Evaluating cardiovascular associations to affective states in Professional Drivers: A study of Australian truck and train drivers

by Doctor Taryn Chalmers
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Under the supervision of
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Thesis Declaration

I, Taryn Chalmers, declare that this thesis is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Life Science at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution.

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Publications, Presentations and Awards

Publications relevant to thesis

Journal articles

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Chalmers, T., Maharaj, S., & Lal, S. (2021). Associations between workplace factors and depression and anxiety in Australian heavy vehicle truck drivers. Annals of work exposures and health, 65(5), 581-590.

Chalmers, T., Lal, S. (2016). Prevalence of affective states in Australian truck and train drivers. Journal of the Australasian College of Road Safety. Vol 27, No 1, pg. 13-18.

Chalmers, T., Lal, S. (2014). Assessing cardiovascular associations to affective states in Australian truck drivers. Journal of the Australasian College of Road Safety. Vol 25, No 3, pg. 23-30

Conference abstracts

Chalmers, T., Lal. S., 2016. The prevalence of negative mood states within a population of Australian professional drivers. Publication date: Oct 2016. 21st International Council on Alcohol, Drugs and Traffic Safety Conference.

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Chalmers, T., Hickey, B. A, Newton, P., Lin, C. T., Sibbritt, D., McLachlan, C. S., Clifton-Bligh, R., Morley, J.W., & Lal, S. (2022). Associations between sleep quality and heart rate variability; implications for a biological model of stress detection using wearable technology. Accepted. IJERPH May 2022.

Chalmers, T., Maharaj, S., Lees, T., Lin, C.T., Newton, P., Clifton-Bligh, R., McLachlan, C.S., Gustin, S.M. and Lal, S., **(**2022**)**. The relationship between neurocognitive performance and HRV parameters in nurses and non-healthcare participants. Brain and Behaviour. 22 February 2022.

Chalmers, T., Hickey, B. A., Newton, P., Lin, C. T., Sibbritt, D., McLachlan, C. S., ... & Lal, S. (2022). Stress Watch: The Use of Heart Rate and Heart Rate Variability to Detect Stress: A Pilot Study Using Smart Watch Wearables. Sensors, 22(1), 151.

Hickey, B. A., Chalmers, T., Newton, P., Lin, C. T., Sibbritt, D., McLachlan, C. S., ... & Lal, S. (2021). Smart Devices and Wearable Technologies to Detect and Monitor Mental Health Conditions and Stress: A Systematic Review. Sensors, 21(10), 3461.

Lees, T*., Chalmers, T.*, Burton, D., Zilberg, E., Penzel, T., Lal, S., & Lal, S. (2021). Electrophysiological brain-cardiac coupling in train drivers during monotonous driving. International journal of environmental research and public health, 18(7), 3741.

*indicates first joint author contribution

Chalmers, T., Maharaj, S., Lees, T., Lin, C.T., Newton, P., Clifton-Bligh, R., McLachlan, C.S., Gustin, S.M. and Lal, S., (2020). Impact of acute stress on cortical electrical activity and cardiac autonomic coupling. Journal of Integrative Neuroscience, 19(2), pp.239-248.

Lees, T.*, Chalmers, T.*, Burton, D., Zilberg, E., Penzel, T., & Lal, S., (2018). Electroencephalography as a predictor of self-report fatigue/sleepiness during monotonous driving in train drivers. Physiological measurement, 39(10), pp.105012.

*indicates first joint author contribution

Conference presentations

Chalmers, T., Lal. S., 2016. The prevalence of negative mood states within a population of Australian professional drivers. Publication date: October 2016. 21st International Council on Alcohol, Drugs and Traffic Safety Conference.

Chalmers, T., Lal. S., 2015. The prevalence of affective and anxious states within a population of Australian professional drivers. Publication date: Oct 2015. Australasian College of Road Safety Conference.

Invited presentations

Invited Panellist – Safework Forum – Brisbane, Australia 2018. Depression in the professional driving industry.

Invited Keynote Speaker – Viva Energy Forum – Sydney, Australia 2018. Depression in truck driving: Does depression drive you?

Invited speaker - CSIRO Pint of Science event, 2017. The prevalence of affective and anxious states within a population of Australian professional drivers.

Invited speaker – Australian Transport Meeting – Melbourne 2016. The prevalence of negative mood states within a population of Australian professional drivers.

Invited keynote panellist - National Road Safety Partnership Program, 2016. The prevalence of negative mood states within a population of Australian professional drivers.

Invited contributions

Invited contributor – National Road Safety Partnership Program Leadership Program – Online Factsheet, 2017. Response to common brain condition is a 'no brainer'.

Radio interviewee – 2SER, Sydney Australia, 2017. Mental health problems in the road freight industry.

Expert interviewee – The WIRE radio – Sydney, 2017. Depression in our Truck Drivers.

Awards

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Young Researcher Stipend 2016 - 21st International Council on Alcohol, Drugs and Traffic Safety Conference, Gramado, Brazil.

