TRAIN DRIVERS MENTAL WORKLOAD AND ALERTNESS UNDER SIMULATED CONDITIONS BASED ON ELECTROENCEPHALOGRAM SIGNALS

NURUL IZZAH BINTI ABD RAHMAN

FACULTY OF ENGINEERING

UNIVERSITY OF MALAYA

KUALA LUMPUR

2013

TRAIN DRIVERS MENTAL WORKLOAD AND ALERTNESS UNDER SIMULATED CONDITIONS BASED ON ELECTROENCEPHALOGRAM SIGNALS

NURUL IZZAH BINTI ABD RAHMAN

DISSERTATION SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ENGINEERING SCIENCE

FACULTY OF ENGINEERING

UNIVERSITY OF MALAYA

KUALA LUMPUR

2013

UNIVERSITI MALAYA

ORIGINAL LITERARY WORK DECLARATION

Name of Candidate: **NURUL IZZAH BINTI ABD RAHMAN** (I.C/Passport No:)

Registration/Matric No: **KGA 100078**

Name of Degree: **MASTER OF ENGINEERING SCIENCE**

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

TRAIN DRIVERS MENTAL WORKLOAD AND ALERTNESS UNDER SIMULATED CONDITIONS BASED ON ELECTROENCEPHALOGRAM SIGNALS

Field of Study:

I do solemnly and sincerely declare that:

(1) I am the sole author/writer of this Work;
(2) This Work is original;
(3) Any use of any work in which copyright exists was done by way of fair dealing and for permitted purposes and any excerpt or extract from, or reference to or reproduction of any copyright work has been disclosed expressly and sufficiently and the title of the Work and its authorship have been acknowledged in this Work;
(4) I do not have any actual knowledge nor do I ought reasonably to know that the making of this work constitutes an infringement of any copyright work;
(5) I hereby assign all and every rights in the copyright to this Work to the University of Malaya ("UM"), who henceforth shall be owner of the copyright in this Work and that any reproduction or use in any form or by any means whatsoever is prohibited without the written consent of UM having been first had and obtained;
(6) I am fully aware that if in the course of making this Work I have infringed any copyright whether intentionally or otherwise, I may be subject to legal action or any other action as may be determined by UM.

Candidate's Signature Date

Subscribed and solemnly declared before,

Witness's Signature Date

Name:

Designation:

ABSTRACT

Train driving may seem simple. Drivers are able to handle train journeys after going through trainings. However, accidents do happen and most of these accidents can be related to human failure. Adverse driving conditions are factors that lead to increased risk of train drivers' failure in performing their task. Thus, there is a need for assessing human factors due to the exposure of different driving conditions.

There are two main objectives in this study. The first is to investigate empirically Malaysian train drivers' mental workload and alertness in various conditions. The second objective is to determine the significant pattern of various mental workloads and alertness of train drivers with reference to different conditions.

The data were collected through experimental study. Fifteen professional train drivers were involved in the study. The experiments were performed in three types of conditions; during daytime, rainy and rainy night. Participants were required to use the train driving simulator set for a total duration of sixty minutes. Electroencephalogram (EEG) signal were collected from six significant placements (F_Z, P_Z, O_1, O_2, P_3 and P_4) to determine the mental workload and alertness required for each task. The mean alpha power was monitored as this signal reflects the variation in mental workload level. Night and rainy setting has shown significant difference pattern from other conditions. The result highlighted that 37% of difference between normal daytime driving and rainy night driving even at the early driving duration. It can be understood that during this driving situation, the mental workload tends to be high and sleepiness occurs which is a sign of low vigilance. This finding also shows that the train drivers tend to have a decrease in mental workload after six minutes of driving during rainy night shift. On the other hand, beta amplitude presented that during rainy and night drive, increment was recorded which may be occurred because of difficulty to see through in the dark.

In the conclusion, the study has shown a significant pattern for night raining condition. It is also highlighted that during night and rainy, the mental workload increases 37% from sunny condition. Meanwhile, it was found out that after six minutes of rainy night driving, a lower mental workload appeared among the train drivers which showing detachment on the works. In addition, it was found out that there is difficulty in term of vision among the train drivers during rainy night drive. It is significant to be aware on this condition since it is very dangerous. This result highlighted that an ergonomic work schedule and work design is needed to tackle the problem to avoid human error.

ABSTRAK

Memandu keretapi mungkin kelihatan mudah. Pemandu mampu untuk mengendalikan perjalanan keretapi selepas melalui beberapa latihan. Walau bagaimanapun, kemalangan masih berlaku dan kebanyakan kemalangan ini boleh dikaitkan dengan kegagalan manusia. Keadaan memandu yang kurang baik adalah faktor-faktor yang membawa kepada peningkatan risiko untuk kegagalan pemandu keretapi dalam melaksanakan tugas mereka yang juga boleh menyebabkan penurunan prestasi kerja mereka. Oleh itu, terdapat keperluan untuk menilai faktor manusia disebabkan kepada pendedahan keadaan pemanduan yang berbeza.

Terdapat dua objektif utama dalam kajian ini. Pertama adalah untuk menyiasat secara empirikal beban kerja mental dan kepekaan pemandu- pemandu kereta api Malaysia dalam pelbagai keadaan. Objektif kedua adalah untuk menentukan corak ketara yang pelbagai bagi beban kerja mental dan kepekaan pemandu keretapi dengan merujuk kepada pelbagai keadaan.

Data dikumpul melalui kajian eksperimen. Lima belas pemandu kereta api profesional terlibat dalam kajian ini. Eksperimen telah dijalankan dalam tiga jenis keadaan; siang, siang dan hujan; malam dan hujan. Peserta dikehendaki untuk menggunakan simulator memandu kereta api yang ditetapkan untuk tempoh jumlah minit 60. Electroencephalogram (EEG) isyarat yang dikumpul dari enam penempatan penting (FZ, PZ, O1, O2, P3 dan P4) untuk menentukan beban kerja mental dan kepekaan yang diperlukan untuk setiap tugas. Min kuasa alfa diperhatikan kerana isyarat ini menggambarkan perubahan dalam tahap beban kerja mental. Persekitaran malam dan hujan telah menunjukkan corak perbezaan yang ketara dari keadaan lain. Hasilnya menunjukkan bahawa 37% daripada perbezaan antara pemanduan siang dan malam yang hujan walaupun pada tempoh memandu awal. Ia dapat difahami bahawa dalam keadaan pemanduan ini, beban kerja mental cenderung untuk menjadi tinggi dan rasa mengantuk timbul yang merupakan tanda-tanda kepekaan yang rendah. Penemuan ini juga menunjukkan bahawa pemandu kereta api cenderung untuk mempunyai penurunan beban kerja mental selepas enam minit memandu semasa dalam keadaan malam yang hujan. Sebaliknya, amplitud beta yang diperoleh semasa memandu dalam keadaan waktu malam yang hujan, kenaikan dicatatkan mungkin berlaku kerana kesukaran untuk melihat dalam keadaan gelap.

Kesimpulannya, kajian ini telah menunjukkan pola yang penting bagi pemanduan dalam keadaan malam yang hujan. Ia juga menyatakan bahawa pada waktu malam yang hujan, beban kerja mental meningkat 37% daripada keadaan cerah. Sementara itu, didapati bahawa selepas enam minit memandu dalam keadaan malam yang hujan, beban kerja mental yang lebih rendah muncul di kalangan pemandu kereta api yang menunjukkan gangguan tumpuan pada kerja. Di samping itu, didapati bahawa terdapat kesukaran dalam jarak penglihatan di kalangan pemandu kereta api semasa memandu dalam keadaan malam yang hujan. Adalah penting untuk mengetahui mengenai keadaan ini kerana ia adalah sangat berbahaya. Hasil kajian ini menekankan bahawa jadual dan reka bentuk kerja yang ergonomik diperlukan untuk menangani masalah ini untuk mengelakkan kesilapan manusia.

Acknowledgements

بسم الله الرحمن الرحيم

Foremost, I would like to express my sincere gratitude to my supervisor Assoc. Prof. Dr. Siti Zawiah Md Dawal and Assoc. Prof. Dr. Ardeshir Bahreininejad for the continuous support of my study and research, for the patience, motivation, enthusiasm, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having a better advisor and mentor for this study.

Besides, I would like to thank the examiners of my candidature defense: Dr. Yap Hwa Jen and Dr. Farazila Yusof for their encouragement, constructive comments, and suggestions.

I am extremely grateful to Assoc. Prof. Dr. Tan Maw Pin as the advisor from the Medical Ethics Committee of University Malaya Medical Center.

I would like to express my very sincere gratitude to Mr. Muslizam, the executive of the MyRA Keretapi Tanah Melayu Berhad (KTMB) for the support to make the data collection at the training center possible. Special thanks to Mr. Mustapha for his assistance in collecting the survey data. In addition, I acknowledge my gratitude to all the staff of KTMB for their support along the data collection process.

Next, I am thankful to my colleagues Kak Hilma, Sofia, Kak Nadya, Kak Syida, Kak Mirta, Buk Novita, and Kak Aisyah for the stimulating discussions, for the time we were working together before deadlines, and for all the fun we have had in the last two years. I will never forget their kindness and moral support during my study. Thanks for the friendship and memories.

Most of all I would like to thank my husband Mr. Mohd Aizat Mohd Salahuddin, without whom I simply would not have finished this study. I dedicate this thesis to him with all my love. Last but not least, my deepest gratitude goes to my beloved parents; Mr. Abd.Rahman Harun and Mrs. Asiah Ahmad for their endless love and prayers. Also thanks to my beloved brother Khairul Anas, for his guidance and encouragement. Also not forgetting my sister and her husband, Nurul Husna and Mohd Zuihairy for their prayers, love and care. To those who indirectly contributed in this research, your kindness means a lot to me.

Table of Contents

List of Figures

List of Tables

Abbreviations

KTMB	: Keretapi Tanah Melayu Berhad
EEG	: Electroencephalogram
EOG	: Electrooculogram
ECG	: Electrocardiogram
HRV	: Heart Rate Variability
REQUEST	: Rail Ergonomics Questionnaire
TLX	: Task Load Index
SWAT	: Subjective Workload Assessment
IWS	: Integrated Workload Scale
OW	: Overall Workload
THAT	: Toronto Hospital Alertness Test
KSS	: Karolinska Sleepiness Scale
FFT	: The Fast Fourier transform
SPSS	: Statistical Package for the Social Sciences
MyRA	: Malaysian Railway Academy
FFT	: Fast Fourier transform

CHAPTER 1

INTRODUCTION

1.1. Background of the Study

Railway transportation comprises of wheeled vehicles that run along railway or railroads. It is capable of high capacity and is also energy efficient. Railway transportation is preferred by many people and is used to go to work at a short distance or even to travel a long way to their hometowns. Meanwhile, for those in the business sector, they prefer to transport their bulky goods and stocks using railway facilities because of its many advantages.

Railway in Malaysia consist of heavy rails, light rail transit (LRT), monorail, commuter, and the latest electrical high speed commuter rail service (ETS). As for the city public transport, LRT, monorail, and commuter services are widely used in Kuala Lumpur, while for public intercity and logistics transportation, ETS and heavy rail are in line for services (Ministry of Finance Malaysia, 2011).

Figure 1.1: Railway transportation in Malaysia

However, being part of the logistic chain that facilitates economic growth does not exclude railway transportation from controversies and issues. Accidents and failures of systems still occur involving faulty interactions between humans and machines. For example, in India, BBC News India reported on 22nd May 2012 that 24 people were killed and 25 were injured after a passenger train collided with a stationary goods train at Penneconda Station in New Delhi (BBC NEWS, 2012). The incident which happened at 3.15 in the morning was said to be caused by carelessness of the train driver who overshot a communication signal. Meanwhile, The Amsterdam Herald reported on 23rd April 2012 that a train crash in Amsterdam killed a 68-year-old woman and left dozens of others injured (Herald, 2012). The collision had been caused by one of the drivers failing to stop at a red signal. General questions have been asked on "How focused is the driver when handling the train?", "What are the safety precautions taken in facing unfavorable situations, weather and environment by the driver?", and "Have the train working environment and parts design been certified ergonomically?". These are some of the worries that not only come from the public but also from the authorities.

Figure 1.2: Train accidents in India. (Source: BBC News, 2012)

There are several contributors to accidents such as poor track condition, faulty machinery and human error. However, Jap et al. (2011) mentioned in their study that almost 75% of all train accidents can be associated to human error. These incidents happen and cause significant losses in terms of cost and lives. Many solutions have been integrated such as better railway infrastructure development and system upgrading. However, the ergonomics approach should be given more attention since human skills and capabilities when handling train devices and machines play a big role in avoiding any catastrophic incidents. Currently, the ergonomics study has been expanded widely with the help of advanced equipments. Many fields including human working environment in industries have been improved after research findings have been used as a guideline (Alberta Employment, 2007; Choobineh et al., 2007).

Table 1.1: Number of persons killed and injured by type of rail accident in 2012.

Cause of rail accident	**Total No. of Cases**	**Number of Victims**	
		Killed	**Injured**
Collision	30	221	1349
Derailment	16	12	149
Others (Explosion, Fire, Stuck)	3	32	34

A specific study on the train drivers' working conditions should be done in order to investigate the situations and problems that lead towards incidents and accidents. Table 1.1 presents the rail accidents happened in year 2012 that have been reported by news in countries around the world. Collision can be seen as the main contributor to the number of victims that were killed and injured. The details are tabulated in Appendix D. The study of workload factors is important in improving workers' wellbeing and safety at work (Galy, Cariou, & Mélan, 2012). It is also important for the researcher, designer and the railway community themselves to use it as a guideline so that a conducive working environment can be created and the working performance of the train driver can be increased to a higher level. As a result, accidents and failure of railway transportation systems can be avoided or at least reduced in the future.

1.2. Problem Statement

Safety issues of railway industry operations are a priority regardless of the worker's level in the organization. However, the human factors of a train driver tend to be one of the most critical issues that affect their performance. Issues can be caused by the train driver's workload which is a crucial human factor for designers and managers. Too little of a workload can cause boredom while when having too many things to do, the driver can become highly stressed and degradation of human performance will occur (Crew Resource Management, 2012; C. S. Hart, 2010; Rail Safety and Standards

Board, 2008). As for the train driver, the work of train driving has three high level functions which are monitoring and being aware, deciding, responding and acting (Rail Safety and Standards Board, 2005). These functions are related to the mental workload level of the train driver and vary depending on the working environment. On the other hand, inappropriate levels of mental workload in a working shift are common in the cab of a train (Goran et al., 1999; Rail Safety and Standards Board, 2005).

Bad weather, poor track route, inappropriate light conditions, and poorly designed control devices are found to be associated with risky driving behavior in a train. Since physiology measurement is one of the most effective ways to study people in a workplace (Brookhuis & de Waard, 2010), it will be used to monitor the train drivers' mental workload and alertness which then can lead into a contribution to the knowledge on how the results vary between different types of driving environments. In addition, a simulator provides safety, flexibility and high potential on the output (e.g. mental workload) that is expected (Brookhuis & de Waard, 2010). Furthermore, observing actual behavior in a simulated work setting using behavioral observation tends to provide a more valid measure (Greenstreet Berman Ltd, 2003).

In addition, research using physiological analysis of train drivers is rare, especially in Malaysia. Most of the studies emphasize on road drivers rather than being concerned about rail transportation (Afizan et al., 2011; Hagemann, 2008). Based on the above evidences, it is timely to focus our research on train drivers. Collecting, recording and analyzing information about train driving tasks in a systematic way particularly for important driving conditions can provide a guideline and reference for proposing and preparing an ergonomic workplace for railway staff.

1.3. Objectives

The objectives of this research are as follows:

1. To investigate empirically train drivers' mental workload and alertness on three conditions
2. To determine the significant pattern of various mental workloads and alertness of train drivers with reference to conditions

1.4. Scope and Limitations

The experimental data for this research were obtained from train drivers who performed driving tasks using the controller of a train driving simulator set for a duration of 60 minutes. In this study, a physiological measurement was done in order to evaluate the mental workload of the train driver. The signals were taken from an electroencephalogram (EEG) and electrooculogram (EOG) which were then classified and transformed into frequency groups, but only alpha and beta rhythms and eye blink intervals were analyzed in this study as these data are related to mental workload and alertness. Different conditions' difficulties were set in order to obtain varying results of the drivers' brain signals after each type of experiment was done.

1.5. Significance of the Study

Rail accidents are evidently complex. However, there are some essential steps in preventing the increasing accidents trends. One of them is a study on the train driver himself. A physiological analysis of train drivers would be a valuable finding in obtaining their working mental workload and alertness. Instead of using only subjective measurements, monitoring brain signals can provide advanced quantitative information in understanding various driving conditions. These findings can also be utilized as a potential for other human factors indicator in future research. Moreover, the research outcome could be used to improve the working environment in the future, which may motivate the train drivers to perform better in their work tasks, thus offering more excellent services for their organization.

1.6. Organization of Chapters

This dissertation is organized into 6 chapters. Chapter 1 serves as an introduction to the thesis. Firstly, sub chapter 1.1 presents the background of the thesis which is mainly about railway industry in Malaysia. The second subchapter describes the problem statement after understanding the situation, while the objectives of the research were clearly stated in the next sub chapter. Finally, in sub chapter 1.4, the scope and limitations of the study were presented to declare the limit and range of this research.

Chapter 2 is the literature review, which presents a detailed account of the train driving information, mental workload and alertness knowledge which are relevant to the study. The mental workload and alertness concept was explained in the sub chapter. Previous work related to this topic were reviewed and presented systematically. The techniques and the various applications considered were also explored. In addition, the working conditions effects on the train drivers' mental workload and alertness were investigated.

In Chapter 3, explanations were made on how this research was done to accomplish the objectives of the study. The initial survey method was also presented in the sub chapter 3.1. Covered in this chapter is a complete description of the experimental design consisting participants criteria, location, apparatus and equipments involved, setup, procedure and instructions that were given to participants. Furthermore, the electrophysiological recording's important details and how the results were analyzed were also included in this chapter.

All the results were presented in Chapter 4. This chapter started with the report on the survey results which reflected the perceptions of the participants on their work. Next the results from the experiments that have been analyzed were stated. The data for all participants were used to perform statistical analysis and comparison between the entire selected variable. The first subsection of the experiment result was the analysis report on demographic data of the participants involve in this study. The EEG analysis results were separated into two main sections which were Mean Alpha Power Analysis section and Mean Beta Power Analysis section. Both of the section contains two additional parameters analysis which are on age and experience.

Next is Chapter 5. This chapter describes the general discussion of this study. The content relates the present findings to those revealed and disclosed in other studies. From the brain signal results, discussions were stated relating to the driving task experiment that has been set up. The relationship between brain signal of the train drivers and the driving conditions were reviewed to have a deeper understanding of the study.

Chapter 6 is the conclusion of the study. It provides the final descriptions of the findings of the research which also includes the suggestions for future research work in the area. This chapter is followed by the reference and appendices.

CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

This chapter presents a detailed account of the train driving information and mental workload knowledge which are relevant to the study. The concept of drivers' mental workload was clarified. The ways in which mental workload were measured are explained referring to previous research. The potential effects of working conditions on the train drivers' mental workload were explored. Figure 2.1 presents the flow of the subtopics of this chapter.

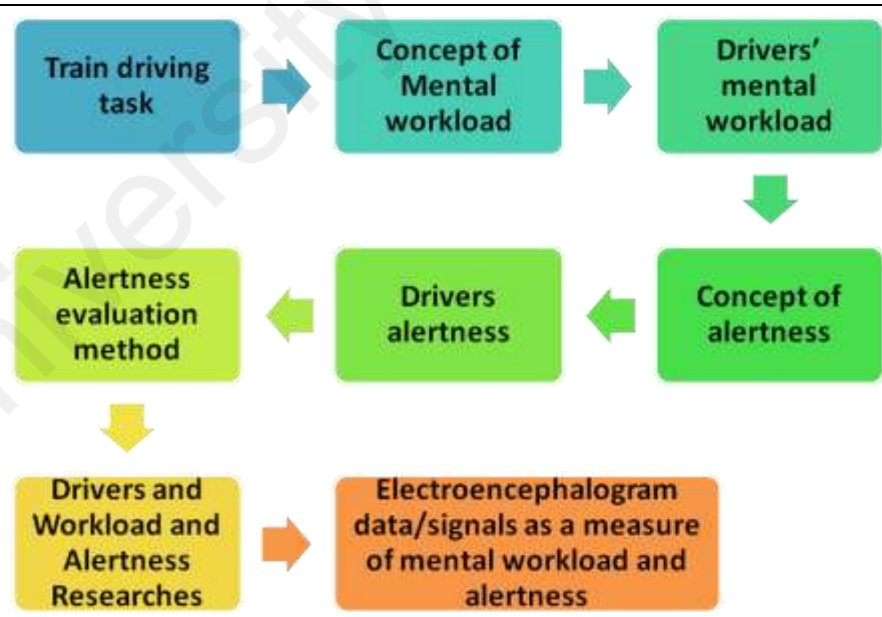

Figure 2.1: The flow of the subtopics of the Literature Review.

Train driving can be described as a dynamic control and decision-making task which involves psychological, technical and social elements (Kecklund et al., 2003; R›ine, 2007). The dynamic control of the train driver can be characterized in terms of human dynamics which are the actions and interactions of personal, interpersonal and social or contextual factors and their effect on behavioral outcomes (Defense Science Board Washington DC, 2009). When it comes to personal and psychological measures, the mental workload is one of the elements that can reflect the individual's performance of work. Verwey (1993) stated that a driver's mental workload can be described as an important factor in causing accidents. It is important to evaluate a train driver's mental workload to ensure the safety and performance of the train and quality of service to passengers (Rail Safety and Standards Board, 2005).

Previously, human mental workloads have been analyzed using questionnaires, which is a technique of qualitative measurement (Hart & Staveland, 1988; Luximon & Goonetilleke, 2001; Reid & Nygren, 1988). This subjective measurement tool has been developed from time to time so that it can be used in a suitable condition. The Institute of Ergonomics at the University of Nottingham has developed the Rail Ergonomics Questionnaire (REQUEST) to monitor a wide range of rail human factors including the mental workload (Ryan et al., 2009). Recently, physiological studies indices to measure mental workload have been investigated. These physiological parameters include Heart Rate Variability (HRV), ECG (Electrocardiogram) and EOG (Electrooculogram) data. Electroencephalogram (EEG) has been identified as an applicable and accurate approach in assessing and determining mental workload (Ryu & Myung, 2005; Rabbi et al., 2009). Thus, it is the aim of this research to determine mental workload base on validated and direct assessment method.

2.2. Train Driving Task

The train driving task is pictured as a sociotechnical task system since it involves psychological, technical and social elements (Roine, 2007). A sociotechnical system can be classified as complex if it involves large problem spaces, social and heterogeneous perspectives, distributed, dynamic and potentially high hazards, many coupled subsystems, automated processes, uncertain data and mediated action via computers or disturbance management (Vicente, 1999; Woods, 1988). The main goal of train driving is to ensure the safety and performance of the train and to ensure high quality of service to passengers.

The primary principles in train driving are basic and important for safety and performance (Rail Safety and Standards Board, 2005). One of the main principles is that the drivers are able to maintain sufficient attention to monitor incoming information and changes to the predicted environment. The train drivers are expected not to be bored and able to remain fully alert at all times. At the same time, they are required to be able to see and reach all equipment related to monitoring, controlling and receiving feedback. In this situation, the control panel is involved and has to ease the train driver in fulfilling the required task (Rail Safety and Standards Board, 2005).

In train driving, the control task can be divided into two which are overall task and subtasks. The overall task generally requires the train driver to transport the passengers or luggage from one place to another safely in an efficient duration without any agitations. The projection of the tasks can be seen in Figure 2.2. When traveling between stations, there are three important subtasks that need to be addressed in order to fulfill the goal. The subtasks under this overall task are to travel between stations on time, stop at stations to let people on or off and leave the stations on time (Roine, 2007). Meanwhile, when reaching the station, there are seven strategies that need to be done to safely let passengers get in or out of the train which is one of them is to stop smoothly and safely at the right station. Lastly, there are five subtasks when leaving the station as the critical one is to reach the travel speed as fast as they can so that delay of time will not happen.

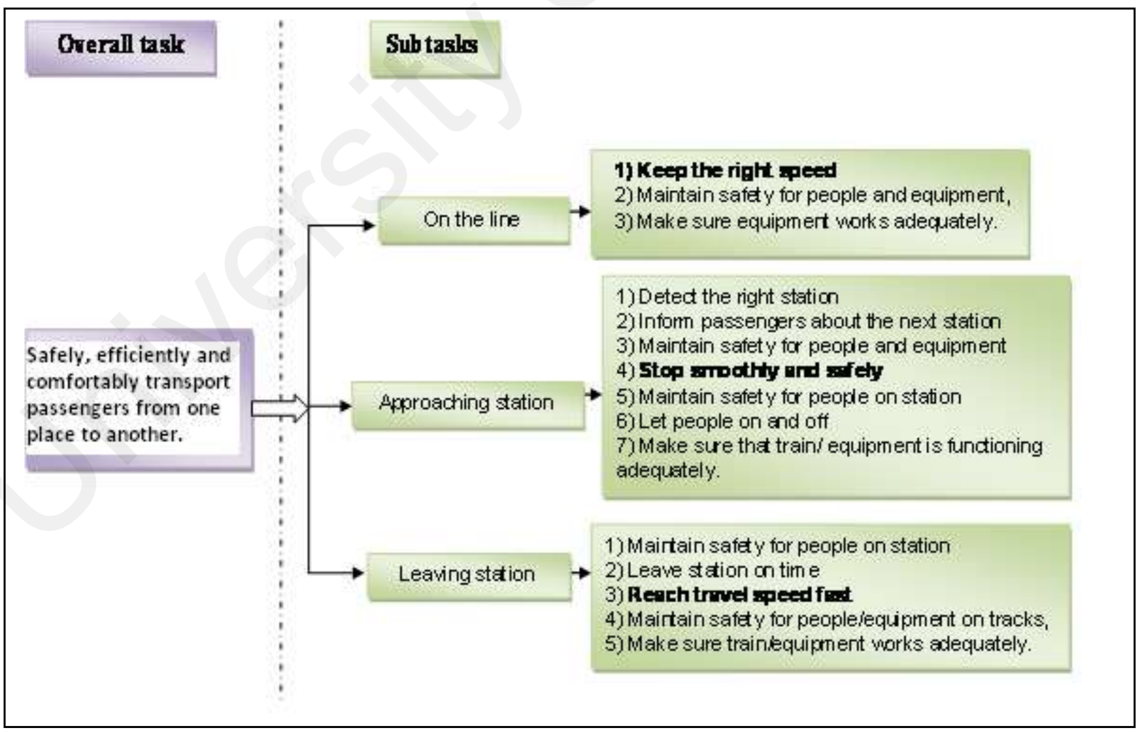

Figure 2.2: A train driving task (Source: Roine, 2007).

