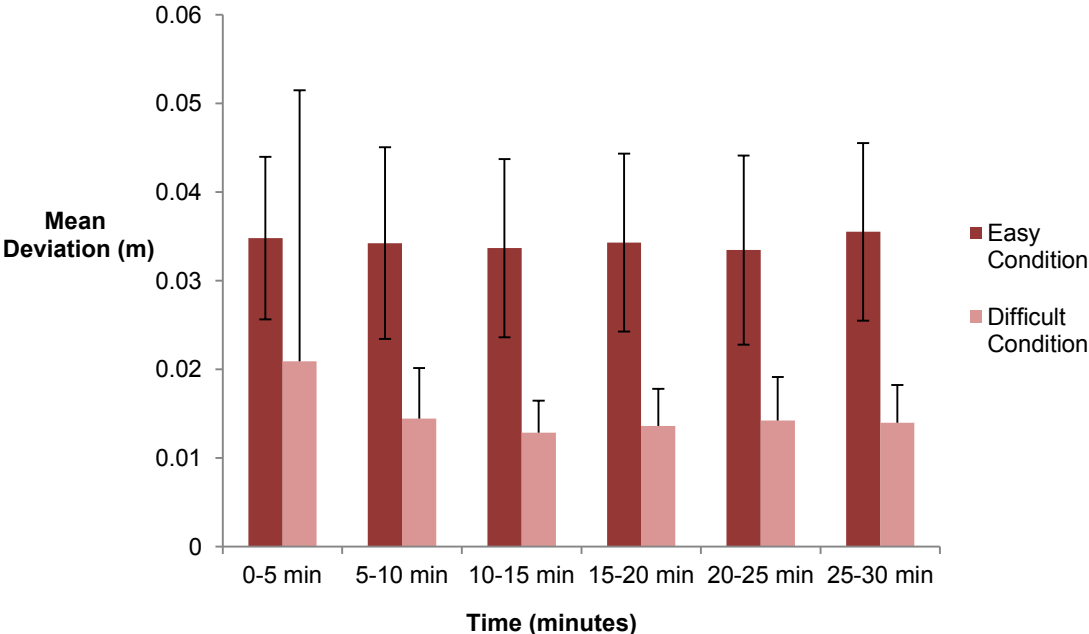


Figure 38: Change in performance over testing duration for an easy and a difficult condition of a driving simulator task.

Figure 38 shows the results of performance in mean deviation for the driving task. It is evident that there is a difference in driving performance between the easy condition and the difficult condition, with the conditions producing statistically significant difference in mean deviation ($p < 0.01$) (Table XIV). The difficult condition was found to produce statistically significantly less deviation in driving performance as appose to the easy condition. This is unexpected as it was previously anticipated that the easy condition would result in better performance than the hard condition. No difference over time was found for mean deviation, as performance remained stable throughout.

Table XIV: Analysis of variance of performance over task duration for an easy and a difficult condition of a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	95.60	<0.01*
TIMES	5, 95	1.44	0.22
CONDITIONS*TIMES	5, 95	0.83	0.53

Objective Input

Objective input was the measure of effort expended in order to maintain performance. Objective input was assessed through breathing frequency, energy expenditure, heart rate and heart rate variability. For analysis, except for heart rate variability, the first time interval was removed in order to analyze data once a steady state had been achieved.

Energy Expenditure

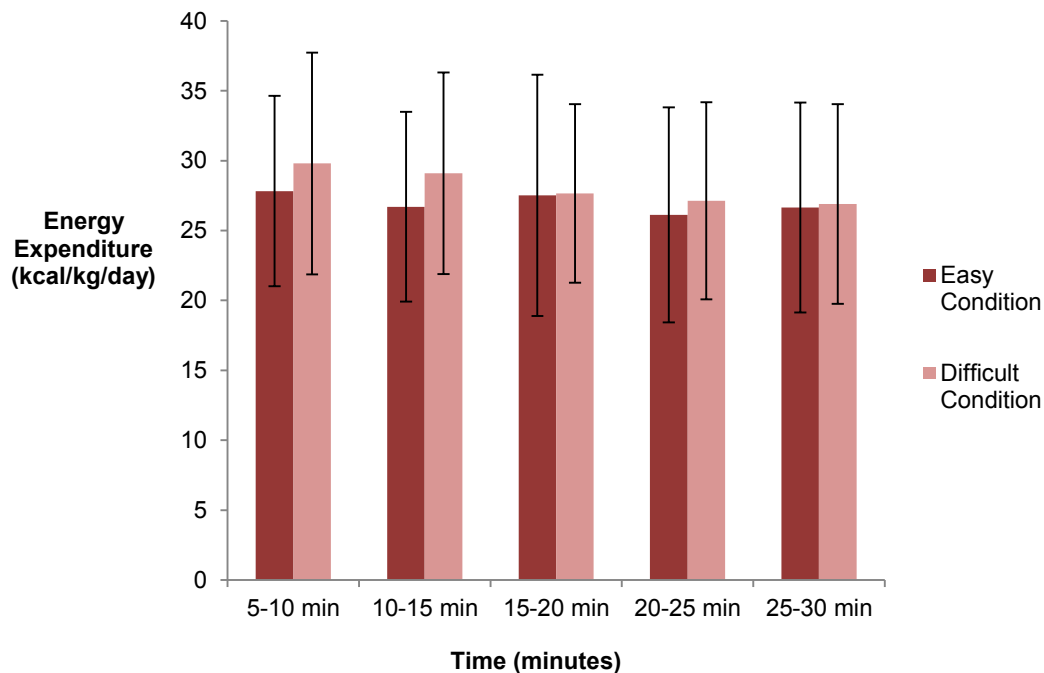


Figure 39: Energy expenditure from 10 minute to 30 minutes of testing duration for an easy and difficult condition of a driving simulator task.

Figure 39 shows the energy expenditure that was experienced throughout task duration. No differences were seen between the easy driving condition and the hard driving condition. Energy expenditure showed a statistically significant decrease over the 30 minutes of testing duration ($p < 0.01$).

Table XV: Analysis of variance of energy expenditure over task duration for an easy and a difficult condition for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.41	0.53
TIMES	4, 76	6.08	<0.01*
CONDITIONS*TIMES	4, 76	2.18	0.08

No statistically significant results were found for the objective input responses of breathing frequency and heart rate or heart rate variability time domain analysis (see Appendix C2).

Heart Rate Variability

Spectral Frequency Analysis

Spectral frequency analysis was additionally performed in order to provide understanding of parasympathetic and sympathetic nervous system activity associated with change in difficulty.

High Frequency – Center Frequency

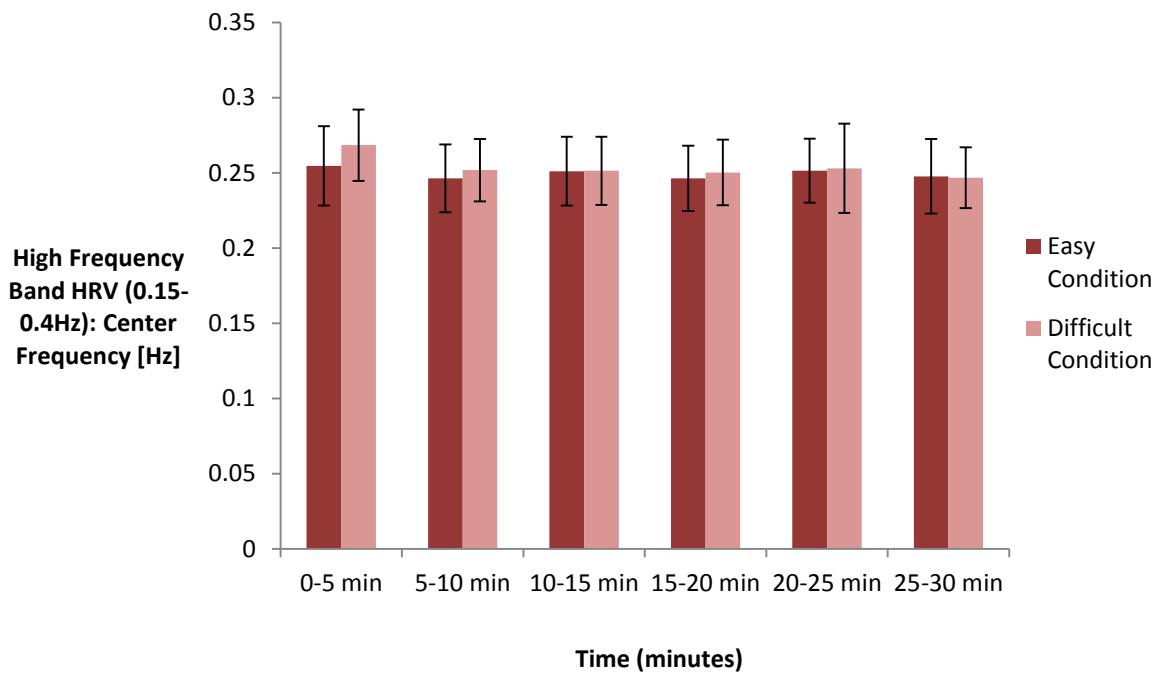


Figure 40: High frequency (center frequency) band heart rate variability over task duration for an easy and a difficult condition of a driving simulator task.

No statistical significant differences was found between the easy and the difficult condition ($p= 0.3$) (Table XVI). A statistically significant decrease over time was observed for the high frequency band heart rate variability (Hz) ($p< 0.1$).

Table XVI: Analysis of variance of high frequency band (center frequency) heart rate variability over task duration for an easy and a difficult condition for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.88	0.36
TIMES	5, 95	5.08	<0.01*
CONDITIONS*TIMES	5, 95	1.22	0.30

LF power relative to (LF+HF)

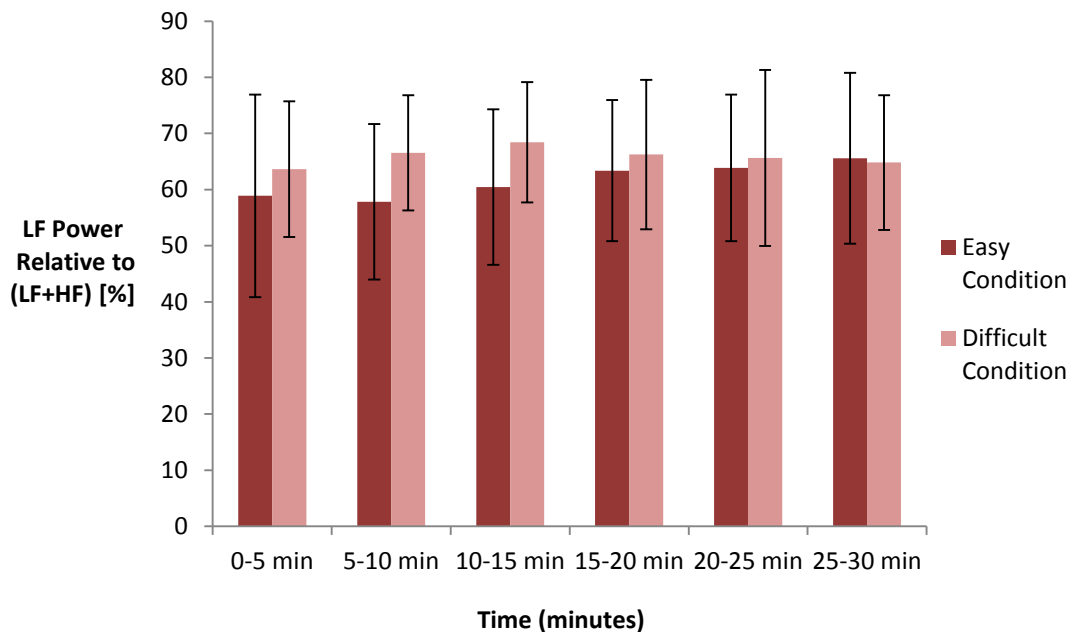


Figure 41: LF power relative to (LF+HF) heart rate variability over task duration for an easy and a difficult condition for a driving simulator task.

No statistical difference was found between conditions for LF/HF ratio. Furthermore, no statistically significant difference was found for the interactional effect of time on task and condition. A statistically significant increase ($p=0.03$) was however found over time (Table XVII) for the LF/HF ratio.

Table XVII: Analysis of variance of heart rate variability LF power relative to (LF+HF) over task duration for an easy and a difficult condition for a driving simulator task (*significance (p<0.05).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	2.00	0.17
TIMES	5, 95	2.51	0.04*
CONDITIONS*TIMES	5, 95	1.90	0.10

No further statistically significant differences were found for the remaining heart rate variability spectral frequency variables (see Appendix C2).

4.2.2. Cause of Aversion

The cause of aversion assessment was achieved through the analysis of subjective and objective efficiency. A multivariate analysis of subjective efficiency, aversion and rate of perceived exertion was assessed for both conditions of difficulty over the task duration. Additionally an analysis of variance was performed for objective efficiency, defined by objective output (performance) over objective input (effort), over duration for each condition.

Subjective Efficiency

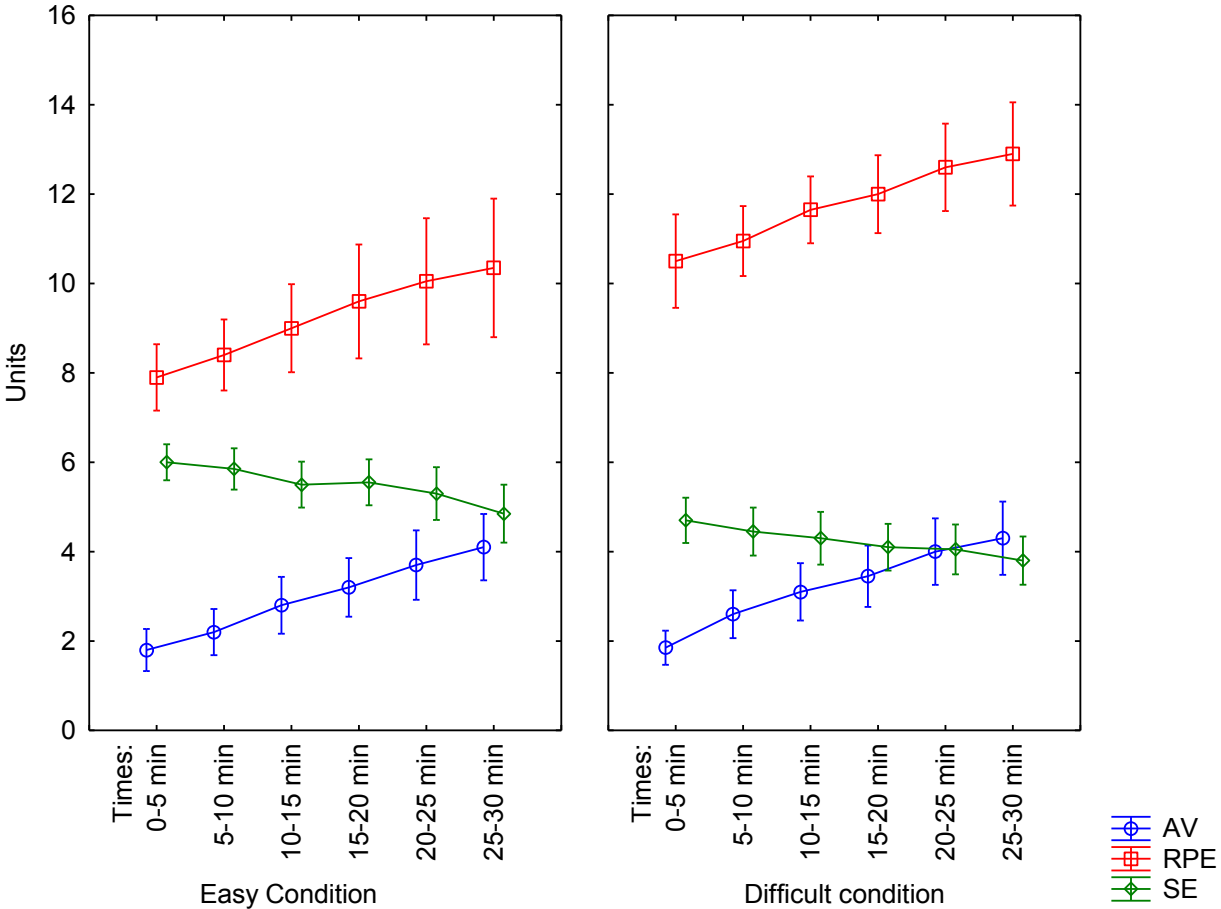


Figure 42: Subjective efficiency over task duration against aversion and rate of perceived exertion for all conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency).

Table XVIII: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (easy and difficult) over time (30 minutes) as factors (*significance $p < 0.05$).

	Degrees of Freedom	F	p
VARIABLE	2, 38	183.34	<0.01*
CONDITIONS	1, 19	7.42	0.01*
TIMES	5, 95	36.91	<0.01*
VARIABLE*CONDITIONS	2, 38	22.33	<0.01*
VARIABLE*TIMES	10, 190	19.81	<0.01*
CONDITIONS*TIMES	5, 95	0.27	0.93
VARIABLE*CONDITIONS*TIMES	10, 190	0.32	0.98

A statistically significant differences was found between conditions ($p=0.013$) such that for effect of condition, a difference in subjective efficiency was found for easy and difficult conditions. The easy condition had a higher starting and ending measure of subjective efficiency in comparison to the hard condition. Additionally, a statistically significant difference was found between the interaction effect of variables and conditions ($p < 0.01$). Statistically significant difference was found over time ($p < 0.01$) with an interactional statistically significant difference for variables and time ($p < 0.01$). With no interactional effect found for condition and time, and similarly, variable and conditions and time, the change over time is the same for easy and difficulty conditions.

Objective Efficiency

According to the objective measures of efficiency, which was assessed through the ratio of performance in mean deviation over effort (heart rate, heart rate variability, breathing frequency, and energy expenditure), there was found to be no statistically significant changes simultaneous for the easy and difficult condition.

4.2.3. Response to Hypothesis

The null hypothesis for the task difficulty investigation stated that there would be no statistically significant difference in aversion experienced between an easy and difficult driving simulator task condition. For the investigation into task difficulty as a possible factor influencing aversion, it can be observed that with the change imposed through a change in difficulty of the driving simulator task this had no effect on the aversion experienced to the task (Figure 35 and Table XI). Thus the null hypothesis cannot be rejected.

Similar to the cause of aversion hypothesis for the task cycles investigation, the null hypothesis stated that no statistically significant difference in efficiency, subjective or objective, would be found over time on task. Although a change in perceived efficiency was found (Figure 42 and table XVIII) for the task difficulty investigation, there was no change in the objective efficiency measured. Thus the alternate hypothesis is tentatively accepted for perceived efficiency and rejected for objectively measured efficiency.

4.4. INVESTIGATION 3 – PERFORMANCE FEEDBACK

To further provide understanding into the effects that varying factors have on the degree of aversion experienced when performing cognitive tasks, an assessment into the providing of knowledge of performance was undertaken. Two conditions were created such that the first condition, participants had no knowledge of performance and the second condition performance feedback was provided. Additionally analysis was performed on subjective and objective variables to ascertain whether this provision of performance had an effect. Secondly, to provide a possible explanation for the cause of aversion analysis of objective and subjective efficiency was assessed.

4.4.1. Factors Influencing Aversion

The following section will provide the graphical representation and analysis of variance for the conditions with performance feedback and without. Firstly, analysis of variance for aversion will be critically assessed between the two conditions over the duration of the task. Additional analysis of variance will be performed for the remaining subjective and objective measures over task duration between the two proposed conditions to further provide evidence into whether performance feedback elicits an effect on these variables. Objective analysis will look at the effect of performance over time for the conditions, followed similarly by the analysis of the objective input measures of breathing frequency, energy expenditure, heart rate and heart rate variability for the two conditions over task duration.

With the recording of subjective measures having occurred at 5 minute intervals, this provided the time interval analysis for all factors influencing aversion.

Subjective Measures

Aversion

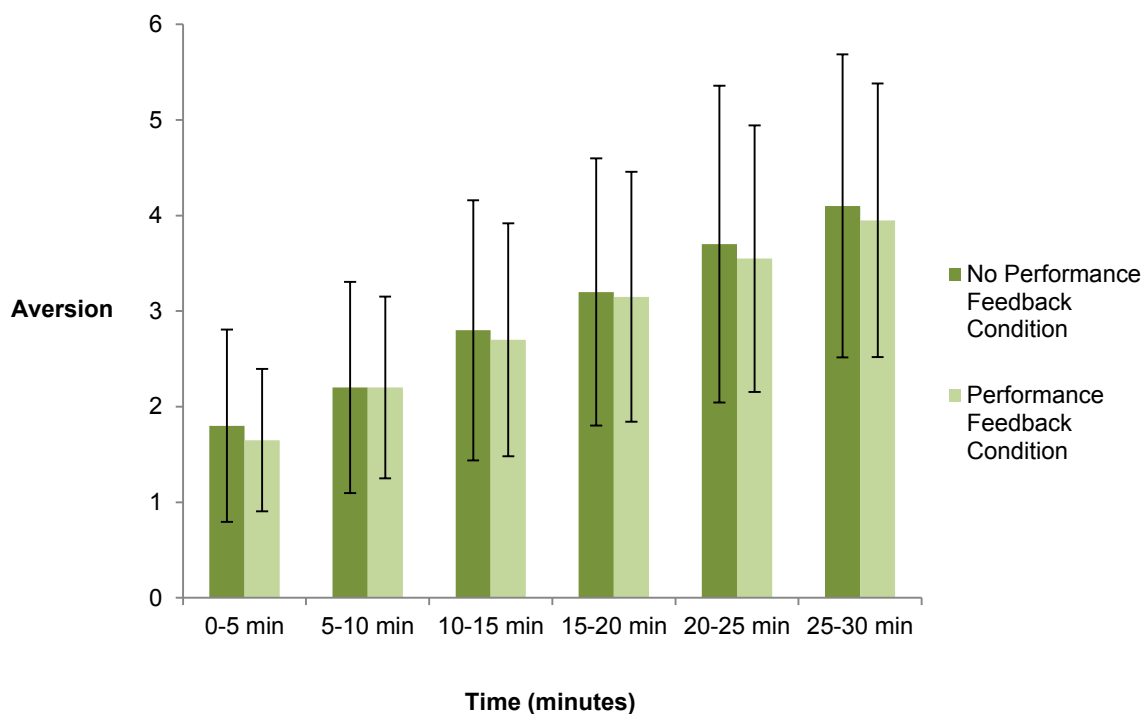


Figure 43: Change in aversion over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Task aversion was found to have a statistically significant increase throughout the duration of the task (Table XIX). Aversion was found to be similar for both conditions showing no statistically significant difference between the condition with performance feedback and the condition without.

Table XIX: Analysis of variance of aversion over task duration for conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.32	0.58
TIMES	5, 95	57.90	<0.01*
CONDITIONS*TIMES	5,95	0.24	0.95

Rate of Perceived Exertion

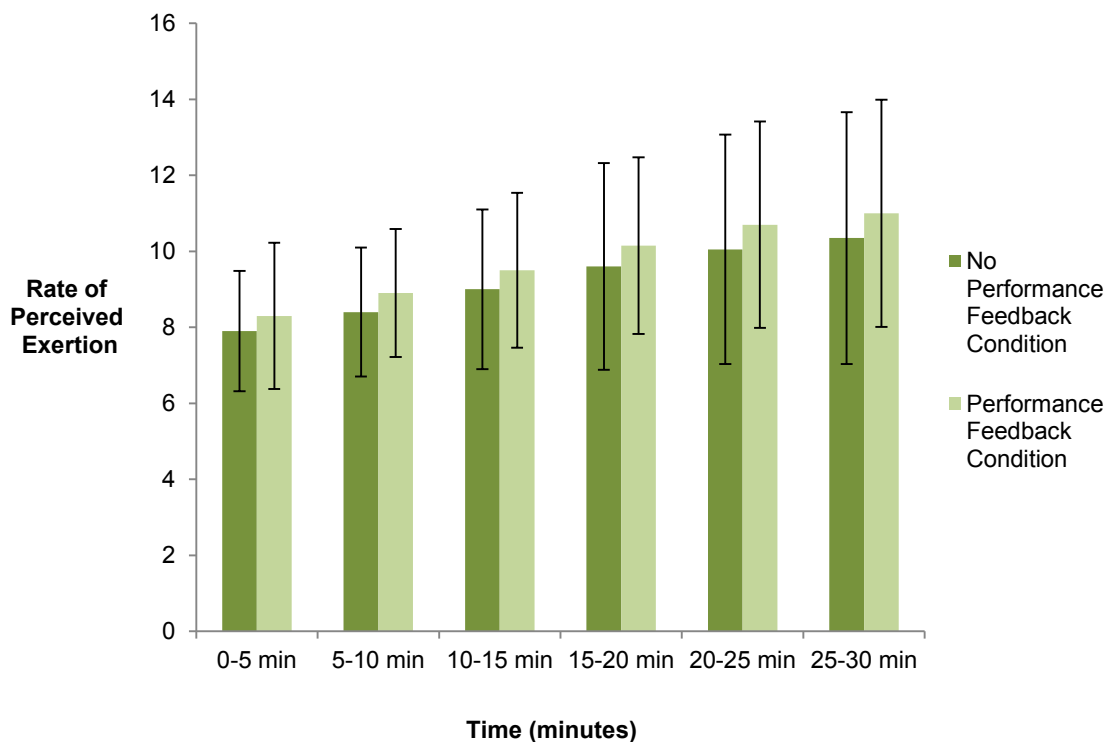


Figure 44: Change in rate of perceived exertion over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

A statistically significant increase was found over time for the analysis of rate of perceived exertion for the investigation into performance feedback. No additional statistically significant differences were found for this subjective variable.

Table XX: Analysis of variance of rate of perceived exertion over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	1.93	0.18
TIMES	5, 95	17.61	<0.01*
CONDITIONS*TIMES	5, 95	0.21	0.96

Subjective Efficiency

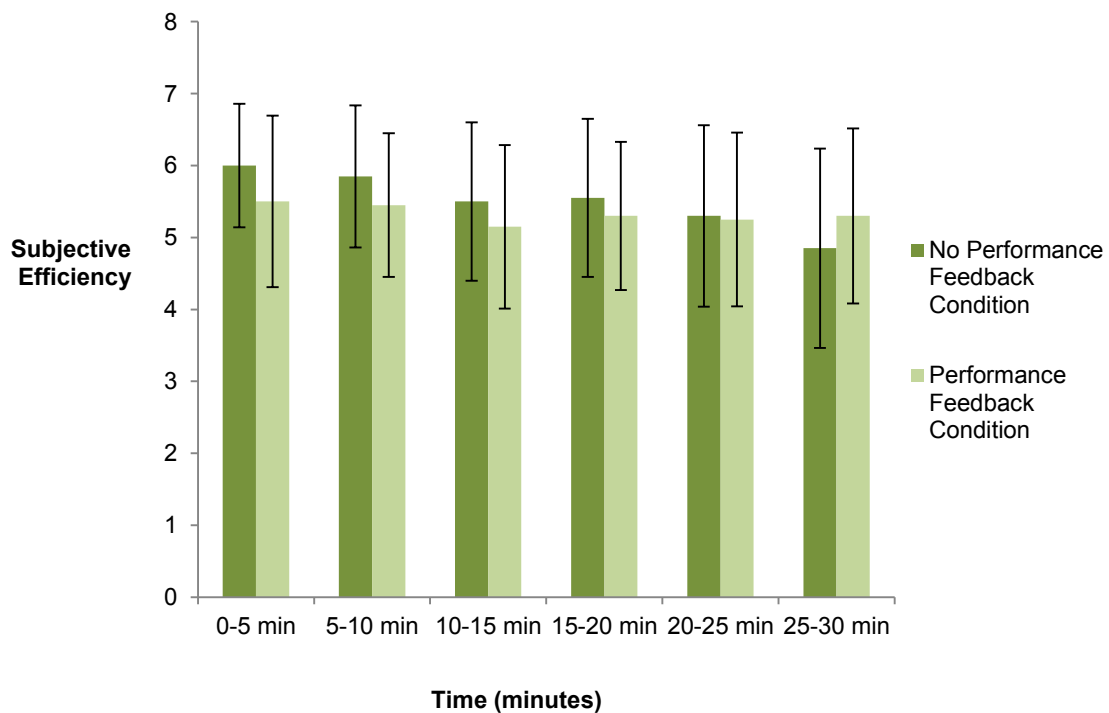


Figure 45: Change in subjective efficiency over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Subjective efficiency was seen to elicit no statistically significant results between the two condition ($p = 0.33$), therefore efficiency was perceived to be the same whether conditions had a feedback mechanism of performance or not. Over time subjective

efficiency was found to elicit a statistically significant decrease. ($p < 0.01$), moreover, there was found to be a statistically significant interaction effect between conditions and time ($p < 0.01$).

Table XXI: Analysis of variance of subjective efficiency over task duration for the conditions with no performance feedback and performance feedback of a driving simulator task (*significance $p < 0.05$)

	Degrees of Freedom	F	p
CONDITIONS	1, 19	1.00	0.33
TIMES	5, 95	5.82	<0.01*
CONDITIONS*TIMES	5, 95	3.48	<0.01*

Objective Output

Due to strong variations according to changes in the curvature of the street the initial output sample interval was set to 5 second to produce one output sample every 5 second.

Performance

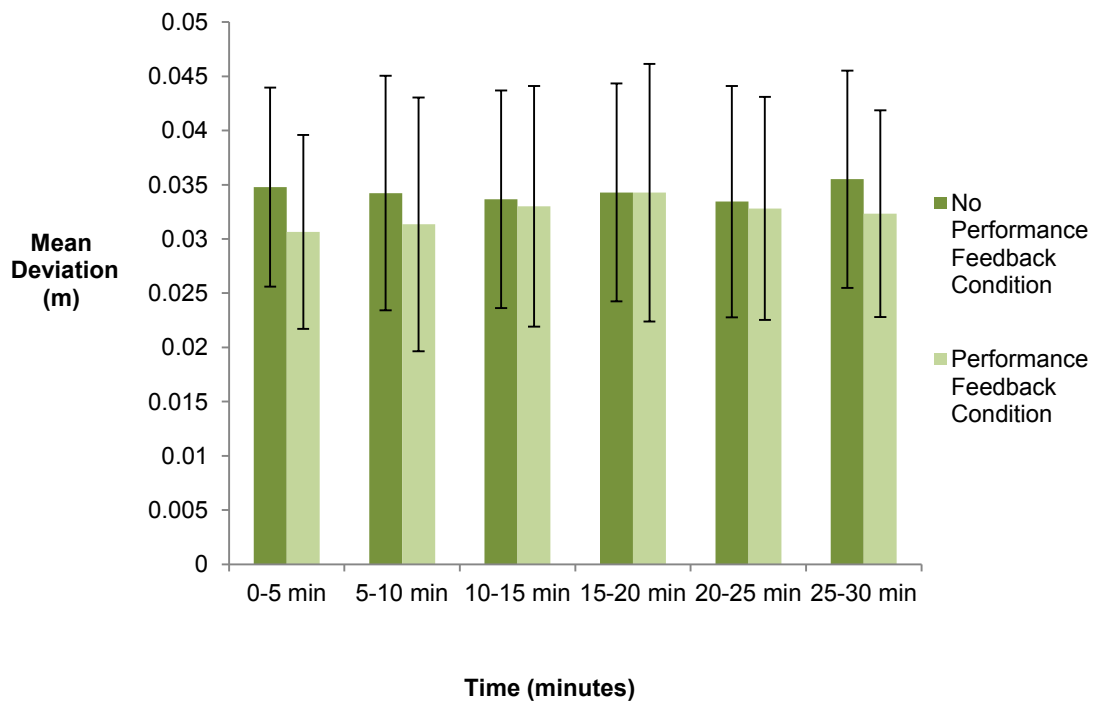


Figure 46: Change in mean deviation for performance over test duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Performance of the two conditions resulted in no statistically significant differences. Mean deviation between the two conditions performed showed no difference ($p= 0.33$), no difference was found over time on condition ($p= 0.18$) and moreover, no statistical difference was found for the interaction of time and condition ($p= 0.12$).

Table XXII: Analysis of variance of performance over task duration for the conditions with no performance feedback and performance feedback of a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.98	0.33
TIMES	5, 95	1.55	0.18
CONDITIONS*TIMES	5, 95	1.77	0.13

Objective Input

Similar to the investigations done prior to this, the first time interval was removed from analysis to assess the fluctuation in effort once a steady state had been achieved. Objective input was assessed to ascertain whether performance feedback elicited a difference in the effort invested into the task over task duration.

Energy Expenditure

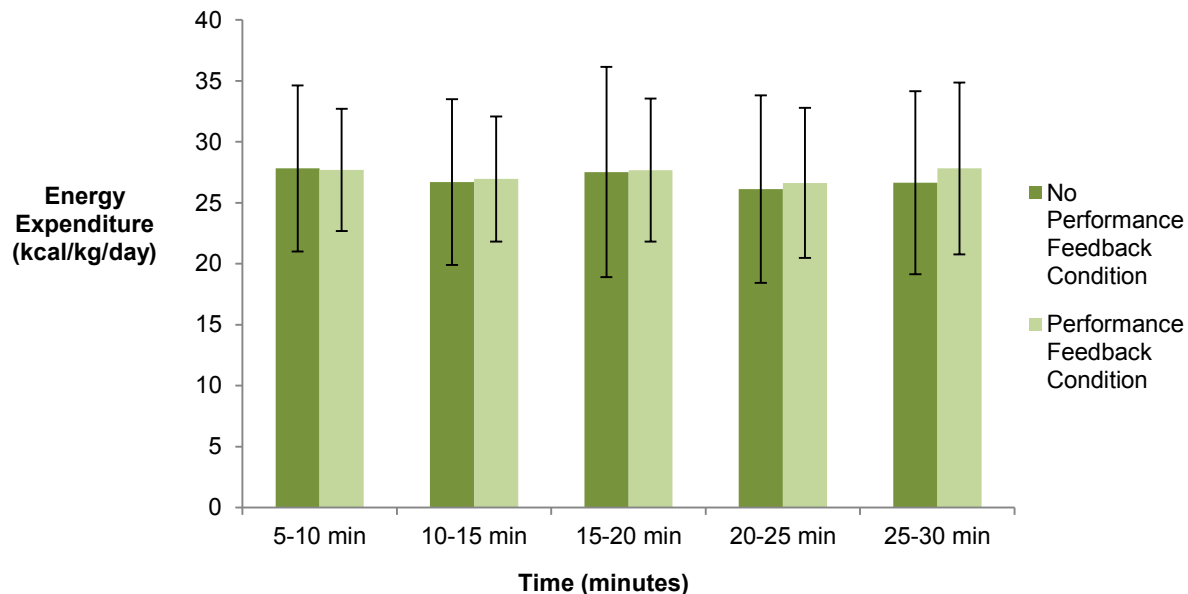


Figure 47: Change in energy expenditure from 10 minutes to 30 minutes of task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Energy expenditure showed a statistically significant decrease over task duration, implying that there was a decrease in kilo calories per kilograms per day over the testing duration ($p=0.03$).

Upon further analysis of the objective input variables of breathing frequency and heart rate, no statistical differences were found to support a difference between the two

conditions in a difference of breath per minute, or beats per minute over the testing duration.

Table XXIII: Analysis of variance of energy expenditure from 10 minutes to 30 minutes of task duration for the conditions with no performance feedback and performance feedback of a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.07	0.79
TIMES	4, 76	2.96	0.03*
CONDITIONS*TIMES	4, 76	0.73	0.57

Heart Rate Variability

Time domain analysis provided a further measure of mental effort invested into task performance, similar to heart rate, energy expenditure and breathing frequency. The spectral frequency analysis was performed to provide insight into the effect the two conditions imposed on the parasympathetic and sympathetic nervous system.

Time Domain Analysis

SDNN

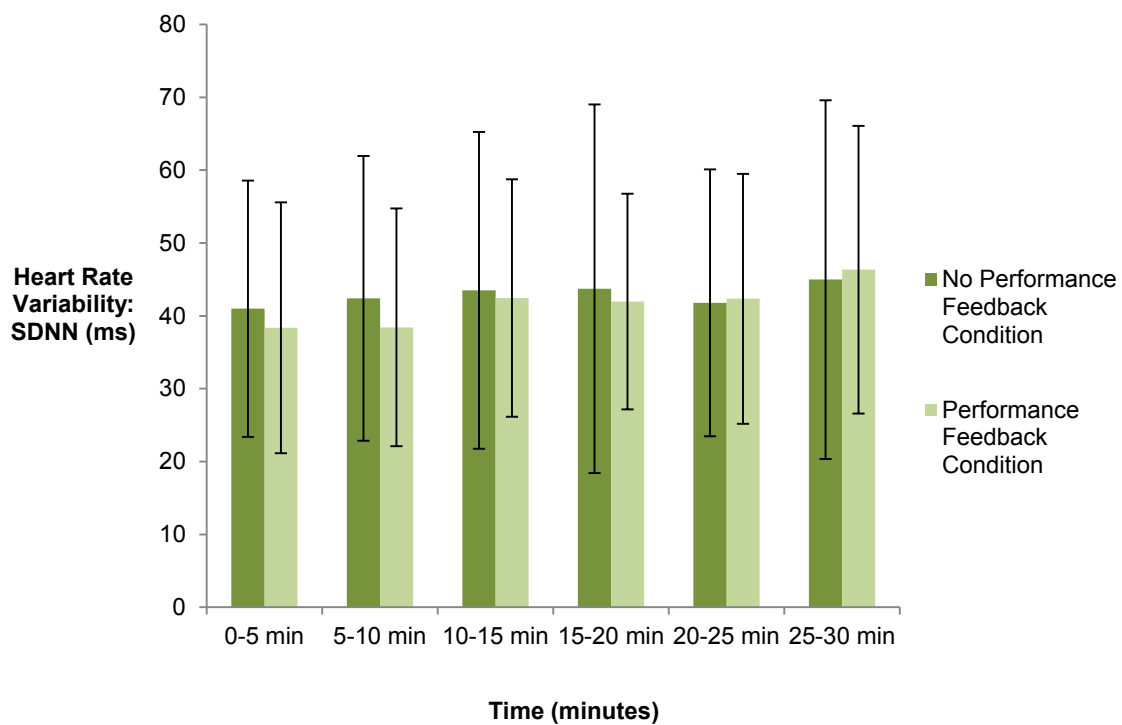


Figure 48: Heart rate variability SDNN over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Through analysis of variance it can be seen that there is a statistically significant increase for heart rate variability SDNN(ms) from the first 5 minute interval to the last (p= 0.02).

Table XXIV: Analysis of variance of heart rate variability SDNN over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.13	0.72
TIMES	5, 95	2.78	0.02*
CONDITIONS*TIMES	5, 95	0.68	0.64

rMSSD

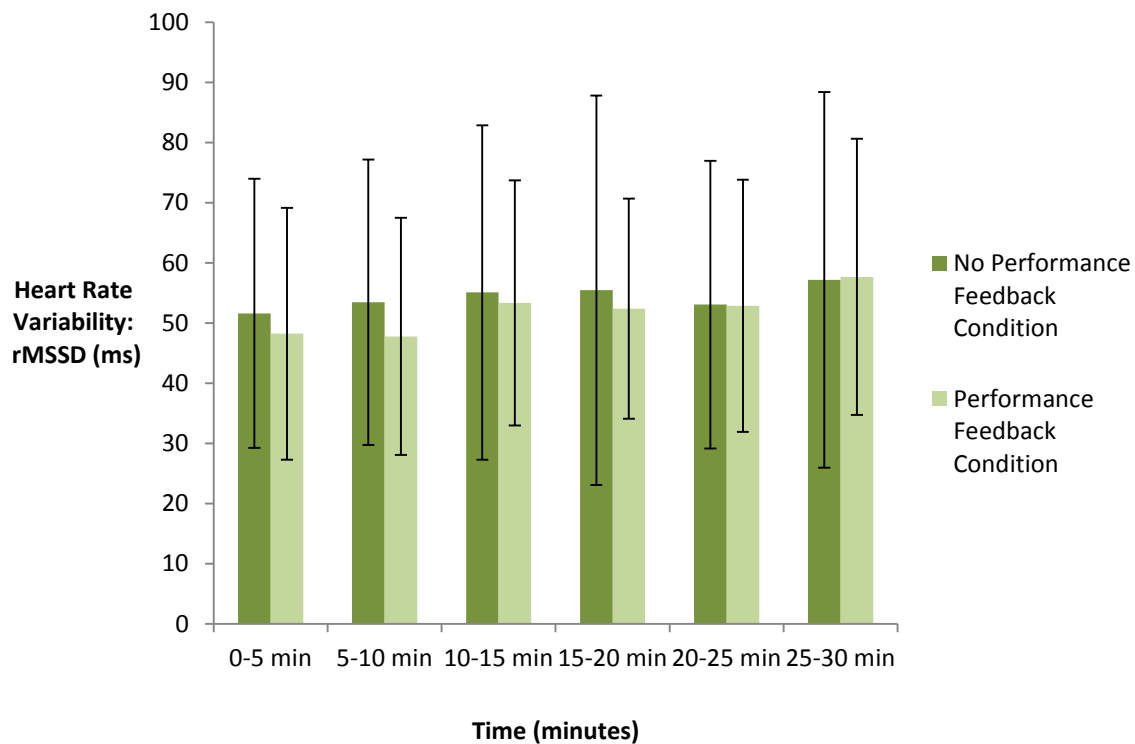


Figure 49: Heart rate variability rMSSD over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Similar to the results from the SDNN analysis of heart rate variability, it can be seen that a similar statistically significant increase for the rMSSD (ms) variable was found ($p = 0.02$).

Table XXV: Analysis of variance of heart rate variability rMSSD over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.27	0.61
TIMES	5, 95	2.98	0.02*
CONDITIONS*TIMES	5, 95	0.57	0.72

Spectral Frequency Analysis

High Frequency - Center Frequency

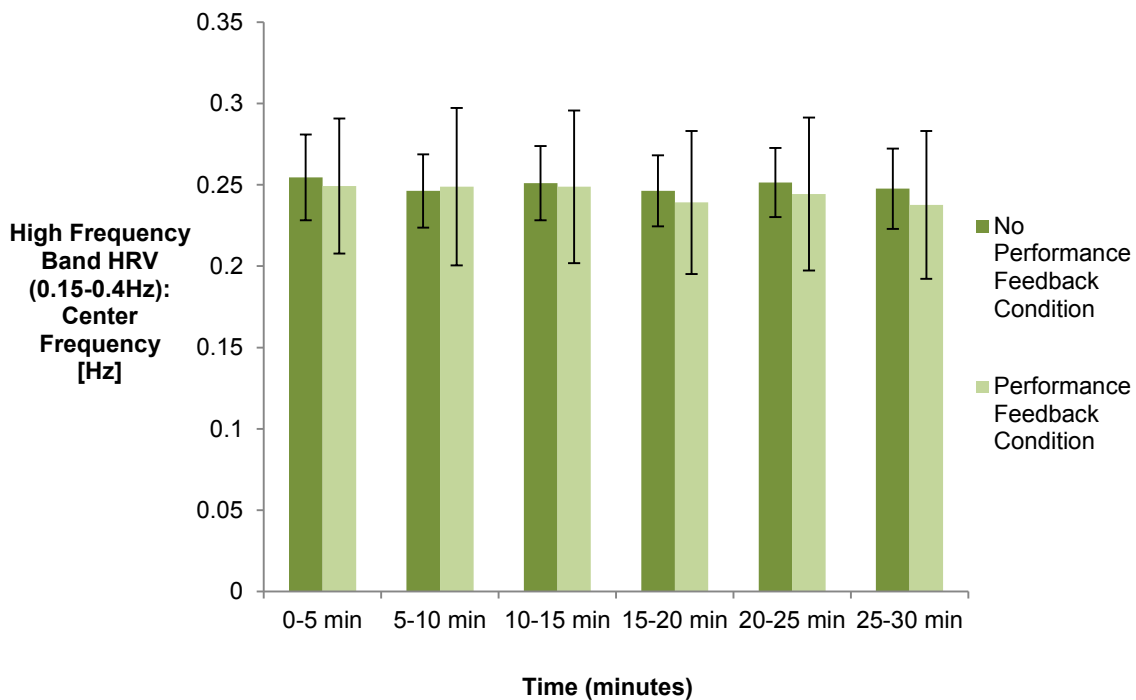


Figure 50: High frequency band heart rate variability (center frequency) over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task.

Analysis of variance of the high frequency band shows only a statistically significant decrease present over time ($p= 0.01$).

Table XXVI: Analysis of variance of high frequency band heart rate variability (center frequency) for the conditions with no performance feedback and performance feedback (*significance $p<0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.34	0.57
TIMES	5, 95	3.01	0.01*
CONDITIONS*TIMES	5, 95	0.96	0.45

Low Frequency - Power

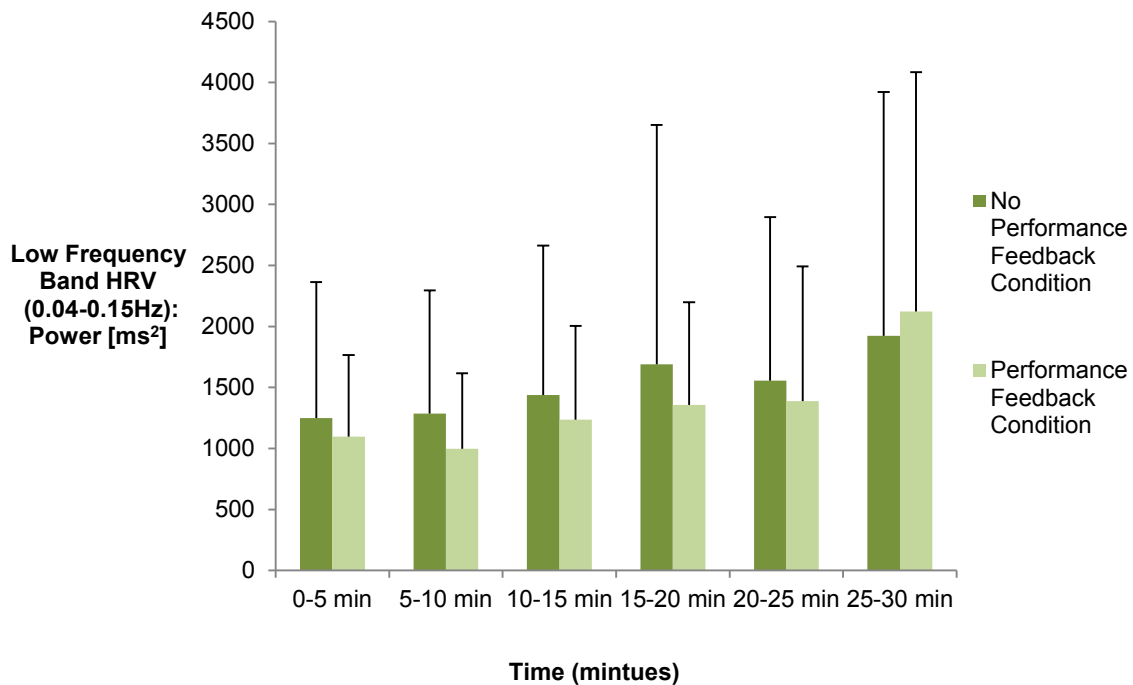


Figure 51: Low frequency band heart rate variability (power) over task duration for conditions with no performance feedback and performance feedback for a driving simulator task.

With regards to the low frequency band heart rate variability (power) (Figure 51) a statistically significant increase trend was found and can be observed from the data displayed.

Table XXVII: Analysis of variance of low frequency band heart rate variability (power) over task duration for conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.40	0.53
TIMES	5, 95	5.03	<0.01*
CONDITIONS*TIMES	5, 95	0.58	0.72

LF power relative to (LF+HF)

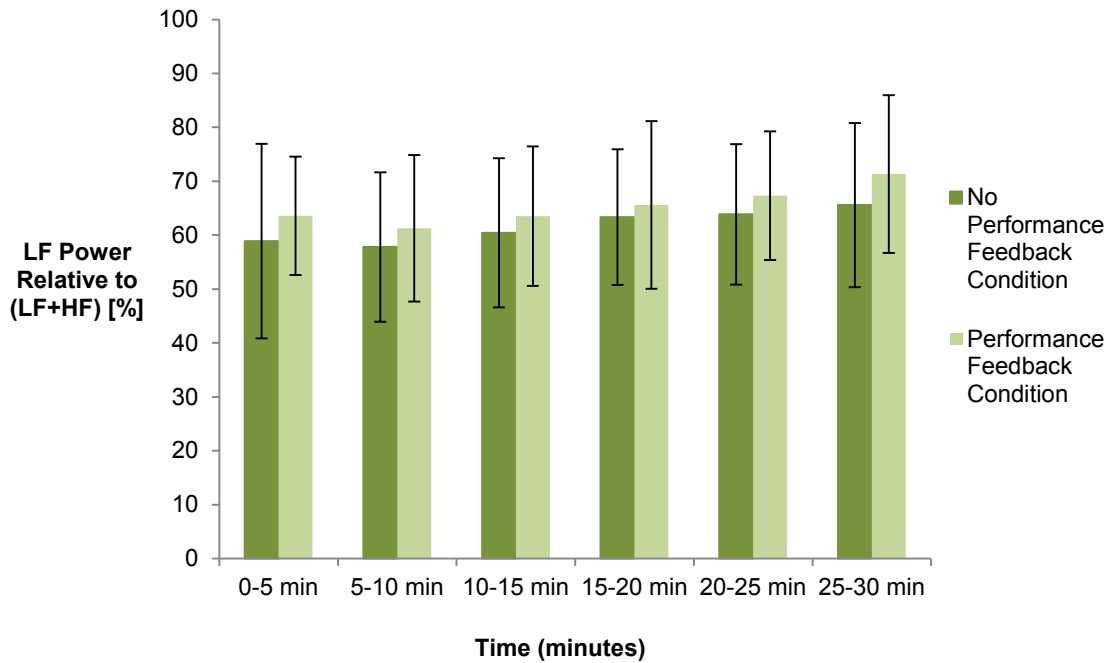


Figure 52: LF power relative to (LF+HF) heart rate variability over task duration for conditions with no performance feedback and performance feedback for a driving simulator task.

For the ratio of LF/HF for heart rate variability a statistically significant increase was found over time ($p < 0.01$) (Table XXVIII). No additional statistically significant differences were found.

Table XXVIII: Analysis of variance of heart rate variability LF power relative to (LF+HF) over task duration for the conditions with no performance feedback and performance feedback for a driving simulator task (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	1, 19	1.68	0.21
TIMES	5, 95	7.45	<0.01*
CONDITIONS*TIMES	5, 95	0.25	0.94

The remaining time domain and spectral frequency variables of heart rate variability were found to result in no statistically significant differences, thus they were not presented in this section (see Appendix C3).

4.4.2. Cause of Aversion

The cause of aversion investigation was achieved through the assessment of subjective and objective efficiency. Perceived efficiency was assessed through a multivariate analysis against aversion and rate of perceived exertion over task duration for both the condition with performance feedback and the condition without performance feedback. Objective efficiency was assessed through the likelihood method such that efficiency was calculated as performance over resources, in this instance, objective input measures.

Subjective Efficiency

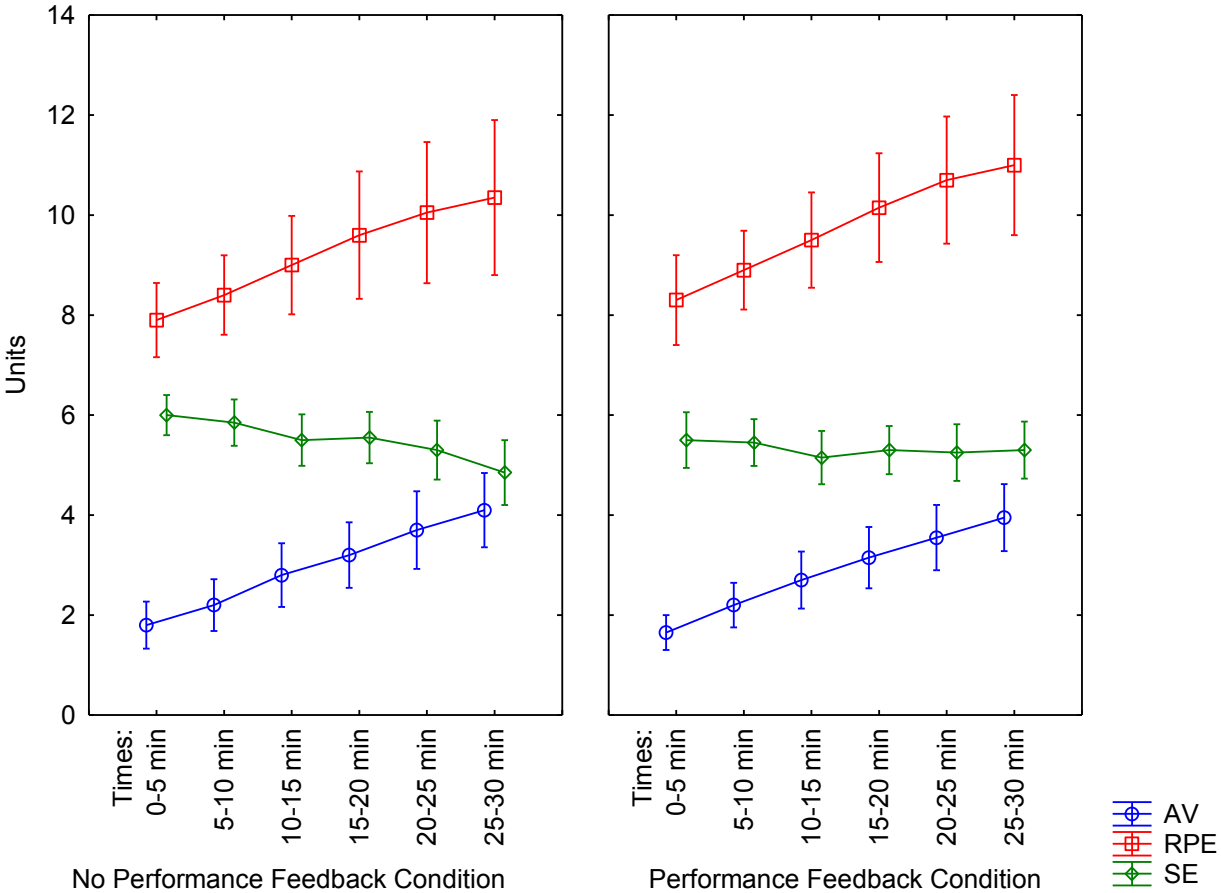


Figure 53: Subjective efficiency over task duration against aversion and rate of perceived exertion for all conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency).