Among the subtasks that have been observed by Roine (2007), we can see that the most critical subtask involves the speed of the train. When the train is on the line phase, the high order subtask is to *keep the right speed*. This involves the acceleration toggle of the control panel. Biemans et al. (2006) stated that control of speed is one of the elements in the decision making of a train driver when performing their work task. While approaching the station, the moving train needs to be stopped smoothly and safely. Therefore, it is important for the train driver to be comfortable and familiar with the accelerating and braking part of the control panel. Meanwhile, when the train is leaving the station, the train driver needs to accelerate and reach the travel speed within a suitable amount of time since each journey has their own expected journey duration from one place to another. At this stage, the acceleration toggle should not give any problems and delays may occur if it does not function adequately.

2.3. Concept of Mental Workload

The definition of mental workload can be simplified as the relationship between the mental demand of a task and the worker being (De Waard, 1996; Leung, 2006). Demand can be defined as the effort to be made in order to achieve a certain goal. A human that was given a goal to achieve will allocate an amount of effort in terms of mental, physical and emotional effort. A task that requires physical strength can be understood to be a physical workload. It can also be related to the dynamic and/or static muscular work of a human being (Oron-Gilad et al., 2008). Meanwhile, emotional workload involves stress and mental strain (Leung, 2006) which is also related to the mental workload.

A literature review of the concept of the mental workload describes mental workload as how the goal is reached and how much resources are required by the task. Thus the mental workload depends not only on the operator but also on the characteristics of the task. Each individual by nature has different ways, capabilities and nature in living their daily life. The tasks that have to be faced everyday are performed with different amounts of resources and are done differently from one person to another. In addition, the individual’s resources also depend on his or her experiences and skills owned (HQs Civil Aviation Authority, 2009). Because of these differences, a given task will not induce the same level of workload for all persons. Meanwhile, the characteristics of a task may result in different amounts of resources needed. A task that has high complexity is a task that has a larger number of stages of processing in order to complete it. A high complexity system can apply a heavy mental workload to the human operators (Hwang, et al, 2007). Difficulty is also one of the task characteristics which are related to the processing effort that is required by the individual for task performance (De Waard, 1996).

Having an appropriate level of mental workload is important for each individual human operator. This is because each individual is expected to perform as anticipated when a task is given. Hwang et al. (2007) stated that for most human operators, the performance indicator will be degraded if the mental workload is either too high or too low. A human operator may go through a delay of information processing or even unable to respond at all to the incoming information when the capacity to process it exceeds the maximum limit (Ryu & Myung, 2005). They also stated that when human operators' mental workload is much lower than the proper level, they will become bored and tend to make mistakes.

There are several previous studies that prove that research on mental workload is very important. Hwang et al. (2007) developed an early warning model that allows the operator or supervisor to monitor operator mental workload by a physiological indicator. Meanwhile Raskin (2000) stated that human-computer interface usability can be strengthened by mental workload measures. In addition, monitoring human operator mental workload also helps in designing appropriate adaptive automation strategies (Kaber & Usher, 2000).The proposed model can also be applied to fields such as aviation, air transportation control, driving and radar vigilance.

2.3.1. Drivers' Mental Workload

A driver's workload can be described as the relationship between the driver and the driving task. It has been defined by Parkes (1991) that the primary task of a driver is the safe control of the vehicle within the traffic environment. A driver is a person who is responsible for operating a transport vehicle in reaching its destination. The destination here can be described as the goal of a demand in a driving task as been discussed previously.

Drivers play an important role in any vehicle whether on the road or railways. Ergonomists are concerned about the drivers' mental workload since an overload of information may lead to distraction while the driving task is performed (Mayser et al., 2003, W.B Verwey, 2000). De Waard (1996) stated a few factors that can affect the driver's workload as in Figure 2.3. These factors were reported to have the capability to increase or decrease the mental workload. For example, instead of reducing demand, feedback may become additional information that has to be processed which then can lead to an increase of workload. Vehicle ergonomic components such as steering wheel position, display layout, pedal, seat height, seat back angle and other vital elements are also included in the environmental factors that can affect the driver's mental workload.

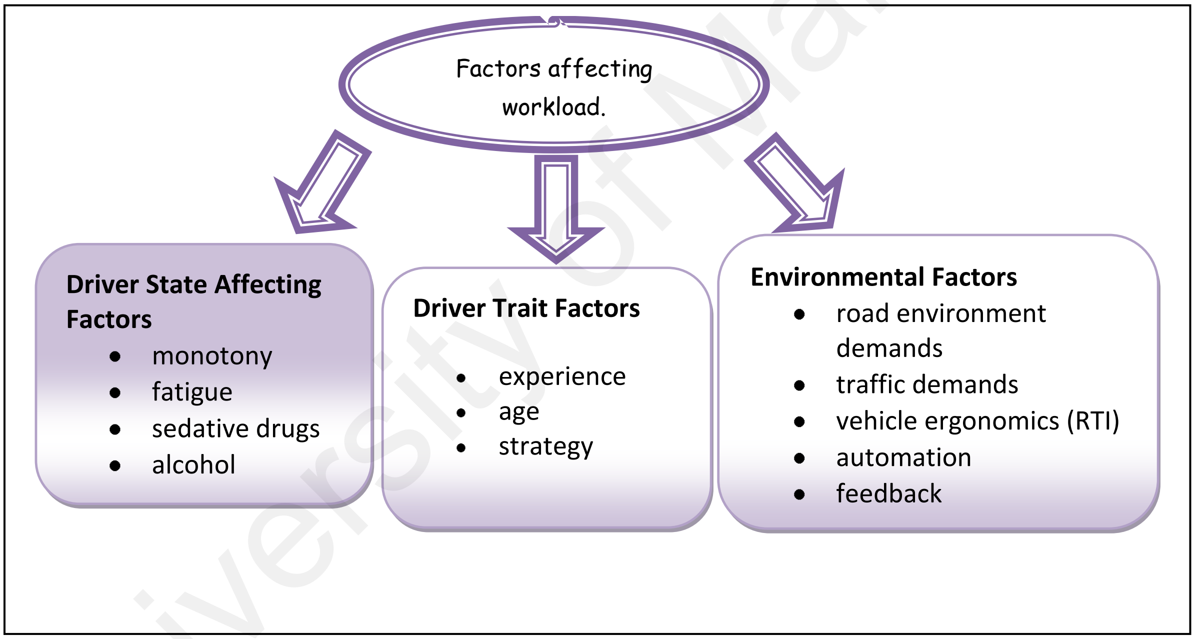

Figure 2.3: Factors that affect driver workload (source: De Waard,1996)

Generally drivers of any transportation vehicle have to go through various different types of conditions and environments while driving. Sometimes the weather changes unexpectedly but the journey must continue whether it is a short or a long distance one. Conflicting weather such as rain makes drivers' work difficult which can cause accidents due to different road conditions. Kilpeläinen et al., (2007) stated that rain is one of the adverse weather conditions which can be considered as a cause of an elevated risk of traffic accidents in northern Europe and northern America. In facing this, drivers have to at least know simple strategies to face the demand during the driving session, especially in adverse environments. It was mentioned by Lee and Triggs (1976) that an increase in environmental complexity during driving negatively affects peripheral stimuli detection.

In addition, night driving is also included in unfavorable driving conditions for certain people. This may be due to the visual inadequacy and human factors such as sleepiness and fatigue. A few studies from previous years concluded that train drivers were especially fatigued during the night time train driving shift (Austin & Drummond, 1986; Rajaratnam & Jones, 2004; Torsvall & Akerstedt, 1987). Austin & Drummond (1986) found out that drivers tend to fall asleep while driving at night. This clearly can be dangerous not only to the drivers themselves but also the passengers.

2.3.2. Mental Workload Evaluation Method

Researchers previously were inspired to study mental workloads after realizing the importance of this human factor. There were three types of measurement that have been used generally to measure mental workload particularly for drivers (HQs Civil Aviation Authority, 2009; Hwang, et al., 2007; Lei & Roetting, 2011; Ryu & Myung, 2005). The first is by directly measuring a driver's performance in criterion tasks. As a part of the evaluation of a human-machine system, performance measures of workload are often supplemented by other types of measures (HQs Civil Aviation Authority, 2009). For driver performance measures, the primary tasks were evaluated based on attention, inferring responses and directly observable operator responses and control actions (Zeitlin, 1998).

The second approach to mental workload estimation assumes that self reported judgments by operators are a useful type of measure (HQs Civil Aviation Authority, 2009; Zeitlin, 1998). This method can simply request the operator to give an opinion on how hard a particular task is. The cognitive technique is essential for lot of workload rating scales such as the Task Load Index (TLX) by Hart & Staveland (1988), Subjective Workload Assessment (SWAT) by Reid & Nygren (1988), Integrated Workload Scale (IWS) by Pickup et al. (2005) and Overall Workload (OW) scale by Vidulich and Tsang (1987). The task experiences are rated by the operators from low to high levels of difficulty. Besides being very useful in a controlled situation, rating scales are administered ex post facto, permitting time and operator self image considerations to moderate the results (Zeitlin, 1998).

The third method that has been very effective in the evaluation of mental workload is by physiological measurement (Hwang, et al., 2007; Lei & Roetting, 2011; Rabbi, et al., 2009; Ryu & Myung, 2005). Each person's physiological responses to mental tasks were different from one another and the result patterns were also different from task to task (Hwang, et al., 2007; Shinji, 2001; Xie & Salvendy, 2000). There are many physiological parameters but those that are widely used by experts are brain signal activity measurement using Electroencephalogram (EEG), Heart Rate, Eye blinking and Heart Rate Variability (HRV). Among these advanced measurements, EEG tool is more acceptable and accurate in providing a quantitative measurement of human performance (Rabbi, et al., 2009; Ryu & Myung, 2005; Chen & Vertegaal, 2004).

2.4. The Concept of Alertness

Alertness can be defined as a measure of being mentally quick, active, and keenly aware of the environment (Mosby, 2009). Being alert is a complex behavioral state that gives major impacts on daily lives. A person that is in an alert condition is conscious: aware of environment, capable of focusing on a task, neither sleepy nor fatigued, and able to concentrate and be motivated (Shapiro et al., 2006). Usually alertness is said to be contradictory to sleepiness condition. It is crucial and risky to be sleepy in unsuitable conditions. It was found out in previous studies that sleepiness is a risk factor for accidents, interpersonal problems, and decreased productivity has also been recognized (Johnson et al., 1999). In addition, alertness can be defined as the capacity of the mind to respond appropriately to external and internal stimuli which reflected that it can be measured by degree(Shapiro et al., 2006).

2.4.1. Driver's Alertness

After understanding what is meant by the mental workload of drivers, it can be seen that it is very closely linked to alertness. Changes in mental workload also result in changes to the level of alertness (Otmani, Rogé, & Muzet, 2005). In land transportation, drivers with high mental workload can have reduced alertness, diverted attention, and inadequate time for information processing (Or & Duffy, 2007). Alertness can be basically defined as the mental state of aroused awareness (Blood, Studdert, & Gay, 2007) and thus decreased alertness is a state of reduced awareness. Alertness and constant attention to the environment are related to many primary brain processes and are linked to psychological constructs.

Figure 2.4: Driver's vision which critically link to alertness

(Picture *source: www.driver-improvement.co.uk*)

There are a few contributors to the change of drivers' alertness level. Long duration of work can result in boredom (Rail Safety and Standards Board, 2008). The same goes for train drivers where an increase of driving time also was found out to be a significant contributor to the decrease of alertness level (Otmani, et al., 2005). Nothing is more frustrating than not being able to sleep and hence amount of sleep also affects one's alertness when working. Impaired alertness may happen due to sleep debts which then negatively affect reaction times, concentration, judgments and decision making (Rail Safety and Standards Board, 2008). Furthermore, nocturnal driving also affects the drivers' alertness. There are two particular times that can cause physiological decrement in alertness, which is in the afternoon and at night (Otmani, et al., 2005). Many researchers reported there was a drop in the alertness level during the night for professional drivers, which can thus jeopardize their work (Gillberg, Kecklund, & Åkerstedt, 1996; Torsvall & åAkerstedt, 1987).

Environmental factors have also been related to changes in alertness. One of the environmental factors is noise. Taylor et al.(2004) found in their study that random and intermittent noise was shown to have negative effects on their task accuracy experiments. Noise is also known to contribute sturdily to a deterioration of the alertness condition of workers when performing their work (Rail Safety and Standards Board, 2008). In addition, the environmental working temperature has also been an influential factor. An overcooling driving condition induces restlessness and hence decreases the alertness and attention particularly to mental tasks, while in heated working conditions one may feel stress and pressure.

2.4.2. Alertness Evaluation Method

Alertness measurements are known to have different types of techniques but two are widely used by many researchers; subjective measurement and qualitative measurement. Shapiro et al. (2006) developed two types of questionnaires to collect data related to alertness. They named the surveys the Toronto Hospital Alertness Test (THAT) and the ZOGIM-A which helped to measure psychometric properties. Otmani et. al (2005) collected scores of the Karolinska Sleepiness Scale (KSS) in their study of sleepiness and alertness of drivers. They found that there was no significant difference between the two driving times of day (afternoon and evening) in the KSS scores.

Nowadays electrophysiological recordings are popular and considered to be a reliable method of assessing a person's alertness (Conradt et al., 1999; Subasi, 2005). EEG signals that indicate spontaneous electrical brain activities are broadly used by researchers to continuously see the vigilance and alertness state of human beings. With the help of a computerized analysis of the EEG, the recording facilitates most of the research and is a strategy used to reduce the time consumed to solve problems.

2.5. Drivers and Workload and Alertness Researches

Some prior research studies about drivers and workload during driving have been summarized in Table 2.1 which most of them used Electroencephalography as their main methodology.

Table 2.1: Some studies about Drivers and Workload

Title : Comparing combinations of EEG activity in train drivers during monotonous driving			
Author (Year)	**Objective**	**Methodology**	**Results**
Budi Thomas Jap, Sara Lal, Peter Fischer (2011)	1. To investigate the changes in EEG activity (delta, theta, alpha, and beta) in train drivers during a monotonous train-driving session 2. To investigate the performance difference in several combinations of EEG activity that might be used as a potential fatigue indicator.	A total of **fifty male** train drivers were recruited to perform a **30-min monotonous train-driving task** while 2-channels of EEG (frontal and temporal) were recorded.	**Significant differences** were found : At the frontal site :theta & alpha activities At the temporal site: delta & theta activities. For the average of frontal and temporal site activities: delta, theta & beta. For temporal site for equation 1 & equation 4 For the average of frontal and temporal site activities: significant differences were found for all four equations. These findings can be utilised as a potential fatigue indicator

Title : Electroencephalographic study of drowsiness in simulated driving with sleep deprivation			
Author	**Objective**	**Methodology**	**Results**
Hong J. Eoh, Min K. Chung, Seong-Han Kim (2005)	To analyze the EEG changes in fatigued subjects while performing a simulated driving task	After a night of sleep deprivation, **eight** subjects were given a dose of caffeine to reduce drowsiness. During about **50 min of continuous driving**, car movements and subject behaviors were recorded on video cameras, and 8 channels of EEG were also recorded	EEG a, b, b/a and (a+y)/b indices showed significant differences between driving periods. In the comparison of road type, EEG a, b, b/a and (a+y)/b indices of the straight section of the driving task were significantly different from those of the curved section. This study also analyzed EEG changes before and after car accidents, showing that b and (a+y)/b were related to the mental alertness level

Title : Wakefulness in young and elderly subjects driving at night in a car simulator			
Author	**Objective**	**Methodology**	**Results**
Arne Lowdena, Anna Anund, Göran Kecklunda, Björn Peters, Torbjörn Åkerstedt (2009)	To investigate the effects of an evening and night drive on wakefulness and driving performance among young and elderly subjects in an advanced moving base driving simulator.	Performance during a 45/min evening and night drive among young (*n* = 10, age range 18–24 years) and elderly (*n* = 10, age range 55–64 years) subjects was studied using a moving base driving simulator. EEG was measured continuously. Every 5 min, subjects	**Sleepiness increased** across each drive and was **higher among young drivers at night**. Relative EEG power increased among older drivers for frequencies of 10–16 Hz. The **sigma** 1 frequency band (12–14 Hz) proved particularly sensitive to

		were rated on the Karolinska Sleepiness Scale (KSS). Saliva cortisol was assessed before and after each drive.	sustained driving and was elevated among subjects in the elderly group. Cortisol levels before and after the evening and night drive showed higher mean levels for elderly subjects. **Young drivers were sleepier** while driving at night. The effects could represent a mobilization of effort and a reorganization of brain firing pattern among older subjects, possibly reflecting better ability and **effort to resist sleepiness.**
Title : Driver's Mental Workload Assessment Using EEG Data in a Dual Task Paradigm			
Author	**Objective**	**Methodology**	**Results**
Shengguang Lei, Sebastian Welke, Matthias Roetting (2009)	1. To develop new approaches of driver state monitoring based on brain signals. 2. To assess the driver mental workload.	Participants were requested to perform the lane change task under three task conditions - primary LCT, LCT with a slow PASAT and LCT with a fast PASAT. The EEG recordings combined with performance data from LCT and PASAT provided plenty information for comprehensive	The analysis of event-related potentials (ERP) revealed that LCT evoked cognitive responses, such as P2, N2, P3b, CNV, and the amplitudes of P3b **decreased with the task load.** A crucial benefit of these findings is that the **increase or**

		understanding of driver's workload.	**decrease of amplitudes of ERP components can be directly used for representing driver's mental workload**.
Title : Influence of Task Combination on EEG Spectrum Modulation for Driver Workload Estimation			
Author	**Objective**	**Methodology**	**Results**
Shengguang Lei, Matthias Roetting (2011)	To investigate the feasibility of using a method based on electroencephalograph y (EEG) for deriving a driver's mental workload index.	An experiment combining a lane-change task and *n*-back task was conducted. The task load levels were manipulated in two dimensions, driving task load and working memory load, with each containing three task load conditions.	The frontal theta activity showed significant increases in the working memory load dimension, but differences were not found with the driving task load dimension. Significant decreases in parietal alpha activity were found when the task load was increased in both dimensions. Task-related differences were also found. The driving task load contributed more to the changes in alpha power, whereas the working memory load contributed more to the changes in theta power. These two task load dimensions caused significant interactive effects on both theta

			and alpha power.
Title : Physical, mental, emotional, and subjective workload components in train drivers			
Author	**Objective**	**Methodology**	**Results**
M. Myrteka, E. Deutschmann -Janickea, H. Strohmaiera, W. Zimmermann b, S. Lawerenzb, G. Brügnera, W. Müllera (1994)	To differentiate between the physical, emotional, mental, and subjective workload components imposed on the drivers during work.	Using 12 train drivers on a high speed track and 11 drivers on a mountain track Simultaneous recording and on-line analysis of heart rate and physical activity, the emotional component in terms of the so-called additional heart rate was separated from the physical component. Mental workload was calculated by the heart rate variability and by shifts in the T-wave amplitude of the ECG. Speed of the train, mode of driving, and stress of the situation were rated by two observers who accompanied the drivers in the cabin.	During speeds up to l00km/h as compared to standstills no heart rate changes occurred, but with speeds from 100 km/h up to 200 km/h heart rate decreased indicating a monotony effect. Heart rate variability and T·wave amplitude indicated higher mental load during driving in most speed categories. Starting the train and coming to a halt showed greater emotional workload as compared to moving. Observer ratings of stress and subjective ratings of stress by the drivers revealed several discrepancies. Discrepancies were also seen between workload as indicated by the physiological parameters, and corresponding stress ratings by the observers

			or by the drivers.
Title : A vision-taste interference model and the EEG measurement			
Author	**Objective**	**Methodology**	**Results**
Tanaka Hisaya, Sato Yuichi (2011)	To test an interference model in the processes of taste and vision information.	The subjects were four healthy males (aged 21–22 years). The experiment was conducted in a laboratory which was not a shielded room, and the lights were turned off during The experiment, i.e., the condition of a dark room. The model was tested with frequency analysis on EEG and using the switch response time. The tasks were matched/miss-matched between taste and vision information about orange juice and apple juice.	There were changes in the **α waves that originated in the visual processing** of a juice package, and changes in the **β waves that originated in the taste processing.** There is the possibility of a parallel processing mechanism in the vision–taste interference.
Title : Evaluation of mental workload with a combined measure based on physiological indices during a dual task of tracking and mental arithmetic			
Author	**Objective**	**Methodology**	**Results**
Kilseop Ryu, Rohae Myung (2005)	To determine the mental effort required for each task A combined measure was developed based on various physiological indices to evaluate the mental workload during a dual task.	Three physiological signals were recorded while ten subjects performed different versions of a dual task composed of tracking and mental arithmetic. These signals were the electroencephalogram (EEG), electrooculogram (EOG), and electrocardiogram (ECG), which were transformed into the	The alpha suppression provided proper information to infer the efforts for the arithmetic task, but not for the tracking task. The blink interval and HRV permitted detailed inferences over the workload of the tracking task, but not for the arithmetic task. These results can be explained in terms of

		suppression of alpha rhythm, eye blink interval, and heart rate variability (HRV), respectively. EEG was recorded using an electrode cap with electrodes placed at FZ, PZ, O1, O2 in the International 10–20 montage	the multiple resources model of workload. The processing indexed by the alpha suppression is inferred to be different from that indexed by the blink interval or HRV. The physiological measures were combined into a single measure using different weight coefficients. The newly developed measure systematically increased with the difficulty of each task and significantly distinguished between the different versions of each task.
Title : EEG Correlates of Task Engagement and Mental Workload in Vigilance, Learning, and Memory Tasks			
Author	**Objective**	**Methodology**	**Results**
Chris Berka, Daniel J. Levendowski , Michelle N. Lumicao, Alan Yau, Gene Davis, Vladimir T. Zivkovic, Richard E. Olmstead, Patrice D. Tremoulet,	To continuously and unobtrusively monitor levels of task engagement and mental workload in an operational environment could be useful in identifying more accurate and efficient methods for humans to interact with technology. To optimize the design	EEG was acquired from 80 healthy participants with a wireless sensor headset (F3-F4,C3-C4,Cz-POz,F3-Cz,Fz-C3,Fz-POz) during tasks including: Multi-level forward/backward-digit-span, grid-recall, trails, mental-addition,20-min 3-Choice Vigilance, and image-learning and memory tests.	Engagement but not workload decreased over the 20-min vigilance test. Engagement and workload were significantly increased during the encoding period of verbal and image-learning and memory tests when compared with the recognition/recall

Patrick L. (2007)	of safer, more efficient work environments that increase motivation and productivity.	EEG metrics for engagement and workload were calculated for each 1-s of EEG.	period. Workload but not engagement increased linearly as level of difficulty increased in forward and backward-digit-span, grid-recall, and mental-addition tests. EEG measures correlated with both subjective and objective performance metrics.
Title : A Mental Workload Predicator Model for the Design of Pre Alarm Systems			
Author	**Objective**	**Methodology**	**Results**
Sheue-ling Hwang Yi-jan Yau Yu-ting Lin Jun Hao Chen (2007)	To develop a real-time, non-intrusive mental workload predicative model by using Group Method of Data Handling (GMDH) to integrate seven physiological indexes into a synthesized index.	**Fifteen** paid NTHU graduate students participated in this experiment (normal eyesight and good health, mean age = 24 years). An experiment including the primary and secondary tasks was designed to simulate the reactor shutdown procedure of the Nuclear Power Plant. The performance of secondary task, the subjective mental workload and seven physiological signals of participant were measured.	The relationship between subject mental workload and the performance of secondary task is highly correlated with Pearson correlation coefficient as 0.691. The **validity of the proposed model** is very **high** with R2=0.85. The proposed model is expected to **provide supervisor a reference value of operator's performance** by giving physiological signals.