For subjective efficiency observed in figure 53, the condition with no performance feedback was seen to be a greater decrease over time, with the condition with performance feedback showing a slight decrease and stabilization in subjective efficiency. Aversion for both conditions displayed similar difference over the task duration

Table XXIX: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (no performance feedback and performance feedback) and time (30 minutes) as factors (*significance $p < 0.05$).

	Degrees of Freedom	F	p
VARIABLE	2, 38	105.56	<0.01*
CONDITIONS	1, 19	0.94	0.34
TIMES	5, 95	23.27	<0.01*
VARIABLE*CONDITIONS	2, 38	1.71	0.19
VARIABLE*TIMES	10, 190	23.52	<0.01*
CONDITIONS*TIMES	5, 95	5.86	<0.01*
VARIABLE*CONDITIONS*TIMES	10, 190	5.36	<0.01*

The multivariate analysis produces statistically significant effects for time, the interaction of variables and time, the interaction of conditions and time and furthermore an interaction for variables and conditions and time.

Objective Efficiency

Through analysis of the objective efficiency data, there was found to be no statistically significant differences for objective output over all the combinations of objective input (breathing frequency, energy expenditure heart rate and heart rate variability) variables across the conditions with performance feedback and without performance feedback simultaneously (see Appendix C3).

4.4.3. Response to Hypothesis

For the performance feedback investigation, the null hypothesis stated that no statistically significant differences would be found between a condition with feedback of performance and a condition without feedback of performance. According to the factor influencing aversion hypothesis, it was anticipated that through the provision of performance feedback to participants when performing a driving simulator task that

there would be a change in the aversion experienced. From the results (Figure 43 and Table XIX) it is evident that the provision of performance had no effect on this willingness to continue the task. Therefore, for the investigation into performance feedback the null hypothesis cannot be rejected.

The null hypothesis for the cause of aversion stated that there would be no statistically significant difference over time for objective and perceived efficiency. The hypothesis into a possible cause of aversion stated that an increased aversion would be attributed to a decrease in efficiency to a task. No statistically significant change was found for the objective efficiency analysis of the cause of aversion, although a statistically significant decrease was found for perceived efficiency (Table XXIX and Figure 53). Thus the alternate hypothesis is rejected for objectively measured efficiency and tentatively accepted for perceived efficiency.

4.5. INVESTIGATION 4 – TASK ALTERNATION

Investigation 4 was the proposed assessment of the effect that alternations between two tasks imposed on aversion experienced. Thus it was hypothesized that conditions with alternations between two tasks would result in a lower aversion experienced in comparison to conditions where no alternations were present. This established the conditions for this investigation such that the first two conditions were conditions with no alternations and would be an evaluation of the two tasks chosen: choice reaction task condition and driving simulator task condition. Two more conditions were established that had alternations imposed between the two tasks and these conditions varied in the frequency at which these alternations occurred, thus: medium alternation condition and a fast alternation conditions.

4.5.1. Factors Influencing Aversion

Analysis of variance was performed on all variables to provide statistical evidence for changes between conditions and for changes in conditions over time to assess whether the presence of alternations elicited a change in aversion and all subjective and objective variables. Additionally, a Tukey post hoc analysis was performed on the last time interval for each variable in order to ascertain which conditions showed the greatest statistically significant difference. The analysis of variance for subjective measures will firstly be assessed followed by the analysis of variance for the objective output in the form of performance and objective input (breathing frequency, energy expenditure, heart rate and heart rate variability). Heart rate variability was assessed through time domain analysis and further through spectral frequency analysis.

Subjective Measures

Aversion

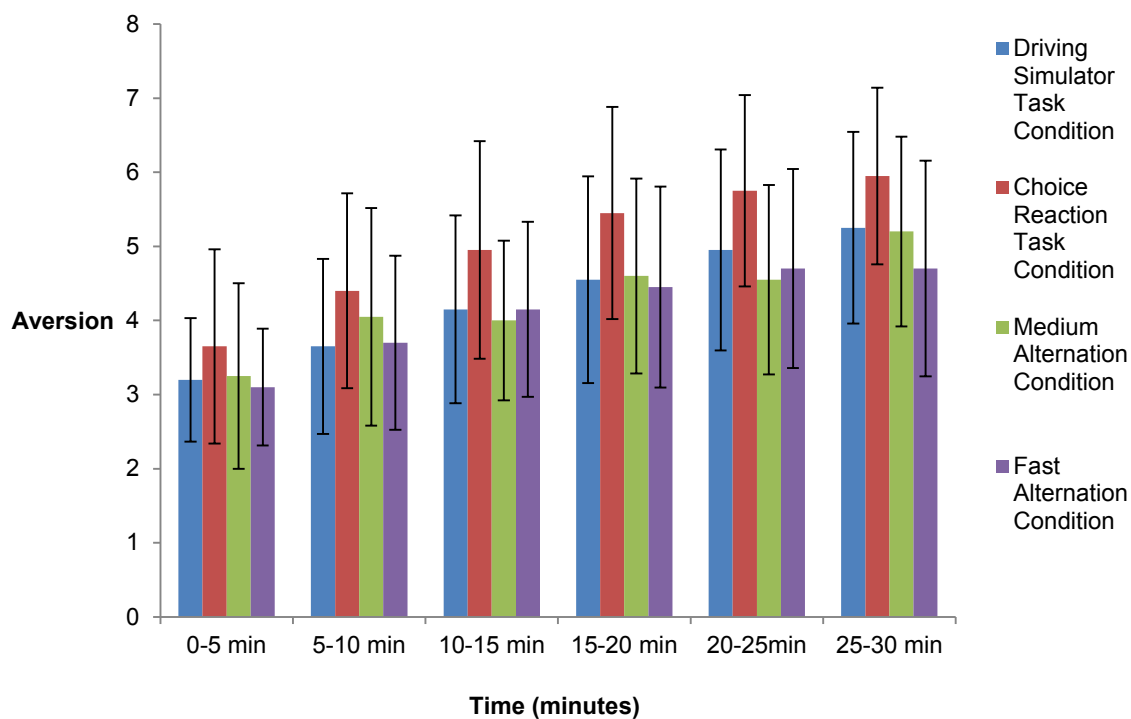


Figure 54: Aversion over task duration for all conditions of the task alternation investigation.

According to the analysis of variance no statistical significance found for the interaction effect of condition and time. A statistically significant increase for aversion was statistically supported such that $p < 0.01$. From figure 54 it can be seen that the slow choice condition resulted in an exaggerated aversion in comparison to the other conditions. According to the analysis done, there was found to be a statistically significant difference identified between conditions ($p < 0.01$). The Tukey post hoc analysis done further provides evidence for that, such that the slow choice condition was statistically significantly different to the medium alternation condition ($p = 0.048$) and the fast alternation condition ($p < 0.01$). Although a difference can be visually seen

between the slow choice condition and the slow driving condition, no statistical difference was found (Table XXX and Table XXXI).

Table XXX: Analysis of variance for aversion over task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	9.95	<0.01*
TIMES	5, 95	86.64	<0.01*
CONDITIONS*TIMES	15, 285	1.37	0.16

Table XXXI: Tukey post hoc analysis for aversion over task duration for the last time interval of all alternation conditions of the task alternation investigation (*significance $p < 0.05$).

	CONDITIONS	{1} - 5.9500	{2} - 5.2500	{3} - 5.2000	{4} - 4.7000
1	Slow Choice 6 Ave		0.07	0.05*	<0.01*
2	Slow Drive 6 Ave	0.07		0.99	0.22
3	Medium 6 Ave	0.05*	0.99		0.30
4	Fast 6 Ave	<0.01*	0.22	0.30	

Rate of Perceived Exertion

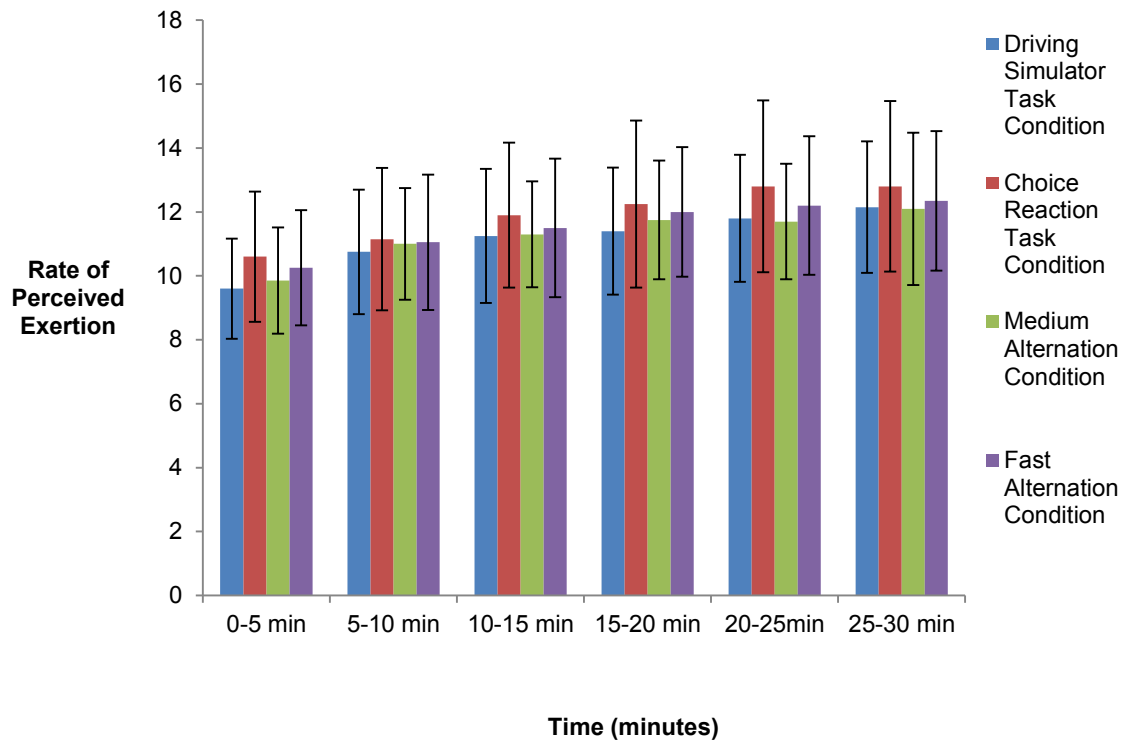


Figure 55: Rate of perceived exertion over task duration for all alternation conditions of the task alternation investigation.

From figure 55 it can be noticed that there is a statistically significant increase for all conditions over the task duration ($p < 0.01$). Tukey post hoc analysis further support this by showing no statistically significant differences found for the last minute analysis between conditions.

Table XXXII: Analysis of variance of rate of perceived exertion over task duration for all alternation conditions in the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	2.24	0.09
TIMES	5, 95	27.71	<0.01*
CONDITIONS*TIMES	15, 285	0.56	0.91

Subjective Efficiency

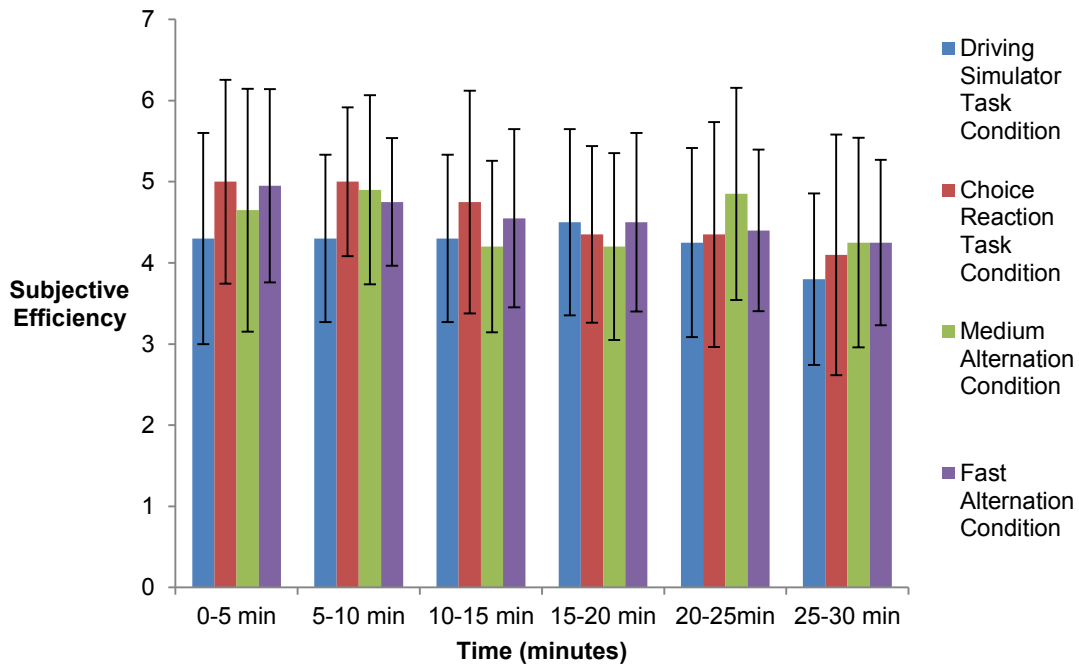


Figure 56: Subjective efficiency over task duration for all alternation conditions for the task alternation investigation.

Over time it was found that there was a statistically significant decrease in the subjective efficiency experienced ($p < 0.01$). Figure 56 showing the developments for subjective efficiency displays the changes over time which resulted in a statistically significant difference experienced for the interaction of conditions and time ($p = 0.012$).

Table XXXIII: Analysis of variance of subjective efficiency over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	2.48	0.07
TIMES	5, 95	3.61	<0.01*
CONDITIONS*TIMES	15, 285	2.05	0.01*

Objective Output

Performance

For the choice reaction task, with regards to analysis, response times of greater than 10 seconds were not included in analysis to account for when subjective responses were given, which incurred responses of greater than 10 seconds.

Similar to the task difficulty and performance feedback investigations for the driving simulator task analysis, initial output sample interval was set to 5 second in order to produce one output sample every 5 seconds. This was set in order to avoid strong variations due to changes in the curvature of the street.

Furthermore, as data was measured against the varying alternation conditions (slow choice reaction task, slow driving task, medium and fast alternation) performance data was reduced and graphically displayed as relative data. Individual performance was relativized against the mean deviation for the driving task, or mean reaction time for the choice reaction task, over the duration of the task. This was in order to facilitate for the changes between and within conditions as the driving task produced results of mean deviation (m) and the choice reaction task produced performance results as mean reaction time (ms). Individual performance over time was thus considered as a 100th percentage for accuracy of deviation and reaction time allowing for variance within the tasks to be minimized and individual intervals were measured against this.

Objective measures were recorded continuously throughout the testing duration. Data was graphically displayed according to the timing of the fast interval alternations – thus data was averaged over 3 minute 20 second intervals in order to provide the same intervals for all four of the testing conditions for all objective variables (performance, breathing frequency, energy expenditure, heart rate and heart rate variability).

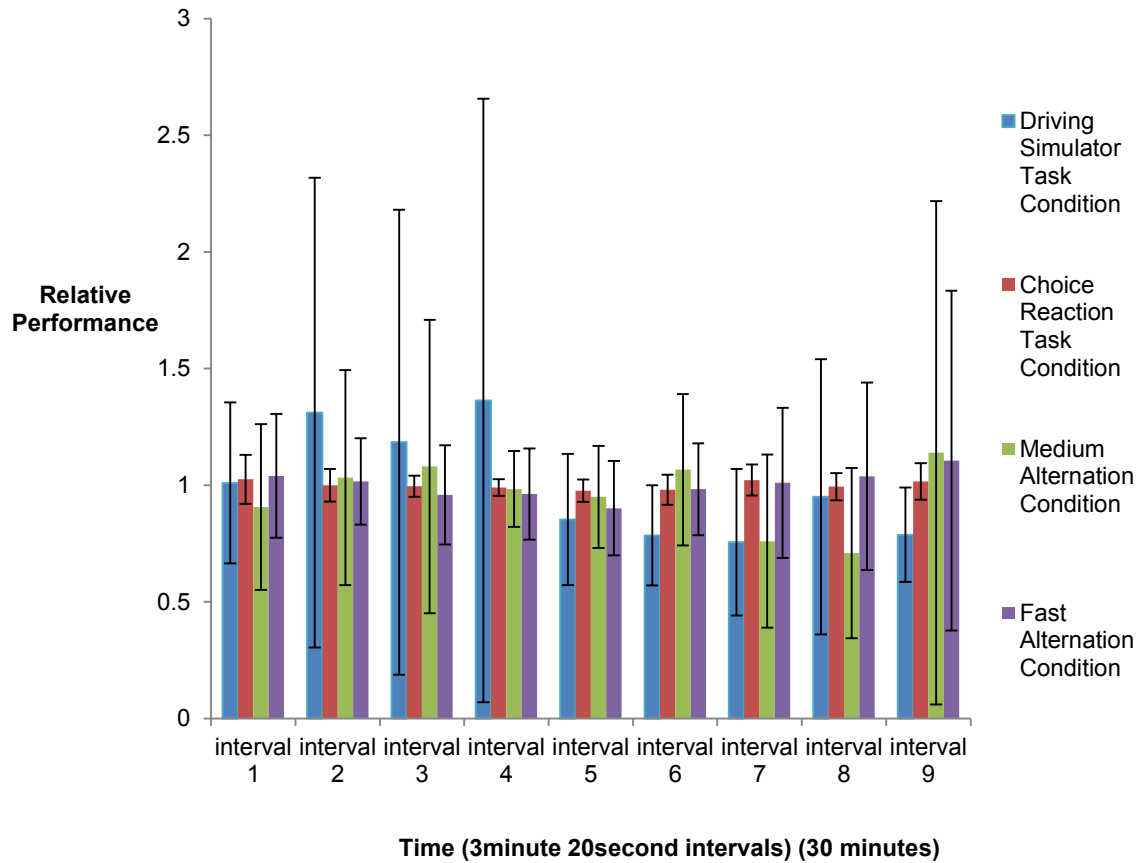


Figure 57: Relative performance over task duration for alternation conditions of the task alternation investigation.

Performance results for all conditions show no statistical difference between conditions. A statistically significant difference was found for the interaction effect of conditions and time ($p=0.02$). No further significance was found for conditions over time.

Table XXXIV: Analysis of variance of relative performance over task duration for all alternation conditions of the task alternation investigation (*significance $p<0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	1.77	0.16
TIMES	8, 152	1.59	0.13
CONDITIONS*TIMES	24, 456	1.69	0.02*

Objective Input

Objective input for the task alternation investigation was similar to the investigations done prior to this, such that, analysis was performed once a steady state had already been achieved. Therefore, for objective input measures (except for heart rate variability), the first two time intervals of 3 minutes and 20 seconds were removed from the analysis of variance.

Breathing Frequency

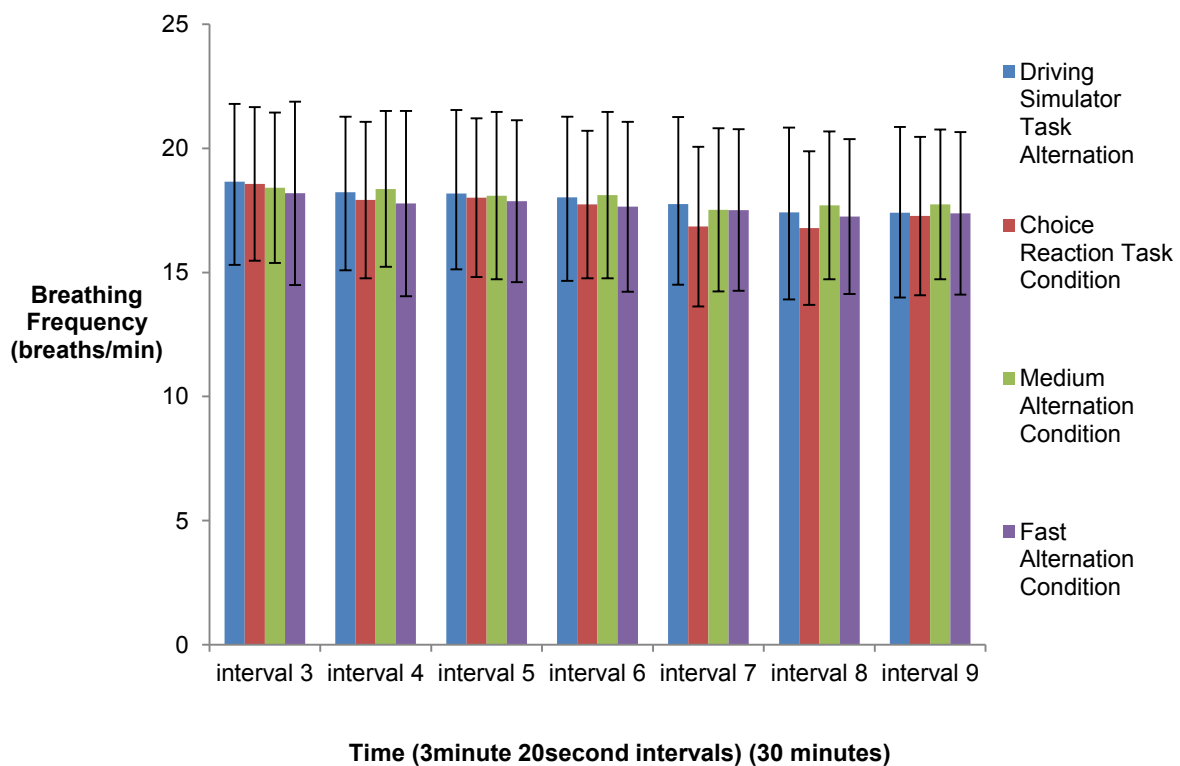


Figure 58: Breathing frequency from 10 minutes to 30 minutes of task duration for all alternation conditions of the task alternation condition.

Breathing frequency was the only physiological response found to show any statistical significance throughout the task alternation experiment. No statistically significant differences were obtained for both energy expenditure and heart rate. Figure 58

displays the statistically significant decrease found for breathing frequency over time ($p < 0.01$) (Table XXXV).

Table XXXV: Analysis of variance of breathing frequency from 10 minutes to 30 minutes of task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	0.42	0.74
TIMES	6, 114	16.42	<0.01*
CONDITIONS*TIMES	18, 342	1.03	0.43

Heart Rate Variability

As previously stated, heart rate variability provided a further analysis of the effort expended when performing the conditions for the task alternation investigation. This was assessed through analysis of variance for the time domain and spectral frequency variables

Time Domain Analysis

SDNN

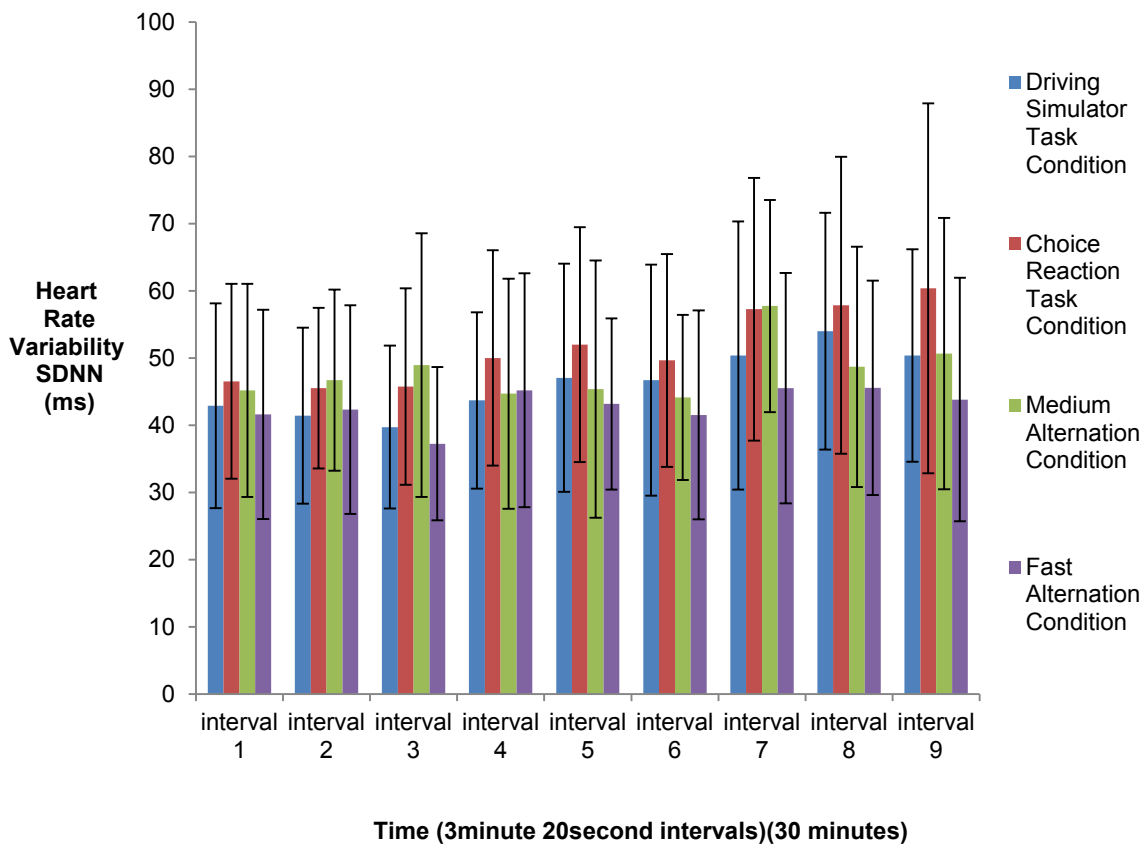


Figure 59: Heart rate variability SDNN over task duration for all alternation conditions for the task alternation investigation.

The figure above show the changes between alternation conditions and the changes over time experienced for heart rate variability SDNN (ms). The figure show that the highest recorded SDNN was found for the slow choice condition consistently throughout with the lowest recording for SDNN found in the fast condition. The difference in the interaction effect between conditions and time were supported by the analysis of variance showing a statistically significant difference found between conditions over time ($p < 0.01$). No statistical significance was found between conditions, however, a statistically significant difference was found in the post hoc analysis for the fast alternation condition (Table XXXVII). Figure 59 further displays an overall statistically significant increase experienced for all alternation conditions with statistical proof ($p < 0.01$).