		The Group Method of Data Handling (GMDH) was applied to integrate these physiological signals to develop a mental workload predictive model.	The proposed model could be **applied to other fields such as aviation, air transportation control, driving and radar vigilance**, etc.
Title : Mental Workload While Driving: Effects on Visual Search, Discrimination, and Decision Making			
Author	**Objective**	**Methodology**	**Results**
Miguel A. Recarte, Luis M. Nunes (2003)	1. To extend the scope of previous studies to perceptual and decision capacities 2. To increase the ecological value of the research by testing other tasks more related to everyday life.	12 participants who drove an instrumented car. Mental workload was manipulated by having participants perform several mental tasks while driving. A simultaneous visual-detection and discrimination test was used as performance criteria.	Mental tasks produced spatial gaze concentration and visual-detection impairment, although no tunnel vision occurred. According to ocular behavior analysis, this impairment was due to late detection and poor identification more than to response selection. Verbal acquisition tasks were innocuous compared with production tasks, and complex conversations, whether by phone or with a passenger, are dangerous for road safety

Title : A new approach to the construct of alertness			
Author	**Objective**	**Methodology**	**Results**
Colin M. Shapiro, Christine Auch, Marlene Reimer, Leonid Kayumova, Ronald Heslegrave, Nada Huterer, Helen Drivera, Gerald M. Devins (2006)	Develop two questionnaires to measure alertness, the Toronto Hospital Alertness Test (THAT) and the ZOGIM-A, and evaluated their psychometric properties.	Examined the correspondence between scores on the THAT and the ZOGIM-A in a sample of sleep clinic outpatients (n=96) with Maintenance of Wakefulness Test (MWT) results after an overnight sleep study, physiological sleep parameters, measures of subjective sleepiness, and two psychosocial variables (psychological well-being and emotional distress). Test–retest reliability was estimated based on responses from an independent sample of 295 sleep clinic outpatients who completed the instruments before and after an overnight sleep study.	High values were observed for both the THAT (rtt=.79) and the ZOGIM-A (rtt=.70). Internal consistency reliability (coefficient alpha) was also high: .96 for THAT and .83 for ZOGIM-A. Neither of the new scales correlated significantly with measures derived from the MWT or nocturnal physiological measures. The two alertness scales did correlate significantly and as hypothesized with subjective measures of sleepiness and other psychosocial measures.
Title : Changes in electrical activity of the brain with vigilance			
Author	**Objective**	**Methodology**	**Results**
A Belyavin, Nicola A Wright (1987)	To study the relationship between EEG and vigilance	Subjects performed tasks of differing complexity over a 15 h period by examining the structural changes of the EEG as vigilance deteriorates. The relationship between	Calculation of canomical variates indicated that two directions explained the changes in vigilance, though one direction was dominant across subjects and tasks, and

		EEG and vigilance was modeled by fitting a linear function of EEG variables to the proportion of missed responses.	likely to reflect decreased arousal. The second direction indicated some evidence for a second underlying change in the EEG related to vigilance in some subjects particularly in the more complex task, and this would reflect mechanisms other than drowsiness. The coefficient of multiple correlations was significant for most subjects, and the relationship is likely to represent changes in arousal. The most useful discriminator of worsening vigilance common to both tasks was beta activity (14−21 Hz)
Title : Alertness management in long-haul flying			
Author	**Objective**	**Methodology**	**Results**
David J.C. Flower (2001)	To assess the acceptability and practicality of developing route- and time-specific advice for British Airways crew members	20 captains and 20 first officers A manual was developed consisting of two sections. The first, containing general information, was based on the core content of the	Further advice cards were developed to cover the entire British Airways long-haul network and the complete Alertness Management package comprises a General

		NASA Fatigue Countermeasures Program. The second part of the manual comprised a series of advice cards together with an index and detailed instructions on their use. Subjects found the advice cards easy to use and helpful and the information booklet clear in outlining the physiology of sleep, alertness and circadian rhythms.	Information section summarising the classroom teaching together with 30 Advice Cards covering 42 different route schedules grouped by direction of travel, time of departure and length of the layover. The cards contain general and specific advice including recommendations for light exposure, rest patterns and meal times presented in written and diagrammatic forms.
Title: Effect of driving duration and partial sleep deprivation on subsequent alertness and performance of car drivers.			
Author	**Objective**	**Methodology**	**Results**
Sarah Otmani, Thierry Pebayle, Joceline Roge, Alain Muzet (2005)	To investigate the effect of partial sleep deprivation and driving duration on subsequent alertness and performance in car drivers	Twenty healthy male subjects, between 25 and 55 years of age, free from any sleep disorder, took part in two simulated driving sessions carried out between 2 p.m. and 4 p.m. Before one session, subjects were sleep deprived as they were allowed to sleep only between 3 a.m. and 7 a.m. during the preceding night. Throughout the driving task, the subjects' driving performance, electroencephalogram and	The results revealed that sleep deprivation had an effect on KSS score but not on the (alpha + theta) spectral power, while driving duration had an effect on these two parameters. This effect was also influenced by sleep restriction. Time on driving task alone had a significant

		Karolinska Sleepiness Scale (KSS) score were recorded.	effect on driving performance; the sleep restriction having only an effect on one of the performances indices studied: the number of right edge-line crossings. These results are interpreted in terms of the relationship between level of alertness and performance impairment

2.6. Electroencephalogram Data/Signals in Measuring Mental Workload and Alertness

The electrical activity from a human scalp that is actualized by the brain structure can be read using a medical imaging technique called electroencephalography (EEG). Niedermeyer & da Silva (1993) define EEG as electrical activity of alternating types observed and stored from the surface of the scalp after being picked up by metal electrodes and conductive media. The mechanism can be seen in Figure 2.4 which shows the flow of Na+ ions towards the cell body. A negative field potential is created when the extracellular regions around the dendrites become negatively charged (Hagemann, 2008). The Fast Fourier transform (FFT) has been used by previous researchers to derive the power spectral density of raw EEG signals to understand the characteristics produced (Teplan, 2002). The brain signals are classified into four different basic groups which are delta (0.5 – 4 HZ), theta (4-8 Hz), alpha (8-13 Hz) and beta (> 13Hz).

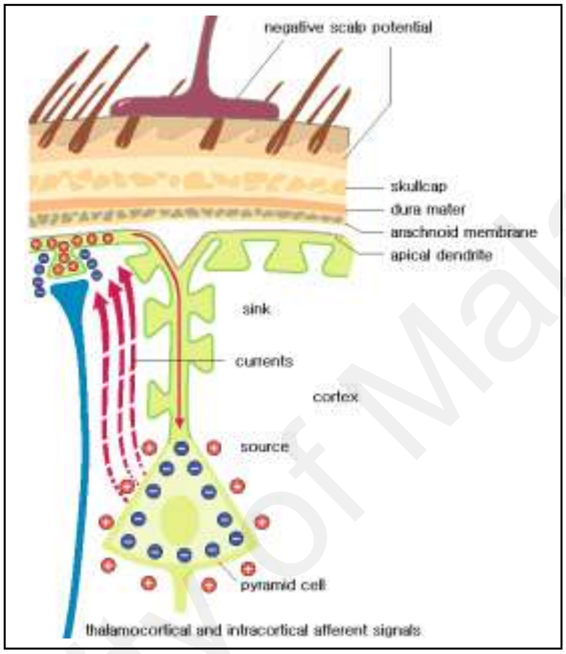

Figure 2.5: Flow of Na+ ions towards the cell body (adapted from Birbaumer & Schmidt, 2006)

Delta wave, which is the slow wave, usually indicates the sleeping condition of a human being. There are several different phases of sleep that can be observed in humans (Brookhuis & de Waard, 2010; Grandjean, 1988). Previous research related theta wave increments with an increase in task load (Gevins et al., 1998; Smith et al., 2001). It was also reported that theta waves show the transition stage between wakefulness and sleep states (Hagemann, 2008). Meanwhile the alpha activity has always been associated with cognitive activities. It will rise when a relaxation or drowsiness potential occurs (Teplan, 2002). In a normal state of wakefulness and alertness, beta waves will occur (Brookhuis & de Waard, 2010).

Prior research has been conducted that reflect the reliability of EEG usage to evaluate mental workload. Ryu and Myung (2005) placed the electrodes at F_Z, P_Z, O_1 and O_2 in the International 10-20 montage with an electronically linked earlobe reference to estimate the mental workload of the operator in their experiments. They reported that alpha suppression could distinguish between the different difficulty levels of the arithmetic task but not between different tracking tasks. In assessing the mental workload in a dual task paradigm for drivers, Lei et al. (2009) used electroencephalography to conduct their experiments that involved task load manipulation (driving task load and working memory load with each containing three task load conditions). The results showed that EEG is a very effective tool to evaluate drivers' mental workload.

Meanwhile, Berka et al. (2007) used EEG as one of their equipment to validate physiological measures of mental workload. They mentioned that EEG workload levels accurately tracked the intended patterns of the tasks designed and the subjective ratings for all tasks except their Trails task. In addition, Lei et al. (2011) performed EEG analysis on participants in which they only focused on frontal-theta power and on parental alpha power. They concluded that increments in a driving task will lead to a decrease in alpha power. It was also stated that electroencephalography is dependable as a provider of sensitive information for driver workload detection.

Alertness is another important measure in completing tasks. Lammers et al. (2005) mention that the EEG pattern can indicate level of alertness. The changes in frequency such as in alpha and beta waves can be used to monitor the excitement potential. A reduction in beta activity was believed to indicate states of weariness and sleepiness as the alertness will decrease (Lal & Craig, 2001). It was also agreed that there is a correlation between a reduction of alertness and a decrease of vigilance level and this can be monitored using EEG signals (Makeig & Inlow, 1993). In addition, the alert state was also expected to produce waves such as low alpha activity and bountiful beta activity (Kecklund, et al., 2003; Subasi, 2005). While the alpha indicator is more constantly associated with performance, one study reported a decrement of beta in the seconds prior to stimulus presentation being a better marker than increased theta (Oken, et al., 2006; Townsend & Johnson, 1979).

2.7. Summary

From the literature review, most prior studies measured mental workload and alertness to understand human work performance trough observation. To date, there has been a lack of focus on the train drivers mental workload and alertness especially in reference to driving condition. It is important to study the effect of different driving conditions on human physiological factor changes. In addition, it can be seen that objective measurement are more promising and accurate. It is suggested that objective data should be used in the new research works.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. Introduction

This chapter presents a description on the research steps taken to accomplish the objective of the study. The methodology was more focus on empirically experimental methods. However, a survey was done to support the perception on the experimental design. The first part of this chapter describes the survey details while the second part presents detailed description of the experimental design consist of participants criteria, parameters, location, apparatus and equipments involved, setup, procedure and instructions that were given to participants.

3.2. Survey

A survey was conducted through a questionnaire to identify the workload of the professional train drivers. The aim of the survey is to investigate their perceptions on the workload and job description at different work condition parameters.

3.2.1. The Survey Instrument

REQUEST (Ryan et al. (2009) questionnaire was used to collect the data. The questionnaire contains questions on broad range of human factors concepts. Six questions from workload and aspect of job sections was selected which related to the research objective. They were put into one set of questionnaire given to the participants. The set was sectioned by the driving conditions; Daytime Driving, Night Driving. Rainy Daytime Driving; Rainy Night Driving. The set of survey instrument can be referred in Appendix A.

3.2.2. Participants

The survey was addressed to the Operation Department Headquarter of Keretapi Tanah Melayu Berhad (KTMB) which is the official main railway transportation operator in Malaysia. Thirty four of experienced train drivers have done the survey. The obtained data of the participants were presented in Chapter 4.

3.2.3. Questionnaire Analysis

The questionnaire analyses were performed using SPSS (version 11.0). The frequency and percentage were used to present the demographic data, personal background and the outcome of the questions. The data were considered as interval and thus parametric statistics were performed (Mullarkey J & S., 1999; Warr, Cook, & Wall, 1979). The percentage of each interval was calculated to see clearly the perceptions rating made by the train drivers.

3.3. Experimental Design

In each experimental design, there are two purposes. Firstly is to provide answers to research questions and secondly is to control variances. Figure 3.1 below presents the sections in the experimental design.

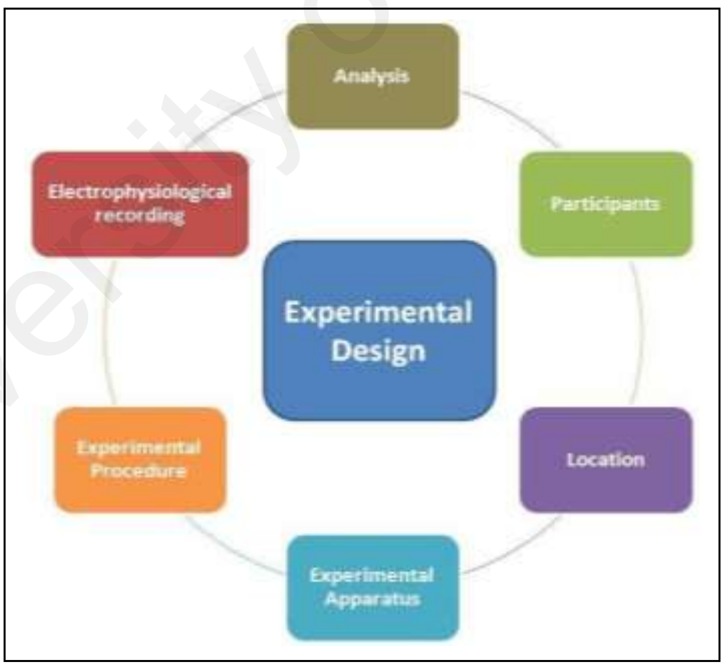

Figure 3.1: Experimental design sections

3.3.1. Participants

Fifteen participants were involved in the experimental study. All of them are male train drivers. Their age were from 24 to 48 years with a mean of 40 (standard deviation = 6.9). All the participants had a valid train driving license. None of them have serious history of illnesses and free of medications which instead could limit compliance of the subject type and affect the physiological measures. All participants read and signed the consent form before the experiment.

3.3.2. Location

The experimental tasks were performed in the Malaysian Railway Academy (MyRA) in Batu Gajah, Perak which operates under Keretapi Tanah Melayu Berhad (KTMB). KTMB is the main train operator in Malaysia which operates since year 1948. Meanwhile, MyRA is a training center for the train drivers in developing the skills and aptitudes needed by KTMB. A room for the experiment has been provided by MyRA which contains a computer-based train driving simulator (Mitsubishi Electric Advance, Japan).

3.3.3. Experimental Apparatus

Three apparatus have been used in the experiment. Some devices were attached to the participants to measure the selected parameters and variables along the duration of the experiment. The apparatus and equipments were as shown the following section.

.

3.3.3.1. The MP150 System and BIOPAC EEG100C Electroencephalogram (EEG)

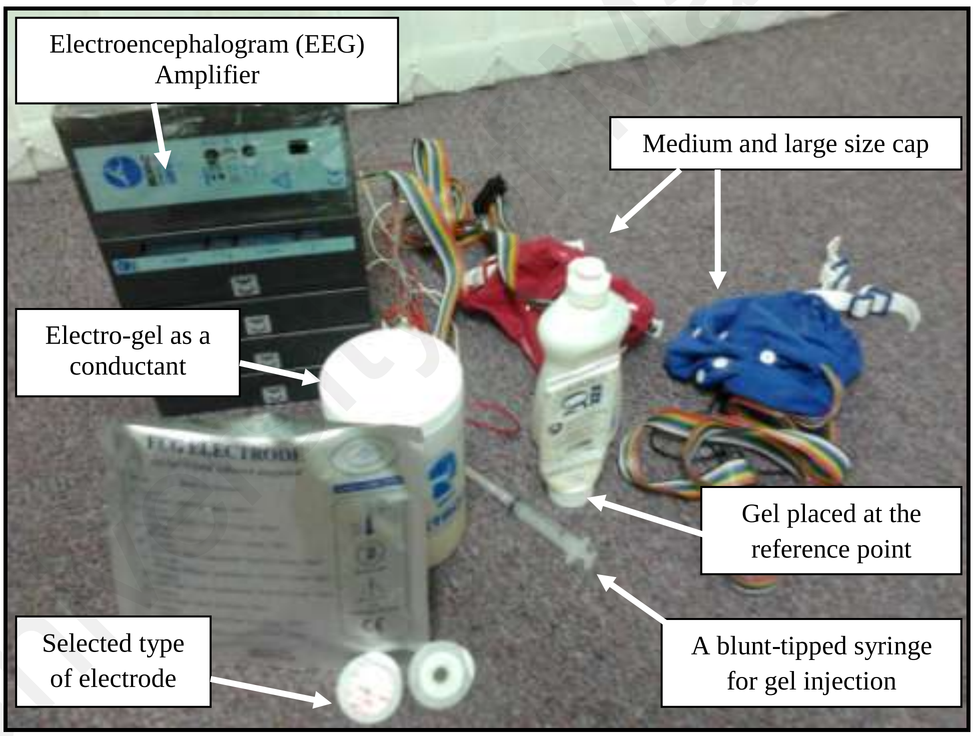

Figure 3.2: All equipment involved in the experiments

The MP150 System is a complete data acquisition system that includes both hardware and software for the acquisition and analysis of life science data. The bioelectric potential related to neuronal activity of the brain was measured using EEG100C Electroencephalogram (EEG) Amplifier. The amplifier helps to amplify the signal and perform unipolar or bipolar measurement. The output can be whether in normal EEG output or alpha wave detection. A software was used to automatically filter the raw EEG signals which in the form of wave activity and analyze the data. At the same time, it helped to remove any Electrooculogram (EOG) artifact in the signals. The frequency bands that can be filtered from the raw EEG are:

Table 3.1: The EEG frequency bands

Bands	**Frequency (Hz)**
Delta	0.5 - 4
Theta	4 - 8
Alpha	8 - 13
Beta	13 - 30
Gamma	36 - 44

The data collection was also completed by the function of a few more apparatus and equipments (Figure 3.2). They are stretch cap, blunt-tipped syringe, gel conductor and electrodes. The stretch cap helped to hold 19 imbedded tin electrodes closely to the participant's head which the electrodes are pre-positioned in the international 10/20 montage. After the cap was in placed, the EEG conductant gel was injected using a blunt-tipped syringe. The electrodes were used at the reference points on the participant’s face.

3.3.3.2. AcqKnowledge® 4.0 Software

The Acq*Knowledge*® 4.0 Software is a part of the MP150 System which allows researchers to perform analysis faster and smoothly. This software was used to complete two basic functions which are acquisition and analysis. The amount of time, rate and all other acquisition parameters was collected easily using this software. In addition, as for the raw EEG data, this software helped to automatically filter the data and remove the EOG artifact in the signals. The function such as viewing, editing and transforming data was done during the data analysis process.

3.3.3.3. DCR-DVD810 DVD Video camera

A video camera was used to record the activities throughout the experiments done by all the participants. During the recording, the situation of doing real train driving task was observed along the experimental task duration. It was used to affirm the data obtain at particular time. The video camera was used with the convenience of a tripod to place it at a suitable place.

Figure 3.3: Video cam for recording the experiment

3.3.4. Experimental Setup

A computer based training driving simulator set consist of a driving software and hardware, speed hand control, a driver seat and a screen. The screen displayed the track that the train was using. The route that has been displayed was the exact train route in Malaysia and had the real environment since the software was developed based on real life situation view. The screen also displayed information such as next destination (station), allocation of time, speed, remaining distance and some technical information as in Figure 3.10. The train driver interacted with the simulator using keyboard, a mouse and also the buttons on the simulator hardware. The control that was used to move, increase or decrease the speed and stop was a multifunction speed hand-operated control. The top view of the setup can be seen in the figure 3.11 below.

Figure 3.4: The screen display of the train simulator

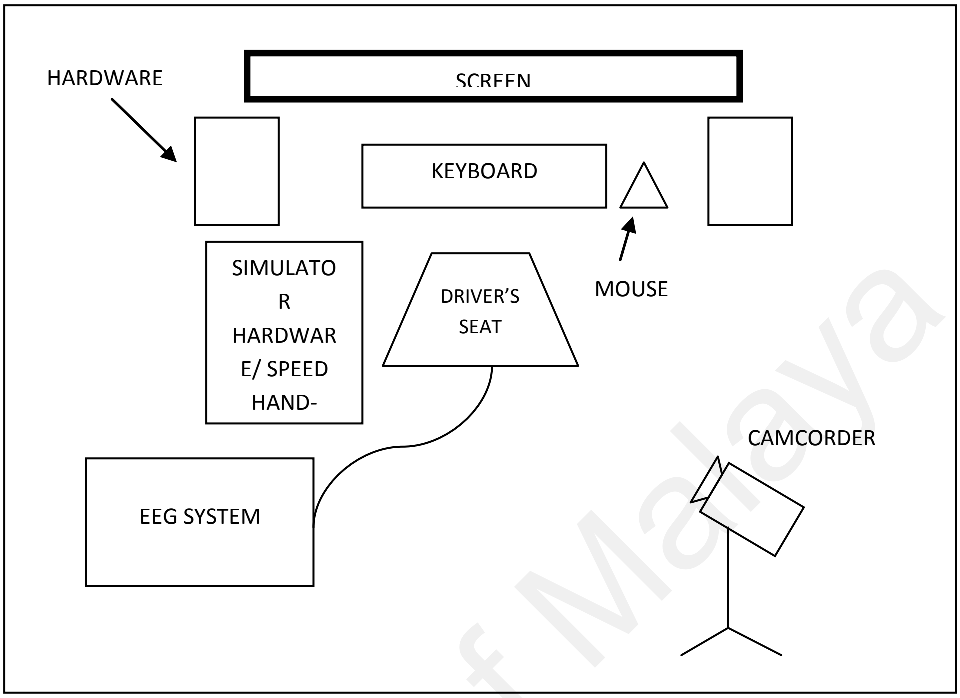

Figure 3.5: The top view of the experimental setup

Figure 3.6: The experimental setup

3.3.5. Experimental Procedure

The initial procedure before starting the task was to collect the participants' demographic data. Various driving conditions (daytime, daytime and raining, night and raining) were represented in three sessions. All participants were asked to complete 60 minutes of monotonous train driving sessions. A repeated measurement design was used with a 5-min break after each session. Each participant was requested to complete three driving session which represented three task load levels (low, moderate and high respectively). The first session was the train driving task in daytime with clear good weather. The second session was set to be a rainy daytime session while the third session was a rainy night driving task. The participants however were given a few minutes of time to familiarize with the controls and the experimental setup to perform the train driving task. The experimental sessions were simplified as in table below.

Table 3.2: The experimental sessions

Session	**Condition**	**Workload**
1	Daytime	Low
2	Daytime and raining	Moderate
3	Night and raining	High

There were two route can be chosen by the train driver, which is journey from Seremban to Kuala Lumpur route or Kuala Lumpur to Ipoh route. Both routes consist of 13 stops before finally arriving the final station.

3.3.6. Electrophysiological recording – EEG and EOG

Physiological recordings were done during the monotonous driving session; collecting electroencephalogram (EEG) and electrooculogram (EOG) data. Both signals were obtained using The MP150 System and BIOPAC set. As shown in Figure 3.13, EEG signals were acquired from six placements of electrodes (F_Z, P_Z, O_1, O_2, P_3 and P_4) in the international 10–20 montage (Andreassi, 2000) and with an electronically linked earlobe reference. Location F_Z is near intentional and motivational center while P_3, P_4 and P_Z contribute to activity of perception and differentiation. Meanwhile primary visual area is located at point O_1 and O_2 (Teplan, 2002). In the meantime EOG recording was done by using electrodes placed above and below the eyes on the right side.

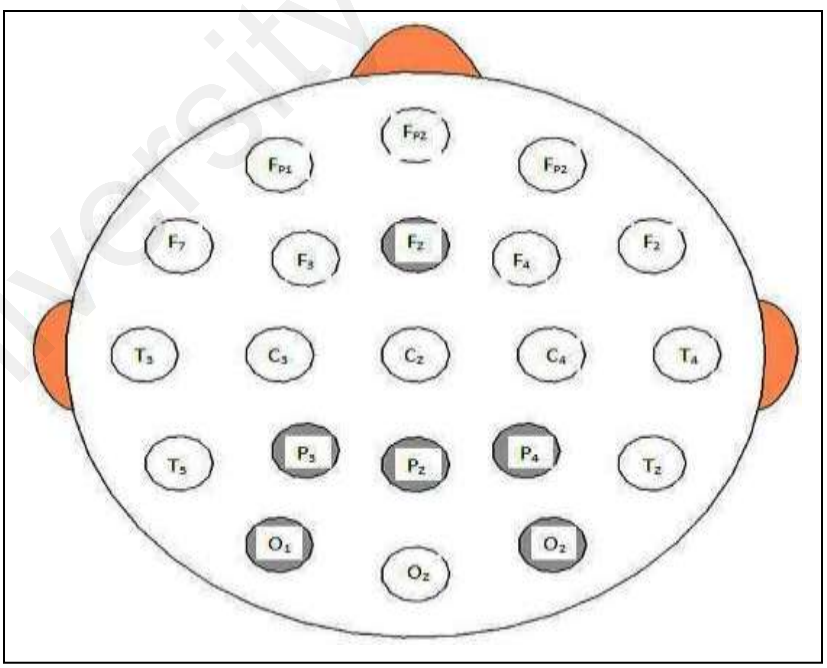

Figure 3.7: Locations of the EEG placements.

3.4. Analysis

There were two types of analysis carried out in this study. AcqKnowledge software was used to perform the signal analysis. The first 120s intervals of the physiological signal from the beginning of each period were excluded from the analysis to eliminate the drifts. The remaining 18-min of the session was then segmented into 6 equal time intervals in order to observe the changes in EEG activities during the driving experiments. Since EEG data contains noises and eye movements artifacts (Lei & Roetting, 2011), EOG data was used to remove them as the measure of the blink interval. The Fast Fourier transform (FFT) analysis was used to extract and estimate for each time interval as the data were smooth using 100% Hanning window. Frequency band, alpha (8-12 Hz) and beta (13 – 30 Hz) was extracted for each task condition and participants. This present study focus only on the selected locations (F_Z, P_Z, O_1, O_2, P_3 and P_4) which the mean alpha power and mean beta power of all the participants was then calculated and put into average.

Next the statistical analyses were conducted to determine the output of the data derived from the EEG software analysis. The Friedman Test was used to analyze the significant differences existed between the mean alpha and beta power data of the three different tasks sessions (S1 to S3) during the 18 minutes duration (6 time intervals). This test is the non-parametric alternative to the one-way ANOVA with repeated measures suitable for this experiment which is a repeated measure. In addition, Kruskal Wallis Test was done to observe the statistical difference among 3 groups of train drivers' age and working experience on both frequency bands. This test is a nonparametric test and allows a comparison of more than two independent variables. With this test, a chi-square statistic is used to evaluate differences in mean ranks to assess the null hypothesis that the medians are equal across the groups (Green & Salkind, 2008).

3.5. Summary

In conclusion, a survey and experimental task were conducted in this study. EEG and EOG were used to collect physiological data. Statistical methods were used to analyze the collected data. Finally, the relevant data were used to develop ergonomic mental workload and alertness proposal in related to driving conditions for train drivers.

CHAPTER 4

RESULTS AND DATA ANALYSIS

4.1. Introduction

This chapter presents the result from the survey and the experiments that have been done. The first subsection of the result was the survey output. It presents the perception of train drivers which also contributed as supporting elements of the experiment design. Meanwhile, the experimental data for all participants were used to perform statistical analysis and comparison between the entire selected variable. The second subsection of the result was the analysis report on demographic data of the participants involve in this study. The EEG analysis results were separated into two main sections which were Mean Alpha Power Analysis and Mean Beta Power Analysis. Both of the section contains two additional parameters analysis which are age and experience.

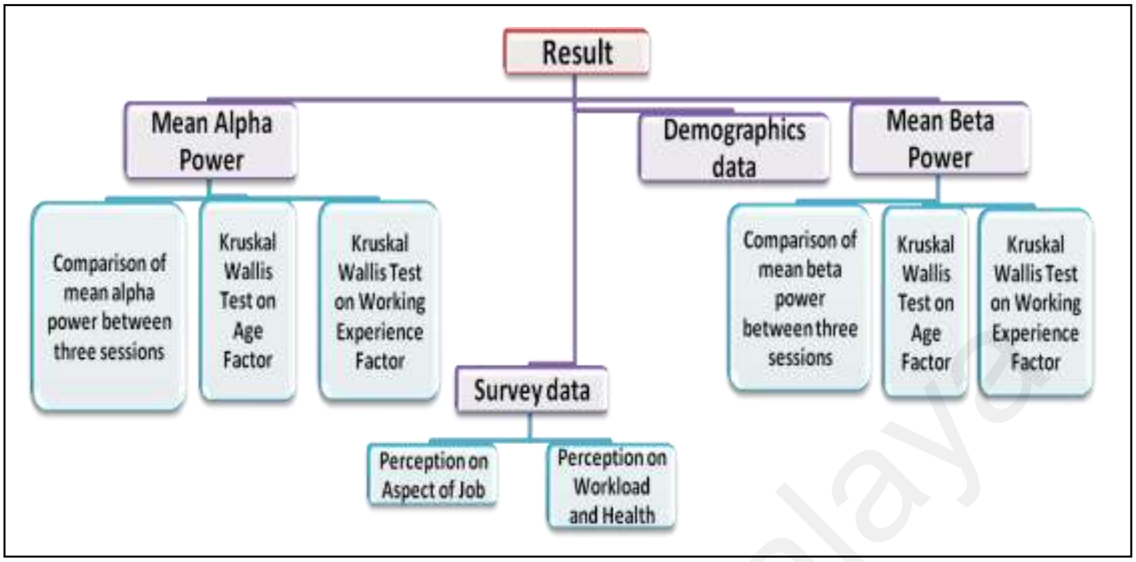

Figure 4.1: Mapping on the sections of the result

4.2. Survey Data

4.2.1. Background of Participants

A total of thirty four qualified train drivers did the survey. They ranged in age between 24 and 55 (mean age = 37.7; standard deviation = 9.1 years) and each had a valid train driving license. All of them are male and eighty eight percent are married. 94% are Malay and 6 % are Indian.

4.2.2. Exploration of Perception on Aspect of Job

Four questions were taken from the job scope section of REQUEST. Question 1 to 4 are opinion towards their work. Only selected data of the survey were prsented in this section which details of the result can be referred in Appendix B. From Question 1 (Figure 4.2), it can be seen that at the highest bar chart that the repondents choose *Strongly agree* that driving at rainy night made them very busy. This refelcted that they need to keep track on many things at one time at night since the environment was dim and blurry due to the rain. The lowest percentage of opinion about this was on daytime driving.

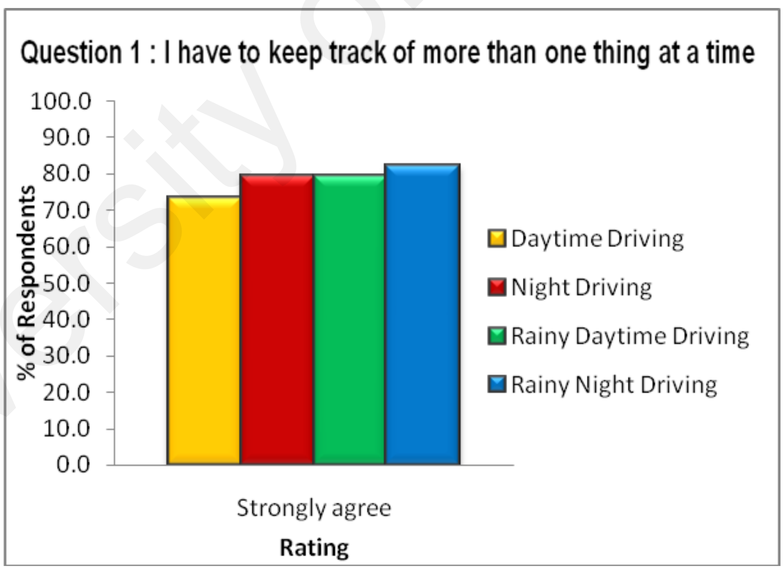

Figure 4.2 : Percentage rating of *Strongly Agree* from question for perception on the work in different driving situations

Meanwhile, for Question 2 regarding needs of extensive mental effort and concentration on the job (Figure 4.3), the respondents choosed *Strongly* agree that it happen the most during night driving (76.5%). Only 67.6% rated for a normal daytime driving condition.

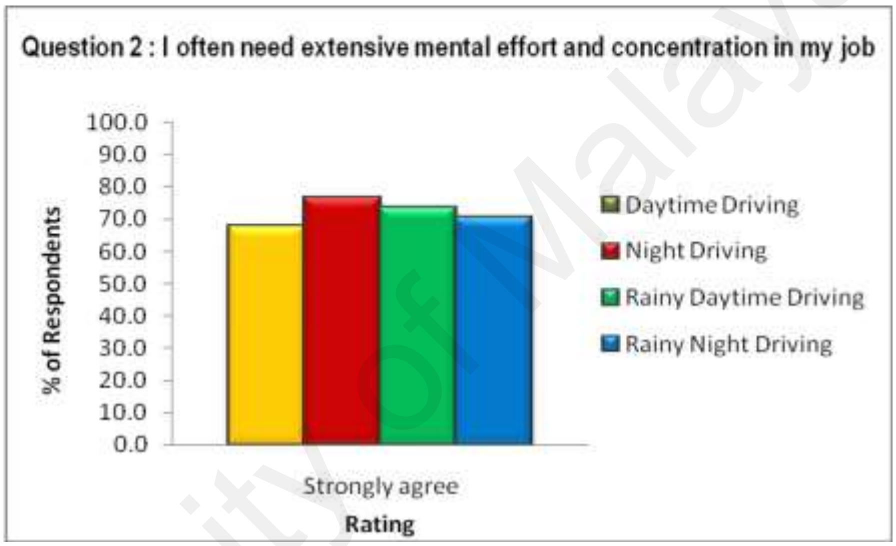

Figure 4.3 : Percentage rating of *Strongly Agree* for perception on extensive mental effort and concentration

With regards to problems that lead into pressure during working in Question 3 (Figure 4.4), the respondents strongly agree that it occurs most when it is raining both on daytime and night. It may be related to phyisical function of the train set such as mirror, wiper and light in the fuzzy condition.

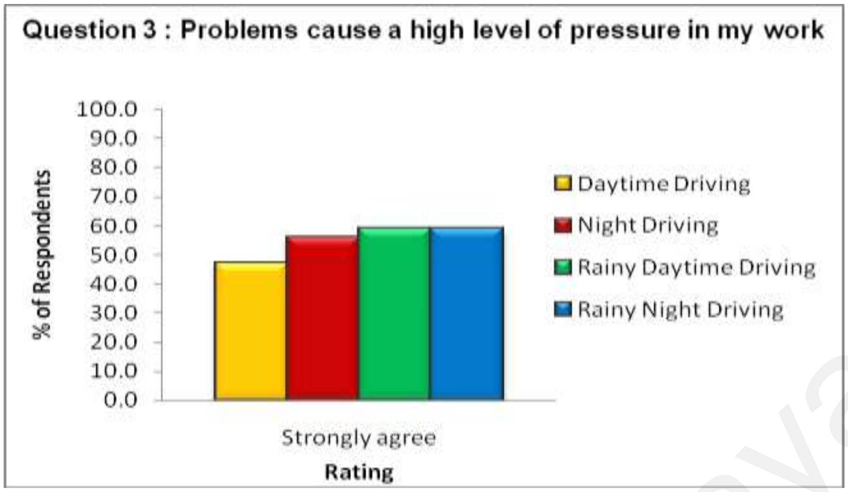

Figure 4.4 : Percentage rating of *Strongly Agree* on question related to pressure during work

Next, Question 4 was regarding error in performing their work (Figure 4.5). Nearly 80% chose *Strongly agree* that night driving error can cause the most safety incident. On the other hand, 76.5% was recorded for rainy night driving which is also high for the comparison.

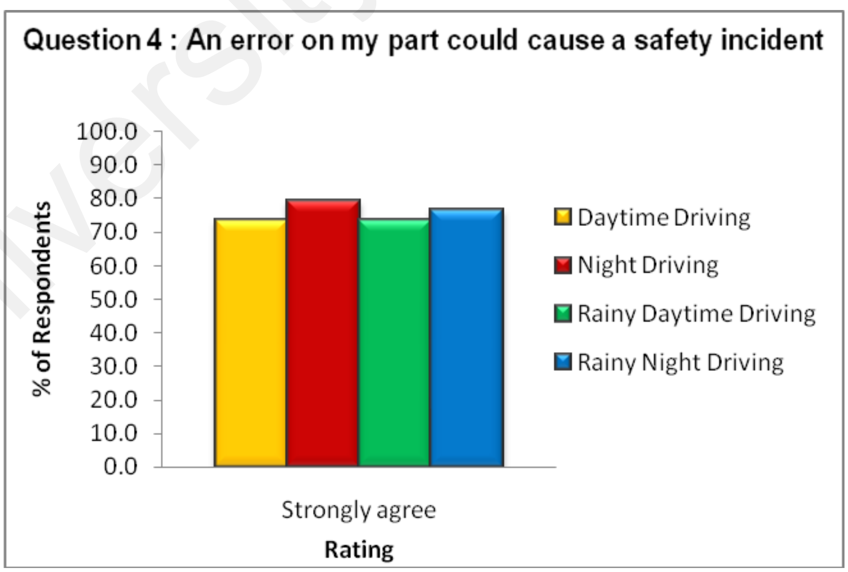

Figure 4.5: Percentage rating on *Strongly Agree* from respondents related to safety incidents

4.2.3. Exploration of Perception on Workload and Health

Respondents were asked about workload related question taken from section 6 of REQUEST. They were asked directly about acceptance of the workload on their service. The result from Question 5 (Figure 4.6) showed that percentage of who chose *Acceptable* was higher compared to *Unacceptable*. However, the percentage that showed unacceptable is highest when it is rainy night driving. About one third of the respondent (35%) give some subjective opinions. Most of them said that unacceptable workload happen during bad weather (rainy, cloudy, hazy) which lead to slippery tracks and limited vision and because of the physical condition of the train itself which the train set not fulfill the standard requirement (example: wiper, brakes). Only a few gave comments on exhaution because of lack of rest and late arrival of train during their working shift.

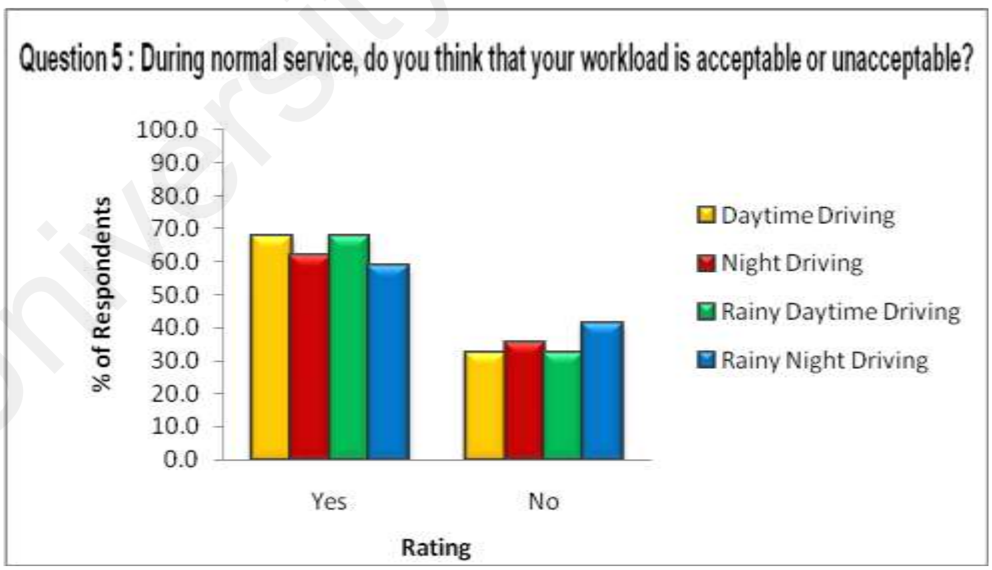

Figure 4.6 : Percentage ratings for perception on the acceptance of workload.

The respondents also were asked about when do they feel fatigue in Question 6. Most of them rated that fatigue happens at the end of the shift. In addition, at the end of the night driving, the highest percentage was recorded as we can see in the bar chart (Figure 4.7). Almost 30% rated it happened in the middle of the shift during daytime driving.

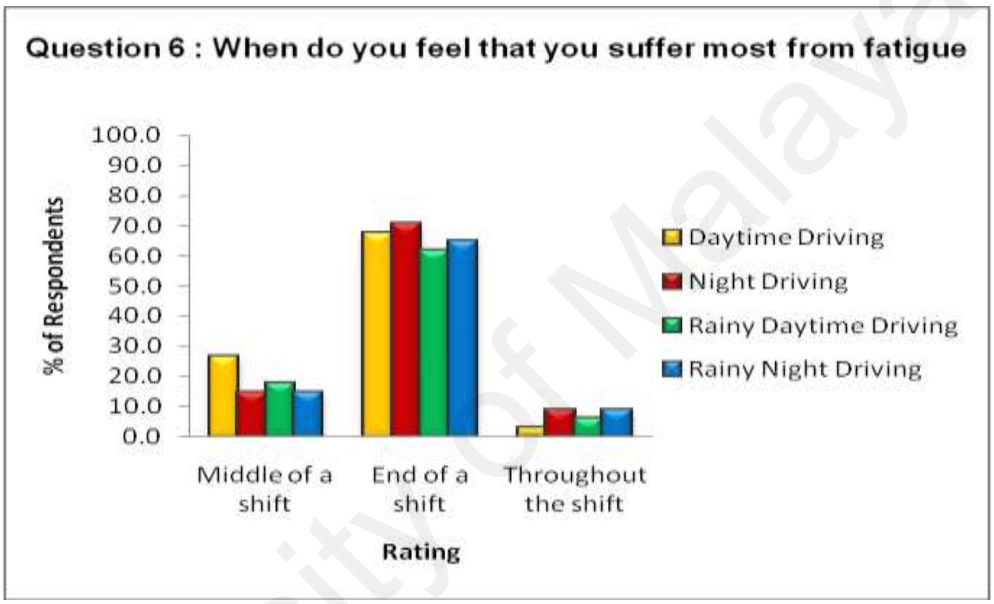

Figure 4.7 : Percentage ratings for perception on fatigue.

4.3. Demographics Data

Fifteen male train drivers participated in the experiments. The participants were healthy and had no history of serious deseases. The mean ages of the subjects were 40 ± 6.9 years (Table 4.1). Meanwhile the mean height and weight of the participants were

168.6 ± 9.2 cm and 74.6 ± 13.1 kg respectively. All of the train drivers have different duration of working experience as a train driver but the mean value is 14 ± 6.1 years.

Table 4.1 : Demographic characteristics of the participants on the experiments schedules

Measurement	Mean	SD
Age (years)	40.0	6.9
Height (cm)	168.6	9.2
Weight (kg)	74.6	13.1
Experience (years)	14.0	6.1

4.4. EEG Mean Alpha Power

One of the objectives of this study is to determine whether there are a significant difference between driving conditions for train drivers' mental workload. In order to verify the differences, the EEG data were analyzed which focus on alpha power since its relates to mental workload. The experimental sessions were mentioned in Table 3.2 of Chapter 3. Subsection 4.4.1 contains mapping of the results on the EEG voltage along the experimetal duration. Meanwhile, from subsection 4.4.2 until 4.4.3, the report were made on the Kruskal Wallis Test on Age and Experience factor for each location of EEG electrode (F_ZP_Z,O_1O_2,P_3P_4).

4.4.1. Comparison of Mean Alpha Power between Three Sessions

Significant main impact of condition were obtained for EEG mean alpha power (8-12Hz) range. The average result from each subject were subtracted and put into a graph. For F_ZP_Z location in Figure 4.8, the mean alpha power decrease at first but started to increase until the final time interval for session 1 (daytime driving). The next session produce result which indicates the mean alpha power increasing over time. Meanwhile for session 3 (rainy night driving), the mean alpha power decreased after second time interval during the night and rainy driving session.

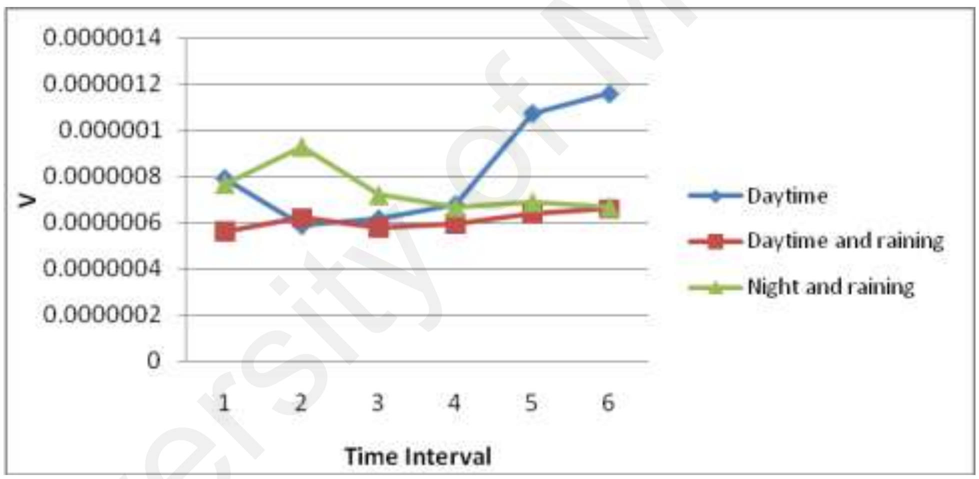

Figure 4.8: Change of mean alpha power over time in three different sessions for location F_ZP_Z

At O_1O_2 location, the EEG mean alpha power was instable for session 1 during the 20 minuites drive. The result was different for session 2 (rainy daytime driving) which the mean alpha power decreased during the 3 time interval and suddenly increased at time interval 4. However the mean alpha power value decreased during the end time. For condition 3, the value started to increase from time interval 1 to 2 but slightly decreased reaching time interval 3. The value continue to increase after that reaching time interval 5 and decreased at the end of the duration.

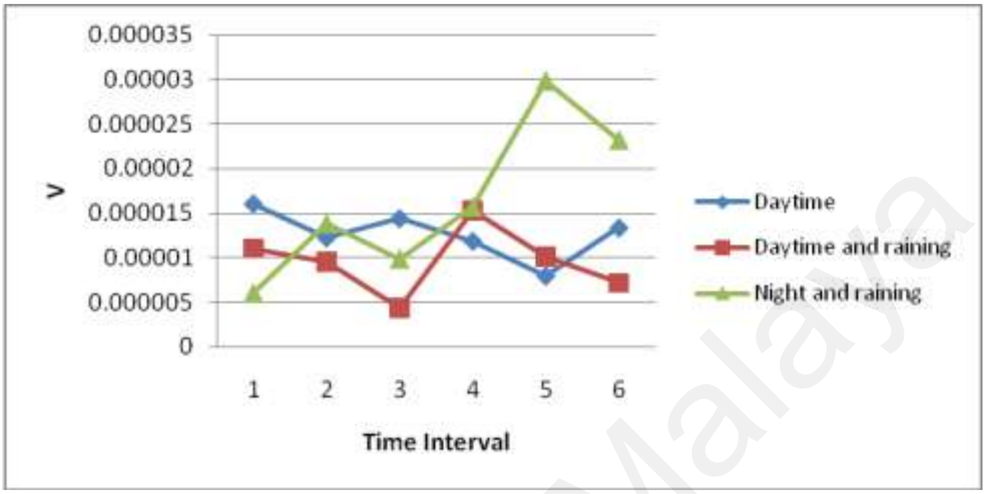

Figure 4.9 : Change of mean alpha power over time for three different sessions at location O_1O_2

Meanwhile, for location P_3P_4, the value of mean alpha power increased at the first 3 time interval in session 1. The value decreased abruptly reaching time interval 4 and increased back until the end of the recording. For condiiton 2, the result shows that after decreased at ealier time interval, the mean alpha power went to a stable result along time interval 2 to time interval 4. However, the value incresead in reaching time interval 6. For session 3, the value increased at the begining but decreased from time interval 4 to time interval 6.

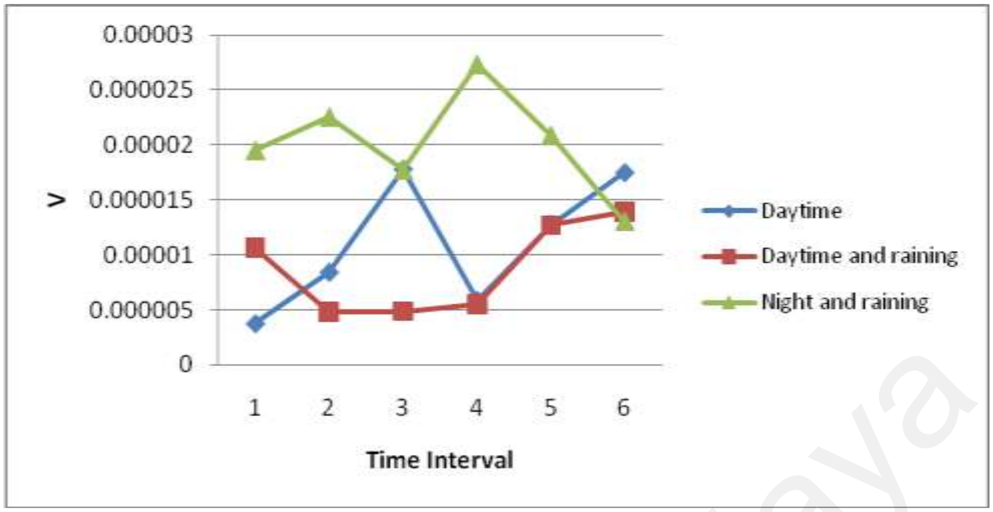

Figure 4.10 : Change of mean alpha power over time in three different sessions for location P_3P_4

A comparison was also made on the mean alpha power between the three different sessions as in table 4.2. There was a statistically significant difference in mean alpha power of signal F_ZP_Z depending on which type of condition to whilst train driving, $\chi^2(2) = 6.333$, $P = 0.042$.

Table 4.2: Friedman Test result for difference of mean alpha power between three sessions on each channel location.

Channels location	Chi-Square	Asymp. Sig.
F_ZP_Z	6.333	0.042*
O_1O_2	3.000	0.233
P_3P_4	4.333	0.115

From the analysis result, it can be seen that only location F_ZP_Z showed significant result between the conditions. Generally it reflected that the workloads between each driving task are was different especially during the rainy night driving condition.

4.4.2. Kruskal Wallis Test on Age Factor

Kruskal Wallis Test was done to observe the statistical difference among 3 groups of age; 21 to 30 years; 31 to 40 years; 41 to 50 years, on the mean alpha value of the participants. Table 4.3 below show the groups and the age range. The analysis was done according to the location of the electrodes (F_ZP_Z, O_1O_2, P_3P_4) for each session (1, 2, 3).

Table 4.3: Groups of age range

GROUP	AGE (years)
GA	21 to 30
GB	31 to 40
GC	41 to 50

4.4.2.1. Mean Alpha Power of Location: F_ZP_Z

The result (Table 4.5) shows that there are **no significant** differences among the three age groups of age on their mean alpha power (x^2=0.838, df =2, p>.05), with a mean rank of 7.50 for GA, 9.75 for GB and 7.33 for GC.

Table 4.4: Kruskal Wallis Test Ranks on session 1 of location F_ZP_Z

	AGE	N	Mean Rank
SESSION1	21 to 30	2	7.50
	31 to 40	4	9.75
	41 to 50	9	7.33
	Total	15	

Table 4.5: Kruskal Wallis Test Statistics on session 1 of location F_ZP_Z

	SESSION1
Chi-Square	.838
df	2
Asymp. Sig.	.658

From the mean ranking results (Table 4.4), it appeared that the alpha power changed along the experiment duration in each age group for Session 1. It can be noted from the small different of Chi square values generated.

The result (Table 4.7) shows that there are **no significant differences** among the three age groups of age on their mean alpha power (x^2=1.728, df =2, p>.05), with a mean rank of 7.50 for GA, 10.50 for GB and 7.00 for GC.

Table 4.6: Kruskal Wallis Test Ranks on session 2 of location F_ZP_Z

	AGE	N	Mean Rank
SESSION2	21 to 30	2	7.50
	31 to 40	4	10.50
	41 to 50	9	7.00
	Total	15	

Table 4.7: Kruskal Wallis Test Statistics on session 2 of location F_ZP_Z

	SESSION2
Chi-Square	1.728
df	2
Asymp. Sig.	.421

From the mean ranking results (Table 4.6), it appeared that the alpha power changed along the experiment duration in each age group for Session 2. It can be noted from the small different of Chi square values generated.

The result (Table 4.8) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=3.579, df =2, p>.05), with a mean rank of 11.00 for GA, 10.50 for GB and 6.22 for GC.

Table 4.8: Kruskal Wallis Test Ranks on session 3 of location F_ZP_Z

	AGE	N	Mean Rank
SESSION3	21 to 30	2	11.00
	31 to 40	4	10.50
	41 to 50	9	6.22
	Total	15	

Table 4.9: Kruskal Wallis Test Statistics on session 3 of location F_ZP_Z

	SESSION3
Chi-Square	3.579
df	2
Asymp. Sig.	.167

From the mean ranking results (Table 4.9), it appeared that the alpha power changed along the experiment duration more in age group GA and GB for Session 3. It can be noted from the moderate different of Chi square values generated.