Table XXXVI: Analysis of variance of SDNN heart rate variability over task duration for all alternation conditions of the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	2.56	0.06
TIMES	8, 152	12.20	<0.01*
CONDITIONS*TIMES	24, 456	2.22	<0.01*

Table XXXVII: Tukey post hoc analysis of the last time interval for SDNN heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	CONDITIONS	{1} - 60.392	{2} - 50.388	{3} - 50.649	{4} - 43.812
1	Slow Choice 9		0.21	0.23	<0.01*
2	Slow Drive 9	0.21		0.99	0.57
3	Medium 9	0.23	0.99		0.54
4	Fast 9	<0.01*	0.57	0.54	

rMSSD

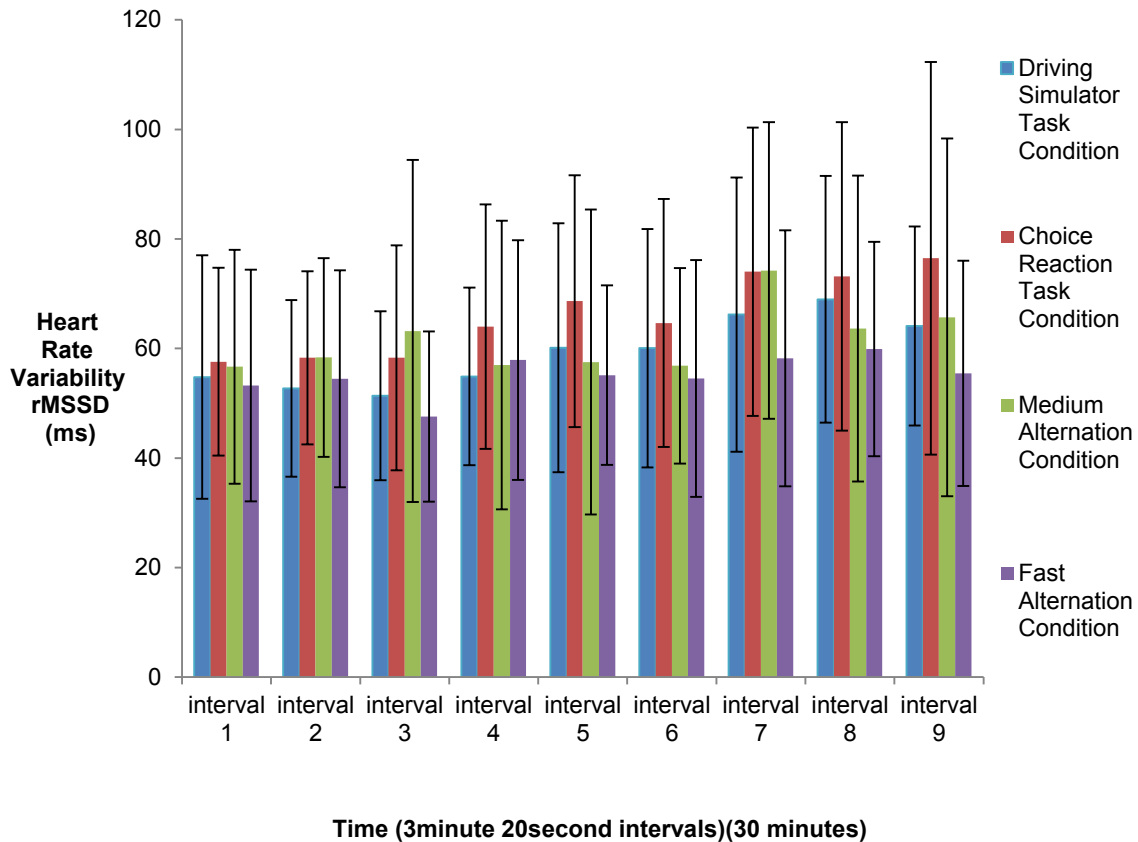


Figure 60: Heart rate variability rMSSD over task duration for all alternation conditions in the task alteration investigation.

According to figure 60, table XXXVIII and XXXIX, results for rMSSD were found to be similar to that of the SDNN heart rate variability. An exaggerated rMSSD (ms) was found for the slow choice condition consistently throughout with the lowest rMSSD (ms) found for the fast condition. This was statistically proven in the post hoc analysis such that the fast condition was found to be statistically significantly different to the remaining conditions ($p=0.03$) (Table XXXIX). The interaction effect of conditions and time were found to be statistically significant ($p<0.01$) and furthermore there was a statistically significant increase experienced over time for all conditions ($p<0.01$) (Table XXXVIII).

Table XXXVIII: Analysis of variance for rMSSD heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	1.65	0.18
TIMES	8, 152	11.45	<0.01*
CONDITIONS*TIMES	24, 456	2.05	<0.01*

Table XXXIX: Tukey post hoc analysis of the last time interval for rMSSD heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	CONDITIONS	{1} - 76.475	{2} - 64.094	{3} - 65.682	{4} - 55.475
1	Slow Choice 9		0.34	0.46	0.03*
2	Slow Drive 9	0.34		0.99	0.64
3	Medium 9	0.46	0.99		0.51
4	Fast 9	0.03*	0.64	0.51	

PNN50

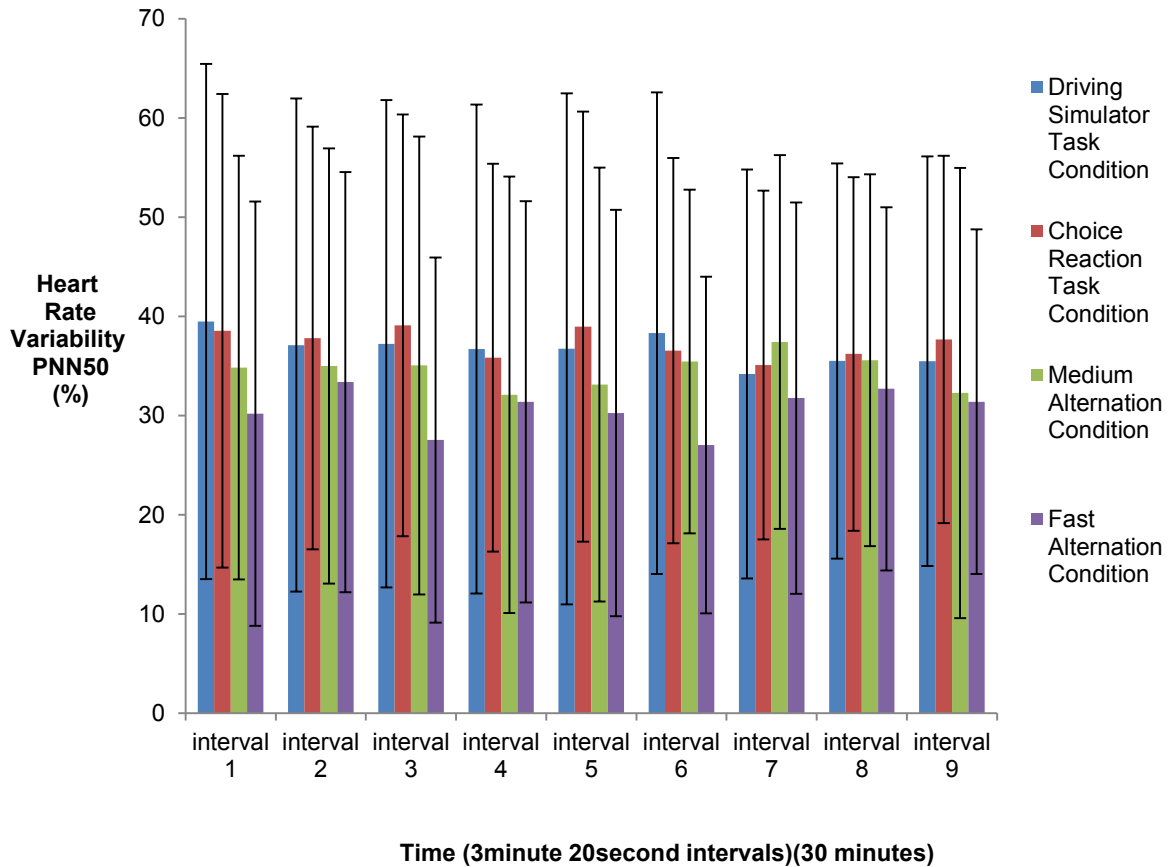


Figure 61: Heart rate variability PNN50 over task duration for all alternation conditions of the task alternation investigation.

Results for PNN50 (%) heart rate variability produced no statistically significant results for condition, such that all alternation conditions has similar PNN50 measures. Furthermore, there was found to be no statistically significant increase or decrease over time experienced (Figure 61; and Table XL). Statistically significant difference was however found for the interaction of conditions and time.

Table XL: Analysis of variance of PNN50 heart rate variability over task duration for all alternation conditions of the task alteration investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	0.85	0.47
TIMES	8, 152	0.60	0.77
CONDITIONS*TIMES	24, 456	1.69	0.02*

PNN30

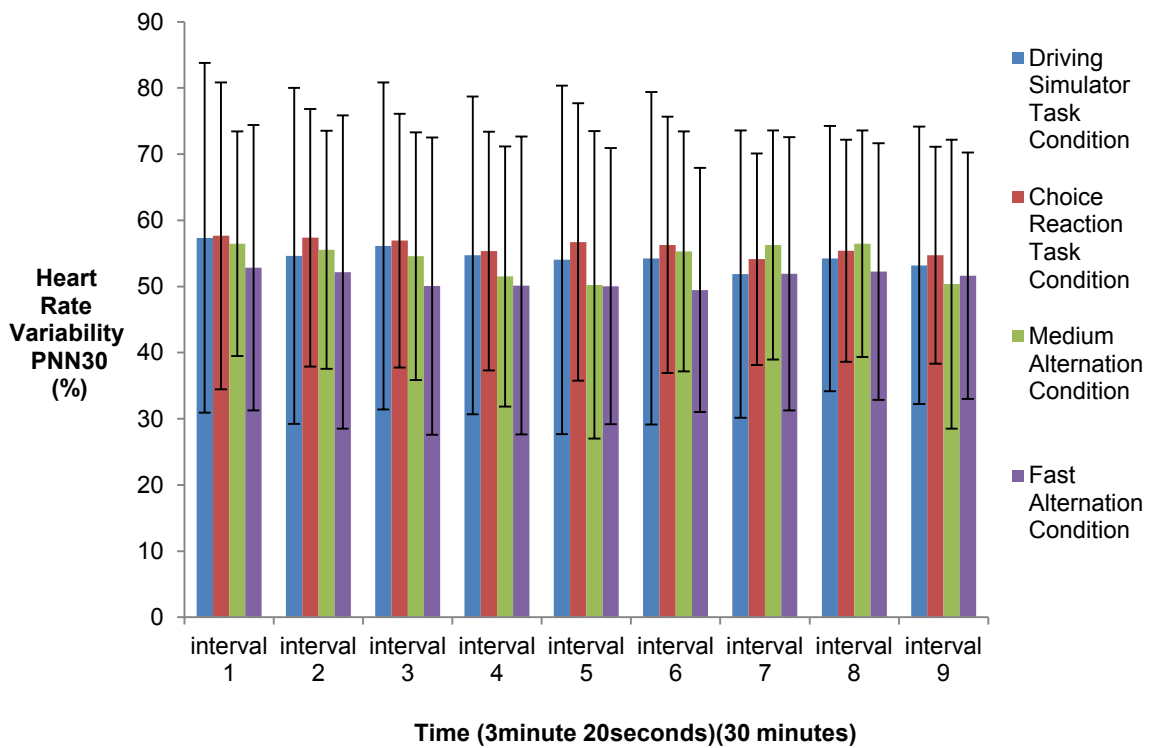


Figure 62: Heart rate variability PNN30 over task duration for all alternation conditions in the task alteration investigation.

It can be observed in figure 62 that an overall statistically significant decrease was found for all alternation conditions. Post hoc analysis on the last time interval did not

further produce any results to satisfy a statistically significant difference between the alternation conditions.

Table XLI: Analysis of variance of PNN30 heart rate variability over task duration for all alternation conditions in the task alternation investigation.

	Degrees of Freedom	F	p
CONDITIONS	3, 57	0.35	0.79
TIMES	8, 152	2.21	0.03*
CONDITIONS*TIMES	24, 456	1.17	0.26

Spectral Frequency Analysis

Low Frequency - Center Frequency

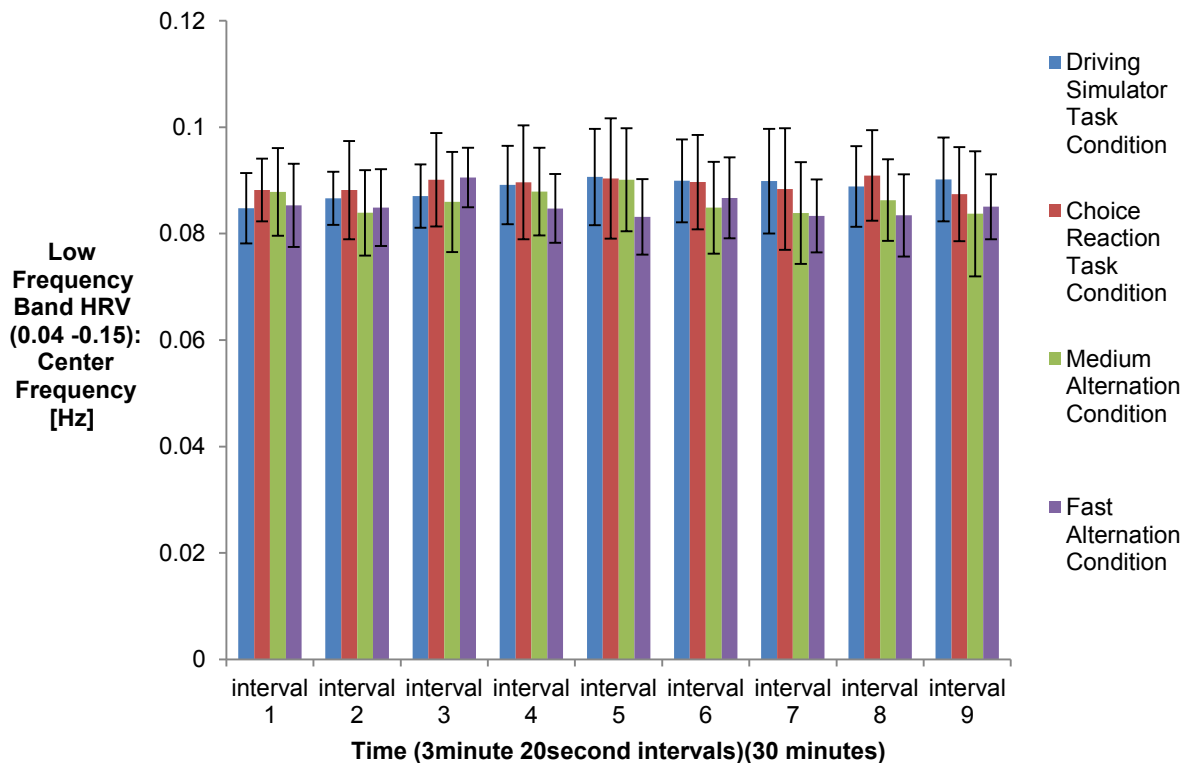


Figure 63: Low frequency band heart rate variability (center frequency) for all alternation conditions for the task alternation investigation.

From table XLII it can be seen that the low frequency center frequency results produced statistically significant differences for all the intended analyzes. Statistical significance was found over time for the low frequency center frequency results. The overall time effect showed an increase in the low frequency center frequency results ($p=0.04$).

The interaction effect of condition and time was found to be statistically significantly different according to table XLII ($p=0.01$). Furthermore there was found, according to table XLII, to be a statistically significantly difference between conditions, however post hoc analysis of the last time interval provided no evidence as to which condition was found to be statistically different to the remaining alternation conditions. Similar results were found for the low frequency power band variable of heart rate variability (see Appendix C4).

Table XLII: Analysis of variance of low frequency band heart rate variability (center frequency) over task duration for all alternation conditions for the task alternation investigation (*significance $p<0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	3.03	0.04*
TIMES	8, 152	2.08	0.04*
CONDITIONS*TIMES	24, 456	1.81	0.01*

High Frequency - Center Frequency

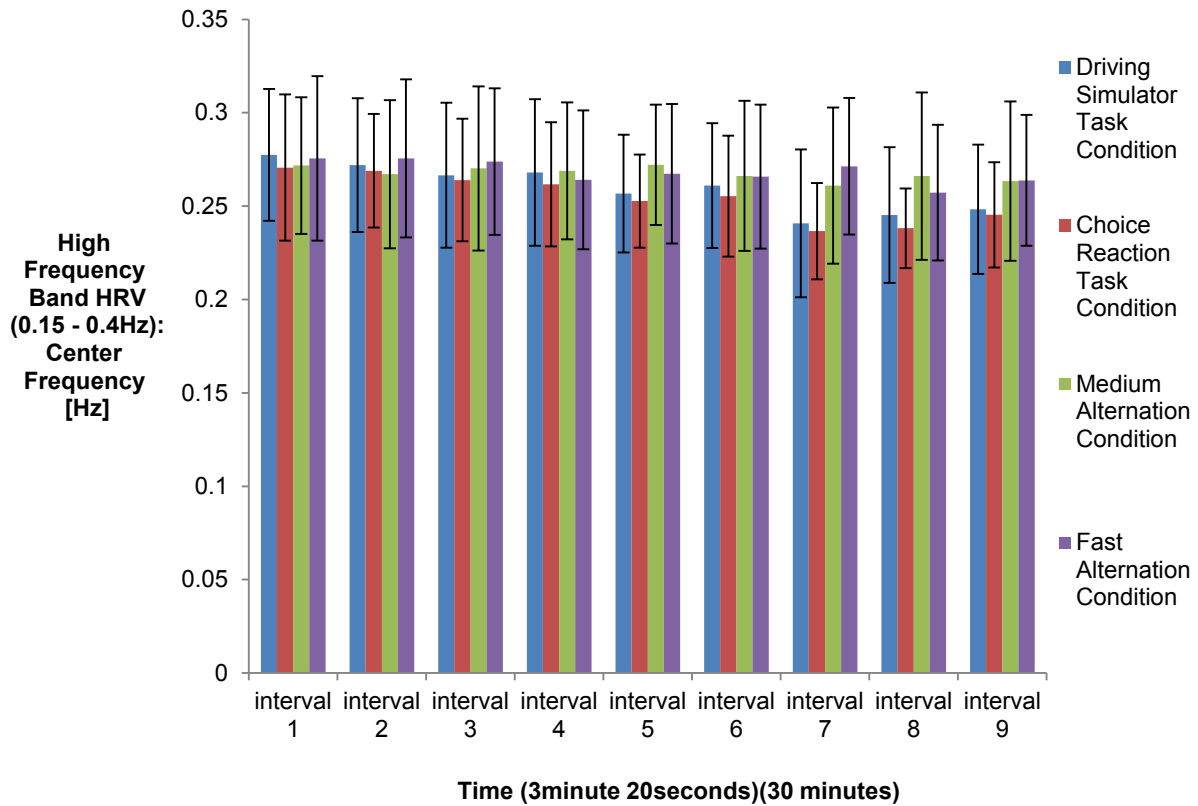


Figure 64: High frequency band heart rate variability (center frequency) over task duration for all alternation conditions for the task alternation investigation.

High frequency center frequency analysis provided statistically significant differences for time effects and an interaction effect between condition and time. Figure 64, displaying changes over time for all alternation conditions, provides visual evidence that there is a statistically significant decrease occurring over the duration of the task time ($p < 0.01$).

Table XLIII: Analysis of variance of high frequency band heart rate variability (center frequency) over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	0.98	0.41
TIMES	8, 152	17.47	<0.01*
CONDITIONS*TIMES	24, 456	2.95	<0.01*

High Frequency - Power

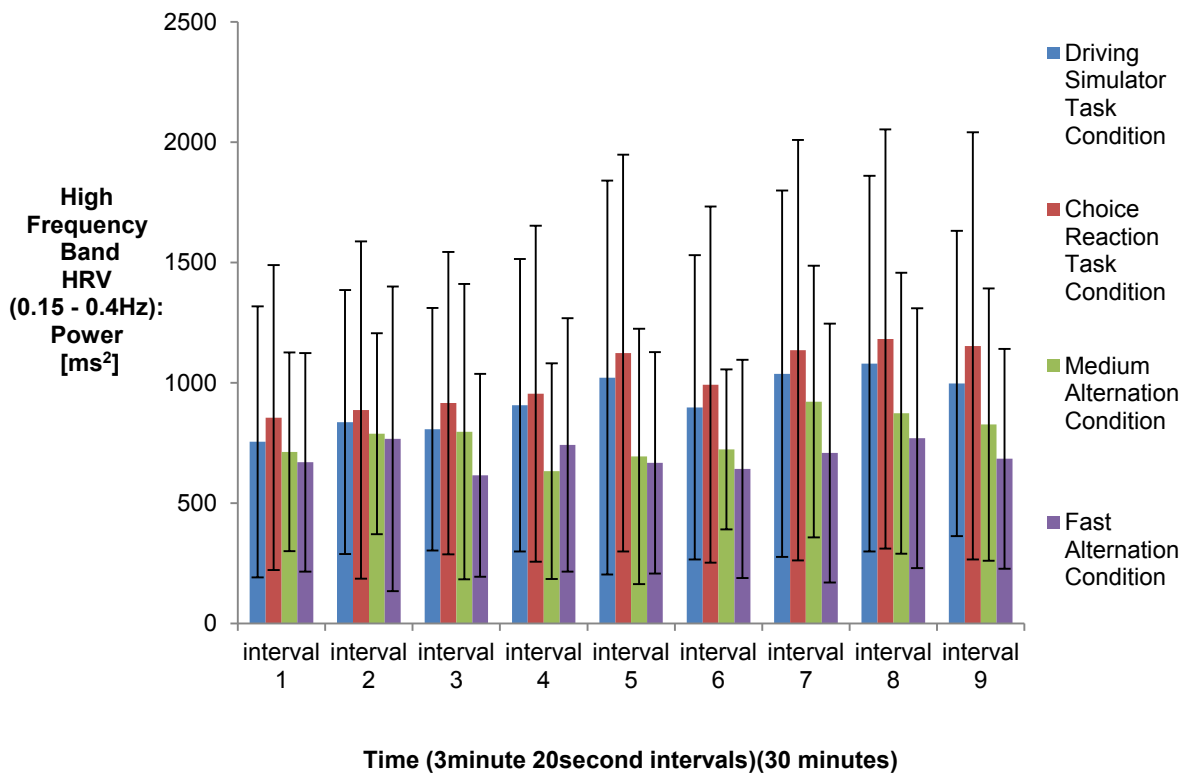


Figure 65: High frequency band heart rate variability (power) over task duration for all alternation conditions for the task alternation investigation.

Analysis of variance for the high frequency power variable has been proven to result in statistically significantly difference over condition time ($p < 0.01$). This is visually

displayed through the use of figure 65 and it can be seen that it was found to statistically significant increase over time. Additionally a statistically significantly different interactional effect was found for conditions and time ($p < 0.01$) (Table XLIV).

Table XLIV: Analysis of variance of high frequency band heart rate variability (power) over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	1.65	0.19
TIMES	8, 152	8.38	<0.01*
CONDITIONS*TIMES	24, 456	1.99	<0.01*

LF power relative to (LF+HF)

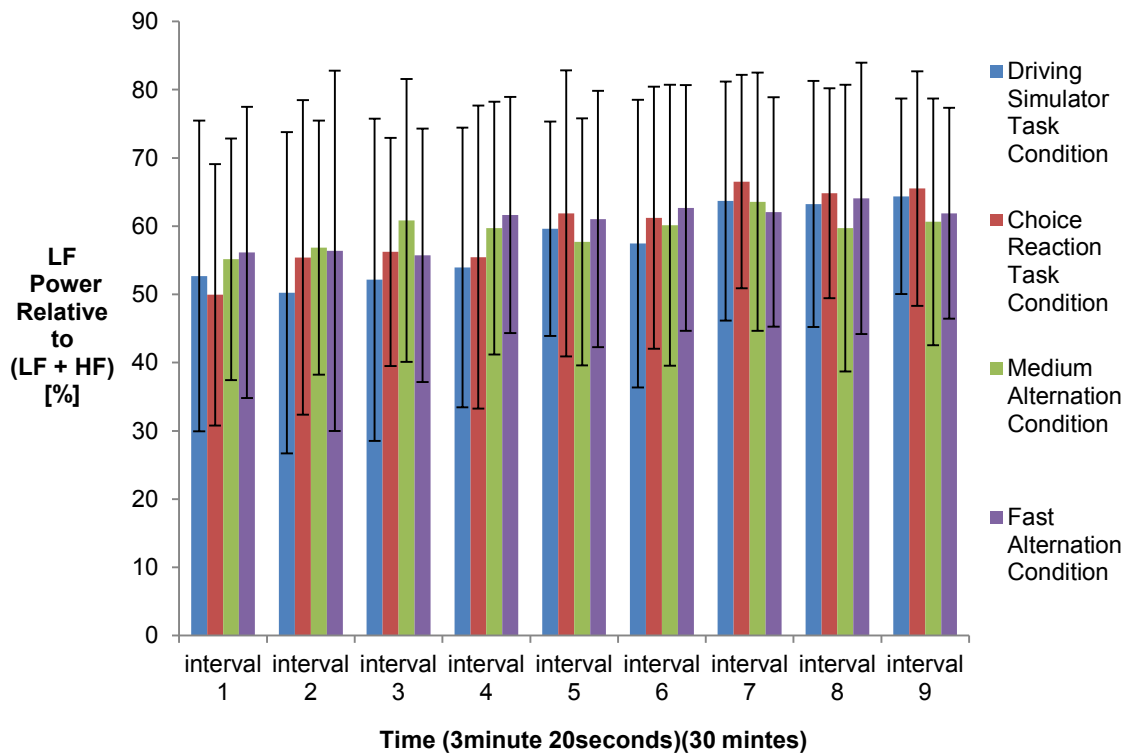


Figure 66: LF power relative to (LF+HF) heart rate variability over task duration for all alternation conditions for the task alternation investigation.

Analysis of variance for the LF power relative frequency was found to only produce a statistically significant difference over the task time. From figure 66 it can be seen that there is a statistically significant increase over time for all alternation conditions ($p < 0.01$) (Table XLV).

Table XLV: Analysis of variance of LF power relative to (LF+HF) heart rate variability over task duration for all alternation conditions for the task alternation investigation (*significance $p < 0.05$).

	Degrees of Freedom	F	p
CONDITIONS	3, 57	0.10	0.96
TIMES	8, 152	10.95	<0.01*
CONDITIONS*TIMES	24, 456	1.38	0.11

4.5.2. Cause of Aversion

The purpose of this analysis was to investigate whether inefficiency could be determined as a possible cause of aversion. This section will firstly examine the subjective efficiency experienced through performance of the conditions, through a multivariate analysis. Secondly, the objective efficiency experienced through task performance will be examined.