Table 4.10: The compilation of statistical difference analysis among 3 groups of age on location F_ZP_Z

	SESSION1	SESSION2	SESSION3
Chi-Square	0.838	1.728	3.579
Asymp. Sig.	0.658	0.421	0.167

From the Table 4.10, it can be seen that there was no significant different in any of the age group on the mean alpha power at location F_ZP_Z.

4.4.2.2. Mean Alpha Power of Location: O_1O_2

The result (Table 4.12) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=0.351, df =2, p>.05), with a mean rank of 9.00 for GA, 8.75 for GB and 7.44 for GC.

Table 4.11: Kruskal Wallis Test Ranks on session 1 of location O_1O_2

	AGE	N	Mean Rank
SESSION1	21 to 30	2	9.00
	31 to 40	4	8.75
	41 to 50	9	7.44
	Total	15	

Table 4.12: Kruskal Wallis Test Statistics on session 1 of location O_1O_2

	SESSION1
Chi-Square	.351
df	2
Asymp. Sig.	.839

From the mean ranking results (Table 4.11), it appeared that the alpha power changed along the experiment duration in each age group for Session 1. It can be noted from the the small different of Chi square values generated.

The result (Table 4.14) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=0.364, df =2, p>.05), with a mean rank of 8.50 for GA, 9.00 for GB and 7.44 for GC.

Table 4.13: Kruskal Wallis Test Ranks on session 2 of location O_1O_2

	AGE	N	Mean Rank
SESSION2	21 to 30	2	8.50
	31 to 40	4	9.00
	41 to 50	9	7.44
	Total	15	

Table 4.14 : Kruskal Wallis Test Statistics on session 2 of location O_1O_2

	SESSION2
Chi-Square	.364
df	2
Asymp. Sig.	.834

From the mean ranking results (Table 4.13), it appeared that the alpha power changed along the experiment duration in each age group for Session 2. It can be noted from the small different of Chi square values generated.

The result (Table 4.16) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=1.703, df =2, p>.05), with a mean rank of 9.50 for GA, 10.00 for GB and 6.78 for GC.

Table 4.15 : Kruskal Wallis Test Ranks on session 3 of location O_1O_2

	AGE	N	Mean Rank
SESSION3	21 to 30	2	9.50
	31 to 40	4	10.00
	41 to 50	9	6.78
	Total	15	

Table 4.16 : Kruskal Wallis Test Statistics on session 3 of location O_1O_2

	SESSION3
Chi-Square	1.703
df	2
Asymp. Sig.	.427

From the mean ranking results (Table 4.15), it appeared that the alpha power changed along the experiment duration in each age group for Session 3. It can be noted from the small different of Chi square values generated.

Table 4.17: The compilation of statistical difference analysis among 3 groups of age on location O_1O_2

	SESSION1	SESSION2	SESSION3
Chi-Square	0.351	0.364	1.703
Asymp. Sig.	0.839	0.834	0.427

From the Table 4.17, it can be seen that there was no significant different in any of the age group on the mean alpha power on location O_1O_2.

4.4.2.3. Mean Alpha Power of Location: P_3P_4

The result (Table 4.19) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=2.221, df =2, p>.05), with a mean rank of 11.50 for GA, 9.13 for GB and 6.72 for GC.

Table 4.18: Kruskal Wallis Test Ranks on session 1 of location P_3P_4

	AGE	N	Mean Rank
SESSION1	21 to 30	2	11.50
	31 to 40	4	9.13
	41 to 50	9	6.72
	Total	15	

Table 4.19: Kruskal Wallis Test Statistics on session 1 of location P_3P_4

	SESSION1
Chi-Square	2.221
df	2
Asymp. Sig.	.329

From the mean ranking results (Table 4.18), it appeared that the alpha power changed along the experiment duration more in age group GA and GB for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.21) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=0.538, df =2, p>.05), with a mean rank of 9.50 for GA, 8.75 for GB and 7.33 for GC.

Table 4.20: Kruskal Wallis Test Ranks on session 2 of location P_3P_4

	AGE	N	Mean Rank
SESSION2	21 to 30	2	9.50
	31 to 40	4	8.75
	41 to 50	9	7.33
	Total	15	

Table 4.21: Kruskal Wallis Test Statistics on session 2 of location P_3P_4

	SESSION2
Chi-Square	.538
df	2
Asymp. Sig.	.764

From the mean ranking results (Table 4.20), it appeared that the alpha power changed along the experiment duration in each age group for Session 2. It can be noted from the small different of Chi values generated.

The result (Table 4.23) shows that there are **no significant differences** among the three groups of age on their mean alpha power (x^2=1.017, df =2, p>.05), with a mean rank of 10.25 for GA, 8.88 for GB and 7.11 for GC.

Table 4.22: Kruskal Wallis Test Ranks on session 3 of location P_3P_4

	AGE	N	Mean Rank
SESSION3	21 to 30	2	10.25
	31 to 40	4	8.88
	41 to 50	9	7.11
	Total	15	

Table 4.23: Kruskal Wallis Test Statistics on session 3 of location P_3P_4

	SESSION3
Chi-Square	1.017
df	2
Asymp. Sig.	.601

From the mean ranking results (Table 4.22), it appeared that the alpha power changed along the experiment duration in each age group for Session 3. It can be noted from the small different of Chi values generated.

Table 4.24: The compilation of statistical difference analysis among 3 groups of age on location P_3P_4

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	2.221	0.538	1.017
Asymp. Sig.	0.329	0.764	0.601

From the Table 4.24, it can be seen that there was **no significant** different in any of the age group on the mean alpha power on location P_3P_4.

4.4.3. Kruskal Wallis Test on Working Experience Factor

Kruskal Wallis Test was also done to observe the statistical difference among 3 groups of train drivers' working experience; less than 10 years; less than 20 years; 20 years and above, on the mean alpha power value of the participants. Table 4.25 below shows the groups and the working experience range. The analysis was done according to the location of the electrodes (F_ZP_Z, O_1O_2, and P_3P_4) for each session (1, 2, 3).

Table 4.25: Groups of working experience range

GROUP	WORKING EXPERIENCE (years)
GI	Less than 10 years
GII	Less than 20 years
GIII	20 years and above

4.4.3.1. Mean Alpha Power of Location: F_ZP_Z

The result (Table 4.27) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=3.822, df =2, p<.05), with a mean rank of 7.50 for GI, 9.40 for GII and 3.67 for GIII.

Table 4.26: Kruskal Wallis Test Ranks on session 1 of location F_ZP_Z

	EXPER	N	Mean Rank
SESSION1	Less than 10 years	2	7.50
	Less than 20 years	10	9.40
	20 years and above	3	3.67
	Total	15	

Table 4.27: Kruskal Wallis Test Statistics on session 1 of location F_ZP_Z

	SESSION1
Chi-Square	3.822
df	2
Asymp. Sig.	.148

From the mean ranking results (Table 4.26), it appeared that the alpha power changed along the experiment duration more in experience group GI and GII for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.29) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=5.064, df =2, p>.05), with a mean rank of 7.50 for GI, 9.60 for GII and 3.00 for GIII.

Table 4.28: Kruskal Wallis Test Ranks on session 2 of location F_ZP_Z

	EXPER	N	Mean Rank
SESSION2	Less than 10 years	2	7.50
	Less than 20 years	10	9.60
	20 years and above	3	3.00
	Total	15	

Table 4.29: Kruskal Wallis Test Statistics on session 2 of location F_ZP_Z

	SESSION2
Chi-Square	5.064
df	2
Asymp. Sig.	.079

From the mean ranking results (Table 4.28), it appeared that the alpha power changed along the experiment duration more in experience group GI and GII for Session 2. It can be noted from the moderate different of Chi values generated.

The result shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=5.064 , df =2, p>.05), with a mean rank of 11.00 for GI, 8.90 for GII and 3.00 for GIII.

Table 4.30: Kruskal Wallis Test Ranks on session 3 of location F_ZP_Z

	EXPER	N	Mean Rank
SESSION3	Less than 10 years	2	11.00
	Less than 20 years	10	8.90
	20 years and above	3	3.00
	Total	15	

Table 4.31: Kruskal Wallis Test Statistics on session 3 of location F_ZP_Z

	SESSION3
Chi-Square	5.064
df	2
Asymp. Sig.	.079

From the mean ranking results (Table 4.28), it appeared that the alpha power changed along the experiment duration more in experience group GI and GII for Session 3. It can be noted from the moderate different of Chi values generated.

Table 4.32: The compilation of statistical difference analysis among 3 groups of experience on location F_ZP_Z

	SESSION1	SESSION2	SESSION3
Chi-Square	3.822	5.064	5.064
Asymp. Sig.	0.148	0.079	0.079

From the Table 4.32, it can be seen that there was no significant different in any of the experience group on the mean alpha power on location F_ZP_Z.

4.4.3.2. Mean Alpha Power of Location: O_1O_2

The result (Table 4.34) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=0.122, df =2, p>.05), with a mean rank of 9.00 for GI, 7.90 for GII and 7.67 for GIII.

Table 4.33: Kruskal Wallis Test Ranks on session 1 of location O_1O_2

	EXPER	N	Mean Rank
SESSION1	Less than 10 years	2	9.00
	Less than 20 years	10	7.90
	20 years and above	3	7.67
	Total	15	

Table 4.34: Kruskal Wallis Test Statistics on session 1 of location O_1O_2

	SESSION1
Chi-Square	.122
df	2
Asymp. Sig.	.941

From the mean ranking results (Table 4.33), it appeared that the alpha power changed along the experiment duration in each experience group for Session 1. It can be noted from the small different of Chi values generated.

The result (Table 4.36) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=0.255, df =2, p>.05), with a mean rank of 8.50 for GI, 7.60 for GII and 9.00 for GIII.

Table 4.35: Kruskal Wallis Test Ranks on session 2 of location O_1O_2

	EXPER	N	Mean Rank
SESSION2	Less than 10 years	2	8.50
	Less than 20 years	10	7.60
	20 years and above	3	9.00
	Total	15	

Table 4.36: Kruskal Wallis Test Statistics on session 2 of location O_1O_2

	SESSION2
Chi-Square	.255
df	2
Asymp. Sig.	.880

From the mean ranking results (Table 4.35), it appeared that the alpha power changed along the experiment duration in each experience group for Session 2. It can be noted from the small different of Chi values generated.

The result (Table 4.38) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=0.332, df =2, p>.05), with a mean rank of 9.50 for GI, 7.95 for GII and 7.17 for GIII.

Table 4.37: Kruskal Wallis Test Ranks on session 3 of location O_1O_2

	EXPER	N	Mean Rank
SESSION3	Less than 10 years	2	9.50
	Less than 20 years	10	7.95
	20 years and above	3	7.17
	Total	15	

Table 4.38: Kruskal Wallis Test Statistics on session 3 of location O_1O_2

	SESSION3
Chi-Square	.332
df	2
Asymp. Sig.	.847

From the mean ranking results (Table 4.37), it appeared that the alpha power changed along the experiment duration in each experience group for Session 3. It can be noted from the small different of Chi values generated.

Table 4.39: The compilation of statistical difference analysis among 3 groups of experience on location O_1O_2

	SESSION1	SESSION2	SESSION3
Chi-Square	0.122	0.255	0.332
Asymp. Sig.	0.941	0.880	0.847

From the Table 4.39, it can be seen that there was no significant different in any of the experience group on the mean alpha power on location O_1O_2.

4.4.3.3. Mean Alpha Power of Location: P_3P_4

The result (Table 4.41) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=2.172, df =2, p>.05), with a mean rank of 11.50 for GI, 8.05 for GII and 5.50 for GIII.

Table 4.40 : Kruskal Wallis Test Rnks on session 1 of location P_3P_4

	EXPER	N	Mean Rank
SESSION1	Less than 10 years	2	11.50
	Less than 20 years	10	8.05
	20 years and above	3	5.50
	Total	15	

Table 4.41 : Kruskal Wallis Test Statistics on session 1 of location P_3P_4

	SESSION1
Chi-Square	2.172
df	2
Asymp. Sig.	.338

From the mean ranking results (Table 4.40), it appeared that the alpha power changed along the experiment duration more in experience group GI and GII for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.43) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=0.322, df =2, p>.05), with a mean rank of 9.50 for GI, 7.60 for GII and 8.33 for GIII.

Table 4.42: Kruskal Wallis Test Ranks on session 2 of location P_3P_4

	EXPER	N	Mean Rank
SESSION2	Less than 10 years	2	9.50
	Less than 20 years	10	7.60
	20 years and above	3	8.33
	Total	15	

Table 4.43: Kruskal Wallis Test Statistics on session 2 of location P_3P_4

	SESSION2
Chi-Square	.322
df	2
Asymp. Sig.	.851

From the mean ranking results (Table 4.42), it appeared that the alpha power changed along the experiment duration in each experience group for Session 2. It can be noted from the small different of Chi square values generated.

The result (Table 4.45) shows that there are **no significant differences** among the three groups of experience on their mean alpha power (x^2=0.675, df =2, p>.05), with a mean rank of 10.25 for GI, 7.45 for GII and 8.33 for GIII.

Table 4.44: Kruskal Wallis Test Ranks on session 3 of location P_3P_4

	EXPER	N	Mean Rank
SESSION3	Less than 10 years	2	10.25
	Less than 20 years	10	7.45
	20 years and above	3	8.33
	Total	15	

Table 4.45: Kruskal Wallis Test Statistics on session 3 of location P_3P_4

	SESSION3
Chi-Square	.675
df	2
Asymp. Sig.	.713

From the mean ranking results (Table 4.44), it appeared that the alpha power changed along the experiment duration in each experience group for Session 3. It can be noted from the small different of Chi square values generated.

Table 4.46: The compilation of statistical difference analysis among 3 groups of experience on location P_3P_4

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	2.172	0.322	0.675
Asymp. Sig.	0.338	0.851	0.713

From the Table 4.46, it can be seen that there was no significant different in any of the experience group on the mean alpha power on location P_3P_4.

4.5. EEG Mean Beta Power

To fulfill part of the objectives, the beta power of EEG data were analyzed since it relates to alertness. The experimental sessions can be refered on Table 3.2. Subsection 4.5.1 contains mapping of the results on the EEG voltage along the experimetal duration. In the meantime, from subsection 4.5.2 until 4.5.3, the report were made on the Kruskal Wallis Test on Age and Experience factor for each location of EEG electrode (F_ZP_Z,O_1O_2,P_3P_4).

4.5.1. Comparison of Mean Beta Power between Three Sessions

From the raw data of EEG, the beta mean beta power has been extracted. The average mean beta power has been calculated and put into graph. As for the first location F_ZP_Z, it can be seen in Figure 4.11 that for session 1, the signal decreased and no much change at the first few minutes. From time interval 4, it started to increase abruptly. For session 2, the signal was quite stilled and only increased a little at the last few time intervals. Meanhile for session 3, it was different which it was increasing from time interval 1 to 2 but gradually decreasing in reaching time interval 6.

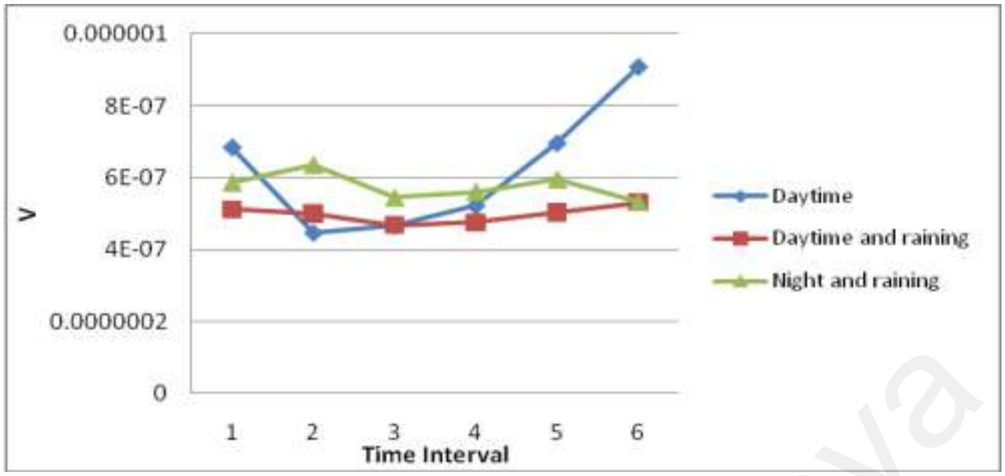

Figure 4.11: Change of mean beta power over time in three different sessions for location F_ZP_Z

For location O_1O_2, which can be seen in Figure 4.12, the EEG mean beta power was quite unstable along the 6 time intervals in session 1. While for session 2, the value increased only at time interval 3 to 4 but back to decrease in reaching time interval 6. However it was different goes to session 3 which the signal was abruptly decreased from time interval 1 to 2 but increased from time interval 3 until the end.

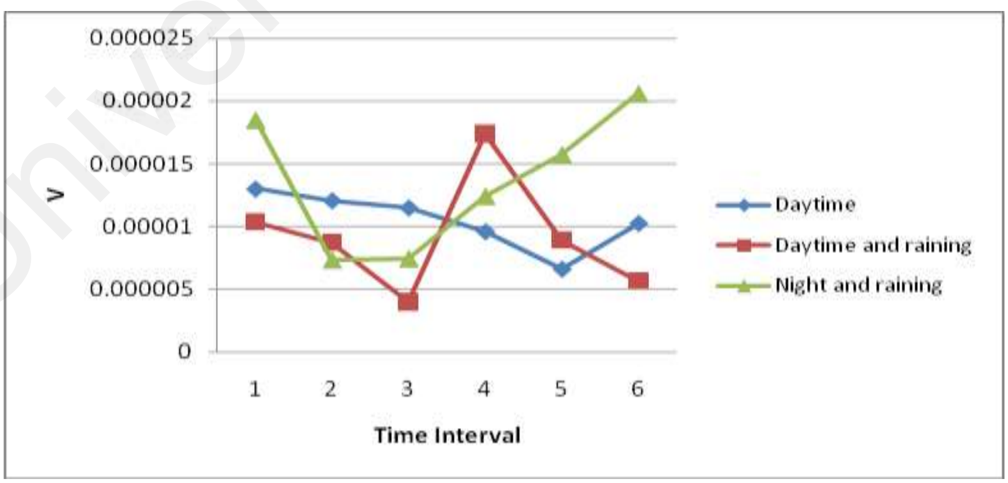

Figure 4.12 : Change of mean beta power over time in three different sessions for location O_1O_2

Meanwhile in Figure 4.13 which is the mean beta power result for location P_3P_4, the signal change drastically increased and decreased during the 20 minits runs. For session 2, the beta signal was quite stable from time interval 2 to 4 and started to increase after that. In addition, for session 3 during the night and rainy driving, the signal was totally unstable which it increased and decreased along the duration until the end of the session. Howerver, the value of mean beta power was the highest at the ending epoch compare to others.

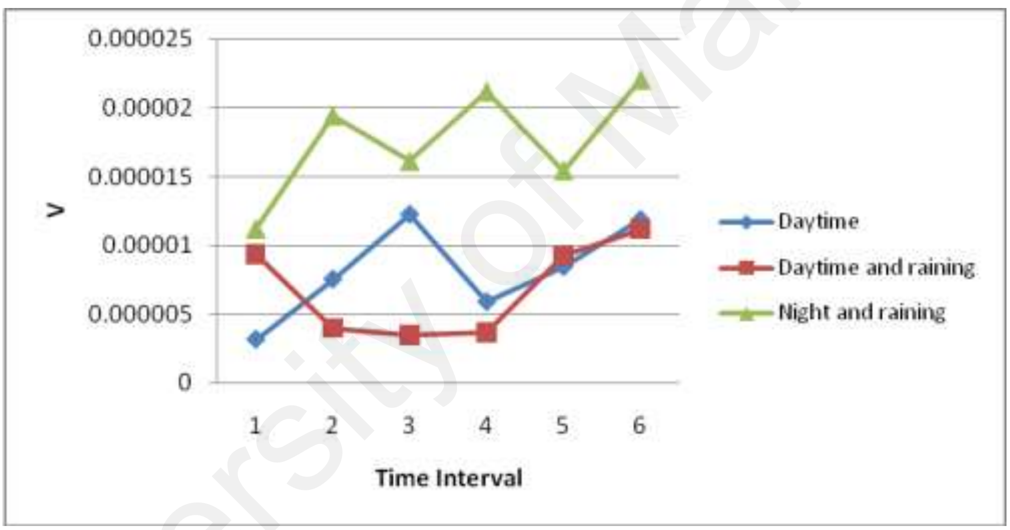

Figure 4.13 : Change of mean beta power over time in three different sessions for location P_3P_4

A comparison also was made on the mean beta power between the three difference sessions as in table 4.47. There was a statistically significant difference in mean beta power of signal P_3P_4 depending on which type of condition to whilst train driving, $\chi^2(2) = 6.333$, $P = 0.042$

Table 4.47: Friedman Test result for difference of mean beta power between three sessions on each channel location.

Channels location	Chi-Square	Asymp. Sig.
F_ZP_Z	4.333	0.115
O_1O_2	2.333	0.311
P_3P_4	6.333	0.042*

From the analysis result, it can be seen that only location P_3P_4 resulted significant result between the conditions. Generally it reflected that the alertness between each driving task is different when facing different driving state.

4.5.2. Kruskal Wallis Test on Age Factor

The Kruskal Wallis Test was done to observe the statistical difference among the three groups of age; 21 to 30 years; 31 to 40 years; 41 to 50 years, on the mean beta power value of the participants. Table 4.48 below show the groups and the age range. The analysis was done according to the location of the electrodes (F_ZP_Z, O_1O_2, P_3P_4) for each session (1, 2, 3).

Table 4.48: Groups of age range

GROUP	AGE (years)
GA	21 to 30
GB	31 to 40
GC	41 to 50

4.5.2.1. Mean Beta Power of Location: F_ZP_Z

The result (Table 4.50) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=0.851, df =2, p>.05), with a mean rank of 7.00 for GA, 9.75 for GB and 7.44 for GC.

Table 4.49: Kruskal Wallis Test Ranks on session 1 of location F_ZP_Z

	AGE	N	Mean Rank
SESSION1	21 to 30	2	7.00
	31 to 40	4	9.75
	41 to 50	9	7.44
	Total	15	

Table 4.50: Kruskal Wallis Test Statistics on session 1 of location F_ZP_Z

	SESSION1
Chi-Square	.851
df	2
Asymp. Sig.	.653

From the mean ranking results (Table 4.49), it appeared that the beta power changed along the experiment duration in each age group for Session 1. It can be noted from the small different of Chi square values generated.

The result (Table 4.52) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=1.518, df =2, p>.05), with a mean rank of 5.00 for GA, 9.75 for GB and 7.89 for GC.

Table 4.51: Kruskal Wallis Test Ranks on session 2 of location F_ZP_Z

	AGE	N	Mean Rank
SESSION2	21 to 30	2	5.00
	31 to 40	4	9.75
	41 to 50	9	7.89
	Total	15	

Table 4.52: Kruskal Wallis Test Statistics on session 2 of location F_ZP_Z

	SESSION2
Chi-Square	1.518
df	2
Asymp. Sig.	.468

From the mean ranking results (Table 4.51), it appeared that the beta power changed along the experiment duration in each age group for Session 2. It can be noted from the small different of Chi square values generated.

The result (Table 4.54) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=0.764, df =2, p>.05), with a mean rank of 8.00 for GA, 9.63 for GB and 7.28 for GC.

Table 4.53: Kruskal Wallis Test Ranks on session 3 of location F_ZP_Z

	AGE	N	Mean Rank
SESSION3	21 to 30	2	8.00
	31 to 40	4	9.63
	41 to 50	9	7.28
	Total	15	

Table 4.54: Kruskal Wallis Test Statistics on session 3 of location F_ZP_Z

	SESSION3
Chi-Square	.764
df	2
Asymp. Sig.	.682

From the mean ranking results (Table 4.53), it appeared that the beta power changed along the experiment duration in each age group for Session 3. It can be noted from the small different of Chi square values generated.

Table 4.55: The compilation of statistical difference analysis among 3 groups of age on location F_ZP_Z

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	0.851	1.518	0.764
Asymp. Sig.	0.653	0.468	0.682

From the Table 4.55, it can be seen that there was no significant different in any of the age group on the mean beta power on location F_ZP_Z.

4.5.2.2. Mean Beta Power of Location: O_1O_2

The result (Table 5.57) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=1.456, df =2, p>.05), with a mean rank of 9.00 for GA, 10.00 for GB and 6.89 for GC.

Table 4.56: Kruskal Wallis Test Ranks on session 1 of location O_1O_2

	AGE	N	Mean Rank
SESSION1	21 to 30	2	9.00
	31 to 40	4	10.00
	41 to 50	9	6.89
	Total	15	

Table 4.57: Kruskal Wallis Test Statistics on session 1 of location O_1O_2

	SESSION1
Chi-Square	1.456
df	2
Asymp. Sig.	.483

From the mean ranking results (Table 4.56), it appeared that the beta power changed along the experiment duration in each age group for Session 1. It can be noted from the small different of Chi square values generated.

The result (Table 4.59) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=0.00, df =2, p>.05), with a mean rank of 8.00 for GA, GB and GC.

Table 4.58: Kruskal Wallis Test Ranks on session 2 of location O_1O_2

	AGE	N	Mean Rank
SESSION2	21 to 30	2	8.00
	31 to 40	4	8.00
	41 to 50	9	8.00
	Total	15	

Table 4.59: Kruskal Wallis Test Statistics on session 2 of location O_1O_2

	SESSION2
Chi-Square	.000
df	2
Asymp. Sig.	1.000

From the mean ranking results (Table 4.58), it appeared that the beta power changed along the experiment duration in each age group for Session 2. It can be noted from the zero value of Chi-square generated.

The result (Table 4.61) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=1.093, df =2, p>.05), with a mean rank of 10.50 for GA, 8.75 for GB and 7.11 for GC.

Table 4.60: Kruskal Wallis Test Ranks on session 3 of location O_1O_2

	AGE	N	Mean Rank
SESSION3	21 to 30	2	10.50
	31 to 40	4	8.75
	41 to 50	9	7.11
	Total	15	

Table 4.61: Kruskal Wallis Test Statistics on session 3 of location O_1O_2

	SESSION3
Chi-Square	1.093
df	2
Asymp. Sig.	.579

From the mean ranking results (Table 4.60), it appeared that the beta power changed along the experiment duration in each age group for Session 3. It can be noted from the small different of Chi square values generated.

Table 4.62 : The compilation of statistical difference analysis among 3 groups of age on location O_1O_2

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	1.456	0.000	1.093
Asymp. Sig.	0.483	1.000	0.579

From the Table 4.62, it can be seen that there was no significant different in any of the age group on the mean beta power on location O_1O_2.

4.5.2.3. Mean Beta Power of Location: P_3P_4

The result (Table 4.64) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=3.797, df =2, p>.05), with a mean rank of 10.50 for GA, 10.88 for GB and 6.17 for GC.

Table 4.63 : Kruskal Wallis Test Ranks on session 1 of location P_3P_4

	AGE	N	Mean Rank
SESSION1	21 to 30	2	10.50
	31 to 40	4	10.88
	41 to 50	9	6.17
	Total	15	

Table 4.64 : Kruskal Wallis Test Statistics on session 1 of location P_3P_4

	SESSION1
Chi-Square	3.797
df	2
Asymp. Sig.	.150

From the mean ranking results (Table 4.63), it appeared that beta power changed along the experiment duration more in age group GA and GB for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.66) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=1.022, df =2, p>.05), with a mean rank of 9.75 for GA, 9.25 for GB and 7.06 for GC.

Table 4.65: Kruskal Wallis Test Ranks on session 2 of location P_3P_4

	AGE	N	Mean Rank
SESSION2	21 to 30	2	9.75
	31 to 40	4	9.25
	41 to 50	9	7.06
	Total	15	

Table 4.66: Kruskal Wallis Test Statistics on session 2 of location P_3P_4

	SESSION2
Chi-Square	1.022
df	2
Asymp. Sig.	.600

From the mean ranking results (Table 4.65), it appeared that the beta power changed along the experiment duration in each age group for Session 2. It can be noted from the small different of Chi values generated.

The result (Table 4.68) shows that there are **no significant differences** among the three groups of age on their mean beta power (x^2=0.889, df =2, p>.05), with a mean rank of 10.50 for GA, 8.38 for GB and 7.28 for GC.

Table 4.67: Kruskal Wallis Test Ranks on session 3 of location P_3P_4

	AGE	N	Mean Rank
SESSION3	21 to 30	2	10.50
	31 to 40	4	8.38
	41 to 50	9	7.28
	Total	15	

Table 4.68: Kruskal Wallis Test Statistics on session 3 of location P_3P_4

	SESSION3
Chi-Square	.889
df	2
Asymp. Sig.	.641

From the mean ranking results (Table 4.67), it appeared that the beta power changed along the experiment duration in each age group for Session 3. It can be noted from the small different of Chi values generated.

Table 4.69: The compilation of statistical difference analysis among 3 groups of age on location P_3P_4

	SESSION1	SESSION2	SESSION3
Chi-Square	3.797	1.022	0.889
Asymp. Sig.	0.150	0.600	0.641

From the Table 4.69, it can be seen that there was no significant different in any of the age group on the mean beta power on location P_3P_4

4.5.3. Kruskal Wallis Test on Working Experience Factor

Kruskal Wallis Test was also done to observe the statistical difference among 3 groups of train drivers' working experience; less than 10 years; less than 20 years; 20 years and above, on the mean beta power value of the participants. Table 4.70 below shows the groups and the working experience range. The analysis was done according to the location of the electrodes (F_ZP_Z, O_1O_2, P_3P_4) for each session (1, 2, 3).

Table 4.70: Groups of working experience range

GROUP	WORKING EXPERIENCE (years)
GI	Less than 10 years
GII	Less than 20 years
GIII	20 years and above

4.5.3.1. Mean Beta Power of Location: F_ZP_Z

The result (Table 4.72) shows that there are **significant differences** among the three groups of working experience on their mean beta power (x^2=6.722, df =2, p<.05), with a mean rank of 7.00 for GI, 9.90 for GII and 2.33 for GIII.

Table 4.71: Kruskal Wallis Test Ranks on session 1 of location F_ZP_Z

	EXPER	N	Mean Rank
SESSION1	Less than 10 years	2	7.00
	Less than 20 years	10	9.90
	20 years and above	3	2.33
	Total	15	

Table 4.72: Kruskal Wallis Test Statistics on session 1 of location F_ZP_Z

	SESSION1
Chi-Square	6.722
df	2
Asymp. Sig.	.035

From the mean ranking results (Table 4.71), it appeared that the beta power changed along the experiment duration more in experience group GI and GII for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.74) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=2.562, df =2, p>.05), with a mean rank of 5.00 for GI, 9.30 for GII and 5.67 for GIII.

Table 4.73: Kruskal Wallis Test Ranks on session 2 of location F_ZP_Z

	EXPER	N	Mean Rank
SESSION2	Less than 10 years	2	5.00
	Less than 20 years	10	9.30
	20 years and above	3	5.67
	Total	15	

Table 4.74: Kruskal Wallis Test Statistics on session 2 of location F_ZP_Z

	SESSION2
Chi-Square	2.562
df	2
Asymp. Sig.	.278

From the mean ranking results (Table 4.73), it appeared that the beta power changed along the experiment duration more in experience group GII for Session 2. It can be noted from the moderate different of Chi values generated.

The result (Table 4.76) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=3.668, df =2, p>.05), with a mean rank of 8.00 for GI, 9.30 for GII and 3.67 for GIII.

Table 4.75: Kruskal Wallis Test Ranks on session 3 of location F_ZP_Z

	EXPER	N	Mean Rank
SESSION3	Less than 10 years	2	8.00
	Less than 20 years	10	9.30
	20 years and above	3	3.67
	Total	15	

Table 4.76: Kruskal Wallis Test Statistics on session 3 of location F_ZP_Z

	SESSION3
Chi-Square	3.668
df	2
Asymp. Sig.	.160

From the mean ranking results (Table 4.75), it appeared that the beta power changed along the experiment duration more in experience group GI and GII for Session 3. It can be noted from the moderate different of Chi values generated.

Table 4.77: The compilation of statistical difference analysis among 3 groups of working experience on location F_ZP_Z

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	6.722	2.562	3.668
Asymp. Sig.	0.035*	0.278	0.160

From the table above, it can be seen that there was no significant different in any of the working experience group on the mean beta power on location F_ZP_Z.

4.5.3.2. Mean Beta Power of Location: O_1O_2

The result (Table 4.79) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=3.522, df =2, p>.05), with a mean rank of 9.00 for GI, 9.10 for GII and 3.67 for GIII.

Table 4.78: Kruskal Wallis Test Ranks on session 1 of location O_1O_2

	EXPER	N	Mean Rank
SESSION1	Less than 10 years	2	9.00
	Less than 20 years	10	9.10
	20 years and above	3	3.67
	Total	15	

Table 4.79: Kruskal Wallis Test Statistics on session 1 of location O_1O_2

	SESSION1
Chi-Square	3.522
df	2
Asymp. Sig.	.172

From the mean ranking results (Table 4.78), it appeared that the beta power changed along the experiment duration more in experience group GI and GII for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.81) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=0.022, df =2, p>.05), with a mean rank of 8.00 for GI, 7.90 for GII and 8.33 for GIII.

Table 4.80: Kruskal Wallis Test Ranks on session 2 of location O_1O_2

	EXPER	N	Mean Rank
SESSION2	Less than 10 years	2	8.00
	Less than 20 years	10	7.90
	20 years and above	3	8.33
	Total	15	

Table 4.81: Kruskal Wallis Test Statistics on session 2 of location O_1O_2

	SESSION2
Chi-Square	.022
df	2
Asymp. Sig.	.989

From the mean ranking results (Table 4.80), it appeared that the beta power changed along the experiment duration in each experience group for Session 2. It can be noted from the small different of Chi values generated.

The result (Table 4.83) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=0.737, df =2, p>.05), with a mean rank of 10.50 for GI, 7.70 for GII and 7.33 for GIII.

Table 4.82: Kruskal Wallis Test Ranks on session 3 of location O_1O_2

	EXPER	N	Mean Rank
SESSION3	Less than 10 years	2	10.50
	Less than 20 years	10	7.70
	20 years and above	3	7.33
	Total	15	

Table 4.83: Kruskal Wallis Test Statistics on session 3 of location O_1O_2

	SESSION3
Chi-Square	.737
df	2
Asymp. Sig.	.692

From the mean ranking results (Table 4.82), it appeared that the beta power changed along the experiment duration in each experience group for Session 3. It can be noted from the small different of Chi values generated.

Table 4.84: The compilation of statistical difference analysis among 3 groups of experience on location O_1O_2

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	3.522	0.022	0.737
Asymp. Sig.	0.172	0.989	0.692

From the Table 4.84, it can be seen that there was no significant different in any of the working experience group on the mean beta power on location O_1O_2.

4.5.3.3. Mean Beta Power of Location: P_3P_4

The result (Table 8.56) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=5.506, df =2, p>.05), with a mean rank of 10.50 for GI, 9.10 for GII and 2.67 for GIII.

Table 4.85: Kruskal Wallis Test Ranks on session 1 of location P_3P_4

	EXPER	N	Mean Rank
SESSION1	Less than 10 years	2	10.50
	Less than 20 years	10	9.10
	20 years and above	3	2.67
	Total	15	

Table 4.86: Kruskal Wallis Test Statistics on session 1 of location P_3P_4

	SESSION1
Chi-Square	5.506
df	2
Asymp. Sig.	.064

From the mean ranking results (Table 4.85), it appeared that the beta power changed along the experiment duration more in experience group GI and GII for Session 1. It can be noted from the moderate different of Chi values generated.

The result (Table 4.88) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=0.458, df =2, p>.05), with a mean rank of 9.75 for GI, 7.95 for GII and 7.00 for GIII.

Table 4.87: Kruskal Wallis Test Ranks on session 2 of location P_3P_4

	EXPER	N	Mean Rank
SESSION2	Less than 10 years	2	9.75
	Less than 20 years	10	7.95
	20 years and above	3	7.00
	Total	15	

Table 4.88: Kruskal Wallis Test Statistics on session 2 of location P_3P_4

	SESSION2
Chi-Square	.458
df	2
Asymp. Sig.	.795

From the mean ranking results (Table 4.87), it appeared that the beta power changed along the experiment duration in each experience group for Session 2. It can be noted from the small different of Chi values generated.

The result (Table 4.90) shows that there are **no significant differences** among the three groups of working experience on their mean beta power (x^2=0.751, df =2, p>.05), with a mean rank of 10.50 for GI, 7.50 for GII and 8.00 for GIII.

Table 4.89: Kruskal Wallis Test Ranks on session 3 of location P_3P_4

	EXPER	N	Mean Rank
SESSION3	Less than 10 years	2	10.50
	Less than 20 years	10	7.50
	20 years and above	3	8.00
	Total	15	

Table 4.90: Kruskal Wallis Test Statistics on session 3 of location P_3P_4

	SESSION3
Chi-Square	.751
df	2
Asymp. Sig.	.687

From the mean ranking results (Table 4.89), it appeared that the beta power changed along the experiment duration in each experience group for Session 3. It can be noted from the small different of Chi values generated.

Table 4.91: The compilation of statistical difference analysis among 3 groups of experience on location P_3P_4

	SESSION1	**SESSION2**	**SESSION3**
Chi-Square	5.506	0.458	0.751
Asymp. Sig.	0.064	0.795	0.687

From the Table 4.91, it can be seen that there was no significant different in any of the working experience group on the mean beta power on location P_3P_4.

CHAPTER 5

DISCUSSION

5.1. Introduction

This chapter aims to present the discussion of this study. The content relates the present findings to those disclosed in other studies. The first section discuss on the result from the survey of the perception of professional train drivers on their workload and jobs aspect. The following sections discuss the results of brain signal obtained from the driving task experiment that has been carried out. The relationship between brain signal of the train drivers and the driving condition were discussed to highlight the significance of the findings.

5.2. Perception of Professional Train Drivers

A survey method has been used to gather data on train drivers' perception on their working condition in relation to the workload and job scope. The sample gathered, which consists of representative of train drivers within the railway industry in Malaysia, was 34 in total, which all of them are professional train drivers. This survey has contributed into the identifying and understanding the view on different type of working shift. More in depth analysis has been done for ratings on responses to an item in the questionnaire on workload.

The result of the ratings on work demand of the train drivers showed in Figure 4.2 reflected that they were most self occupied by their work during rainy night driving. This means that they have to be more alert at this driving condition. This findings are parallel with what has been discussed by Kilpeläinen et al. (2007), which they stated that in bad weather, drivers need to know strategies to face the demand by the situation. In addition, the train drivers' perceptions were more inclined to strongly agree that night driving will contribute more on extensive mental effort and concentration as in result of Question 2 (Figure 4.3). This may due to the vision matter and the urge to fight the sleepy condition. The result supports several previous studies which stated that night activity induces more sleepiness in brain signal compared to daytime activity (Lowden et al., 2009; Torsvall and Åkerstedt, 1983).

Stress due to work problems can be the worst thing to happen at workplace. As the Question 3 (regarding to stress) were asked to the respondents, they rated 'strongly agree' (Figure 4.4) for this situation happens the most when it is raining, whether it is daytime or at night. This reflected that when it is raining, a lot of difficulties may happen and one of them might be the communication and network system problem. The rain mechanisms cause degradation in the received signal quality of communication system (Robert, A. N., 2000). This mater also can be related to Question 4 about error during working. Night driving and night rainy driving has been rated as the cause of most safety incidents. When any difficulty or problem happens, safety strategies need to be established, while with the limitations at night and in rainy weather, it can be hard to apply the techniques learned from safety trainings. To avoid incidents from getting worse, the train drivers need to be assisted with good working equipments and systems. Efficient work systems do motivate workers to perform their work excellently, encourage development of the worker skills, and provide them incentives to participate in decision making.

Analysis also has been done to assess the train drivers' perception on workload (Question 5). In all conditions, workload was rated higher as 'acceptable' compared to 'unacceptable'. But to highlight the findings, it is high at rainy night driving situation. Some of them give some subjective opinions about this matter, which they stated that when it is raining - especially at night, the tracks tend to be slippery. The dark environment made things worse since it causes limitation in the vision. Some drivers' visual abilities maybe relevant only to specific types of condition (Davison, P. A., 1979). In addition, physical condition also seems to be one of the causes of unacceptable workload. A good condition of working place and equipments (e.g.: brake, wiper, light) are important for train transportation especially during emergency situation. Violations are inevitable in conditions where work area or equipment is poorly designed or understaffed (Rail Safety and Standards Board, 2008). The facilities can ease the train drivers to perform the safety techniques in facing emergency or dangerous situation. For question regarding fatigue (Figure 4.7), the respondent mostly rated that it happens at the end of shift. The highest percentage was on night driving situation. The roadside visual stimulation have an impact on driving fatigue and the interruptions of monotony may alleviate the build up of drowsiness when driving on highly repetitive or very under-stimulating road environments (Thiffault et al., 2003).

5.3. Alpha Activity and its Significance to Mental Workload

In this study, the mental activities were investigated in the experiments on participants performing the driving task at three conditions (daytime, rainy daytime and rainy night drive). The driving tasks placed demands upon a train driver during the driving duration which resulted in different levels of mental workload individually. If a person is underload, the level of alertness and attention will be reduced (De Waard & Brookhuis, 1997). This leads to distractions and diversion of attention occurring and at the same time insufficient capacity and time fitted for information processing.

The change of EEG signal during the duration of experiment was analyzed. The experiment demonstrated the effect of time and condition of driving task to the brain signal. Three types of electrode placement were investigated in this research. Location F_Z is near intentional and motivational center while P_3, P_4 and P_Z contribute to activity of perception and differentiation while primary visual area can be found below point O_1 and O_2 (Teplan, 2002).

When comparing different driving sessions, significant difference was found for alpha power of channel location F_ZP_Z ($p=0.042$). It explains that the alpha activity can differentiate between the different loads of each task. This result supports previous findings by Ryu and Myung (2005) where the value of alpha can distinguish between different difficulty level of tasks. The alpha power in Session 1 is low at early until the middle stage of the experiment (Figure 4.8). This may be caused by the tendency to focus more and engage with the task (Seen et al., 2010; Nikhil et al.,2008). In reaching the final time interval, the drivers tended to show more calmness which reflected in the increment of alpha activity. Since it was reaching to the end of the short duration which was the destination for that session, they were in a more relaxed mood. However, the results do not coincide with that of Myrtek et al. (1994) in their study, which shows that at “start” and “braking”, the workload component was higher during those modes of driving.

There was no significant difference found for channel location O_1O_2 (Figure 4.9). However, there was a slight increase in the signal near the end of Session 3 signal. This shows that the mental load seemed to be lower and sleepiness occurred at this time. The alpha power increment can be associated to an increase of sleepiness (Lowden et al., 2009). Since O_1O_2 channel location is near the primary visual area (Teplan, 2002), the increment of the signal demonstrated that a higher demand were put on the eyes in order to avoid from falling asleep. In addition, the result supported several previous studies that during night drives, the alpha activity recorded an increment above daytime level in the experiments (Torsvall and Åkerstedt, 1983; Åkerstedt et al.; 1984).

For location P_3P_4, the alpha activity of Session 3 was high for most of the time which reflected a lower memory load and reduction of vigilance. This finding agrees with a previous argument by study that an increase in alpha activity is the most reliable indicator of vigilance (Torsvall and Åkerstedt, 1987). Performance within the simulation also become worse notably during the night and rainy setting, since the alpha readings recorded higher values along the recording duration compared to the other two sessions. Previous studies showed that the increment of alpha power during night conditions reflect worse driving performance (Gillberg et al.,2009; Lowden et al., 2009). Since Session 3 was the final session, the drivers might have felt tired and needed to rest. Alpha rhythms may yield when the brain is at relative rest due to high oscillations of high proportions of alpha generators in phases (Lei et al.,2011).

5.4. Beta Activity and its Significance to Alertness

The beta activity was analyzed to see the alertness pattern during the train driving experiment. No significant difference was found for beta activity at location F_ZP_Z between the three sessions. This is because beta power are not affected by the task difficulty (Gevin et al., 1998). The signal activity was quite stable generally for all of the sessions. However for Session 1, there was a slight increase at the end of the duration. It was stated in a previous study that the beta activity usually decreased at the end drive level as driver started getting fatigue (Jap et al., 2011). The explanation of the contradiction of the result might be that the driver was still not tired at the early experiment duration and far from feeling fatigue. They showed tendency to finish the first session with high level of alertness which beta waves are related to alertness and arousal (Grandjean, 1988).

It can also be seen from the study that there was no significant difference found for location O_1O_2 between all the driving sessions. Nevertheless, during the rainy and night drive (Session 3), the beta signal increases, this might be because it was hard to see through the darkness, as it was in the night setting condition of the experiment. This present study relates to a previous study, which stated that with the presence of visual presentation during a task, beta waves will decrease compared with the task given without visual presentation (Tanaka and Sato, 2011). In this current study, it can be said that during the last session, the driver might have difficulty on the vision in completing the task. As beta potential was also related to alertness increment (Belyavin & Wright, 1987; Lal & Craig, 2001), it can be seen here that the drivers tend to increase the alertness when they have difficulty in the vision. They were trying to give more attention to the task and were alert on the incoming things upfront by demanding more strength of their eyes.

Significant different was found for beta activity at the P_3P_4 location during the monotonous driving sessions. It was clear to see that beta activity (Figure 4.13) for session 3 recorded very unstable and different values compared to the other two sessions. Since channel P_3P_4 contributes to perception and differentiation (Teplan, 2002), the drivers might be having confusion of perception during the fuzzy rainy driving condition and affects their alertness. The result showed changes and alteration of the beta activity which has been associated to instability of the drivers' conditions and performance (Townsend & Johnson, 1979; Wierwille & Ellsworth, 1994). In addition, beta wave reduction is also a clear sign of weariness and sleepiness of human (Lal et al., 2001).

5.5. Relationship of Age and Experience on EEG Signals

The Kruskal Wallis test was done on age factor and there was no significant different was found between all the EEG signals of all the participants. It is contradict with previous studies which reported that there was a main effect of age was found for higher frequency of EEG signal including beta power (Lowden et al., 2009). In addition, an increase in faster frequency bands like beta has been shown to correlate to aging (Duffy et al., 1984). The explanation for this might be that the reaction and interaction of the train drivers in any age groups were not really different from each other during the experiments. This may due to the same working techniques and culture of all of them when working regardless of age.

On the other hand, only one location of EEG signal was found to have significant difference in relation to different working experience factors. This result coincides with a study on visual acquisition which they found out that there were differences between experienced drivers and novices (Crundall et al., 1998). Experienced drivers usually select visual strategies according to the complexity of the journey. Since the significant difference was found at location F_ZP_Z, it seems that the drivers differentiated the complication of the task. Meanwhile, new drivers have no or inflexible strategies to meet the changing demands during driving sessions. From the current study results, it can be seen that the beta power (location F_ZP_Z) of participants with experience of less than 20 years encountered most change which reflected their alertness instability. A previous study highlighted that a significant different was found in cognitive workload levels between experienced and inexperienced drivers (Patten et al., 2006). Thus, more trainings and experience may provide attention resource which than can give advantages to the driver in facing new or unexpected traffic solution.

5.6. Implication on Occupational Health

Apparently, the EEG results showed the most different of signals elicited in Session 3 (rainy night driving). The alpha power was observed to be decreasing at time interval two to three during rainy night session at all channel location. This finding showed that the train drivers tend to have an increase mental workload after six minutes of train driving during rainy night shift.

Meanwhile, the results reflected the sleepiness conditions of the participants. Night driving particularly has been confirmed to induce more sleepiness (Lowden et al., 2009; Otmani et al., 2005).The result also showed that there was 37% of difference between day and night rainy drive even at the early duration. In real working situations, it is very dangerous for a train driver to feel sleepy or even accidentally doze off while working. Specifically for safety considerations, a proper working timetable or duty-shift must be arranged properly so that the drivers can arrange their sleeping hours before working. There is a distinct relationship between railway accidents and locomotive crew while on duty or shift work (Budi et al., 2011). Moreover, the availability of the schedule may enhance the motivation of the train drivers to perform in their work tasks, and thus offer an excellent service for the organization. An efficient work schedule is important in increasing the motivation and satisfaction of workers (McAuliffe et al., 2009).

Furthermore, in focusing on safety factors, some improvements and additional measures can be proposed since the results also reveal that darkness (night) and rainy day conditions, there might be vision problems for the train driver. Even at the early time interval, the result illustrated difference between normal daytime driving and rainy night driving in term of vision. This can be related to design matters. For example, an infrared camera could be installed at the front of the cab that can improve visibility, especially in the blind spots. Meanwhile, with the help of sufficient bright lighting at the front of the cab, the train driver should be able to view the route at the control panel display at least 1 mile ahead. Thus the train driver can react earlier to problems and extra work demands especially during night-shifts and rainy days. The braking distance of a train depends on the speed of the train when the brakes are applied (Barney et al., 2001). Therefore, if a train driver is able to detect a danger earlier upfront, he can react quickly by applying a stopping act to the train.

CHAPTER 6

CONCLUSION

6.1. Conclusion and Application

It was found from the EEG experiments conducted that mental workload and alertness are different in each driving conditions. The alpha power showed a significant difference on intentional and motivational center of the train drivers. At the same time, it also contributes to activity of perception and differentiation, indicating that load of each driving condition is different.

In the conclusion, the study has shown a significant pattern for night raining condition. It is also highlighted that during night and rainy, the mental workload increases 37% from sunny condition. Meanwhile, it was found out that after six minutes of rainy night driving, a lower mental workload appeared among the train drivers which showing detachment on the works. Additionally, it was found out that there is difficulty in term of vision among the train drivers during rainy night drive. It is important pay more attention in this condition since it is very dangerous and more risky in term of the safety.

Suggestions that utilizing significant different results of mental workload and alertness variables have been made to provide improvement strategies on current railway transportation system. Since driving in rainy night condition contribute the most into sleepiness and low of alertness, it is important to apply and use this study to design working environments that reduce the risk of unnecessary incidents such as accidents due to unsuitable workload and inadequate alertness of the drivers. These findings can be utilized to manage the schedule of work efficiently and suggest a better design of working environment for the train drivers. Thus, a broader sense of ergonomics can be applied which ensure an excellent stability between the organization as a whole, its people, working practices and technology.

6.2. Future work Recommendations

The results have shown that EEG experimental work is an efficient and effective method to monitor the mental workload and alertness. It is proposed here for future work that more different conditions of train driving can be provided by the train driving simulator such as interruption of people or animals on the rail tracks, sudden electricity shortage and other weather dilemmas. This is important for a more thorough understanding of train driver working conditions, which will increase the safety level of rail transportation. Furthermore, artificial intelligence can be used to analyze the data and develop a new useful model for the industry.

In addition, the techniques may also be used to monitor other factors such as fatigue, stroke and physical weakness of the train driver by analyzing different frequency of the EEG signals. At the same time, other quantitative measurement such as muscle activity, blood pressure, and heart rate can be conducted to strengthen the result, so that comparisons can be made to clarify the efficiency of each technique.

Furthermore, the effects of environmental factors also can be investigated in the train cab such as lighting, air humidity, temperature and noise. Thus the results can be applied for safety and management of railway workers and also at the same time to the system designers of other industry.

REFERENCES

Afizan, A., Qinggang, M, Eran, A. E. & Hartini, A. (2011). Non-Intrusive Physiological Measurement for Driver Cognitive Distraction Detection: Eye and Mouth Movements. *International Journal of Advanced Computer Science, 1*(3), 92-99.