Subjective Efficiency

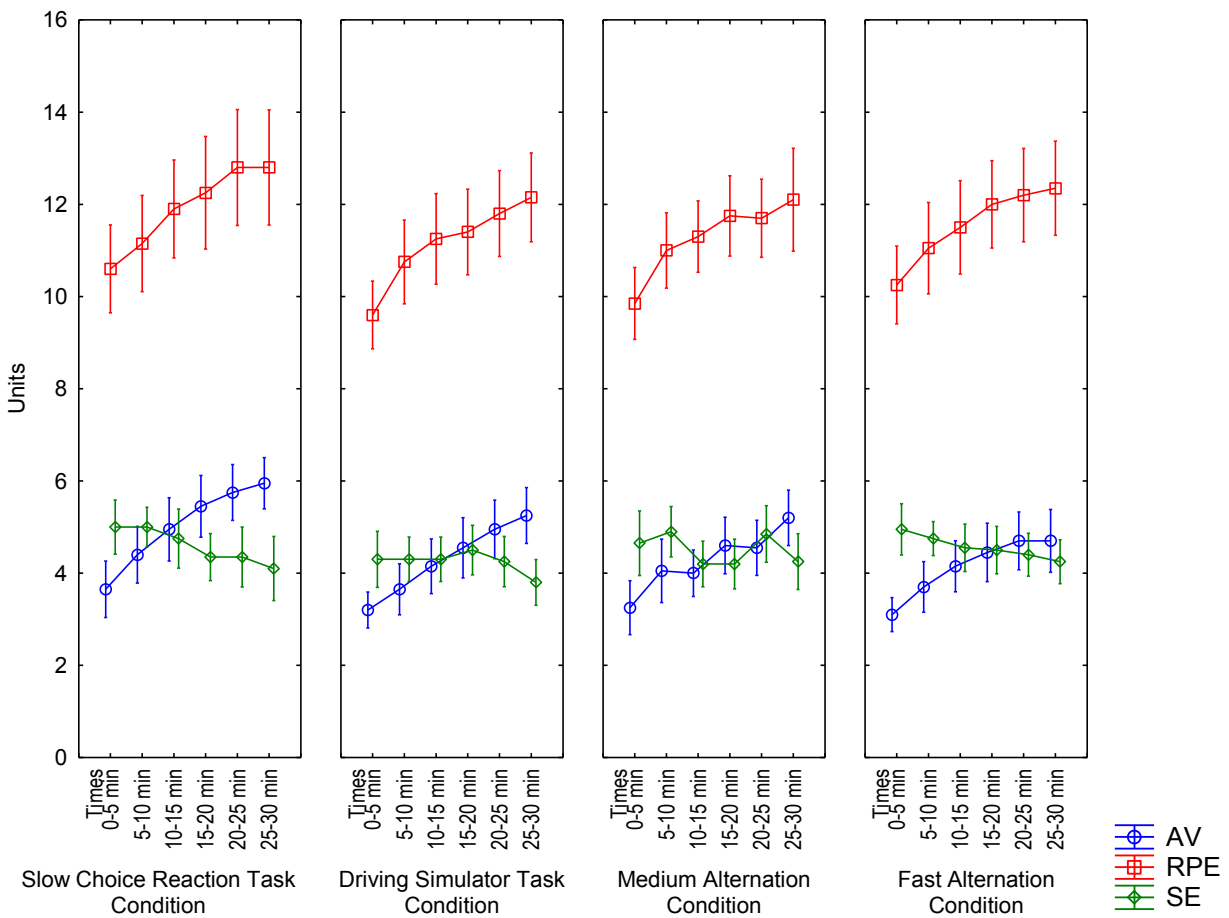


Figure 67: Subjective efficiency over task duration against aversion and rate of perceived exertion for all alternation conditions (where AV: aversion, RPE: rate of perceived exertion and SE: subjective efficiency).

Similar to the experiments performed prior to this, subjective efficiency is seen to statistically significantly decrease throughout task time with statistically significant increase found for both rate of perceived exertion and aversion ($p < 0.01$) (Table XLVI). Additionally significance was found between conditions ($p < 0.01$) and over time ($p < 0.01$).

Table XLVI: Multivariate analysis of variance for the variables rate of perceived exertion, subjective efficiency and aversion with conditions (choice reaction task, driving simulator task, medium alternation and fast alternation) and duration (30 minutes) as factors (*significance $p < 0.05$).

	Degrees of Freedom	F	p
VARIABLE	2, 38	222.04	<0.01*
CONDITIONS	3, 57	8.60	<0.01*
TIMES	5, 95	67.51	<0.01*
VARIABLE*CONDITIONS	6, 114	1.68	0.13
VARIABLE*TIMES	10, 190	17.69	<0.01*
CONDITIONS*TIMES	15, 285	0.98	0.47
VARIABLE*CONDITIONS*TIMES	30, 570	1.26	0.16

Objective Efficiency

Upon analysis of the objective efficiency data over time; efficiency calculated by objective output over objective input (relative performance / breathing frequency, heart rate, heart rate variability and energy expenditure), no statistical statistically significant results was found for all combinations of objective efficiency.

4.5.3. Response to Hypothesis

The null hypothesis stated that there would be no statistically significant difference found between aversion and the four conditions of the task alternation investigation (choice reaction task condition, driving simulator task condition, medium alternation condition, fast alternation condition). Figure 54 and tables XXX and XXXI; display a

statistically significant difference between the conditions of the task alternation investigation, such that the choice reaction task condition resulted in a statistically significantly higher aversion experienced. Thus the alternate hypothesis is tentatively accepted, such that alternations imposed change the aversion experienced towards a task.

Similar to all the investigations done prior to this, the null hypothesis stated that over time there would be no statistically significant difference in efficiency (objective and perceived). With no changes in the objective efficiency found, although a there was a change in perceived efficiency over time (Figure 67 and Table XLVI), the alternate hypothesis is rejected for the cause of aversion for objectively measured efficiency and tentatively accepted for perceived efficiency.

CHAPTER V

5. DISCUSSION

The following chapter looks into the results obtained for all four investigations undertaken. The discussion will primarily be based on the two main hypotheses, the factors influencing aversion hypothesis through the four investigations undertaken and the cause of aversion hypothesis. The structure of the discussion comprises four sections: the factors influencing aversion with subsections for task cycle, task difficulty, performance feedback and task alternation; task effects with subsections for the four investigations; cause of aversion analysis of the four investigations; and time effects for all of the investigations undertaken. Summaries of the results have been put in table form to aid in understanding the discussion. Task effects and time effects will be looked at to provide further evidence and understanding of the results obtained and additionally to provide an increase in the body of knowledge of task aversion and possible causes thereof.

5.1. FACTORS INFLUENCING AVERSION

The factors influencing aversion hypothesis was based on the assumption that by changing the original conditions of the tasks in the varying investigations; (change in cycling of information, difficulty, providing performance feedback and the alternation frequency of tasks) that the level of aversion measured would be less and show a slower rate of increase over time. From this it could be concluded whether aversion is affected by the type of tasks, the structure of tasks and components specific to tasks.

5.1.1. Investigation 1: Task cycles

Table XLVII: Summary of condition effect and interaction effect for condition and time results for the task cycle investigation (X denotes a statistically significant difference where $p < 0.05$).

Variables	Condition effect	Interaction effect for condition and time
RPE		X
Subjective Efficiency		
Aversion	X	X
Performance		
Breathing Frequency		
Energy Expenditure		
Heart Rate		
Heart Rate Variability		

Aversion was evident and exacerbated in the repetitive condition (Figure 26). This was anticipated in the hypothesis, as it was expected that a monotonous task (repetitive) would provide a greater subjective sensation to stop the task at hand due to an insufficient cognitive stimulation. The constant and new stimulation experienced through the cycling of new information (non-repetitive condition) provided a greater willingness to continue the task, thus proving the hypothesis that by changing the information cycled, there is reduced monotony for the operator and less aversion to the task. The statistically significant interaction effect for condition and time effect furthermore support the hypothesis as the non-repetitive condition showed a slower rate of increase in aversion than the repetitive condition (Figure 26 and table I).

Boredom due to monotony is manifested in the concepts of arousal, effort and stress (O'Hanlon, 1981). In order to maintain behavioural efficiency, and task execution, the

point of optimal arousal depends upon the complexity of information processing. Arousal is largely dependent on sensory stimulation (O’Hanlon 1981). During the repetitive condition, there was little sensory stimulation, provided by the changes in the reading text errors. From this, it can be deduced, that arousal levels for the repetitive condition would have been low and, due to the task remaining the same, the information processing would have been equivalent for both conditions. The non-repetitive condition provided a greater sensory stimulation to the participants resulting in a less monotonous state and therefore participants were less adverse to the task.

5.1.2. Investigation 2: Task Difficulty

Table XLVIII: Summary of condition effects and interaction effects of condition and time results for the task difficulty investigation (X denotes a statistically significant difference where $p < 0.05$).

Variables	Condition effects	Interaction effects of condition and time
RPE	X	
Subjective Efficiency	X	
Aversion		
(Performance)	(X)	
Breathing Frequency		
Energy Expenditure		
Heart Rate		
Heart Rate Variability		

The task difficulty concept was based on the difficulty law of motivation formulated by Ach (1910). The difficulty law of motivation states a person’s intention to try to perform a task would vary with the task’s perceived difficulty (Capa *et al.*, 2008). This was formulated to be a representation of aversion, as aversion is seen as the willingness to continue a task (Hockey, 1997; Holding, 1993) and with changes in intention to perform

and motivation, according to the change in difficulty, there would be a change in aversion experienced. It was anticipated that an increased difficulty would elicit a lower rating of aversion experienced due to increased motivation to perform (Capa *et al.*, 2008).

From the analysis of aversion (Figure 35 and Table XI), it can however be seen, that there was no perceived difference in aversion experienced between the difficult condition and the easy condition, such that the participants perceived the easy and the difficult condition to elicit the same degree of willingness to continue. The change in difficulty, according to the difficulty law of motivation may not have been great enough to elicit enough motivation to try harder, thus resulting in a greater willingness to continue the task. With the increase in difficulty, there may not have been a sufficient change to the task to inhibit the monotony effect as seen in task cycles. Therefore, both conditions may have been perceived as equally monotonous resulting in no change in the aversion experienced. However, it may be assumed that the difficulty law of motivation does not follow the same difference for task aversion. This can be assumed as rate of perceived exertion showing a statistically significant difference such that participants perceived the difficult condition to require more effort than the easy condition (Figure 35 and Table XLVIII).

The performance feedback investigation followed on from the task difficulty experiment in order to further ascertain whether motivation in the form of feedback of performance does contribute to the level of aversion experienced when performing cognitive tasks.

5.1.3. Investigation 3: Performance Feedback

Table XLIX: Summary of condition effects and the interaction effects of condition and time results for the performance feedback investigation (X denotes a statistically significant difference where $p < 0.05$).

Variables	Condition effect	Interaction effect of condition and time
RPE		
Subjective Efficiency		X
Aversion		
Performance		
Breathing Frequency		
Energy Expenditure		
Heart Rate		
Heart Rate Variability		

The purpose of studying performance feedback and its relation to aversion was based on achievement motivation (Capa *et al.*, 2008; Capa and Audiffren, 2009). As stated in the concept formation section of the methodology chapter, the study of performance feedback was based on perceptions of computer gaming in comparison to perceptions of the driving simulator task. Individuals who play computer games and similarly performed the driving simulator task for extensive periods of time, showed lower perceived aversion to the game than to performance of a driving simulator task. This provided the factors influencing aversion hypothesis for this investigation as this may be due to continuous performance feedback, associated with computer gaming, and therefore greater achievement motivation resulting in a willingness to continue. If feedback is positive there may be a change in motivation towards tasks in the decision to relax and reduce effort investment or aspire to even higher levels of achievement through performance (Fairclough and Roberts, 2011). Similarly, if feedback is negative,

operators could disengage from the task effectively abandoning the active goal or strengthening the resolve and aim to improve performance (Fairclough and Roberts, 2011). According to Fu *et al.* (2011), feedback plays a crucial role in motivation as it provides information to the user on how well they are performing and how individual performance compares to their goals.

This provided an incentive to study whether the knowledge of performance had an effect on the willingness to continue the task at hand. With changes in possible strategies due to knowledge of performance, would there be a change to the subjective aversion to a task experienced? It is widely acknowledged that feedback is necessary to ensure learning as it assists in the processes of shaping perception, cognition or actions of the operator (Serge *et al.*, 2012). However, with mastery of tasks, such that the driving simulator was considered a skill in this investigation, feedback should adapt, thus the use of a general feedback system which was used to inform the participants about their current and overall performance (Serge *et al.*, 2012). This general feedback system provided the participants with information on what they were doing correctly or, incorrectly and provided guidance to allow for revision to their own performance such as described by Serge *et al.* (2012).

When analyzing the effects of performance feedback on the aversion measures obtained (Figure 43 and Table XLIX), it can be seen that there is no statistically significant difference experienced. This implies that with or without a performance feedback, participants felt the same level of aversion to the task. Aversion is found to not be affected by performance feedback as previously hypothesized. Thus it can be noted that performance feedback is not the factor that influences the aversion experienced when performing computer games in comparison to the driving simulator task. The willingness to continue and thus the pleasure of performing computer games must be attributed to another factor.

This leads to further questioning as to whether aversion is dependent on tasks; task specific variables, particularly motivation in the form of task difficulty and performance

feedback; or if it is presents more as a function of time on task due to compensatory control or fatigue. For the driving simulator, task aversion may still be experienced as high and show no statistically significant differences between conditions due to the monotonous aspect of the driving simulator task and can be concluded from the task cycles experiment results, in an exaggerated aversion experienced due to lack of cognitive stimulation.

5.1.4. Investigation 4: Task alternations

Over the preceding years much attention has been given to the mental cost of switching between relatively simple cognitive tasks (Chamberland and Tremblay, 2011). The greater body of knowledge of task switching and thus task alternation suggest that switching back and forth between tasks leads to greater decrements in performance than performing a single task repeatedly (Chamberland and Tremblay, 2011). The American Psychological Association (2006) further concludes that subjective reports suggest task alternation from one cognitive activity to another produces a substantial cost in performance and productivity (Chamberland and Tremblay, 2011). However, no attention has been given to individual perceptions to task aversion and the willingness to continue with alternating tasks. This provided the impetus to study task alternation and its effect on task aversion. It was anticipated that by alternating tasks, as opposed to a repetitive, non-alternation condition, that there would be a decrease in the monotonous aspects of the non-alternation condition and thus less aversion experienced.

Table L: Summary of condition effects, interaction effect between condition and time and post hoc analysis effects for the task alternation investigation (X denotes a statistically significant difference where $p < 0.05$).

Variables	Condition effects	Interaction effect of condition and time	Post Hoc Analysis
RPE			
Subjective Efficiency			
Aversion	X		Choice reaction task condition different (↑) to medium condition and fast condition
Performance		X	
Breathing Frequency			
Energy Expenditure			
Heart Rate			
Heart Rate Variability			
- SDNN		X	Fast alternation condition statistically significant different (↓)
- rMSSD		X	Fast alternation condition statistically significantly different (↓)
- PNN50		X	
- PNN30		X	
- LF Centre Frequency		X	
- LF Power		X	
- HF Centre Frequency		X	
- HF Power		X	

According to the results obtained (Table L and Figure 54), aversion was found to be statistically significantly different between non-alternation conditions (choice reaction task condition) and the alternation conditions. The choice reaction task condition, which was a condition with no alternations over task time, resulted in a statistically significantly increased aversion compared to the medium alternation and the fast alternation condition. Additionally no statistically significant difference was found between the choice reaction task condition and the drive simulator task condition further supporting the hypothesis that alternations causes decreased aversion.

The decreased aversion experienced in the alternation conditions may further be attributed to the investigation of task cycles performed. The alternation conditions provide a greater cognitive stimulation and therefore arousal with the changing between the choice reaction task and the driving simulator task, such that the entire task is perceived as less monotonous. The less monotonous state results in a greater willingness to continue the task as opposed to the non-alternation monotonous condition (choice reaction task condition). Furthermore, with no statistically significant difference found between the medium alternation condition and the fast alternation condition, it can be deduced that the frequency of alternation does not affect the willingness to continue; simply an alternation has a great enough effect to reduce aversion to the task.

5.1.5. Summary of Factors Influencing Aversion

From the four investigations undertaken it can be seen that the biggest contributing factor associated with condition effects on aversion (cycling of information, structure with task alternations and task specific variables: difficulty and performance feedback) is monotony.

The cycling of new information/stimulus present in the first investigation resulted in a statistically significant decreased effect on task aversion due to the less repetitive and thus less monotonous state. The task difficulty and performance feedback investigations did not produce any statistically significant changes in task aversion, as the changes

elicited by the difficulty and performance feedback mechanism did not result in a great enough variation from the task to decrease the monotonous aspect of the driving simulator task. Additionally conditions with alternation in tasks resulted in a decreased aversion compared to conditions with no alternations, again attributed to a less monotonous state imposed by the alternation of two tasks.

5.2. TASK EFFECTS

Task effect refers to differences in conditions for the respective investigations. Differences will be discussed in order to identify whether changes imposed through condition changes, had further effects on the other dependent variables measured. This could provide further understanding of whether aversion is task or task structure dependent or whether aversion is more prevalent with time on task.

5.2.1. Investigation 1: Task Cycles

Subjective Measures

Through analysis of the task effects of the remaining subjective measures it can be seen that rate of perceived exertion, which was the measurement of exertion required in order to maintain task execution, showed no perceived effort difference between the two conditions (Figure 27 and Table XLVII). Furthermore, no statistical difference was found from the subjective efficiency perceived between the two conditions (Figure 27 and table XLVII). This provides unexpected evidence as participants found that although they were more adverse to the repetitive condition in comparison to the less monotonous non-repetitive condition, they perceived the exertion to maintain task performance as the same. Not only did they perceive the conditions to have the same level of effort, their subjective efficiency was similar for both conditions. Participants found that they were attaining the same level of efficiency, such that they were identifying as many misspelt words, and reading at a similar pace in the monotonous

condition, with the same level of effort as when the cycling of information was constantly new and updated.

Objective Measures

This was reiterated in the performance data, as no statistical significance was found between the conditions for reading speed (Figure 29) and errors – with errors being the number of misspelt words missed in the reading text. Finally, no statistical significance was found for either of the physiological measures (heart rate variability, heart rate, breathing frequency and energy expenditure) between the two conditions.

Reading can be understood as automatic processing. Automatic processing is not limited by short-term memory capacity, requires little or no effort and is absent of the operators direct control (Pattyn *et al.*, 2008). Furthermore, automatic processing requires extensive consistent training to develop (Pattyn *et al.*, 2008). For a further understanding, according to Rasmussen's skill, knowledge and rule based model of information processing, reading is further restated as a skill, with smooth execution of the task through extensive practice with no conscious monitoring (Embry, 2000). Embry (2000) states that it is only occasionally necessary to check on progress when operating in this mode, and that strong habits take over when attention is diverted by distraction and when unfamiliar activities are embedded in a familiar context. Hockey's (1997) works on the compensatory control regulation of human performance reiterate this. Hockey's model outlines two levels of control: the lower level routine regulation, which is labeled as the "automatic" control loop which requires no active regulation or effort; and the higher level effort-based control loop.

As it has been established that reading is a skill, processing requires little to no conscious control, this provides some evidence to the difference, or lack of differences experienced for the repetitive and the non-repetitive conditions. Both conditions were reading based tasks, and thus are highly practiced and require no conscious monitoring. Even though the repetitive condition provided no new stimulation in the form of the content being cycled, it was still a highly practiced skill and the information processing

of the task remained the same as for the non-repetitive condition thus providing similar performance results.

Changes in physiological measures have been associated with energy mobilization and further with the investment of mental effort (Fairclough and Houston, 2004). Hockey (1997) states that increase in demands at this automatic level are not felt as effortful and control of performance appears automatic. This provides an explanation of the perception of effort and physiological similarity between the repetitive and the non-repetitive conditions. With no changes in the information processing chain between the conditions, and no effort experienced by the body, no physiological differences would have been found. No further cognitive costs were imposed by the change in the conditions, regardless of the monotony of the repetitive condition thus, physiological results had no statistical difference between repetitive and non-repetitive conditions.

In summary, upon the attainment of a skill, the linear relationship between cognitive demand and mental effort investment becomes disengaged (Fairclough *et al.*, 2005). Through the repeated practice of skills there is a formulation of strategies where cognitive processes responsible for effective performance are reinforced and automated. These strategies allow individuals to rationalize and reduce mental effort investment, allowing for sustained and selective effort investment through expertise (Fairclough *et al.*, 2005). This provides a reduction in the level of mental effort required to perform tasks thereby reducing the level of mental workload experienced by the individual (Hockey, 1997). "A skilled person may produce adequate performance on a demanding task with minimal investment of mental effort whereas a novice could not" (Fairclough *et al.*, 2005, p. 172). This is associated with physiological consequences, as the need to invest mental effort is alleviated. Physiological measure to task demand is determined to some extent by the expertise of the individual due to the decreased mental effort required by expertise (Fairclough *et al.*, 2005).

5.2.2. Investigation 2: Task Difficulty

Subjective Measures

The remaining subjective measures for the task difficulty investigation provide unexpected results, as rate of perceived exertion was seen to be statistically significantly different between tasks as well as subjective efficiency. What can be deduced from these findings is that although participants perceived the difficult condition to require statistically significantly more effort to perform than the easy condition and the perceived efficiency to be worse for the difficult condition, the willingness to continue the task was the same for both the easy and the difficult condition. According to Capa *et al.* (2008) subjective difficulty should mediate the relationship between achievement motivation and the invested mental effort, therefore further analysis was performed on the mental effort required of the two conditions.

Physiological Measures

Fairclough *et al.* (2005) state that the investment of mental effort is synonymous with a switch into a controlled mode of information processing in response to increased complexity, temporal demands and other determinants of high cognitive demand. According to this notion, an increase in difficulty between tasks should elicit a higher cognitive demand due to the increase in vigilance and attention needed in order to maintain performance, and the difference in effort invested. With reference to the increased difficulty elicited by the narrow road, participants would need a greater attention demand to maintain the car in the confines of the road as there was a greater tendency for the car to stray across the center line into the adjacent lane or off the side of the road. It was thus expected that a higher difficulty condition should result in a greater effort investment. When analyzing the physiological data, representative of effort investment for this investigation, it can however be seen that no statistically significant difference between conditions were found for all physiological data (heart rate, heart rate variability, breathing frequency and energy expenditure). The findings for the heart rate measures are supported by a study performed by Brookings *et al.* (1996) where the

physiological responses of changes in workload during simulated air-traffic control were assessed. There was found to be no statistically significant differences in heart rate with the subsequent greater demand in cognitive workload.

Obrist *et al.* (1978) found that when assessing subjects performing an aversive task that there were tonic increases in heart rate and systolic blood pressure, and that these increases were related to task difficulty. Increases in heart rate were larger when the task was difficult than when it was easy or impossible to perform (Pattyn *et al.*, 2008). Contrary to this, in studies done by Carroll *et al.* (1986a; 1986b) where it was found that during performance of tasks varying in difficulty, heart rate was affected but the effects of task difficulty were not linear. The easy task evoked a larger increase in additional heart rate than did the difficult or impossible tasks. There is clear contention as to the effect task difficulty imposes on physiological data specifically heart rate. Some research has shown that cardiovascular changes are influenced by subjective rather than objective task difficulty (Pattyn *et al.*, 2008). Carroll *et al.* (1986a and 1986b) found that the increase in cardiovascular activity during solving mental tasks correlated with subjectively assessed effort or engagement in the tasks.

As discussed, the amount of effort expended in performing a task is predicted to increase proportionally with the level of perceived difficulty (Capa *et al.*, 2008). Therefore the higher the subjective difficulty level the more the individual invests effort in the task. However from the results observed, although there was a clear difference in the subjective perception of effort between conditions, no objective difference of effort were observed (Table XLVIII). The absence of statistical difference for the physiological data suggests that the degree of difficulty may not have been difficult enough to elicit an increased demand of effort. Furthermore, this provides questions as to whether subjective ratings of effort can accurately predict task difficulty.

Performance Measures

Upon investigation into the performance data between the two conditions, it can be seen from Figure 38 and table XLVIII that performance between the two tasks did

statistically significantly differ. With the difficult condition being perceived as more difficult according to the subjective perception of exertion, the result for performance could support the notion that perceived difficulty results in the intention to try harder, however this has no effect on aversion experienced. The difficult condition was found to produce statistically significantly lower mean deviation performance in comparison to the easy condition; therefore, participants performed better under the difficult condition than the easy condition.

A possible explanation for the results found for effort and performance is the “underload” and “overload” view. According to Pattyn *et al.* (2008) overload can be described as performance failure in vigilance as a consequence of depletion in information processing resources reflecting limitations in effortful attention. The underload hypothesis can be characterized as reduced alertness, and lowered attention, while overload can be characterized as diverted attention and insufficient capacity and time for adequate information processing (Brookhuis and de Waard, 2010). In this investigation, the easy condition can be seen as an underload condition due to boredom. As an underload situation, this would provide evidence for the greater deviation in driving performance, due to the monotony of the driving simulator tasks. The reduced alertness and lowered attention could be attributed to the decrease in performance of the easy condition in comparison to the difficult condition. No further effort investment was required for the easy “underload” condition or the difficult condition as through performance of the driving simulator over time, the task was learnt and may have been converted to skilled information processing (task cycle discussion on skills and effort investment).

The inverted U theory was first proposed by Yerkes and Dodson (1908) and stated a relationship between performance and arousal. Performance efficiency was seen to increase with increasing arousal, however only to a point until arousal levels became too high and performance efficiency would decrease (de Grey Birch, 2012). Arousal, according to Brown (1994) can be seen as a function of stimulation from the task and the environment. Performance decrements therefore are observed during prolonged

monotonous tasks due to reduced stimulation from the unchanging environment and context of the tasks (de Grey Birch, 2012). Thus performance is negatively affected when arousal is low and when arousal is too high (Staal, 2004; De Grey Birch, 2011).

The increased performance for the difficult condition could suggest that the difficult condition was in the optimal workload for performance, where an optimal level of arousal is described for optimal performance (Pattyn *et al.*, 2008). This provides an explanation for the increased performance in the difficult condition compared to the easy condition. "Driver mental workload should be optimal, i.e. not too high, not too low, to ensure adequate driving performance" (Brookhuis and de Waard, 2010, p 902). With regards to aversion, although it was anticipated that the higher difficulty would elicit lower levels of aversion than the easy condition, this was not the case.

In summary, it may have been that the difficult condition did not impose a great enough degree of difficulty to show effects to aversion, and effort expenditure. There were no effort differences between the tasks which could be attributed to the acquisition of a skill similar again to the task cycles experiment. Although subjective measures were worse for the difficult condition, performance for the difficult condition resulted in an improved mean deviation in comparison to the easy condition. This could suggest that the difficult condition for this investigation was at the zone of optimal performance further showing that no effort expenditure was needed. For further investigation, more degrees of difficulty need to be employed in order to assess whether the increased performance was due to optimal workload performance spectrum, and whether a condition that is perceived as impossible would result in changes between conditions.

5.2.3. Investigation 3: Performance Feedback

Subjective Measures

For both the remaining subjective measures (RPE and subjective efficiency) it was found that there was no difference experienced between the condition with performance feedback and the condition without (Figure 44 and 45; Tables XX and XXI). A condition

on time interaction effect was however found for the subjective efficiency variable. From these results it can be deduced that participants found that there was no greater perceived expenditure of effort when they had knowledge of performance, and that they perceived efficiency to be the same whether performance feedback was available or not. However, with the performance feedback condition, the condition on time interaction shows that there was a more gradual decrease in perceived efficiency over time. This will be discussed in more detail in the time effects section.

Performance feedback not only provides information on how well individuals are performing relative to their goal, it further allows individuals to know how effective specific behaviours are for a given task (Fu et al., 2011). According to this notion, participants may have employed effective behavioural strategies in the condition with no performance feedback, in order to perceived efficiency and rate of perceived exertion, to be the same for the condition with feedback.

However, no significance was found between the two conditions which can further be attributed to the repetitive nature of the task in that there was no change in the task, except for the performance feedback modulator, thus perception of the task could have remained the same. In summary, it can be concluded that performance feedback does not have an effect on perceived effort and perceived efficiency; however, this could be further studied in a more complex task situation with a different task.

Physiological Measures

Performance feedback allows operators to monitor how much task effort is required to achieve specific objectives. This enables individuals to learn what task strategies are most effective, learn what level of task effort is required to perform effectively and furthermore revise strategies and effort needed in order to enhance task performance (Fu et al., 2011). From the results obtained in table XLIX it can be seen that there was no statistically significant difference found for physiological results, as a measure of effort, between the condition with no performance feedback and the condition with. This could imply that there was no change in strategies of effort expenditure between the two

conditions. Participants utilized the same amount of effort throughout both conditions with the assumption that correct strategies for effort expenditure were put in place during the condition without performance feedback, in accordance with the non-performance feedback condition.