Alberta Employment, I. A. I. (2007). Strategic Workforce Planning. *Guidelines For Industry And Employers*, from http://eae.alberta.ca/documents/RRM/RRM-PUB_strategic_workforce_planning.pdf

Andreassi, J. L. (2000). *Psychophysiology: Human Behavior and Physiological Response*. New Jersey London: Lawrence Erlbaum Associates, Hillsdale.

Austin, A., & Drummond, P. D. (1986). Work problems associated with suburban train driving. *Applied Ergonomics, 17*(2), 111-116.

Barney, D., Haley, D., & Nikandros, G. (2001). *Calculating train braking distance*. Paper presented at the Proceedings of the Sixth Australian workshop on Safety critical systems and software - Volume 3, Brisbane, Australia.

BBC NEWS. (2012, 22 May). Deadly train crash in south India's Andhra Pradesh Retrieved 1 July 2012, 2012, from http://www.bbc.co.uk/news/world-asia-india-18155973

Belyavin, A., & Wright, N. A. (1987). Changes in electrical activity of the brain with vigilance. *Electroencephalography and Clinical Neurophysiology, 66*(2), 137-144.

Berka C, Levendowski D. J., Lumicao M. N., Yau A., Davis G., Zivkovic V. T. (2007). EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. *Aviation, Space, and Environmental Medicine, 78*(5), B231-244.

Biemans, M., Swaak, J., & Wibbels, M. (2006). *Cabin information support for enhanced decision-making of train drivers.* Paper presented at the The 16th World Congress on Ergonomics (IEA2006), Maastricht, The Netherlands.

Brookhuis, K. A., & de Waard, D. (2010). Monitoring drivers' mental workload in driving simulators using physiological measures. *Accident Analysis & Prevention, 42*(3), 898-903. doi: 10.1016/j.aap.2009.06.001

Chen, D., & Vertegaal, R. (2004). Using Mental Load for Managing Interruptions in Physiologically Attentive User Interfaces *CHI*. Vienna, Austria.

Choobineh, A., Hosseini, M., Lahmi, M., Khani Jazani, R., & Shahnavaz, H. (2007). Musculoskeletal problems in Iranian hand-woven carpet industry: Guidelines for workstation design. *Applied Ergonomics, 38*(5), 617-624. doi: http://dx.doi.org/10.1016/j.apergo.2006.06.005

Conradt, R., Brandenburg, U., Penzel, T., Hasan, J., Värri, A., & Peter, J. H. (1999). Vigilance transitions in reaction time test: a method of describing the state of alertness more objectively. *Clinical Neurophysiology, 110*(9), 1499-1509. doi: 10.1016/s1388-2457(99)00115-7

Crew Resource Management. (2012). Crew Resource Management- Module 3: Fatigue and Workload Management from http://www.crewresourcemanagement.net/5/30.html

Crundall, D., & Underwood, G. (1998). Effects of experience and processing demands on visual information acquisition in drivers. *Ergonomics 41*, 448-458.

D. C. Blood, V. P. Studdert, & C. C. Gay. (Eds.). (2007) Saunders Comprehensive Veterinary Dictionary (3 ed.). Elsevier, Inc.

Davison, P. A. (1979). The role of drivers' vision in road safety *Applied Ergonomics, 10*(2), 125-139. doi: 10.1016/0003-6870(79)90076-0

De Waard, D. (1996). *The measurement of drivers' mental workload.* Ph.D, University of Groningen, Haren, The Netherlands.

Defense Science Board Washington Dc. (2009). Report of the Defense Science Board Task Force on Understanding Human Dynamics. Washington Dc: Office of the Under Secretary of Defense For Acquisition, Technology, and Logistics Washington, D.C.

Duffy, F. H., Albert, M. S., McAnulty, G., & Garvey, A. J. (1984). Age-related differences in brain electrical activity of healthy subjects. *Annals of Neurology, 16*(4), 430-438.

Galy, E., Cariou, M., & Mélan, C. (2012). What is the relationship between mental workload factors and cognitive load types? *International Journal of Psychophysiology, 83*(3), 269-275. doi: 10.1016/j.ijpsycho.2011.09.023

Gevins, A., Smith, M. E., Leong, H., McEvoy, L., Whitfield, S., Du, R., & Rush, G. (1998). Monitoring Working Memory Load during Computer-Based Tasks with EEG Pattern Recognition Methods. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 40*(1), 79-91. doi: 10.1518/001872098779480578

Gillberg, M., Kecklund, G., & Åkerstedt, T. (1996). Sleepiness and performance of professional drivers in a truck simulator - Comparisons between day and night driving. *Journal of Sleep Research, 5*(1), 12-15.

Goran Kecklund, Torbjorn Akerstedt, Michael Ingre, & Soderstrom, M. (1999). Stress Research Report no 288 *Train drivers' working conditions and their impact on safety, stress and sleepiness: a literature review, analyses of accidents and schedules*: National Institute for Psychosocial Factors and Health (IPM).

Grandjean, E. (1988). *Fitting The Task To The Man*. London: Taylor and Francis.

Green, S. B., & Salkind, N. J. (2008). *Using SPSS for Window and Macintosh:Analyzing and understanding data* (5th ed.). Upper Saddle River: NJ : Pearson Prentice Hall.

Greenstreet Berman Ltd. (2003). Competence assessment for the hazardous industries *Research Report 086*: Health and Safety Executive.

Hagemann, K. (2008). *The alpha band as an electrophysiological indicator for internalized attention and high mental workload in real traffic driving.* Doctoral degree, Universität Düsseldorf.

Hart, C. S. (2010). *Assessing the Impact of Low Workload in Supervisory Control of Networked Unmanned Vehicles.* Master of Science in Aeronautics and Astronautics, United States Air Force Academy, United States.

Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In A. H. Peter & M. Najmedin (Eds.), *Advances in Psychology* (Vol. Volume 52, pp. 139-183): North-Holland.

Herald, A. (2012, 23 April). Fatal train crash probably caused by driver missing red signal Retrieved 10 July 2012, 2012, from http://www.amsterdamherald.com/index.php/allnews-list/223-20120423-traincrash

HQs Civil Aviation Authority. (2009). Flight Standards Directorate *Concept of Mental Workload* (pp. 1-5). Pakistan.

Hwang, S.-l., Yau, Y.-j., Lin, Y.-t., & Chen, J. H. (2007). A Mental Workload Predicator Model for the Design of Pre Alarm Systems. *Engineering Psychology and Cognitive Ergonomics*, *4562*, 316–323.

Jap, B. T., Lal, S., & Fischer, P. (2011). Comparing combinations of EEG activity in train drivers during monotonous driving. *Expert Systems with Applications, 38*(1), 996-1003. doi: 10.1016/j.eswa.2010.07.109

Johnson, E. O., Breslau, N., Roth, T., Roehrs, T., & Rosenthal, L. (1999). Psychometric evaluation of daytime sleepiness and nocturnal sleep onset scales in a representative community sample. *Biological Psychiatry, 45*(6), 764-770. doi: http://dx.doi.org/10.1016/S0006-3223(98)00111-5

K. Seen , S. Mohd Tamrin, & G. Meng. (2010). Driving Fatigue and Performance among Occupational Drivers in Simulated Prolonged Driving. *Global Journal of Health Science, 2*(1).

Kaber, D. B., & Usher, J. M. (2000). Preface: Cognitive engineering in automated systems design. *Human Factors and Ergonomics in Manufacturing & Service Industries, 10*(4), 363-367.

Kecklund, L., Olsson, E., Jansson, A., Kecklund, G., & Ingre, M. (2003). *The Train-Project: Effects of Organizational Factors, Automatic Train Control, Work Hours and Environment: Suggestions for Safety Enhancing Measures.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society Annual Meeting

Kilpeläinen, M., & Summala, H. (2007). Effects of weather and weather forecasts on driver behaviour. *Transportation Research Part F: Traffic Psychology and Behaviour, 10*(4), 288-299. doi: 10.1016/j.trf.2006.11.002

Lal, S. K. L., & Craig, A. (2001). A critical review of the psychophysiology of driver fatigue. *Biological Psychology, 55*(3), 173-194. doi: 10.1016/s0301-0511(00)00085-5

Lammers, G. J., Brookhuis, K. A., Declerck, A., Eling, P., Linskens, I., Overeem, S., Coenen, A. (2005). Vigilance; evaluation and measurement. *NSWO, 16*, 21-35.

Lee, P. J. N., & Triggs, T. J. (1976). *The effect of driving demand and roadway environment on peripheral visual detections.* Paper presented at the ARRB Proceedings, Australia

Lei, S., & Roetting, M. (2011). Influence of Task Combination on EEG Spectrum Modulation for Driver Workload Estimation. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 53*(2), 168-179. doi: 10.1177/0018720811400601

Lei, S., Welke, S., & Roetting, M. (2009). *Driver's Mental Workload Assessment Using EEG Data in a Dual Task Paradigm.* Paper presented at the Proceedings of The

21st (Esv) International Technical Conference On The Enhanced Safety Of Vehicles, Stuttgart, Germany

Leung, A. W.-s. (2006). *Neurophysiological Correlates of Performance and Fatigue in Study of Mental Workload.* Doctor of Philosophy, The Hong Kong Polytechnic University, Hong Kong.

Lowden, A., Anund, A., Kecklund, G., Peters, B., & Åkerstedt, T. (2009). Wakefulness in young and elderly subjects driving at night in a car simulator. *Accident Analysis & Prevention, 41*(5), 1001-1007. doi: 10.1016/j.aap.2009.05.014

Luximon, A., & Goonetilleke, R. S. (2001). Simplified subjective workload assessment technique. *Ergonomics, 44*(3), 229-243. doi: 10.1080/00140130010000901

Makeig, S., & Inlow, M. (1993). Lapses in alertness: Coherence of fluctuations in performance and EEg spectrum. *Electroencephalography and Clinical Neurophysiology, 86*(1), 23-35.

Mayser C, Piechulla W, Weiss K.-E, & König W. (2003, May 07th-09th). *Driver workload monitoring.* Paper presented at the The 50th-Anniversary Conference of the GfA and the XVII Annual ISOES Conference, Munich.

McAuliffe, E., Manafa, O., Maseko, F., Bowie, C., & White, E. (2009). Understanding job satisfaction amongst mid-level cadres in Malawi: the contribution of organisational justice. *Reproductive Health Matters, 17*(33), 80-90. doi: 10.1016/s0968-8080(09)33443-6

Ministry of Finance Malaysia. (2011). Economic Report *CHAPTER 3 Economic Performance and Prospects*.

Mosby. (Ed.) (2009)   (8th ed.). Elsevier.

Myrtek, M., Deutschmann-Janicke, E., Strohmaier, H., Zimmermann, W., Lawerenz, S., BrÜGner, G., & MÜLler, W. (1994). Physical, mental, emotional, and subjective workload components in train drivers. *Ergonomics, 37*(7), 1195-1203. doi: 10.1080/00140139408964897

Nelson, R. A. (2000). Rain How It Affects the Communications Link. *Applied Technology Institute, 97*(53).

Niedermeyer, E., & Silva, F. H. L. d. (1993). *Electroencephalography: Basic principles, clinical applications and related fields* (Vol. 3rd edition). Philadelphia: Lippincott, Williams & Wilkins.

Nikhil R. Pal, Chien-Yao Chuang, Li-Wei Ko, Chih-Feng Chao, Tzyy-Ping Jung, Sheng-Fu Liang, & Lin, C.-T. (2008). EEG-Based Subject- and Session-independent Drowsiness Detection: An Unsupervised Approach. *EURASIP Journal on Advances in Signal Processing*.

Oken, B. S., Salinsky, M. C., & Elsas, S. M. (2006). Vigilance, alertness, or sustained attention: physiological basis and measurement. *Clinical Neurophysiology, 117*(9), 1885-1901. doi: 10.1016/j.clinph.2006.01.017

Or, C. K. L., & Duffy, V. G. (2007). Development of a facial skin temperature-based methodology for non-intrusive mental workload measurement. *Occupational Ergonomics 7*.

Oron-Gilad, T., Ronen, A., & Shinar, D. (2008). Alertness maintaining tasks (AMTs) while driving. *Accident Analysis & Prevention, 40*(3), 851-860. doi: 10.1016/j.aap.2007.09.026

Otmani, S., Rogé, J., & Muzet, A. (2005). Sleepiness in professional drivers: Effect of age and time of day. *Accident Analysis and Prevention*, *37*(5), 930-937.

Parkes, A. M. (1991). *Data Capture Techniques For RTI Usability Evaluation*. Paper presented at the DRIVE Conference (1991 : Brussels, Belgium). Advanced telematics in road transport. Vol. II, Brussels, Belgium.

Patten, C. J. D., Kircher, A., Östlund, J., Nilsson, L., & Svenson, O. (2006). Driver experience and cognitive workload in different traffic environments. *Accident Analysis & Prevention*, *38*(5), 887-894. doi: 10.1016/j.aap.2006.02.014

Pickup, L., Wilson, J. R., Norris, B. J., Mitchell, L., & Morrisroe, G. (2005). The Integrated Workload Scale (IWS): A new self-report tool to assess railway signaller workload. *Applied Ergonomics*, *36*(6), 681-693. doi: 10.1016/j.apergo.2005.05.004

R›ine, S. (2007). *A formative analysis of the train driving task.* The University of Oslo, Oslo. Retrieved from http://urn.nb.no/URN:NBN:no-16193

Rabbi, A. F., Ivanca, K., Putnam, A. V., Musa, A., Thaden, C. B., & Fazel-Rezai, R. (2009, 3-6 Sept. 2009). *Human performance evaluation based on EEG signal analysis: A prospective review.* Paper presented at the Engineering in Medicine and Biology Society, 2009. EMBC 2009. Annual International Conference of the IEEE.

Rail Safety and Standards Board. (2005). Train Driver Workload Principles Guidance Note *Train Driver Mental Workload*. London: The Institute For Occupational Ergonomics Centre For Rail Human Factors.

Rail Safety and Standards Board. (2008). Understanding Human Factors a guide for the railway industry.

Rajaratnam, S. M. W., & Jones, C. B. (2004). Lessons about sleepiness and driving from the Selby rail disaster case: R v Gary Neil Hart. *Chronobiology International, 21*(6), 1073-1077.

Raskin, J. (2000). *The humane interface: new directions for designing interactive systems*: ACM Press/Addison-Wesley Publishing Co. New York, NY, USA

Reid, G. B., & Nygren, T. E. (1988). The Subjective Workload Assessment Technique: A Scaling Procedure for Measuring Mental Workload. In A. H. Peter & M. Najmedin (Eds.), *Advances in Psychology* (Vol. Volume 52, pp. 185-218): North-Holland.

Ryan, B., Wilson, J. R., Sharples, S., Morrisroe, G., & Clarke, T. (2009). Developing a Rail Ergonomics Questionnaire (REQUEST). *Applied Ergonomics, 40*(2), 216-229. doi: 10.1016/j.apergo.2008.04.006

Ryu, K., & Myung, R. (2005). Evaluation of mental workload with a combined measure based on physiological indices during a dual task of tracking and mental arithmetic. *International Journal of Industrial Ergonomics, 35*(11), 991-1009. doi: 10.1016/j.ergon.2005.04.005

Shapiro, C. M., Auch, C., Reimer, M., Kayumov, L., Heslegrave, R., Huterer, N., Devins, G. M. (2006). A new approach to the construct of alertness. *Journal of Psychosomatic Research, 60*(6), 595-603. doi: http://dx.doi.org/10.1016/j.jpsychores.2006.04.012

Shinji, M. (2001). Multivariate workload evaluation combining physiological and subjective measures. *International Journal of Psychophysiology*, *40*(3), 233-238. doi: 10.1016/s0167-8760(00)00191-4

Smith, M. E., Gevins, A., Brown, H., Karnik, A., & Du, R. (2001). Monitoring task load with multivariate EEG measures during complex forms of human-computer interaction. . *Human Factors, 43*, 366–380.

Subasi, A. (2005). Automatic recognition of alertness level from EEG by using neural network and wavelet coefficients. *Expert Systems with Applications, 28*(4), 701-711.

T. Åkerstedt, L. Torsvall, & M. Gillberg. (1984). Sleepiness in laboratory and field experiments. In E. R. W.P. Koella, H. Schulz (Ed.), *Sleep, Gustav Fischer Verlag* (pp. 88-89). Stuttgart.

Tanaka, H., & Sato, Y. (2011). A vision-taste interference model and the EEG measurement. *Artificial Life and Robotics, 16*(3), 393-397. doi: 10.1007/s10015-011-0958-0

Taylor, W., Melloy, B., Dharwada, P., Gramopadhye, A., & Toler, J. (2004). The effects of static multiple sources of noise on the visual search component of human inspection. *International Journal of Industrial Ergonomics, 34*(3), 195-207. doi: 10.1016/j.ergon.2004.04.002

Teplan, M. (2002). Fundamentals Of Eeg Measurement. *Institute of Measurement Science, Slovak Academy of Sciences, 2*, 1-11.

Thiffault, P., & Bergeron, J. (2003). Monotony of road environment and driver fatigue: A simulator study. *Accident Analysis and Prevention, 35*(3), 381-391.

Torsvall, L., & åAkerstedt, T. (1987). Sleepiness on the job: continuously measured EEG changes in train drivers. *Electroencephalography and Clinical Neurophysiology, 66*(6), 502-511. doi: 10.1016/0013-4694(87)90096-4

Torsvall, L., & Åkerstedt, T. (1983). Sleepiness and irregular work hours. *Sleep Research, 12*.

Townsend, R. E., & Johnson, L. C. (1979). Relation of frequency-analyzed EEG to monitoring behavior. *Electroencephalography and Clinical Neurophysiology, 47*(3), 272-279.

Verwey, W. B. (1993). How can we prevent overload of the driver? In I. A. M. Parkes & S. Franzén (Eds.), *Driving future vehicles* (pp. 235-244). London: Taylor & Francis.

Verwey, W. B. (2000). On-line driver workload estimation. EŒects of road situation and age on secondary task measures. *Ergonomics, 43*, 187-209.

Vicente, K. J. (1999). *Cognitive work analysis: toward safe, productive, and healthy computer-based work.* London: Lawrence Erlbaum Associates, Inc.

Vidulich, M. A., & Tsang, P. S. (1987). Absolute Magnitude Estimation and Relative Judgement Approaches to Subjective Workload Assessment. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 31*(9), 1057-1061. doi: 10.1177/154193128703100930

Wierwille, W. W., & Ellsworth, L. A. (1994). Evaluation of driver drowsiness by trained raters. *Accident Analysis and Prevention, 26*(5), 571-581.

Woods, D. D. (1988). Coping with complexity: the psychology of human behaviour in complex systems *Tasks, errors, and mental models* (pp. 128-148): Taylor \& Francis, Inc.

Xie, B., & Salvendy, G. (2000). Review and reappraisal of modelling and predicting mental workload in single- and multi-task environments. *Work & Stress, 14*(1), 74-99. doi: 10.1080/026783700417249

Zeitlin, L. (1998). Micromodel for Objective Estimation of Driver Mental Workload from Task Data. *Transportation Research Record: Journal of the Transportation Research Board, 1631*(-1), 28-34. doi: 10.3141/1631-05

Appendix A

The survey instrument

Name:	Age:
Weight:	Height:
Gender : M / F	Experience (years):
Race : Malay / Chinese / Indian	Status : Single / Married / Others

Breakdown of the questions on Aspect of Job, Workload and Health in REQUEST

	Question	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	I have to keep track of more than one thing at a time	1	2	3	4	5
2	I often need extensive mental effort and concentration in my job	1	2	3	4	5
3	Problems cause a high level of pressure in my work	1	2	3	4	5
4	An error on my part could cause a safety incident	1	2	3	4	5

Please rate the following aspects of your job during **Daytime Driving**

	Question	Yes	No
5	During normal service, do you think that your workload is acceptable or unacceptable? (Example : In term of attention , visual, auditory, interference, situational stress) If yes, are there any particular times? (Example : During uncertain weather)	……………………………………………… ……………………………………………… ………………………………………………	

	Question	Start of a shift	Middle of a shift	End of a shift	Throughout the shift	Not applicable
6	When do you feel that you suffer most from fatigue					

Please rate the following aspects of your job during **Night Driving**

	Question	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	I have to keep track of more than one thing at a time	1	2	3	4	5
2	I often need extensive mental effort and concentration in my job	1	2	3	4	5
3	Problems cause a high level of pressure in my work	1	2	3	4	5
4	An error on my part could cause a safety incident	1	2	3	4	5

	Question	Yes	No
5	During normal service, do you think that your workload is acceptable or unacceptable? (Example : In term of attention , visual, auditory, interference, situational stress) If yes, are there any particular times? (Example : During uncertain weather)	……………………………………………………… ……………………………………………………… ………………………………………………………	

	Question	Start of a shift	Middle of a shift	End of a shift	Throughout the shift	Not applicable
6	When do you feel that you suffer most from fatigue					

Please rate the following aspects of your job during **Rainy Daytime Driving**

	Question	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	I have to keep track of more than one thing at a time	1	2	3	4	5
2	I often need extensive mental effort and concentration in my job	1	2	3	4	5
3	Problems cause a high level of pressure in my work	1	2	3	4	5
4	An error on my part could cause a safety incident	1	2	3	4	5

	Question	Yes	No
5	During normal service, do you think that your workload is acceptable or unacceptable? (Example : In term of attention , visual, auditory, interference, situational stress) If yes, are there any particular times? (Example : During uncertain weather)	……………………………………………… ……………………………………………… ………………………………………………	

	Question	Start of a shift	Middle of a shift	End of a shift	Throughout the shift	Not applicable
6	When do you feel that you suffer most from fatigue					

Please rate the following aspects of your job during **Rainy Night Driving**

	Question	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
1	I have to keep track of more than one thing at a time	1	2	3	4	5
2	I often need extensive mental effort and concentration in my job	1	2	3	4	5
3	Problems cause a high level of pressure in my work	1	2	3	4	5
4	An error on my part could cause a safety incident	1	2	3	4	5

	Question	Yes	No
5	During normal service, do you think that your workload is acceptable or unacceptable? (Example : In term of attention , visual, auditory, interference, situational stress) If yes, are there any particular times? (Example : During uncertain weather)	…………………………………………………… …………………………………………………… ……………………………………………………	

	Question	Start of a shift	Middle of a shift	End of a shift	Throughout the shift	Not applicable
6	When do you feel that you suffer most from fatigue					

Appendix B

Survey Data

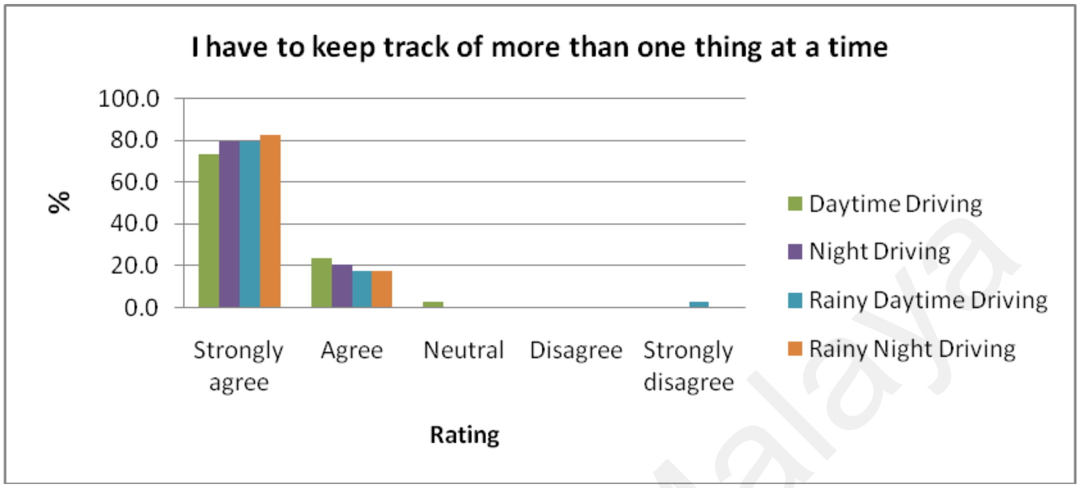

Figure B.1 : Percentage ratings from question for perception on the work at different driving situations.

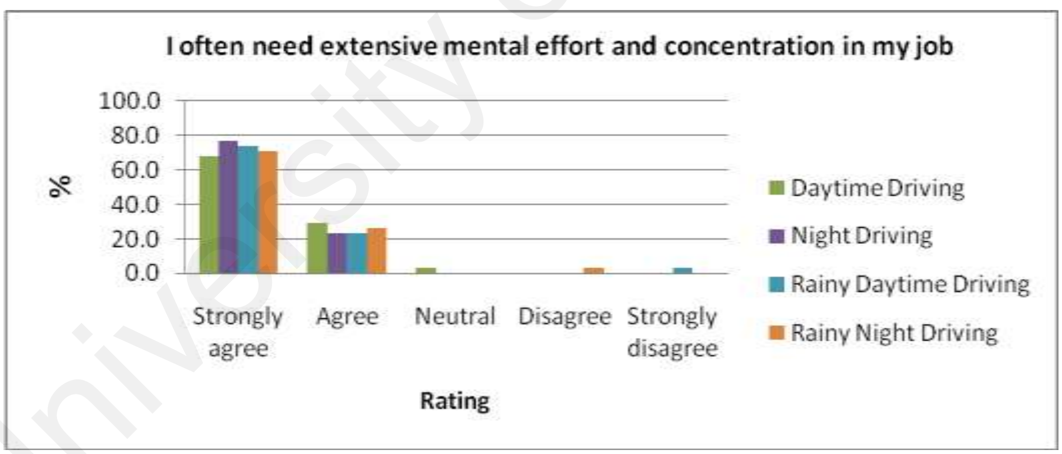

Figure B.2 : Percentage ratings for perception on extensive mental effort and concentration.