According to Fu *et al.* (2011), feedback can have a positive effect on learning and performance up to a certain point, however as feedback frequency increases and reaches a high level, cognitive demand necessary to process and respond to feedback information may become overwhelming. Fu *et al.* (2011) state that at this high frequency of feedback, an individual's cognitive resources are directed away from the task, thus reducing task effort and ultimately interfering with task performance. The continuous feedback may have caused a diversion of cognitive resources away from the task and towards the processing of increased feedback information and, therefore a reduction in task effort providing no differences between tasks (Fu *et al.*, 2011). In order to substantiate this however, performance needs to be assessed.

Performance

The use of performance feedback during simulated tasks allows individuals to make better use of feedback information to learn key strategies to improve performance over time (Fu *et al.*, 2011). Feedback serves as a learning mechanism as it highlights effective and ineffective behaviours and task strategies that help individuals to select the strategies and behaviour that will enhance task performance (Fu *et al.*, 2011). Performance feedback over time will be looked at later in this chapter, although when assessing the results between the two conditions there was no statistically significant differences experienced (Figure 46 and Table XLIX).

General performance feedback was continuously provided to the participants throughout the task time in order to provide knowledge of results and include verification information (Serge *et al.*, 2012). The continuous feedback may have imposed a negative effect on performance, such that no change in performance was experienced between conditions, as expertise of a task increases. Providing feedback on information

can be distracting to the participant and add unnecessary cognitive load as stated by Serge *et al.* (2012). However, with no overt changes in effort between the two conditions, it can be seen that this theory of Serge *et al.* (2012) does not hold. Fu *et al.* (2011) provided conflicting evidence to Serge *et al.* (2012) additional cognitive load notion, by stating that continuous feedback may result in diversion of effort from the task and impair an individual's ability to improve performance over time. This provides some explanation for the lack of changes in effort and performance in the condition with performance feedback, as feedback can divert cognitive resources away from on-task activities and towards self-regulatory or off-task activities that can impede performance (Fu *et al.*, 2011).

However, it must be noted that with experience of the task, such that as the feedback became more routine, feedback became less distracting and thus the task could have become monotonous (Fu *et al.*, 2011). Following on from the results of the task cycles experiment and the monotonous repetitive condition, no further investment of effort would have been seen with any change in performance.

Another possible explanation for the lack of changes in performance is found within the study performed by Serge *et al.* (2012) on static and dynamic feedback. Although general feedback was chosen for the purpose of this experiment due to the lack of learning required with the skill based driving simulator task, general feedback may inhibit performance due to a lack of learning from participants as to what exactly they are doing wrong when performance feedback is negative (Serge *et al.*, 2012).

It can be summarized from this experiment that performance feedback has no effect on perception of the task according to rate of perceived exertion and subjective efficiency, and similarly performance feedback does not alter performance or mental effort expended in this task. However, due to the repetitive and monotonous nature of the task, further investigation should be done into performance feedback on a more complex task with varying frequencies of feedback and differing types of feedback such as dynamic or static feedback.

5.2.4. Investigation 4: Task Alternation

Subjective Measures

According to the notion put forth by Chamberland and Tremblay (2011) from subjective reports, it is often suggested that a substantial cost in performance and productivity is associated with switching from one cognitive activity to another. From this it was expected that participants should subjectively perceive a decrease in efficiency with increasing frequency of alternation. Contrary to this, it was further anticipated that a greater efficiency would be perceived between the conditions with alternations as opposed to the conditions without. However, it was found that participants perceived the conditions to result in the same perceived efficiency throughout. Even between the conditions with no alternation (choice reaction task condition and drive simulator task condition) and alternations enforced, results suggest that perceived efficiency was similar. In addition, no change in rate of perceived exertion was seen for alternations and between the conditions with and without alternations.

An additional assumption was that the choice reaction task conditions, which consisted of a greater information processing demand due to the identification of stimulus and decision component, would result in a decreased efficiency and a greater rate of perceived exertion in comparison to the driving simulator task (slow drive). Correspondingly, the driving simulator task, having a low central executive component, would result in a greater efficiency due to a reduced rate of perceived exertion associated with the lower information processing demand. From these results however, it can be assumed that the subjective measures do not follow any preconceived assumptions related to task alternation – in that there were no changes with frequency of alternation, no changes between conditions with and without alternation and no change between a task with low information processing and greater central executive demand.

Performance Measures

As previously ascertained, switching back and forth between tasks has been suggested to lead to performance decrements, and with accumulating evidence, this has been seen to occur with slower response times and more errors than if performing a single task repeatedly (Chamberland and Tremblay, 2011). This lowering of performance has been associated with switching costs in task alternation. Switching costs according to some researchers reflect the time needed to reconfigure task set (Chamberland and Tremblay, 2011; Monsell, 2003). Task set is considered to include all the parameters that are required to perform a task such as goals of the particular task and the rules required for performance of that task (Liefoghe *et al.*, 2005). The assumption is that when a task is performed, only the settings associated with that task are present in working memory and with switching from one task to another, the alternative task settings must be retrieved from long-term memory (Liefoghe *et al.*, 2005). Another possible interpretation of switch costs is reflecting time needed to resolve passive interference from previous trials. When performing task switches associated with task alternation, it is often assumed to require the activation of the relevant task set and the suppression of the irrelevant task set (Liefoghe *et al.*, 2005). However according to Chamberland and Tremblay (2011), task sets remain activated for a substantial amount of time which creates interference when another alternate task is performed.

According to the performance results obtained for the task alternation investigation, it can be seen that no significance was found between conditions. Although an interactive condition on time effect was found, the post hoc analysis shows no effects between the conditions, in that the conditions with or without alternations did not produce statistically significant differences in performance, the frequency changes in alternation did not show an effect on performance, and the two tasks did not statistically significantly differ from each other with regards to performance.

The lack of significance for the performance variable provides evidence that the alternations did not produce a switching cost that could have impaired performance.

According to Chamberland and Tremblay (2011), there is evidence that under some circumstances two tasks can be performed simultaneously with very little cost if they do not share the same content or do not share similar processes. As previously discussed, the tasks chosen for this investigation were done so based on shared processes, providing differing levels of information processing required. The choice reaction task required a greater use of the central executive as stimulus had to be identified, the stimulus had to be processed according to rules set forth by the task and a decision had to be made as to which response to give. The driving simulator task however, required little information processing as the central executive activation was low. Chamberland and Tremblay (2011) further go on to state that Gillie and Broadbent (1989) found no cost in resuming a primary task after an interruption when the interruption task was simple or very different from the primary task, providing even more evidence for the lack of changes in performance associated with this investigation into task alternation.

Physiological Measures

No statistically significant differences were found for the physiological measures of breathing frequency, energy expenditure and heart rate. Heart rate variability was however found to show a statistically significant interaction effect on condition and time. According to the post hoc analysis further performed a statistically significant difference was found for heart rate variability SDNN and rMSSD for the fast alternation condition. The fast alternation condition resulted in a statistically significantly lower SDNN and rMSSD. According to heart rate variability research, a decreased heart rate variability has been typically associated with a greater mental workload (Fairclough and Houston, 2004; Fairclough and Roberts, 2011; Fairclough *et al.*, 2005; Sosnowski *et al.*, 2010). From this it can be assumed that alternations do require a greater mental demand, and further that the frequency of alternations results in a greater mental demand.

With alternation, greater demands can be associated with the retrieval of task settings from the phonological loop. During task performance relevant task rules are kept active in working memory and when a task is alternated the content must be changed

(Liefvooghe *et al.*, 2005). The phonological loop is necessary in task alternation as the participant is updated with information that is retrieved from long-term memory. A further close relationship with the central executive is needed in order to adjust this content of the phonological loop with the execution of the new task (Liefvooghe *et al.*, 2005). The alternative understanding is that participants must actively disengage previous task sets when attempting the new task, in order to perform the relevant one with a resulting greater switch cost in that condition (Chamberland and Tremblay, 2011). From both of these assumptions and the results obtained, it can be assumed that the process of alternating between tasks imposes a greater mental demand in comparison to no alternations occurring. This greater mental demand can either be attributed to the retrieval of task set from long term memory or due to active disengagement from the previous task.

5.3. CAUSE OF AVERSION

The efficiency hypothesis was an investigation into the possible cause of the phenomenon of aversion. It was hypothesized that aversion may be the subjective or objective representation of cognitive inefficiency. In order to assess the hypothesis of cognitive inefficiency as a possible cause of aversion, efficiency was assessed through a subjective rating of efficiency and through objective measures. This was done by the analysis of objective output (performance) over objective input (physiological measures) according to the likelihood model proposed by Smith and Street (2005) in Hoffman (2012).

The efficiency hypothesis was based on the assumption that with a statistically increasing aversion over time there would be an opposite statistical decrease in subjective and objective efficiency. In order to prove that inefficiency was the cause of aversion, objective efficiency would need to follow the same trend as subjective efficiency to substantiate the hypothesis. Additionally with the changes imposed by the tasks' cycling of new information, difficulty, performance feedback and alternations, it

was anticipated that there would further be a greater sense of efficiency due to the changes, and an interaction effect of condition and time effect. This was expected to result in a slower increase rate in aversion and additionally a slower decreased rate of subjective and objective efficiency over time between the conditions. Each investigation result will be discussed with a further general discussion on the efficiency hypothesis.

5.3.1. Investigation 1: Task Cycles

Table LI: Summary of time on task effects and interaction effect of condition and time results for the task cycle investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).

Variables	Time-on task effect	Interaction effect of condition and time
RPE	↑	X
Subjective Efficiency	↓	
Aversion	↑	X
Objective Efficiency		

Figure 33 displays the assessment of subjective efficiency in comparison to the rate of perceived exertion, as a measure for subjective input, and aversion for the non-repetitive condition, and repetitive condition respectively. From the hypothesis it was expected that with the increase in aversion there would be a consistent decrease in the efficiency experienced. Aversion according to table LI was seen to statistically significantly increase over time of task, with significance additionally seen with the interaction of condition and time. Subjective efficiency was seen to statistically significantly decrease over the testing time (Table LI). According to the hypothesis, from the subjective perspective, an increasing aversion over time is apparent with a decreasing subjective efficiency. However, with no change for interaction effect of condition and time for the subjective efficiency, it can be assumed that the change in the cycling of information did not impose any effect on subjective efficiency. It seems that

participants are unable to judge efficiency correctly; similarly, with the increase in aversion over time, there was a statistically significant increase in the rate of perceived exertion over time and an interaction effect of condition and time (Table LI). This provides an indication that aversion could follow a similar trend to the perception of exertion required to maintain performance of the task.

Figure 34 shows representation of the objective efficiency difference against aversion for non-repetitive and repetitive conditions respectively. No statistically significant data was found throughout for efficiency overtime, with figures 34 displaying that efficiency remained stable throughout regardless of the statistically significantly increasing aversion over time. This was found for all objective measures, which further provides reasoning that participants may not be able to judge efficiency correctly, and will further be investigated in the performance feedback condition.

Although the subjective efficiency shows statistically significant decreasing results throughout, objective efficiency does not. In order to have proved the efficiency hypothesis, there would have to have been a statistically significant decrease over time for efficiency. This was not found and thus it can be concluded that the cause hypothesis for objective measures is not supported – an objective efficiency decrement does not cause task aversion for this investigation.

5.3.2. Investigation 2: Task Difficulty

Table LII: Summary of time on task effects and interaction of condition and time results for the task difficulty investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).

Variables	Time-on-task effect	Interaction of condition and time
RPE	↑	
Subjective Efficiency	↓	
Aversion	↑	
Objective Efficiency		

The results for the efficiency hypothesis are similar to those found by the task cycle investigation. According to the subjective efficiency, it was found that over time with increasing aversion, there was an opposite effect on the perceived efficiency, showing a decrease over time (Figure 42 and Table LII). Furthermore, with the decreasing efficiency over time for both the easy and difficult conditions there was an increase in the rate of perceived exertion.

To substantiate the efficiency hypothesis, not only would there have to be a decreasing subjective efficiency over time, this would additionally have to be reflected in the objective efficiency over time. Through analysis of the objective efficiency it was found that there were no statistically significant decreases in objective efficiency over time. According to this data, it can be concluded again that aversion is not a manifestation of inefficiency.

Additionally, no interaction effect was found for subjective efficiency. According to the notion that the change in task, in this case the increased difficulty would result in a greater efficiency perception, the results were unexpected. It was found that the difficult condition resulted in a lower starting rating of subjective efficiency and proceeded to further decrease over time. With the improved performance found for the difficult condition (Figure 38 and table XIV), the greater rate of perceived exertion (Figure 36 and table XII) may distort subjective efficiency and therefore have a greater impact on aversion than anticipated.

5.3.3. Investigation 3: Performance Feedback

Table LIII: Summary of time on task effects and interaction effects of condition and time results for the performance feedback investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).

Variables	Time-on-task effect	Interaction effect of condition and time
RPE	↑	
Subjective Efficiency	↓	X
Aversion	↑	
Objective Efficiency		
Performance		

Similarly to both previous investigations, it can be seen that over time, subjective efficiency to statistically significantly decreased (Table LIII) with no changes found for objective efficiency for conditions with and without performance feedback, with aversion statistically significantly increasing throughout the task time. With no changes found for objective efficiency over time and aversion still increasing, this further reiterates that aversion is not caused by inefficiency. However, the decrease in subjective efficiency over time could be related to aversion.

The performance feedback investigation results show an interaction effect of condition over time for subjective efficiency, in that there was a slower rate of decrease for the performance feedback condition. Aversion was however not seen to result in interaction effect of condition and time which could imply, as previously stated, that participants are unable to judge efficiency correctly.

By providing a performance feedback, this allowed participants to have a more accurate perception of subjective efficiency, as participants they were able to accurately see performance throughout. As there were no differences in performance between the two

conditions and no statistical differences between the conditions for subjective efficiency, this indicates that participants were able to fairly accurately judge performance in the condition with no performance feedback. This could imply that participants are not able to accurately judge rate of perceived exertion, therefore, rate of perceived exertion may have an effect on subjective efficiency and may have a further effect on aversion.

5.3.4. Investigation 4: Task Alternation

Table LIV: Summary of time on task effects and interaction effects of condition and time results for the task alternation investigation (arrows denote a statistically significant increase or decrease where $p < 0.05$).

Variables	Time-on-task effects	Interaction effect of condition and time
RPE	↑	
Subjective Efficiency	↓	
Aversion	↑	
Objective Efficiency		

Similar to previous investigations, the task alternation study produced outcomes in accordance with the result that task aversion cannot be attributed to inefficiency. With a decreased subjective efficiency there was found to be an increased aversion (Table LIV) with no change found for objective efficiency over time. Furthermore, there was no interaction effects found, such that the alternations would result in a decreased rate in the increasing aversion and a slower decreasing rate for subjective efficiency.

5.3.5. Summary of Efficiency Considerations

The likelihood method proves a measure of efficiency consistent with the definition of the ratio of work output to work input (Hoffman, 2012). The proposed method was undertaken as empirical studies in educational psychology have used the likelihood formula to test the superiority of different modalities to investigate the cognitive

efficiency of reading (Choi and Clark, 2006). Furthermore, the likelihood method has been tested to identify the efficiency of performance under conditions of increasing complexity or restricted learning conditions (Hoffman and Schraw, 2009).

Even with the statistically significant decrease in subjective efficiency over time, there is no objective support to base that aversion could be due to an inefficiency of cognitive processing. The statistically significant decrease of subjective efficiency throughout could be attributed to the rate of perceived exertion experienced, as seen with the performance feedback condition. Aversion however may mask efficiency perception such that the operator may misjudge efficiency as is further seen with the effects for subjective efficiency for the performance feedback condition. According to O'Hanlon's review on boredom (1981), it is acknowledged that an individual's recognition of performance failures only occur post-failure when performing monotonous tasks that induce boredom. This implies that as the task was monotonous, participants may not be able to perceive errors incurred correctly, thus limiting the ability to judge efficiency. Hulst *et al.*'s. (2001) work on fatigue state that fatigue may occur as early as 30 minutes into task execution, and with this the ability to monitor the efficiency of one's own performance and judgment of one's own ability might deteriorate. In automatic tasks it was found to be not possible to monitor the cognitive operations underway with the result that it was no longer possible to assess accurately one's own efficiency and actively modulate the on-going process (Natale *et al.*, 2003).

As previously ascertained, the tasks that were performed for the entire study were considered skills, and involved highly automated processing. In order for a task to become a skill, sustained practice is required to reach the data limits on task efficiency (Fairclough *et al.*, 2005). When a skill reaches a maximum level, such that when cognitive efficiency has peaked and physical limitations constrain any further improvement of performance, the individual has reached the data limits of task efficiency (Fairclough *et al.*, 2005). This provides some evidence for disproving the efficiency hypothesis for the task. As the task is already a skill, cognitive efficiency has peaked. Cognitive efficiency cannot decrease, as the task is a skill and automatic

strategies have been reinforced in order to maintain automatic information processing at the expense of further invested effort (Fairclough *et al.*, 2005). This is further reinstated by the works of Hoffman (2012) as the view of cognitive efficiency assumes a task-dependent inverse relationship between expertise and efficient cognition. However, Hoffman (2012) states that this method of cognitive efficiency calculates the relative efficiency between individuals and provides no measure of optimal cognition.

5.4. TIME EFFECTS

As previously acknowledged, time effects for the study on aversion were further examined due to the lack of evidence found to substantiate that aversion could be attributed to deviations in efficiency. Aversion is seen to be more dependent on time on task, thus an analysis of time effects may provide a better understanding of the cause of aversion. For this section, summary of results will initially be presented; each variable will be then be discussed in detail according to each investigation in order to provide a conclusion for the time effects.

Table LV: Summary of time on task effect results for all investigations undertaken (arrows denote a statistically significant increase or decrease where $p < 0.05$).

Variables	Task Cycles	Task Difficulty	Performance Feedback	Task Alternation
Aversion	↑	↑	↑	↑
RPE	↑	↑	↑	↑
Subjective Efficiency	↓	↓	↓	↓
Performance	↑			
Breathing Frequency				↓
Energy Expenditure		↓	↓	
Heart Rate				
Heart Rate Variability				
- SDNN	↑		↑	↑
- rMSSD			↑	↑
- PNN50				
- PNN30				↓
- HF (center frequency)		↓	↓	↓
- HF (power)				↑
- LF (center frequency)	↑			↑
- LF (power)			↑	↑
- LF Power Relative		↑	↑	↑

5.4.1. Subjective Measures

For all the investigations undertaken a common trend was found for rate of perceived exertion over time. Rate of perceived exertion was consistently seen to increase statistically significantly over the task time. When conditions have a monotonous aspect to them it is important to note that when mental workload is inadequate, either too low or too high, this may lead to imperfect perception, insufficient attention and inadequate

information processing (Brookhuis and de Waard, 2010). In order to substantiate this, the physiological measures need to be assessed.

Additionally, further results for the task cycles investigation found that with aversion and rate of perceived exertion increasing over time, there was found to be an interaction effect of task on time. As discussed, a possibility for this interaction effect may suggest that aversion is influenced by the perception of effort experienced.

5.4.2. Physiological Measures

Breathing Frequency and Energy Expenditure

The investigation of breathing frequency and energy expenditure was an examination into whether these variables could be used as indicators of mental workload and to analyze whether energy expenditure can provide for a metabolic measure of cognitive demand. The results from the investigation provide conflicting results. The task cycles investigation proved no statistically significant difference over time for either measure, while task difficulty and performance feedback investigations showed a statistically significant decrease of energy expenditure. Breathing frequency for the task alternation investigation resulted in a statistically significant decrease over time.

It was assumed, according to the works of Backs and Seljos (1994) on task difficulty and energy expenditure, that a greater mental effort would elicit greater metabolic activity. Back and Seljos (1994) found that central processing has a small but statistically significant effect on energy expenditure that increases with the mental effort devoted to the task. Contrary to this the task cycles and task alternation investigation showed no statistically significant change in energy expenditure and task difficulty and performance feedback showed a statistically significant decrease in energy expenditure. Carroll *et al.* (1986a; 1986b) state that energy expenditure as measured by oxygen consumption and carbon dioxide production found during performance of mental tasks cannot be evidence that information processing has its own metabolic cost, and instead this is associated with somatomotor activity (Back and Seljos, 1994). Furthermore,

Madsen *et al.* (1992) reiterate that mental tasks under both stress and no stress conditions do not lead to an increase in global cerebral metabolic rate and mental tasks do not demand enhanced energy expenditure (Sosnowski *et al.*, 2010).

According to Fairclough *et al.* (2005), it is widely acknowledged that increased respiration and heart rate are broadly representative of energy mobilization or mental effort to meet increased task demand. With only changes found for the task alternation investigation and opposition to the notion put forth by Fairclough *et al.* (2005) with respect to breathing frequency, it is unclear whether breathing frequency can be used as a measure for mental effort.

Heart Rate and Heart Rate Variability

It is well known that solving mental tasks elicits tonic increases in cardiovascular activity, with the best explanation of these changes offered by the concept of active coping (Sosnowski *et al.*, 2010). Heart rate for all investigations was nonetheless found to produce no differences over task time.

Time Domain Analysis

Heart rate variability is commonly used to investigate central regulation of the autonomic system, psychological processes, physiological processes and cognitive workload (Berntson *et al.*, 1997). According to Brookhuis and de Waard (2010), mental workload has a clear impact on heart rate and heart rate variability. It has been typically understood that higher measures of heart rate variability are found when subjects are relaxed and unengaged in mentally demanding tasks, with low levels of heart rate variability typically observed when there is engagement of attention demanding operations or when investing mental effort (Meijman, 1997)

Coincidentally, when analyzing the heart rate variability data, it was found that heart rate variability SDNN increased over time for tasks cycles, task alternation (additional rMSSD increase over time) and performance feedback (additional rMSSD increase over time). No changes over time were however found for the task difficulty investigation.

The heart rate variability showed an opposite effect to the normal reaction to mentally demanding tasks. The increase in heart rate variability SDNN and rMSSD (task alternation and performance feedback) shows a withdrawal of effort from the task. Fairclough *et al.* (2005) provide supporting evidence to these findings for heart rate and heart rate variability, in that automatic processing has a resultant effect of a reduced requirement of mental effort. To reiterate the works of Fairclough *et al.* (2005), the reduction of mental effort during skilled performance may be characterized within the cognitive domain by an increase of automatic information processing at the expense of effortful, controlled processing (Schneider and Fisk, 1982). Automatic information processing is associated with a number of physiological consequences as the requirement to invest mental effort is alleviated (Fairclough *et al.*, 2005).

According to the works of Holding and Hockey (1980, 1997), reluctance to further invest effort into task performance is central to mental fatigue and the most reliable characterization of mental fatigue. Hulst (2001) states that strategy shifts can be expected to occur in order to maintain operational performance associated with increasing effort costs. Hockey (1997) further acknowledges that fatigue has an adaptive role by moving toward less effort demanding modes of response in order to economize effort thereby maintaining adequate performance. However, in order to deduce if the reduction of effort was associated with fatigue, performance needs to be assessed.

Spectral Analysis

For all investigations the most unexpected results were found in the spectral analysis of heart rate variability. The task cycles investigation only produced a statistically significant decrease over time for the LF center frequency band; however no significance was found for LF/HF activity over time. With no change in the LF/HF ratio for task cycles, no conclusion can be drawn according to the spectral analysis for the task cycles investigation.

Task difficulty resulted in an increased LF center frequency over time with additional increase in the LF/HF ratio. The performance feedback investigation produced decreased HF center frequency, increased LF power activity and finally an increased LF/HF activity over time. The task alternation investigation produced results in all frequencies of heart rate variability such that: LF center frequency and power increased statistically significantly, there was decreased activity for the HF center frequency, increased activity for HF power and increased LF/HF ratio activity over time.

According to Berntson *et al.* (1997) the LF variability may be a useful clinical marker and may provide an important index of mental effort or other cognitive processes in physiological studies. The majority of recent research suggests the LF band is a reflection of both autonomic branches, as vagal blockade also produces some modifications of this LF heart rate variability (Berntson *et al.*, 1997). Therefore it can be assumed that the LF band is an indicator of both sympathetic and parasympathetic activity. The increased activity of the LF band for task difficulty, performance feedback and task alternations suggest that there is indication of increased workload or effort (Fairclough *et al.*, 2005).

The high frequency band of heart rate variability which is described as depicting the parasympathetic activity and vagal tone (Berntson *et al.*, 1997) was shown to statistically significantly decrease over time for performance feedback and task alternations. The parasympathetic or vagal tone has been found to decrease when task demands are high and vagal tone measures have been found to influence the rate of respiration under increased memory demand or multitasking (Fairclough *et al.*, 2005). The decreased parasympathetic activity, typically known as the “rest and relax” function of the autonomic nervous system, shows that with the task over time, there was sufficient task demand to elicit a response to heart rate variability.

The low frequency/high frequency ratio may be reflective of mental workload activity and reflect sympathetic modulations (de Grey Birch, 2012). A decrease in this LF-HF ratio can either indicate an increase in parasympathetic or sympathetic activity as this

ratio is commonly used to indicate the balance between the two (Berntson *et al.*, 1997) According to Patel *et al.*, (2011) decreases in this LF/HF ratio have been previously related to a more drowsy state, while an increase in this ratio have been known to indicate a greater mental workload or alertness.

The findings for heart rate variability (increase in LF/HF ratio, increased LF frequency and decreased HF frequency), provides an indication that over time, the tasks elicited a great enough mental workload to be represented in heart rate variability spectral frequency analysis. However, according to the other physiological measures the statistically significant changes observed do not reflect an increase in mental workload. A conclusion that can be drawn from this, is that tasks over time imposed a great enough mental workload, which was represented in the spectral analysis of heart rate variability, but did not elicit responses to other physiological measures. This could provide reasoning for the greater perceived exertion measured by the increasing rate of perceived exertion over time.

5.4.3. Performance

Over the course of prolonged task performances, it is well understood that there is an increase difficulty to maintain task set and thus performance can be impaired (Hulst *et al.*, 2001). Performance in all investigations were found to be maintained throughout the task time (table LV), with an additional increasing performance over time found for the task cycles investigation. Although aversion which has previously been associated with mental fatigue, was found to increase over time it cannot be assumed that this was due to fatigue according to the concept of fatigue as expressed by a performance decrement (Boksem *et al.*, 2005; Hulst *et al.*, 2001; Linden *et al.*, 2003), as performance was maintained throughout.

The maintenance of performance could be attributed to the compensatory control mechanism as described by Hockey (1997) in that increased mental demand, displayed by the spectral analysis activity of heart rate variability, showed an investment of mental effort to maintain performance throughout the task time. To reiterate, Kahneman (1973)

stated that costs associated with performance maintenance may be interpreted as an expenditure of mental resources, and experienced subjectively as mental effort as well as being accompanied by increased levels of sympathetic dominance and displayed through physiological changes (Kahneman, 1973). However the decreased activity of heart rate variability time analysis must be noted, as this may have indicated a withdrawal of effort during fatigue, as described by Hockey (1997) and Hulst (2001), as an economizing of effort.

In summary of the discussion undertaken for time effect energy expenditure cannot be assumed to show representation of metabolic activity of cognitively demanding work. Breathing frequency may not be an accurate measure for mental workload. Heart rate showed no changes over time on task for all variables, suggesting that heart rate may not have been sensitive enough to measure mental workload. Time domain analysis of heart rate variability showed a withdrawal of effort in the SDNN and rMSSD variables. The increased activity over time of these variables may be attributed to the classification of the task performed as skilled tasks. However, the increased heart rate variability activity could imply fatigue, as fatigued participants according to Hockey (1997) show tendencies to move to strategies of reduced effort.

Rate of perceived exertion was seen to statistically significantly increase over task time, which could be attributed to the increased mental demand associated with spectral changes in heart rate variability. The spectral analysis of heart rate variability could further support the compensatory control approach that aversion is found due to an increased mental effort required in order to maintain performance. However, performance was found to show no change, and coincidentally there was a statistically significant increase in the task cycles investigation. With no change found in performance fatigue it cannot be concluded based on the findings that fatigue is defined as a performance decrement.

5.5. DISCUSSION OF PROCEDURE

The discussion of procedure considers the limitations and compromises made in the formation and execution of this study. As the study was performed under time constraints, concessions were made in order for the study to be completed and still maintain the integrity of the investigation process. Upon analysis of data further limitations to the study became apparent and through discussion of these, this will aid in further investigation of this nature.

Participants for this study were chosen out of the Rhodes University student population, in particular, students from the Human Kinetics and Ergonomics department. The decision to use these students provided a large number of available participants for testing that were mostly familiar with the cognitive tasks chosen. Similarly, students are accustomed to computer gaming and cognitively demanding work, which further provided a level of expertise and familiarity when performing the tasks. Although this is not representative of the population who perform cognitively demanding work for 8 hours a day, the sample fulfilled the basic criteria for the study of task aversion experienced when performing cognitively demanding tasks.

In order to assess as many factors that influence aversion in the limited amount of time, conditions were shared for the task difficulty and performance feedback investigations. As stated, the easy condition for the task difficulty investigation comprised of the condition with no performance feedback for the performance feedback investigation. Thus three conditions were tested for the two investigations between 20 participants. Similarly, four conditions were decided on to be tested between 20 participants for the task alternation investigation such that the effect of alternations was investigated as well as the influence of alternation frequencies on aversion. The number of testing sessions through the within repeat design of investigations and the effects thereof, such that aversion from the previous testing session may be carried over to the following testing session, was compensated for by allowing rest days between testing sessions of three or more days.

However, through performance of the investigations and analysis of the data, limitations to the study became apparent. Participants were instructed prior to commencement of the testing session to avoid any mentally exerting tasks in order to avoid mental fatigue through accumulation of mental stress. However, as stated, the sample was university students, and as testing was performed during normal university hours, this amount of strenuous mental activity preceding testing was limited. This may have had an effect on aversion, as subjects may have had an exaggerated aversion to the task upon starting the testing session, or participants may have already been in a fatigued state upon commencement of the tasks, and it may have had an effect on performance. As precautions were put in place to avoid the carry over effect of aversion between the testing sessions, three or more rest days may not have been sufficient to avoid the carry over effect, and some participants may have already been adverse to the task at the beginning of the following session. As there was no control over what may have occurred during those resting days participants may have been fatigued from other mental activity. For future assessment of aversion, the amount of mental activity prior to testing should be strictly regulated and further time of day of the testing sessions should be controlled in order to avoid circadian influences on data collection.

Specifically for the task cycles investigation, as stated in the protocol, participants were required to actively read through the text, word for word, and avoid skim reading. However, for the repetitive condition, as participants had read through the same paragraphs continuously for the 30 minutes, skim reading may have become prevalent and this was unavoidable. In order to improve the reliability and validity of the task, this could be improved by the nature of the tasks. As a reading task is plausible for this study, perhaps a different form of task would reduce the probability of skim reading and thus an increased performance with regards to improved reading speed.

As stated a large part of the sample were specifically students out of the Human Kinetics and Ergonomics department of Rhodes University, many of these participants were already familiar to the tasks being performed, especially the driving simulator. This provided some form of habituation to the testing, however, this may have had an effect

on the subjective measures, specifically aversion. As participants had already performed previous studies with the driving simulator, they may have had a preconceived level of aversion to the task, which could have impacted on the aversion rating and thus the willingness to continue.

For the task alternation investigation and the study of task difficulty and performance feedback, it was apparent through the duration of testing that three (task difficulty and performance feedback) and four separate testing sessions proved to be excessive for the participants. It was clear that the level of aversion prior to the third and fourth condition was higher than that of the first two sessions and may have contributed to exaggerated aversion ratings. This was however compromised for by permutations of the conditions. However, for future investigations it is advised that no more than two testing session per participant be performed. It would be advisable to rather employ more participants for investigations and rather create two separate investigations such that performance feedback had two separate conditions and the alternation frequency investigation become an investigation on its own.

CHAPTER VI

6. CONCLUSION

The purpose of this study was to provide further understanding of the concept of aversion that arises when performing cognitively demanding tasks. Aversion is a negative consequence of cognitive task performance, although there is little understanding of this phenomenon. The presence of aversion can have a detrimental impact on task performance and further productivity of the operator. The aim was to highlight possible design deficits of tasks in order to reduce the sensation of aversion. Similarly, as little is known about task aversion this investigation hoped to provide some understanding as to whether task aversion is dependent on task factors or an appearance of time on task through inefficiency. Possible theories behind task aversion were further assessed through time on task analysis.

This chapter provides a summary of procedures of the investigations undertaken and the results obtained in order to provide conclusive evidence based on the hypotheses put forth. Furthermore, recommendations will be discussed for further studies of task aversion.

6.1. SUMMARY OF PROCEDURE

The study undertaken into task aversion was divided into four varying investigations. Each investigation highlighted different aspects of cognitive tasks in order to establish whether these aspects had an effect on aversion experienced through cognitively demanding work. All investigation conditions were assessed for 30 minute durations. Conditions for each investigation were tested on separate occasions with three or more days separating conditions to reduce and potentially eliminate a carry-over effect of aversion. Sixty participants were used for the study with a distribution of 20 participants each for investigation one and four and 20 participants for investigation two and three.

Participants for each investigation were equal in gender with a mean age of 22 and were matched to the investigation according to experience of the driving simulator, reading and choice reaction task.

The first investigation analyzed the effect of information cycled to the participant. This consisted of two proof reading task conditions where condition one was repetitive, cycling the same information to the participant over the task time, and condition two was a non-repetitive condition such that the information continuously changed over the task duration. The second investigation provided change in the form of task difficulty to a driving simulator tracking task. Again, two conditions were evaluated with the first condition providing an easy driving task and the second a difficult driving task. Difficulty was established through changes in the road width. The third investigation on performance feedback and task aversion was performed through a driving simulator tracking task and formed part of the task difficulty investigation such that the easy condition for task difficulty provided the condition with no performance feedback. The second condition for the performance feedback investigation comprised of the same settings as for the no performance feedback condition, with change being supplied in the form of a performance feedback modulator visually displayed on the car. Finally, the last investigation consisted of alternations varying in frequency between a choice reaction task and a driving simulator tracking task. Conditions were defined by the provision of alternations and the frequency of alternations: such that, condition one and two were performance of the choice reaction task and the driving simulator task, providing no alternations, condition three was medium alternations between tasks, and fast alternations between the two tasks comprising the last condition.

For all investigations, variables of interest remained the same and were tested throughout task time. Subjective variables were recorded and analyzed at 5 minute intervals throughout testing time for all investigations. Subjective measures consisted of a visual analogue scale for aversion (1-7), a visual analogue scale for efficiency (1-7) and Borg's Rate of Perceived Exertion scale (6-20). Objective measures were recorded throughout the investigations and consisted of heart rate, heart rate variability, energy

expenditure and breathing frequency. Recording periods of 5 minutes were adhered to prior and post testing sessions, in order to obtain resting and recovery measures for all psychophysiological measures. Analysis of objective measures were at 5 minute intervals for investigations into task cycles, task difficulty and performance feedback. The first 5 minute interval was discarded for analysis due to the analysis of physiological data once a steady state had been achieved for heart rate, energy expenditure and breathing frequency. The objective analysis for task alternation occurred over three minute and 20 second intervals and the first two intervals (heart rate, breathing frequency and energy expenditure) were discarded for analysis. Performance measures were recorded throughout and assessed at 5 minute intervals in the form of reading speed (words per minute) and errors (%) for the task cycles investigation and mean deviation (m) for task difficulty and performance feedback. The task alternation performance measures recorded were mean response time median (s) for the choice reaction task, and mean deviation (m). Relative performance for task alternations was calculated over the mean performance over time and analyzed at 3 minute and 20 second intervals according to the fast alternations.

Further analysis was performed for objective efficiency. Efficiency was calculated according to objective output (performance) over all possible objective input measures (psychophysiological measures). Efficiency was assessed over time on task.

6.2. SUMMARY OF RESULTS

Condition effect results for the task cycles investigation showed a significance for aversion and further interaction significance for task and time for rate of perceived exertion. No additional significance was found between conditions for subjective efficiency, performance or any physiological measures. Results are indicative of the hypothesis, such that a repetitive task with no cycling of new stimulus would results in an aggravated aversion.

The task difficulty task effects analysis resulted in the difficult condition producing a statistically significantly greater perceived mental effort (RPE) with a statistically significantly lower subjective efficiency. Contrary to this the hard condition resulted in statistically significantly improved performance with no significance found for any physiological measures (breathing frequency, heart rate, heart rate variability and energy expenditure). The resultant assumption is that the difficult condition appears to be in the zone of optimal workload with task difficulty not having any effect on aversion (no statistically significant difference)

Significance was only found for an interaction effect of condition and time for performance feedback. No significance was found for the condition of any subjective measures (aversion, subjective efficiency and RPE), performance or physiological variables (breathing frequency, heart rate, heart rate variability and energy expenditure). Performance feedback has no effect on aversion.

Condition effects of the task alternation investigation resulted in a statistically significant increased aversion for the slow choice reaction task, indicating alternations produce an effect on aversion, although frequency of alternation did not affect aversion. Similarly, the fast alternation condition resulted in the greatest mental demand according to the statistically significant decreased heart rate variability SDNN and rMSSD. Interaction significance was found for performance and all spectral and time domain analysis variables of heart rate variability, although post hoc analysis provided no significance between conditions.

All investigations provided similar efficiency results such that subjective efficiency was seen to statistically significantly decrease over time with an additional interaction effect for performance feedback. No objective efficiency differences were observed through all four investigations with the statistically significant increasing trend of aversion for all investigations (interaction effect for task cycles). Aversion does not change over time due to objective inefficiency.

Time on task effects produced the most conclusive findings for the investigation into task aversion. Rate of perceived exertion was seen to statistically significantly increase for all investigations, with no objective increases in physiological measures (breathing frequency, heart rate, and energy expenditure). Energy expenditure statistically significantly decreased over time for task difficulty and performance feedback investigation suggesting that energy expenditure does not provide a metabolic measure of cognitive workload. Breathing frequency statistically significantly decreased for the task alternation investigation providing unclear evidence as to whether breathing frequency can be used as a measure of cognitive workload. A reduction in mental effort was seen by the increase in heart rate variability SDNN for task cycles, performance feedback and task alternation with additional increases for rMSSD for task alternation and performance feedback. However, evidence of a greater mental workload was presented in the statistically significant increase in LF center frequency for task alternation; increased LF power for task alternation and performance feedback; decreased HF center frequency for performance feedback; task difficulty and task alternation and increased LF/HF ratio (power relative) for task difficulty; performance feedback and task alternation. Performance was maintained throughout all investigations with an exception found for the increased performance in the task cycles investigation.

6.3. CONCLUSION

Conclusive findings for this investigation will be divided into the two main hypotheses with further conclusions from task effects and time effects discussed.

This empirical investigation into task aversion provided conclusive findings for the factors influencing aversion hypothesis. Aversion was found to be affected by the monotonous aspect of the repetitive condition of task cycles and the slow choice condition of task alternation investigations. The new cycling of information and the induction of alternations between tasks produced a statistically significant alleviation of

aversion. Conclusively it can be assumed that monotony can be explained for the aggravated effect on aversion. With no findings for task specific variables (difficulty and performance feedback), it may be theorized that an additional provoking effect on task aversion may be attributed to time on task.

The efficiency hypothesis theorized that aversion was a sensation that arose due to either a subjective or objective inefficiency of performance of cognitive tasks. Objective efficiency, defined by the measure of objective output (performance) over objective input (physiological measures), was found to produce no statistically significant changes for all investigations concluding that objective efficiency was being maintained throughout regardless of the increasing aversion. According to the discussion this could be attributed to the attainment of skills in that cognitive efficiency has peaked. Subjective efficiency did however follow the hypothesis in that it continuously decreased for all investigations with increasing aversion. The interaction effect for subjective efficiency in the performance feedback investigation suggests that aversion may mask subjective efficiency and that operators of cognitive tasks are unable to perceive efficiency correctly.

Although the effects between conditions was not an initial enquiry for this study, the results provide some conclusive findings for investigations into task cycles, task difficulty, performance feedback and task alternations. With no overt changes between tasks for the task cycles investigation, this reiterates the maintenance of performance with no additional effort for skilled information processing. The task difficulty investigation proved that difficult condition produced increased performance with no additional effort. This implies that the difficult condition, according to the inverted U principle for arousal and performance was in the zone of optimal performance with the easy condition considered as an “underload” with decreased performance, for the same effort expenditure. By providing performance feedback to participants, the rate of decrease of subjective efficiency was found to improve, with no change to performance, subjective effort or objective effort. The provision of performance feedback had no overt changes to a condition with any knowledge of performance. The task alternation

investigation was found to result in no evident changes in subjective measures, except to aversion. The fast alternation condition resulted in a decreased heart rate variability spectral analysis indicative of a greater mental effort expended. With no differences found for the other alternation conditions, performance or physiological measures, it can be assumed that alternation does effect task mental effort investment, and the frequency of alternation further imposes a greater mental demand. The lack of changes associated with condition effects was attributed to the skilled processing of all tasks such that no additional effort was required for performance maintenance (Fairclough *et al.*, 2005).

Time effects resulted in the most unexpected findings according to previous theories put in place for task aversion. Heart rate provided no conclusive findings for time effect for all investigations. Breathing frequency was reduced over time for the task alternation investigation only, providing evidence that breathing frequency may not be indicative of mental effort. Energy expenditure for task difficulty and performance additionally provided a decreased rate over time. This decreased rate could provide justification that mental effort does not have its own metabolic cost, as mental demand was prevalent throughout the spectral analysis investigation of heart rate variability for task difficulty, performance feedback and task alternation. According to this finding, it could be assumed that aversion could relate to the increased mental demand associated with the compensatory control theory of aversion. Additionally, the increase in mental demand shown by the spectral analysis could provide justification for the increase in rate of perceived exertion. Perceived exertion may mimic the spectral activity of heart rate variability, such that rate of perceived exertion follows a similar trend to aversion, and may provide some indication that aversion may be dependent on the perception of mental effort consistent with the compensatory control theory.

With the increased mental demand shown by the parasympathetic and sympathetic activity of the spectral analysis of heart rate variability, an opposing reaction was found with the decreased activity for heart rate variability SDNN and rMSSD. The decreased activity could be attributed to Hockey's (1997) theory of fatigue and conservation of

effort. Mental fatigue is associated by a reduction in effort due to strategy shifts to maintain adequate performance (Hulst *et al.*, 2001), however, as fatigue is generally characterized as a decrement in performance, which was not found for this investigation, it is unclear whether the aversion experienced could be attributed to mental fatigue. In conclusion, it is still uncertain whether the time effects associated with this investigation on aversion could be due to compensatory control or the presence of mental fatigue. A possible assumption is that the spectral analysis changes may be attributed to general arousal which is associated with performance maintenance with the change in heart rate variability SDNN and rMSSD. This provides an indication of passive fatigue associated with the monotony of the task.

6.4. RECOMMENDATIONS

Future investigations into contributing and alleviating factors associated with aversion experienced when performing cognitively demanding tasks, and the probable cause of task aversion, should take the following recommendations into consideration:

1. As monotony was found to be a considerable provoking factor to the appearance of aversion due to the simplistic skill based tasks chosen, it would be interesting and helpful to consider the aversion experienced when performing more complex tasks. Due to the conclusive findings that skill based tasks result in a peaked efficiency it may be recommended that a more complex task and the potential to learn while performing tasks may provide variations to aversion experienced.
2. Personality types for task aversion investigations should further be considered. As aversion is primarily a subjective sensation that arises from performance of cognitively demanding tasks over time, it is important to take personality types into consideration. Introvert and extrovert participants may experience aversion and further subjective measures differently and therefore differing ratings of

aversion may result. Additionally mood analysis could be further performed as aversion may be affected by varying moods associated with specific tasks.

3. The repetitive use of participants within investigations could further provide deviations within results. Although rest days were adhered to between conditions, there may have been a skewing of aversion ratings due to knowledge of the task from a previous condition. It is recommended that participants have no prior experience of the tasks as previous knowledge may create a preconceived aversion to the task prior to task execution and result in exaggerated aversion ratings.
4. It is recommended that further investigation be done on the possible link associated with rate of perceived exertion, parasympathetic and sympathetic activity of the spectral analysis of heart rate variability, and aversion. The greatest unexpected significance over time arose from measures of heart rate variability which suggests both an increase in mental demand according to the spectral analysis and a decreased demand according to the time domain analysis. Both measures provide support for the compensatory control theory of aversion and the theory of mental fatigue and aversion. Further studies on the presence of aversion in cognitive tasks need to highlight whether aversion is in fact present due to mental fatigue or the compensation of additional effort in maintaining performance.
5. Furthermore, it is recommended that investigations be undertaken on perceived efficiency. From the results it is apparent that participants were unable to perceive efficiency correctly when compared to objective efficiency results. With no possible explanation for this notion from this study, further investigations should be carried out into why individuals cannot rate efficiency correctly.
6. Due to the time restrictions of this study, as stated in the concept formation section of the methodology chapter, additional factors influencing aversion were discarded for investigation. It is recommended that factors such as time feedback

to participants and particularly the performance of dual task and the effect of aversion be investigated. Another possible factor not previously discussed in this study is the effect of time breaks throughout task performance and the influence of these time breaks on the aversion experienced.

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Note: Asterisked Citations * are secondary sources. These were not directly consulted and are referenced as fully as primary sources, indicated in brackets, permit

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8. APPENDICES

APPENDIX A

General Information

1. Letter of information to the subject
 - i. Task Cycles Investigation
 - ii. Task Difficulty and Performance Feedback Investigations
 - iii. Task Alternation Investigation
2. Consent Form

APPENDIX A1 (i)

Letter of Information to Subject for Task Cycle Investigation

Dear _____

Thank you for agreeing to participate as a subject in my Masters research thesis entitled

AN EMPIRICAL STUDY OF TASK AVERSION

AIMS

Aversion is a concept that is poorly understood. It is a sensation experienced when performing a mentally demanding task for an extended period of time. To define it, it is an unwillingness to continue with the present task. The purpose of my research is to establish whether aversion to a mentally demanding task is due to efficiency. Efficiency is a discrepancy between the amount of mental effort input, and the output of performance. Through variations in the mentally demanding tasks, such as how repetitive the task is, I am hoping to discover whether there will be an increase in efficiency of performing that task (less mental input for more output in performance). I am furthermore hoping to discover whether this increase in efficiency will decrease the sensation of aversion experienced to the task.

PROCEDURE

You will be required to come to the Human Kinetics and Ergonomics department on three separate days for testing. All testing will take place during the day. Please refrain from engaging in the following activities **24hours before** coming into the laboratory to allow for the conditions to be standardized. Please inform me on the day of the test if you did partake in any of these practices as this will affect the accuracy of the results obtained:

1. DO NOT DRINK ALCOHOL
2. TRY NOT TO TAKE ANY MEDICATION (such as painkillers, panado, any flu medication etc.) EXCEPT FOR PRESCRIPTION MEDICATION
3. DO NOT PERFORM ANY STRENOUS, COGNITIVELY DEMANDING WORK (drive long distances)
4. DO NOT DO ANY STRENOUS PHYSICAL ACTIVITY

Two hours prior to testing please:

5. Do not consume any stimulants (such as coffee, red bull, coke etc.) or take any medication as this will increase your heart rate.
6. Please ensure that you eat a good meal 2hours prior to the testing and then please refrain from eating anything after that.
7. Do not take any medication that may cause drowsiness.

If you do not adhere to these, please notify the researcher on arrival.

During the first session, I will explain the protocol to you in detail, after which you will be required to sign an informed consent form and a subject characteristics form. Upon completion, the first session of the testing will commence. The subject characteristics form ensures that participants meet the criteria needed to ensure accurate data collection. Testing requires a reading task that involves identifying double letter errors in the text, for example: bookk. Heart rate variability, heart rate, subjective effort expenditure, energy expenditure, task aversion, subjective efficiency and performance (speed and accuracy) measured throughout. This will be repeated during the two sessions, with condition performed once, on separate days. The conditions are defined by the task cycle such that condition 1 involves reading the same text repeatedly with varying errors and condition 2 – reading a non-repeated text with varying errors. Data will be coded with your participant information separately and will be stored on a computer until the research is printed, upon which it will be destroyed.

With your permission, I will be taking some photographs during the testing session which will be used solely for the purpose of my research and will be destroyed on completion of my research. If the photo is used in the printed copy of my research, I will blank out the face, ensuring anonymity.

RISKS AND BENEFITS

Risk incurred through testing may mental fatigue. Mental fatigue could provide further risk if a highly cognitive, attention demanding task is performed post testing, that could be life threatening, such as driving a car home from testing

However, participants are required to stay in the testing area for a designated period of 20 minutes, in order to recover from any risks imposed through testing, however there is minimal chance of any risk occurring. Participation in this study is however voluntary, thus you have the right to stop testing at any time without any prejudice or pressure to continue. Participant Benefits include a greater understanding of the concept of task aversion and the factors that contribute to it.

Upon completion of my thesis, feedback of performance will be made available to you if you like, in the form of a PDF copy of my completed thesis.

Thank you for showing an interest in this study. I hope you will learn a lot from this and that you enjoy the experience. If you have any further questions please do not hesitate to contact me directly.

Yours sincerely

Megan Sunshine (Human Kinetics and Ergonomics Masters student)

APPENDIX A1 (ii)

Letter of Information to Subject for Task Difficulty and Performance Feedback Investigation

Dear _____

Thank you for agreeing to participate as a subject in my Masters Research thesis entitled

AN EMPIRICAL STUDY OF TASK AVERSION

AIMS

Aversion is a concept that is poorly understood. It is a sensation experienced when performing a mentally demanding task for an extended period of time. To define it, it is an unwillingness to continue with the present task. The purpose of my research is to establish whether aversion to a mentally demanding task is due to efficiency. Efficiency is a discrepancy between the amount of mental effort input, and the output of performance. Through variations in mentally demanding tasks, namely an increase in task difficulty, or by providing visual feedback of performance, I am hoping to discover whether there will be an increase in efficiency of performing that task (less mental input for more output in performance). I am furthermore hoping to discover whether this increase in efficiency will decrease the sensation of aversion experienced to the task.

PROCEDURE

You will be required to come to the Human Kinetics and Ergonomics department on three separate days for testing. All testing will take place during the day. Please refrain from engaging in the following activities **24hours before** coming into the laboratory to allow for the conditions to be standardized. Please inform me on the day of the test if you did partake in any of these practices as this will affect the accuracy of the results obtained:

1. DO NOT DRINK ALCOHOL
2. TRY NOT TO TAKE ANY MEDICATION (such as painkillers, panado, any flu medication etc.) EXCEPT FOR PRESCRIPTION MEDICATION
3. DO NOT PERFORM ANY STRENOUS, COGNITIVELY DEMANDING WORK (drive long distances)
4. DO NOT DO ANY STRENOUS PHYSICAL ACTIVITY

Two hours prior to testing please:

5. Do not consume any stimulants (such as coffee, red bull, coke etc.) or take any medication as this will increase your heart rate.
6. Please ensure that you eat a good meal 2hours prior to the testing and then please refrain from eating anything after that.
7. Do not take any medication that may cause drowsiness.

If you do not adhere to these, please notify the researcher on arrival.

During the first session, I will explain the protocol to you in detail, after which you will be required to sign an informed consent form and a subject characteristics form. Upon completion, the first session of the testing will commence. The subject characteristics form ensures that participants meet the criteria needed to ensure accurate data collection. Testing requires either a stimulus identification task, or a driving simulator task. You will be randomly assigned to either of these tasks. Heart rate variability, heart rate, subjective effort expenditure, energy expenditure, task aversion, subjective efficiency and performance (speed and accuracy) will be measured throughout. This will be repeated during the three sessions, with each condition performed once. The conditions are defined by a visual feedback of performance or a varying level of difficulty (low difficulty/high difficulty). Data will be coded with your participant information separately and will be stored on a computer until the research is printed, upon which it will be destroyed.

With your permission, I will be taking some photographs during the testing session which will be used solely for the purpose of my research and will be destroyed on completion of my research. If the photo is used in the printed copy of my research, I will blank out the face, ensuring anonymity.

RISKS AND BENEFITS

Risk incurred through testing may include simulator sickness or mental fatigue. Simulator sickness is nausea experienced when performing the driving task, due to following a line with a moving background. Upon discontinuation of the task, this can be reversed. Mental fatigue could provide further risk if a highly cognitive, attention demanding task is performed post testing, that could be life threatening, such as driving a car home from testing

However, participants are required to stay in the testing area for a designated period of 20 minutes, in order to recover from any risks imposed through testing, however there is minimal chance of any risk occurring. Participation in this study is however voluntary, thus you have the right to stop testing at any time without any prejudice or pressure to continue. Participant Benefits include a greater understanding of the concept of task aversion and the factors that contribute to it.

Upon completion of my thesis, feedback of performance will be made available to you if you like, in the form of a PDF copy of my completed thesis.

Thank you for showing an interest in this study. I hope you will learn a lot from this and that you enjoy the experience. If you have any further questions please do not hesitate to contact me directly.

Yours sincerely

Megan Sunshine (Human Kinetics and Ergonomics Masters student)

APPENDIX A1 (iii)

Letter of Information to Subject for Task Alternation Investigation

Dear _____

Thank you for agreeing to participate as a subject in my Masters research thesis entitled

AN EMPIRICAL STUDY OF TAK AVERSION

AIMS

Aversion is a concept that is poorly understood. It is a sensation experienced when performing a mentally demanding task for an extended period of time. To define it, it is an unwillingness to continue with the present task. The purpose of my research is to establish whether aversion to a mentally demanding task is due to efficiency. Efficiency is a discrepancy between the amount of mental effort input, and the output of performance. Through variations in mentally demanding tasks, such as the way they the task is structured, I am hoping to discover whether there will be an increase in efficiency of performing that task (less mental input for more output in performance). I am furthermore hoping to discover whether this increase in efficiency will decrease the sensation of aversion experienced to the task.

PROCEDURE

You will be required to come to the Human Kinetics and Ergonomics department on three separate days for testing. All testing will take place during the day. Please refrain from engaging in the following activities **24hours before** coming into the laboratory to allow for the conditions to be standardized. Please inform me on the day of the test if you did partake in any of these practices as this will affect the accuracy of the results obtained:

1. DO NOT DRINK ALCOHOL
2. TRY NOT TO TAKE ANY MEDICATION (such as painkillers, panado, any flu medication etc.) EXCEPT FOR PRESCRIPTION MEDICATION
3. DO NOT PERFORM ANY STRENOUS, COGNITIVELY DEMANDING WORK (drive long distances)
4. DO NOT DO ANY STRENOUS PHYSICAL ACTIVITY

Two hours prior to testing please:

5. Do not consume any stimulants (such as coffee, red bull, coke etc.) or take any medication as this will increase your heart rate.
6. Please ensure that you eat a good meal 2hours prior to the testing and then please refrain from eating anything after that.
7. Do not take any medication that may cause drowsiness.

If you do not adhere to these, please notify the researcher on arrival.