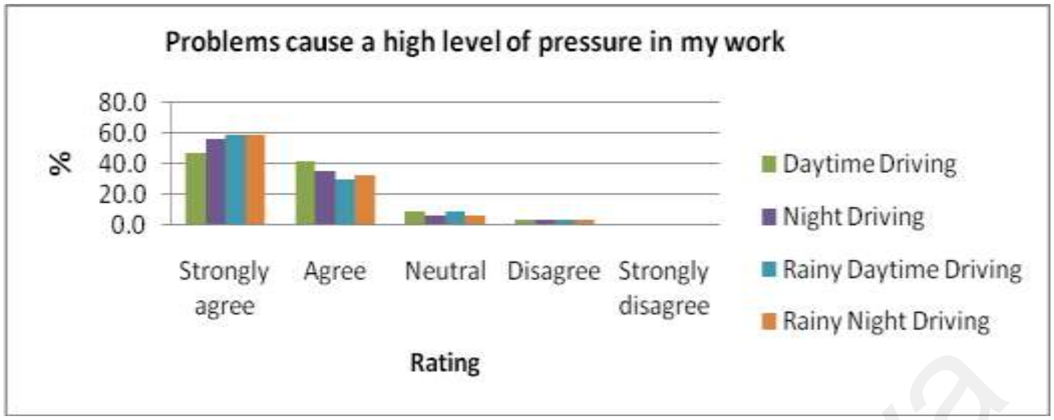

Figure B.3 : Percentage ratings related to pressure during work.

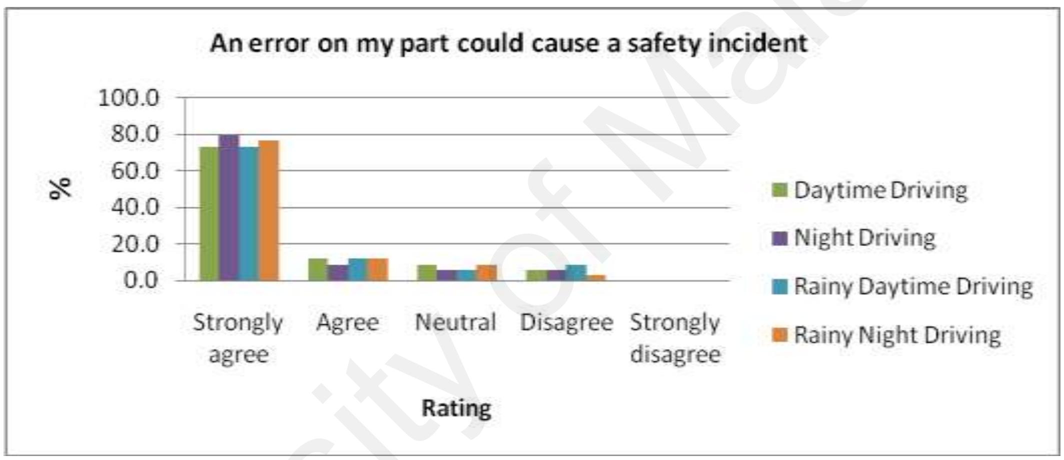

Figure B.4: Percentage ratings from respondents related to safety incidents.

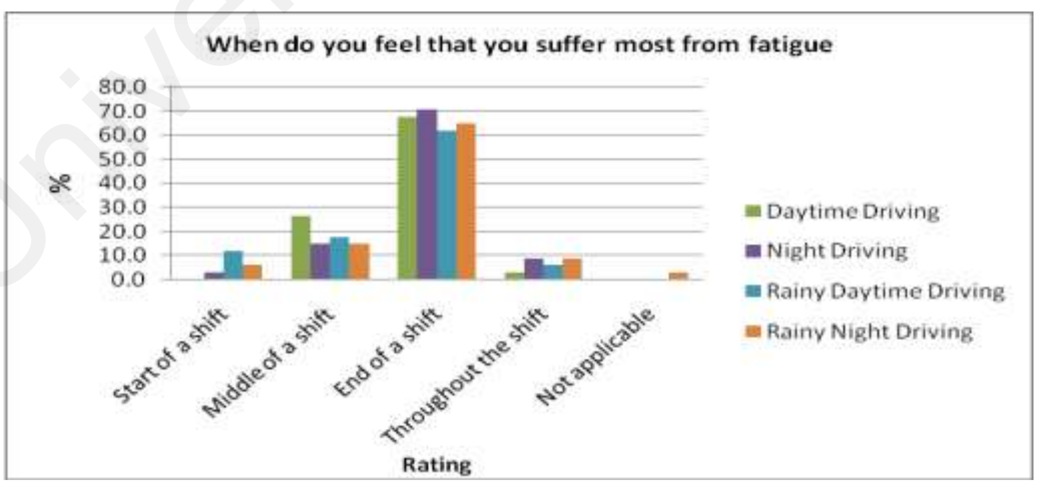

Figure B.5 : Complete percentage ratings for perception on fatigue .

Appendix C

Data of mean alpha power

Table C.1: Mean alpha power over time interval in three different sessions for location F_ZP_Z

TIME INTERVAL	SESSION 1 (V)	SESSION 2 (V)	SESSION 3 (V)
1	7.92E-07	5.62E-07	7.68E-07
2	5.87E-07	6.21E-07	9.28E-07
3	6.16E-07	5.79E-07	7.21E-07
4	6.79E-07	5.95E-07	6.69E-07
5	1.08E-06	6.39E-07	6.91E-07
6	1.16E-06	6.6E-07	6.69E-07

Table C.2: Mean alpha power over time interval in three different sessions for location O_1O_2

TIME INTERVAL	SESSION 1 (V)	SESSION 2 (V)	SESSION 3 (V)
1	1.61E-05	1.1E-05	6.03E-06
2	1.23E-05	9.57E-06	1.38E-05
3	1.44E-05	4.39E-06	9.85E-06
4	1.19E-05	1.53E-05	1.57E-05
5	7.99E-06	1.01E-05	2.98E-05
6	1.34E-05	7.18E-06	2.32E-05

Table C.3: Mean alpha power over time interval in three different sessions for location P_3P_4

TIME INTERVAL	SESSION 1 (V)	SESSION 2 (V)	SESSION 3 (V)
1	3.72E-06	1.07E-05	1.95E-05
2	8.41E-06	4.81E-06	2.25E-05
3	1.78E-05	4.87E-06	1.77E-05
4	5.87E-06	5.54E-06	2.73E-05
5	1.28E-05	1.27E-05	2.08E-05
6	1.75E-05	1.39E-05	1.3E-05

Data of mean beta power

Table C.4: Mean beta power over time interval in three different sessions for location F_ZP_Z

TIME INTERVAL	SESSION 1 (V)	SESSION 2 (V)	SESSION 3 (V)
1	6.85E-07	5.12E-07	5.87E-07
2	4.47E-07	5E-07	6.36E-07
3	4.66E-07	4.68E-07	5.45E-07
4	5.22E-07	4.75E-07	5.61E-07
5	6.96E-07	5.02E-07	5.95E-07
6	9.08E-07	5.31E-07	5.32E-07

Table C.5: Mean beta power over time interval in three different sessions for location O_1O_2

TIME INTERVAL	SESSION 1 (V)	SESSION 2 (V)	SESSION 3 (V)
1	1.3E-05	1.04E-05	1.85E-05
2	1.21E-05	8.74E-06	7.37E-06
3	1.15E-05	4E-06	7.48E-06
4	9.61E-06	1.74E-05	1.25E-05
5	6.61E-06	8.93E-06	1.58E-05
6	1.03E-05	5.65E-06	2.06E-05

Table C.6: Mean beta power over time interval in three different sessions for location P_3P_4

TIME INTERVAL	SESSION 1 (V)	SESSION 2 (V)	SESSION 3 (V)
1	3.14E-06	9.33E-06	1.12E-05
2	7.52E-06	3.98E-06	1.94E-05
3	1.22E-05	3.47E-06	1.61E-05
4	5.88E-06	3.65E-06	2.12E-05
5	8.41E-06	9.23E-06	1.55E-05
6	1.18E-05	1.12E-05	2.2E-05

Appendix D

Rail Accidents Analysis

Table D.1: No of persons killed and injured by type of accident and country.

Month	Country	Cause	Number of Victims		Number of cases
			Killed	Injured	
January 2012	United States	Collision		2	6
	Germany	Collision	1	3	
	United States	Collision			
	Spain	Collision		6	
	Canada	Derailment			
	Canada	Derailment			
February 2012	United States	Stuck on track		6	7
	India	Derailment	3	50	
	Spain	Collision		11	
	Norway	Derailment		5	
	Indonesia	Collision		4	
	Argentina	Collision	51	700	
	Canada	Derailment	3	30	
March 2012	Poland	Collision	16	58	2
	Ireland	Explosion		1	
April 2012	Germany	Collision	3	13	2
	Netherlands	Collision	1	117	
May 2012	Romania	Collision		92	3
	India	Collision	25	43	
	India	Derailment	4	50	
June 2012	Germany	Collision		28	2
	United States	Collision	3		
July 2012	United States	Collision	2		6
	United States	Collision	2		
	South Africa	Collision		26	
	Egypt	Collision	15		
	United States	Collision		2	

	India	Fire	32	27	
August 2012	Argentina	Collision		35	3
	United States	Derailment	2		
	United Kingdom	Derailment			
September 2012	Italy	Collision	1	25	1
October 2012	United States	Collision		50	6
	Indonesia	Derailment			
	Indonesia	Derailment			
	Philippines	Derailment		8	
	Slovakia	Collision		23	
	United States	Derailment		5	
November 2012	Ukraine	Derailment			10
	Australia	Collision		9	
	United Kingdom	Derailment		1	
	Moldova	Collision	4	6	
	Burma	Collision	27	80	
	United States	Collision	4	16	
	Egypt	Collision	60		
	South Korea	Collision			
	Italy	Collision	6		
	United States	Derailment			
December 2012	United States	Derailment			1

Source:

1. Gast, Phil (7 January 2012). "3 trains in accident in northwest Indiana". CNN International. Retrieved 24 January 2012.
2. Aufräumarbeiten nach tödlichem Zugunglück begonnen" (in German). Kieler Nachrichten. 13 January 2012. Retrieved 14 January 2012.
3. Freight train hits semi on Montana Hi-Line". Seattle Post-Intelligencer. 17 January 2012. Retrieved 24 January 2012.
4. "Un choque de trenes en la estación del Clot causa al menos 25 heridos" (in Spanish). La Vanguardia. 19 January 2012. Retrieved April 24, 2012.

5. Burke, Vince (January 2012). "Train derails near Hay Lakes". The Camrose Canadian. Retrieved April 24, 2012.
6. "Wainwright train derailment is third rail incident in past week". Edmonton Journal. January 23, 2012. Retrieved April 24, 2012.
7. "Amtrak Derailment In Leoni Township, Mich. Leaves At Least 6 Hurt". Huffington Post. 1 February 2012.
8. "Assam accident: 3 killed, 50 injured as train derails near Guwahati". The Indian Express. February 3, 2012. Retrieved April 24, 2012.
9. "Un tren de Rodalies descarrila en Mataró (in spanish)". La Vanguardia. 9 February 2012.
10. "Vestfoldbanen stengt iallfall til onsdag" (in Norwegian). Verdens Gang. 21 February 2012. Retrieved April 24, 2012.
11. "Argentina audits trains after crash killed 51". USA Today. 28 February 2012. Retrieved April 24, 2012.
12. "Three confirmed dead after Via train derails west of Toronto". Globe and Mail. Retrieved 25 February 2012.
13. "Poland suffers deadly train crash near Szczekociny". BBC News. March 4, 2012. Retrieved March 4, 2012.
14. "DART driver injured in minor explosion". RTE News Ireland. March 6, 2012. Retrieved March 9, 2012.
15. "Driver injured in DART explosion". newstalk. March 6, 2012. Retrieved March 9, 2012.
16. "3 killed in German train crash, police say". CNN. April 13, 2012. Retrieved April 24, 2012.
17. "More than 100 injured as trains collide in Amsterdam". CNN. Retrieved 22 April 2012.
18. "Dutch experts examine train crash site". The Age. 2012-04-23. Retrieved 2012-04-22.
19. Realitatea.net – Bucharest: Tram accident with more than 92 injuries in Pasajul Lujerului
20. "Hampi Express accident: 25 dead; minister blames driver, says he jumped signal". PTI. Retrieved 31 July 2012.
21. "Four killed 50 injured in train mishap". Jago Punjab. Retrieved 2 June 2012.
22. http://www.derwesten.de/staedte/essen/ursache-fuer-schweren-strassenbahn-unfall-in-essen-unklar-id6759539.html
23. http://abcnews.go.com/US/wireStory/ntsb-train-wait-okla-crash-16649357#.T-pfZrX2Yeo
24. http://www.chicagotribune.com/news/local/suburbs/northbrook/chi-couple-found-in-wreckage-of-train-derailment-identified-20120706,0,5846788.story
25. "Train Derailment, Explosion cause mile-wide evacuation". Media General Communications Holdings, LLC.. Retrieved 11 July 2012.
26. "South Africa: Mpuma Crash Toll Reaches 26". allAfrica. 13 July 2012. Retrieved 22 September 2012.
27. "Train derails in Egyptian capital Cairo". BBC News Online. Retrieved 17 July 2012.

28. Sam Hartle (July 21, 2012). "Two hurt in Missouri train derailment". KSHB-TV. Retrieved July 28, 2012.
29. "India train fire kills 47 in Andhra Pradesh". 30 July 2012.
30. "Mitre Line train derails in Retiro station; 6 hospitalized". Buenos Aires Herald. August 6, 2012. Retrieved September 10, 2012.
31. Halsey III, Ashley (21 August 2012). "In Maryland train deaths, more questions than answers". Washington Post. Retrieved 21 August 2012.
32. "Sellafield train derails as floods hit Cumbria". BBC News Online. Retrieved 30 August 2012.
33. "One killed, 25 injured in Italian train crash". Retrieved 25 September 2012.
34. http://www.mb.com.ph/articles/378843/bicol-train-derailed-scores-rescued
35. http://bratislava.sme.sk/c/6582926/zrazka-vlakov-v-bratislave-rusnovodic-je-v-kritickom-stave.html
36. Kyiv-Sevastopol train derails near Zaporizhzhia, no victims reported
37. Safety fears after fatal crash
38. "Angus train derailment 'may have been deliberate'". BBC News Online. Retrieved 6 November 2012.
39. “A train rammed a wedding minibus in Moldova" (in Russian). November 5, 2012.
40. "Burma train crash and fire kills 25". 9 November 2012.
41. "City spokesman: 4 dead, 17 hospitalized after train hits veterans parade float in West Texas". November 15, 2012.
42. "Officials: Vets' float crossed track after signals". CBS News. 2012-11-18. Retrieved 2012-11-18.
43. "Egypt bus crash kills 50 children near Manfalut". BBC. November 17, 2012.
44. "Subway accident in South Korea leaves 40 injured". Voice of Russia. November 22, 2012.
45. "Report: Train slams into vehicle in southern Italy, killing 6". CNN. November 25, 2012.
46. "Train hits van in southern Italy, killing six". Reuters. November 25, 2012.

"Tanker derailment in NJ blamed on bridge failure". Associated Press. 2012-11-30. Retrieved 2012-11-30.

Appendix E

Research Ethics

Consent form

BORANG MAKLUMAT DAN KEIZINAN PESERTA
PARTICIPANT INFORMATION AND CONSENT FORM
(PROJEK PENYELIDIKAN)
(RESEARCH PROJECT)

Tajuk Kajian: ____

Nama Penyelidik: ____

Mengapa kajian ini dijalankan? - Kami ingin mengkaji tentang kesan-kesan keadaan psikologi pemandu dan hubungan dengan pemanduan keretapi.

Apakah aktiviti yang terlibat ? - Penyelidikan ini melibatkan pengambilan video, kaji selidik menafsir keadaan ketika bekerja dan menggunakan panel kawalan keretapi serta pengambilan bacaan signal Electroencephalogram (EEG) and Electrooculogram (EOG).

Berapa lamakah kajian ini akan di jalankan? – maksimum 2 jam

Sebagai peserta bagi kajian ini, saya faham bahawa:

1. Penyertaan saya sukarela dan saya boleh berhenti untuk menyertai kajian ini pada bila-bila masa, tanpa denda.

2. Saya menyedari tentang penyertaan saya ini.

3. Tiada risiko-risiko yang terlibat dalam penyertaan kajian ini.

4. Semua soalan-soalan saya tentang kajian telah dijawab dengan memuaskan.

5. Saya telah menerima wang saguhati bagi penyertaan saya ini sebanyak RM ________

Saya telah membaca dan memahami perkara atas, dan memberi persetujuan untuk menyertai:

Tandatangan Peserta:__________________________________ Tarikh:__________

Saya telah menjelaskan perkara atas dan menjawab semua soalan ditanya oleh peserta:

Tandatangan Penyelidik : _______________________________ Tarikh:__________

Letter of Appointment of Assoc. Prof. Dr. Siti Zawiah Md Dawal as a group member of a project under Medical Ethics Committee

UNIVERSITI MALAYA

PUSAT PERUBATAN UM

MEDICAL ETHICS COMMITTEE
UNIVERSITY MALAYA MEDICAL CENTRE

ADDRESS: LEMBAH PANTAI, 59100 KUALA LUMPUR, MALAYSIA
TELEPHONE: 03-79493209/2251 FAXIMILE: 03-79494638

NAME OF ETHICS COMMITTEE/IRB: Medical Ethics Committee, University Malaya Medical Centre **ADDRESS:** LEMBAH PANTAI 59100 KUALA LUMPUR	**ETHICS COMMITTEE/IRB REFERENCE NUMBER:** 925.4
PROTOCOL NO: **TITLE:** The Malaysian Falls Intervention Trial (MyFAIT)	
PRINCIPAL INVESTIGATOR: Assoc. Prof. Tan Maw Pin **TELEPHONE:** **KOMTEL:**	**SPONSOR:** UMMC

The following item [✓] have been received and reviewed in connection with the above study to be conducted by the above investigator.

[✓] Application Form — Ver date: 06 Jun 12
[✓] Study Protocol — Ver date:
[ ] Investigator's Brochure — Ver date:
[✓] Patient Information Sheet — Ver date:
[✓] Consent Form
[ ] Questionnaire
[✓] Investigator(s) CV's (Dr. Chan Wah Kheong)

and have been [✓]

[✓] Approved
[ ] Conditionally approved (identify item and specify modification below or in accompanying letter)
[ ] Rejected (identify item and specify reasons below or in accompanying letter)

Comments:

Investigator are required to:
1) *follow instructions, guidelines and requirements of the Medical Ethics Committee.*
2) *report any protocol deviations/violations to Medical Ethics Committee.*
3) *provide annual and closure report to the Medical Ethics Committee.*
4) *comply with International Conference on Harmonization – Guidelines for Good Clinical Practice (ICH-GCP) and Declaration of Helsinki.*
5) *note that Medical Ethics Committee may audit the approved study.*

Date of approval: 20th JUNE 2012

c.c Head
Department of Medicine

Deputy Dean (Research)
Faculty of Medicine

Secretary
Medical Ethics Committee
University Malaya Medical Centre

PROF. DATUK LOOI LAI MENG
Chairman
Medical Ethics Committee

UNIVERSITI MALAYA

PUSAT PERUBATAN UM

MEDICAL ETHICS COMMITTEE
UNIVERSITY MALAYA MEDICAL CENTRE

ADDRESS: LEMBAH PANTAI, 59100 KUALA LUMPUR, MALAYSIA
TELEPHONE: 03-79493209/2251 FAXIMILE: 03-79494638

MEDICAL ETHICS COMMITTEE COMPOSITION, UNIVERSITY MALAYA MEDICAL CENTRE
Date: 20th JUNE 2012

Member (Title and Name)	Occupation (Designation)	Male/Female (M/F)	Tick (✓) if present when above items were reviewed
Chairperson: Y. Bhg. Prof. Datuk Looi Lai Meng	Senior Consultant Department of Pathology	Female	✓
Deputy Chairperson: Prof. Kulenthran Arumugam	Senior Consultant Medical Education Research and Development Unit (MERDU)	Male	✓
Secretary (non-voting): Cik Norashikin Mahmood	Scientific Officer Department of Quality, UMMC	Female	✓
Members: 1. Y. Bhg. Prof. Dato' Patrick Tan Seow Koon	Deputy Director (Professional) University Malaya Medical Centre	Male	✓
2. Y. Bhg. Prof. Datin Zahurin Mohamed	Head Department of Pharmacology	Female	✓
3. Prof. Tan Chong Tin	Representative of Head Department of Medicine	Male	
4. Dr. Ng Chong Guan	Representative of Head Department of Psychological Medicine	Male	✓
5. Assoc. Prof. April Camilla Roslani	Representative of Head Department of Surgery	Female	✓
6. Tuan Haji Amrahi Buang	Chief Pharmacist Pharmacy Centre University Malaya Medical Centre	Male	
7. Y. Bhg. Assoc .Prof. Datin Grace Xavier	Representative of Dean (Research Fellow) Faculty of Law University Malaya	Female	
8. Y. Bhg. Datin Aminah bt. Pit Abdul Rahman	Public Representative	Female	✓
9. Madam Ong Eng Lee	Public Representative	Female	

Comments: The MEC of University Malaya Medical Centre is operating according to ICH-GCP guidelines and the Declaration of Helsinki. Member's no. 7, 8 & 9 are representatives from Faculty of Law in the University Malaya and the public. They are independent of the hospital or trial site.

PROF. DATUK LOOI LAI MENG
Chairman
Medical Ethics Committee

UNIVERSITI MALAYA
PUSAT PERUBATAN UM
JAWATANKUASA ETIKA PERUBATAN
PUSAT PERUBATAN UNIVERSITI MALAYA
ALAMAT: LEMBAH PANTAI, 59100 KUALA LUMPUR, MALAYSIA
TELEFON: 03-79493209 FAKSIMILI: 03-79494638

Permohonan Menjalankan Projek Penyelidikan
(Application to Conduct Research Project)

1. 1. Tajuk projek *(Project title):* The Malaysian Falls Intervention Trial (MyFAIT)

2. Penyiasat utama (*Principal investigator*):

2.1 Nama *(Name)* : Tan Maw Pin

2.2 Jawatan *(Designation)* : Associate Professor

2.3 Jabatan *(Department)* : Department of Medicine

2.4 E-mel *(E–mail)* : mptan@ummc.edu.my

Sila lampirkan 'curriculum vitae' yang ringkas *(Please attach your brief CV)*

3. Penyiasat-penyiasat lain *(Other investigators):*

	Nama *(Name)*	Jawatan & Jabatan *(Designation & Department)*	Tandatangan/Cop *(Signature & Stamp)*
3.1	Ng Chin Teck	Associate Professor, Department of Medicine	
3.2	Mazlina Mazlan	Senior Lecturer, Department of Rehabilitation Medicine	
3.3	Khoo Ee Ming	Professor, Department of Primary Care Medicine	
3.4	Sajaratulnisah Othman	Associate Professor, Department of Primary Care Medicine	
3.5	Siti Zawiah Md Dawal	Associate Professor, Deparment of Design and Manufacturing Engineering, Faculty of Engineering	

4. Keadaan projek, jika berkenaan *(Project status, if applicable):*

4.1 Projek ini adalah projek *(This project is)* [/ x] BA *(New)* Baru [ ] Sambungan *(Continuation)*

4.2 Jika sambungan, sila beri butir-butir berikut:
(If it is a continuation project, please give details as follows) :

a. Tajuk asas projek *(jika berlainan)* :
(Initial project title [if applicable])

b. Tarikh bermula (Date of commencement) :

c. Tarikh akan siap *(Date of completion)*:

d. Bantuan diterima dahulu dari *(Previous sponsorship)*:

e. Jumlah bantuan yang telah diterima *(Amount of sponsorship)*:

5. Nyatakan jika projek ini adalah sebahagian keperluan pengajaran ijazah/lepasan ijazah
(Please state whether this project is for fulfilment of basic/postgraduate degree)

5.1 [x] Ya/*Yes*
(Nyatakan pengkhususan ijazah, samada Sarjana Muda, Sarjana atau PhD / *State name of degree, e.g Bachelor, Master or PhD)*

Masters and PhD recruitment ongoing. MMed masters will be commencing recruitment and assessments initially.

5.2 [ ] Tidak/*No*

6. Geran untuk kajian (Nyatakan sumber geran) / *Research funding (State source of funding)*

6.1 [ ] Tiada geran / *No funding* [ ] Tiada geran diperlukan /*No funding needed*

[ ] Untuk dimohon kemudian/*To apply later*

6.2 [ ] Penaja kajian / *Trial sponsor* - Nyatakan nama penaja/*State name of sponsor*

____

6.3 [x] Geran kajian / *Research fund* – Nama geran kajian / *Name of fund/research*

Appendix F
Pictures of the experiments session

Figure F.1 : Participant 1 driving the daytime session

Figure F.2 : Participant 1 driving the rainy daytime session

Figure F.3 : Participant 1 driving the rainy night session

Figure F.4 : Participant 2 driving the daytime session

Figure F.5 : Participant 2 driving the rainy daytime session

Figure F.6: Participant 2 driving the rainy night session

Appendix G

Publications

ISI JOURNAL

1. Nurul Izzah Abd Rahman, Siti Zawiah Md Dawal and Ardeshir Bahreininejad. Mental workload monitoring on train drivers using Electroencephalogram patterns.Submitted to International Journal Of Industrial Ergonomics
2. Nurul Izzah Abd Rahman, Siti Zawiah Md Dawal and Ardeshir Bahreininejad. Monitoring the alertness of train drivers using electroencephalogram patterns. Submitted to Applied Ergonomics

CONFERENCE

1. Nurul Izzah Abd Rahman, Siti Zawiah Md Dawal and Ardeshir Bahreininejad.Workload and job aspects investigation on train drivers during different driving conditions. Submitted to 3rd International Conference on Advanced Materials Research (ICAMR 2013)

2. Nurul Izzah Abd Rahman, Siti Zawiah Md Dawal and Ardeshir Bahreininejad.Train drivers' alertness monitoring using Electroencephalogram patterns. Submitted to 17th International Conference on. Industrial Engineering Theory, Applications and Practice.

3. Nurul Izzah Abd Rahman, Siti Zawiah Md Dawal and Ardeshir Bahreininejad. The Effects of Driving Environment on the Mental Workload of Train Drivers. Submitted to International Conference on Ergonomics (ICE 2013).