During the first session, I will explain the protocol to you in detail, after which you will be required to sign an informed consent form and a subject characteristics form. Upon completion, the first session of the testing will commence. The subject characteristics form ensures that participants meet the criteria needed to ensure accurate data collection. Testing involves a combination of stimulus identification tasks and driving task performed on a computer, with heart rate variability, heart rate, subjective effort expenditure, energy expenditure, task aversion, subjective efficiency and performance (speed and accuracy) measured throughout. This will be repeated during the four sessions, with condition performed once on separate days. The conditions are defined by the frequency of alternations between the stimulus identification task and driving task. Data will be coded with your participant information separately and will be stored on a computer until the research is printed, upon which it will be destroyed.

With your permission, I will be taking some photographs during the testing session which will be used solely for the purpose of my research and will be destroyed on

completion of my research. If the photo is used in the printed copy of my research, I will blank out the face, ensuring anonymity.

RISKS AND BENEFITS

Risk incurred through testing may include simulator sickness or mental fatigue. Simulator sickness is nausea experienced when performing the driving task, due to following a line with a moving background. Upon discontinuation of the task, this can be reversed. Mental fatigue could provide further risk if a highly cognitive, attention demanding task is performed post testing, that could be life threatening, such as driving a car home from testing

However, participants are required to stay in the testing area for a designated period of 20 minutes, in order to recover from any risks imposed through testing, however there is minimal chance of any risk occurring. Participation in this study is however voluntary, thus you have the right to stop testing at any time without any prejudice or pressure to continue. Participant Benefits include a greater understanding of the concept of task aversion and the factors that contribute to it.

Upon completion of my thesis, feedback of performance will be made available to you if you like, in the form of a PDF copy of my completed thesis.

Thank you for showing an interest in this study. I hope you will learn a lot from this and that you enjoy the experience. If you have any further questions please do not hesitate to contact me directly.

Yours sincerely

Megan Sunshine

(Human Kinetics and Ergonomics Masters student)

APPENDIX A2

Consent Form

SUBJECT CONSENT FORM

I, _____ having been fully informed of the research entitled:

AN EMPIRICAL STUDY OF TASK AVERSION

Do hereby give my consent to act as a subject in the above named research.

I am fully aware of the procedures involved as well as the potential risks and benefits attendant to my participation as explained to me verbally. In agreeing to participate in this research, I waive any legal recourse against the researchers of Rhodes University, from any and all injuries sustained. This waiver shall be binding upon my heirs and personal representatives. I realize that it is necessary for me to promptly report to the researchers any signs or symptoms indicating any abnormality or distress. I am aware that I may withdraw from participation, without consequences, at any time during the research. I was not pressured into participating in this research test and did so voluntarily. I am aware that my anonymity will be protected at all times and that all the information collected, including photographs taken, may be used and published for statistical or scientific purposes. I have read this subject consent form and any questions that may have occurred to me have been answered to my satisfaction.

SUBJECT (OR LEGAL REPRESENTATIVE)

(Print name) (Signed) (Date)

PERSON ADMINISTRATING INFORMED CONSENT

(Print name) (Signed) (Date)

WITNESS

(Print name) (Signed) (Date)

APPENDIX B

Subjective Rating Scales

1. Borg's Rate of Perceived Exertion Scale
2. Aversion Scale
3. Subjective Efficiency Scale

APPENDIX B1

Borg's Rate of Perceived Exertion Scale

6	No exertion at all
7	
8	Extremely light
9	Very light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very hard
18	
19	Extremely hard
20	Maximal exertion

Borg-RPE-Scale

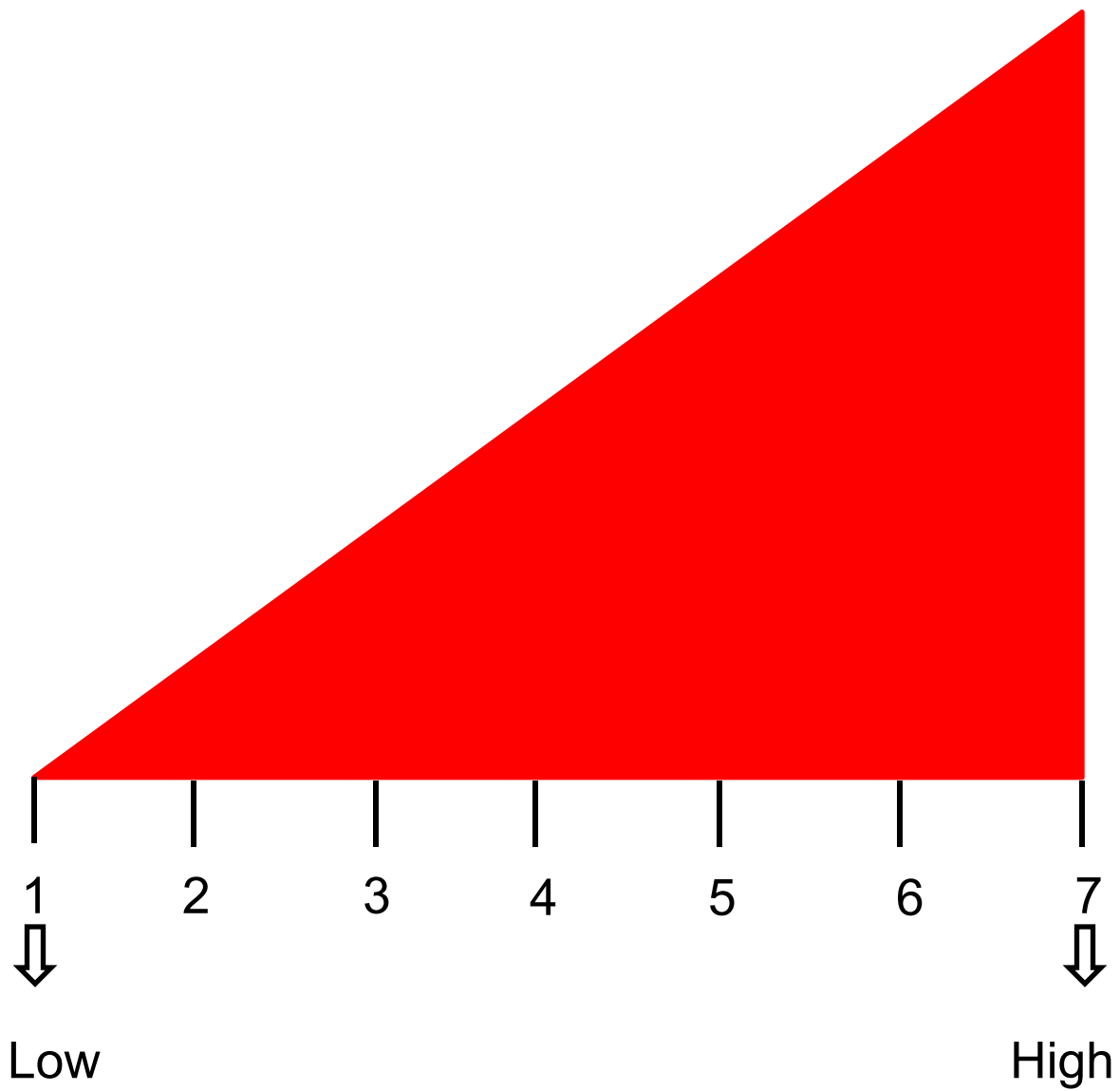
®

© Gunnar Borg 1970, 1985, 1998

APPENDIX B2

Aversion Scale

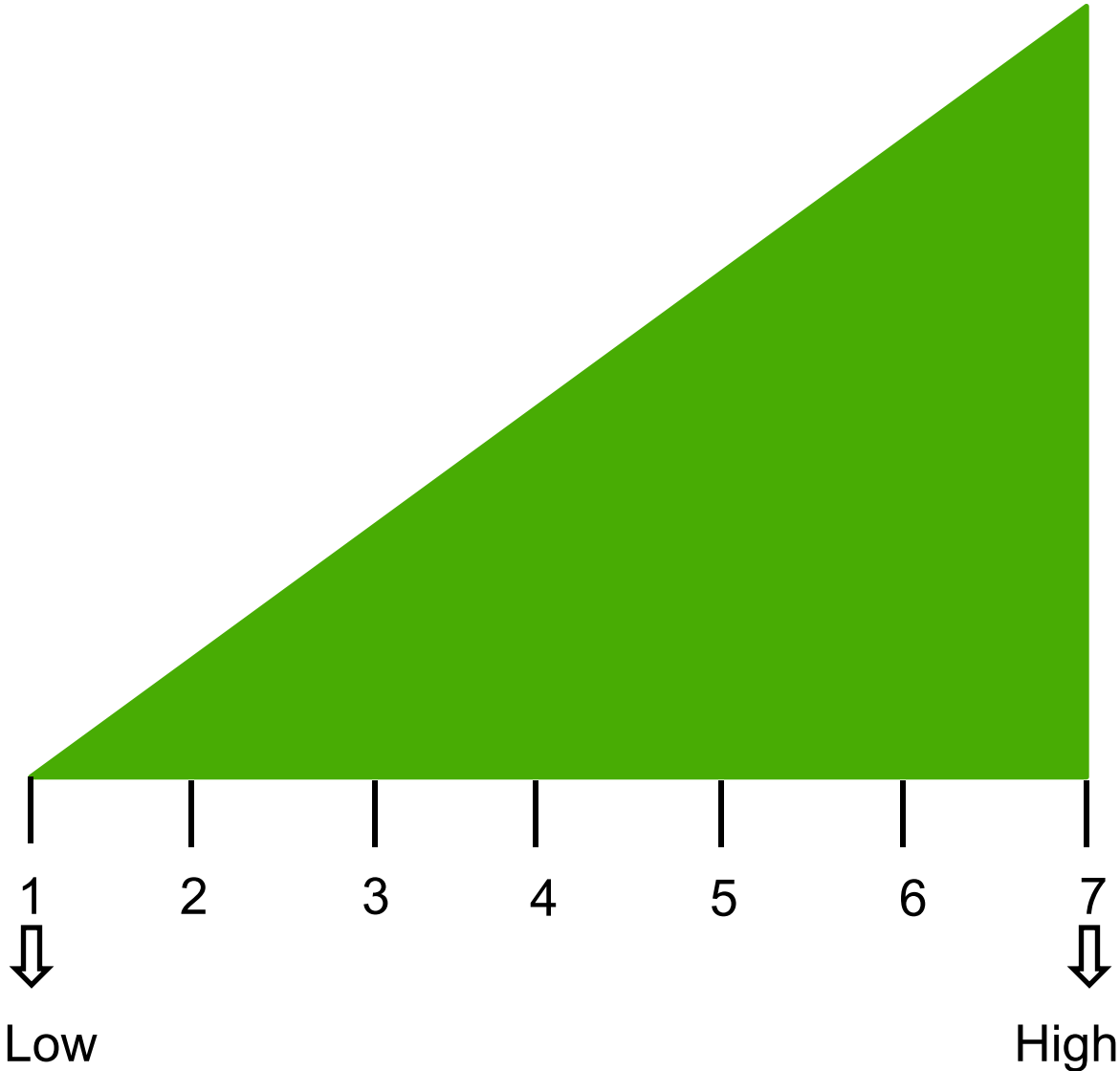
AVERSION



APPENDIX B3

Subjective Efficiency Scale

EFFICIENCY



APPENDIX C

Summary Report

1. Task Cycles
2. Task Difficulty
3. Performance Feedback
4. Task Alternation

APPENDIX C1

Raw statistical data (processed in statistica, version 10)

TASK CYCLES

Performance – Errors

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.61	0.44
TIMES	5, 95	1.75	0.13
CONDITIONS*TIMES	5, 95	1.45	0.21

Objective Input – Energy Expenditure

	Degrees of Freedom	F	p
CONDITIONS	1, 19	1.03	0.32
TIMES	4, 76	2.49	0.05
CONDITIONSS*TIMES	4, 76	0.46	0.77

Objective Input – Breathing Frequency

	Degrees of Freedom	F	p
CONDITIONS	1, 19	2.25	0.15
TIMES	4, 76	1.11	0.36
CONDITIONS*TIMES	4, 76	0.53	0.71

Heart Rate Variability – rMMSD

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.94	0.35
TIMES	5, 95	1.69	0.14
CONDITIONS*TIMES	5, 95	1.97	0.09

Heart Rate Variability – PNN30

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.94	0.35
TIMES	5, 95	0.13	0.98
CONDITIONS*TIMES	5, 95	1.57	0.17

Heart Rate Variability – PNN50

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.18	0.67
TIMES	5, 95	0.84	0.52
CONDITIONS*TIMES	5, 95	1.06	0.39

Heart Rate Variability - HF (0.15-0.4Hz): Power [ms²]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.23	0.64
TIMES	5, 95	0.35	0.88
CONDITIONS*TIMES	5, 95	0.40	0.85

Heart Rate Variability - HF (0.15-0.4Hz): Center Frequency [Hz]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.88	0.36
TIMES	5, 95	1.70	0.14
CONDITIONS*TIMES	5, 95	0.85	0.52

Hear Rate Variability - LF (0.04-0.15Hz): Power [ms²]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.06	0.81
TIMES	5, 95	1.08	0.38
CONDITIONS*TIMES	5, 95	0.56	0.73

Heart Rate Variability - LF power relative to (LF+HF) [%]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.09	0.77
TIMES	5, 95	1.94	0.10
CONDITIONS*TIMES	5, 95	0.59	0.71

Efficiency – Breathing Frequency versus Reading Speed Non-repetitive Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.01	0.10

Efficiency – Breathing Frequency versus Reading Speed Repetitive Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.61	0.18

Efficiency – Energy Expenditure versus Reading Speed Non-repetitive Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.84	0.50

Efficiency – Energy Expenditure versus Reading Speed Repetitive Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.22	0.93

Efficiency – Heart Rate versus Reading Speed Non-repetitive Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.12	0.35

Efficiency – Heart Rate versus Reading Speed Repetitive Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.79	0.54

Efficiency – HRV SDNN versus Reading Speed Non-repetitive Condition

	Degrees of Freedom	F	p
TIMES	5, 95	0.19	0.96

Efficiency – HRV SDNN versus Reading Speed Repetitive Condition

	Degrees of Freedom	F	p
TIMES	5, 95	1.25	0.29

Efficiency – HRV rMSSD versus Reading Speed Non-repetitive Condition

	Degrees of Freedom	F	p
TIMES	5, 95	2.62	0.02*

Efficiency – HRV rMSSD versus Reading Speed Repetitive Condition

	Degrees of Freedom	F	p
TIMES	5, 95	0.22	0.95

APPENDIX C2

TASK DIFFICULTY

Objective Input - Heart Rate

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.14	0.71
TIMES	4, 76	0.92	0.46
CONDITIONS*TIMES	4, 76	1.99	0.10

Objective Input – Breathing Frequency

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.74	0.41
TIMES	4, 76	1.07	0.38
CONDITIONS*TIMES	4, 76	1.56	0.20

Heart Rate Variability – SDN

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.15	0.70
TIMES	5, 95	1.34	0.25
CONDITIONS*TIMES	5, 95	0.25	0.94

Heart Rate Variability – rMSSD

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.21	0.65
TIMES	5, 95	1.38	0.24
CONDITIONS*TIMES	5, 95	0.32	0.90

Heart Rate Variability – PNN50

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.55	0.47
TIMES	5, 95	0.40	0.85
CONDITIONS*TIMES	5, 95	1.20	0.32

Heart Rate Variability – PNN30

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.0002	0.99
TIMES	5, 95	1.72	0.14
CONDITIONS*TIMES	5, 95	0.46	0.81

Heart Rate Variability – High Frequency (0.15-0.4Hz): Power [ms²]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	2.74	0.11
TIMES	5, 95	1.34	0.25
CONDITIONS*TIMES	5, 95	1.25	0.29

Heart Rate Variability – Low Frequency (0.04-0.15Hz) Centre Frequency [Hz]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.19	0.66
TIMES	5, 95	0.50	0.78
CONDITIONS*TIMES	5, 95	0.59	0.71

Heart Rate Variability – Low Frequency (0.04-0.15Hz): Power [ms²]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.20	0.66
TIMES	5, 95	1.57	0.17
CONDITIONS*TIMES	5, 95	1.25	0.29

Efficiency – Heart Rate versus Mean Deviation Easy Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.11	0.36

Efficiency – Heart Rate versus Mean Deviation Difficult Condition

	Degr. of - Freedom	F	p
TIMES	4, 76	2.64	0.04*

Efficiency – Breathing Frequency versus Mean Deviation Easy Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.58	0.68

Efficiency – Breathing Frequency versus Mean Deviation Difficult Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.47	0.22

Efficiency – Energy Expenditure versus Mean Deviation Easy Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.06	0.38

Efficiency – Energy Expenditure versus Mean Deviation Difficult Condition

	Degrees of Freedom	F	p
TIMES	4, 76	3.48	0.01*

Efficiency – HRV SDNN versus Performance Easy Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.63	0.64

Efficiency – HRV SDNN versus Performance Difficulty Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.11	0.088

Efficiency – HRV rMSSD versus Performance Easy Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.50	0.74

Efficiency – HRV rMSSD versus Performance Difficult Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.08	0.09

APPENDIX C3

PERFORMANCE FEEDBACK

Objective Input – Heart Rate

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.02	0.88
TIMES	4, 76	1.46	0.22
CONDITIONS*TIMES	4, 76	1.07	0.38

Objective Input – Breathing Frequency

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.24	0.63
TIMES	4, 76	1.09	0.37
CONDITIONS*TIMES	4, 76	1.07	0.38

Heart Rate Variability – PNN50

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.06	0.81
TIMES	5, 95	1.68	0.15
CONDITIONS*TIMES	5, 95	0.71	0.62

Heart Rate Variability – PNN30

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.00	0.99
TIMES	5, 95	1.72	0.14
CONDITIONS*TIMES	5, 95	0.46	0.81

Heart Rate Variability – High Frequency (0.15-0.4Hz): Power [ms²]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	1.06	0.32
TIMES	5, 95	0.85	0.52
CONDITIONS*TIMES	5, 95	1.81	0.12

Heart Rate Variability – Low Frequency (0.04-0.15Hz) Centre Frequency [Hz]

	Degrees of Freedom	F	p
CONDITIONS	1, 19	0.34	0.57
TIMES	5, 95	1.92	0.10
CONDITIONS*TIMES	5, 95	0.23	0.95

Efficiency – Heart Rate versus Mean Deviation No Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.11	0.36

Efficiency – Heart Rate versus Mean Deviation Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.63	0.65

Efficiency – Breathing Frequency versus Mean Deviation No Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.58	0.68

Efficiency – Breathing Frequency versus Mean Deviation Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.63	0.04

Efficiency – Energy Expenditure versus Mean Deviation No Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	1.06	0.38

Efficiency – Energy Expenditure versus Mean Deviation Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.33	0.06

Efficiency – HRV SDNN versus Mean Deviation No Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.63	0.64

Efficiency – HRV SDNN versus Mean Deviation Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.34	0.06

Efficiency – HRV rMSSD versus Mean Deviation No Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	0.50	0.74

Efficiency – HRV rMSSD versus Mean Deviation Performance Feedback Condition

	Degrees of Freedom	F	p
TIMES	4, 76	2.81	0.03*

APPENDIX C4

TASK ALTERNATIONS

Objective Input – Energy Expenditure

	Degrees of Freedom	F	p
CONDITIONS	3, 57	1.46	0.24
TIMES	6, 114	1.23	0.30
CONDITIONS*TIMES	18, 342	1.23	0.24

Hear Rate Variability - LF (0.04-0.15Hz): Power [ms²]

	Degrees of Freedom	F	p
CONDITIONS	3, 57	1.05	0.38
TIMES	8, 152	7.99	<0.01*
CONDITIONS*TIMES	24, 456	1.94	<0.01*

Efficiency – Heart Rate versus Relative Performance Choice Reaction Task Condition

	Degrees of Freedom	F	p
TIMES	6, 114	1.31	0.26

Efficiency – Heart Rate versus Relative Performance Driving Simulator Task Condition

	Degrees of Freedom	F	p
TIMES	6, 114	2.33	0.04*

Efficiency – Heart Rate versus Relative Performance Medium Alternation Condition

	Degrees of Freedom	F	p
TIMES	6, 114	1.92	0.08

Efficiency – Heart Rate versus Relative Performance Fast Alternation Condition

	Degrees of Freedom	F	p
TIMES	6, 114	0.64	0.70

Efficiency – Breathing Frequency versus Relative Performance Choice Reaction Task Condition

	Degrees of Freedom	F	p
TIMES	6, 114	1.92	0.08

Efficiency – Breathing Frequency versus Relative Performance Driving Simulator Task Condition

	Degrees of Freedom	F	p
TIMES	6, 114	1.86	0.09

Efficiency – Breathing Frequency versus Relative Performance Medium Alternation Condition

	Degrees of Freedom	F	p
TIMES	6, 114	1.48	0.19

Efficiency – Breathing Frequency versus Relative Performance Fast Alternation Condition

	Degrees of Freedom	F	p
TIMES	6, 114	0.74	0.62

Efficiency –Energy Expenditure versus Relative Performance Choice Reaction Task Condition

	Degrees of Freedom	F	p
TIMES	6, 114	0.99	0.44

Efficiency –Energy Expenditure versus Relative Performance Driving Simulator Task Condition

	Degrees of Freedom	F	p
TIMES	6, 114	1.97	0.08

Efficiency –Energy Expenditure versus Relative Performance Medium Alternation Condition

	Degrees of Freedom	F	p
TIMES	6, 114	2.01	0.07

Efficiency –Energy Expenditure versus Relative Performance Fast Alternation Condition

	Degrees of Freedom	F	p
TIMES	6, 114	0.46	0.84

Efficiency – HRV SDNN versus Relative Performance Choice Reaction Task Condition

	Degrees of Freedom	F	p
TIMES	8, 152	2.92	<0.01*

Efficiency – HRV SDNN versus Relative Performance Driving Simulator Task Condition

	Degrees of Freedom	F	P
TIMES	8, 152	3.15	<0.01*

Efficiency – HRV SDNN versus Relative Performance Medium Alternation Condition

	Degrees of Freedom	F	p
TIMES	8, 152	2.16	0.03*

Efficiency – HRV SDNN versus Relative Performance Fast Alternation Condition

	Degrees of Freedom	F	p
TIMES	8, 152	0.81	0.59

Efficiency – HRV rMSSD versus Relative Performance Choice Reaction Task Condition

	Degrees of Freedom	F	p
TIMES	8, 152	3.38	<0.01*

Efficiency – HRV rMSSD versus Relative Performance Driving Simulator Task Condition

	Degrees of Freedom	F	p
TIMES	8, 152	3.23	<0.01*

Efficiency – HRV rMSSD versus Relative Performance Medium Alternation Condition

	Degrees of Freedom	F	p
TIMES	8, 152	2.12	0.04*

Efficiency – HRV rMSSD versus Relative Performance Fast Alternation Condition

	Degrees of Freedom	F	p
TIMES	8, 152	0.84	0.57

Last Interval Tukey Post Hoc Analysis

Rate of Perceived Exertion

	TASKS	{1} - 12.800	{2} - 12.150	{3} - 12.100	{4} - 12.350
1	Slow Choice 6		0.41	0.34	0.70
2	Slow Drive 6	0.41		0.999447	0.96
3	Medium 6	0.34	0.99		0.93
4	Fast 6	0.70	0.96	0.93	

Subjective Efficiency

	TASKS	{1} - 4.1000	{2} - 3.8000	{3} - 4.2500	{4} - 4.2500
1	Slow Choice 6		0.52	0.90	0.90
2	Slow Drive 6	0.52		0.18	0.18
3	Medium 6	0.90	0.180107		1.00
4	Fast 6	0.90	0.18	1.00	

Relative Performance

	TASKS	{1} - 1.0166	{2} - .78751	{3} - 1.1391	{4} - 1.1055
1	Slow Choice 9		0.69	0.94	0.97
2	Slow Drive 9	0.69		0.338213	0.43
3	Medium 9	0.94	0.34		0.99
4	Fast 9	0.97	0.43	0.99	

Heart Rate

	TASKS	{1} - 73.444	{2} - 72.043	{3} - 72.408	{4} - 74.261
1	Slow Choice 7		0.85	0.93	0.97
2	Slow Drive 7	0.85		0.99	0.58
3	Medium 7	0.93	0.99		0.71
4	Fast 7	0.97	0.58	0.71	

Breathing Frequency

	TASKS	{1} - 17.275	{2} - 17.403	{3} - 17.745	{4} - 17.380
1	Slow Choice 7		0.99	0.76	0.99
2	Slow Drive 7	0.99		0.89	0.99
3	Medium 7	0.76	0.89		0.87
4	Fast 7	0.99	0.99	0.87	

Energy Expenditure

	TASKS	{1} - 21.530	{2} - 21.790	{3} - 22.035	{4} - 24.295
1	Slow Choice 7		0.99	0.98	0.14
2	Slow Drive 7	0.99		0.99	0.21
3	Medium 7	0.98	0.99		0.29
4	Fast 7	0.14	0.21	0.29	

Heart Rate Variability

PNN50

	TASKS	{1} - 37.687	{2} - 35.488	{3} - 32.280	{4} - 31.403
1	Slow Choice 9		0.97	0.68	0.57
2	Slow Drive 9	0.97		0.91	0.84
3	Medium 9	0.69	0.91		0.99
4	Fast 9	0.57	0.84	0.99	

PNN30

	TASKS	{1} - 54.732	{2} - 53.200	{3} - 50.357	{4} - 51.635
1	Slow Choice 9		0.99	0.82	0.93
2	Slow Drive 9	0.99		0.94	0.99
3	Medium 9	0.82	0.94		0.99
4	Fast 9	0.93	0.99	0.99	

High Frequency (0.15-0.4Hz): Power [ms²]

	TASKS	{1} - 1153.6	{2} - 997.91	{3} - 826.85	{4} - 684.42
1	Slow Choice 9		0.86	0.36	0.09
2	Slow Drive 9	0.86		0.83	0.40
3	Medium 9	0.36	0.83		0.89
4	Fast 9	0.09	0.40	0.89	

High Frequency (0.15-0.4Hz): Centre Frequency [Hz]

	TASKS	{1} - .24537	{2} - .24838	{3} - .26347	{4} - .26384
1	Slow Choice 9		0.99	0.23	0.22
2	Slow Drive 9	0.99		0.39	0.37
3	Medium 9	0.23	0.39		0.99
4	Fast 9	0.22	0.37	0.99	

Low Frequency (0.04-0.15Hz): Power [ms2]

	TASKS	{1} - 2538.0	{2} - 1818.5	{3} - 1990.4	{4} - 1089.8
1	Slow Choice 9		0.65	0.81	0.09
2	Slow Drive 9	0.65		0.99	0.64
3	Medium 9	0.81	0.99		0.47
4	Fast 9	0.09	0.64	0.47	

Low Frequency (0.04-0.15Hz) Centre Frequency [Hz]

	TASKS	{1} - .08744	{2} - .09018	{3} - .08374	{4} - .08506
1	Slow Choice 9		0.75	0.53	0.82
2	Slow Drive 9	0.75		0.09	0.25
3	Medium 9	0.53	0.09		0.96
4	Fast 9	0.82	0.25	0.96	

LF power relative to (LF+HF) [%]

	TASKS	{1} - 2538.0	{2} - 1818.5	{3} - 1990.4	{4} - 1089.8
1	Slow Choice 9		0.65	0.81	0.09
2	Slow Drive 9	0.65		0.99	0.64
3	Medium 9	0.81	0.99		0.47
41	Fast 9	0.09	0.64	0.47	