Winner of the Best Poster (Junior), 30th Combined Health Science Conference; New Horizons 2013. Sydney, Australia.

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List of Abbreviations

ABS = Australian Bureau of Statistics

ANS = Autonomic nervous system

BITRE = Bureau of Infrastructure, Transport and Regional Economics

BMI = Body mass index

Blood pressure = BP

CVD = Cardiovascular disease

DBP = Diastolic blood pressure

DFAT = Department of Foreign Affairs and Trade

ECG = Electrocardiogram

FFT = Fast Fourier Transform

GVA = Gross value added

HF = High frequency

HPA = Hypothalamic-pituitary-adrenal

HR = Hazard ratio

HR = Heart rate

HRV = Heart rate variability

Hz = Hertz

km = Kilometre

LAQ = Lifestyle Appraisal Questionnaire

LBP = Lower back pain

LBS = Lower back symptoms

LF = Low frequency

LF:HF = Low frequency to high frequency ratio (sympathovagal balance)

MAO-A = Monoamine-oxidase A

NZ = New Zealand

OR = Odds ratio

PNS = Parasympathetic nervous system

POMS = Profile of Mood States

SBP = Systolic blood pressure

SNS = Sympathetic nervous system

TP = Total Power

UK = United Kingdom

USA = United States of America

UTS HREC = University of Technology Sydney Human Research Ethics Committee

WCH = White coat hypertension

WHO = World Health Organisation

Abstract

Introduction: Train and truck drivers experience a myriad of unique occupational workplace factors, such as monotonous driving conditions, long hours spent sitting, the necessity of strict mental alertness, workplace social isolation and the potential for “person under vehicle” events. These conditions have been postulated to contribute to a high incidence of health conditions such as depression, anxiety and cardiovascular disease (CVD) amongst this population. Although often occurring independently of one another, the link between depression and cardiovascular risk is well established.

Methods: 120 professional drivers (60 truck drivers, 60 train drivers) were recruited from the local community. Participants complete a battery of mood state questionnaires to assess levels of negative mood states such as depressive and anxious symptomology, and questionnaires to quantitate lifestyle and workplace risk factors. Participants then completed a baseline (resting) and active (driving) task while concurrent ECG data was collected to obtain HRV parameters.

Results: Truck drivers reported significantly more risk factors for chronic diseases, such as smoking, alcohol use, sedentary activity levels and stress, than the train driving cohort. Truck drivers also reported higher levels of all negative states, including depressive and anxious symptomology, stress, fatigue and anger.

Conclusion: This study highlights important workplace factors that may be linked with negative mental states, and their potential implications within the workplace. The

promotion of improved mental health within this occupation would not only improve the health of the individual drivers but may also mitigate mental health associated absenteeism and improve commuter safety. Buddy driving systems, regular workplace ToolBox talks and forums and a commitment to mental awareness are strategies that have been successfully employed in other industries. Given the societal responsibility of professional drivers, protecting and promoting the psychosocial health of these individuals is paramount to not only a healthy workforce, but a safe community. This study is important, as the psychophysiological health of Australia's professional drivers has been somewhat overlooked in the past. Given the large number of workers employed within this industry, and the potential personal and public implications of a suddenly unwell driver, it is vital that policies and workplace practices are designed to optimise the health of these individuals. Collectively, the findings from the present study provide a novel perspective on the physiological and psychological health of Australian professional drivers.

Chapter One – Introduction

1.1 Professional driving in Australia

Professional driving plays a fundamental role in the affluence of Australia. From the movement of commuters from regional to metropolitan areas, to the transport of goods and produce between cities, professional driving within Australia is central to the country's competitive economic prosperity. For the purpose of this study, professional driving will be considered to encompass truck and train driving for both private and commercial use.

1.1.1 Truck Driving in Australia

Australia's unique landscape and the large distances between metropolitan hubs have facilitated the recent exponential expansion of the road freight industry. With long distances between cities and a low population density, Australia's road freight has evolved into the primary means by which goods are transported within this country. Australia's distinctive infrastructure and inimitable road freight trades are fundamental assets, which expedite competitive national and international trading. Australia's road transports activities generates 137.2 billion dollars in economic output, accounting for 1.73% of the national Gross Domestic Product (Australian Bureau of Statistics, 2018). Road freight contributed 47.6 billion dollars to Australia economy in the 2019-2020 financial year, accounting for 81% of the revenue generated by the freight transport sector (IBISWorld, 2020). Road transport is the primary means of transporting freight between businesses, with 72% of the freight in total transported in Australia being conveyed via the road freight system (Bureau of Infrastructure Transport and Regional Economics, 2009). Australia's road systems span over 810,000 kilometres, with the person per kilometre of road ratio amongst the smallest in the western world (Figure 1) (ABS, 2012). As a result, Australia is the greatest employer of road freight when measured by tonnes moved per kilometre per capita (Austroads, 2000) (Figure 2).

Figure 1 Road network lengths and population

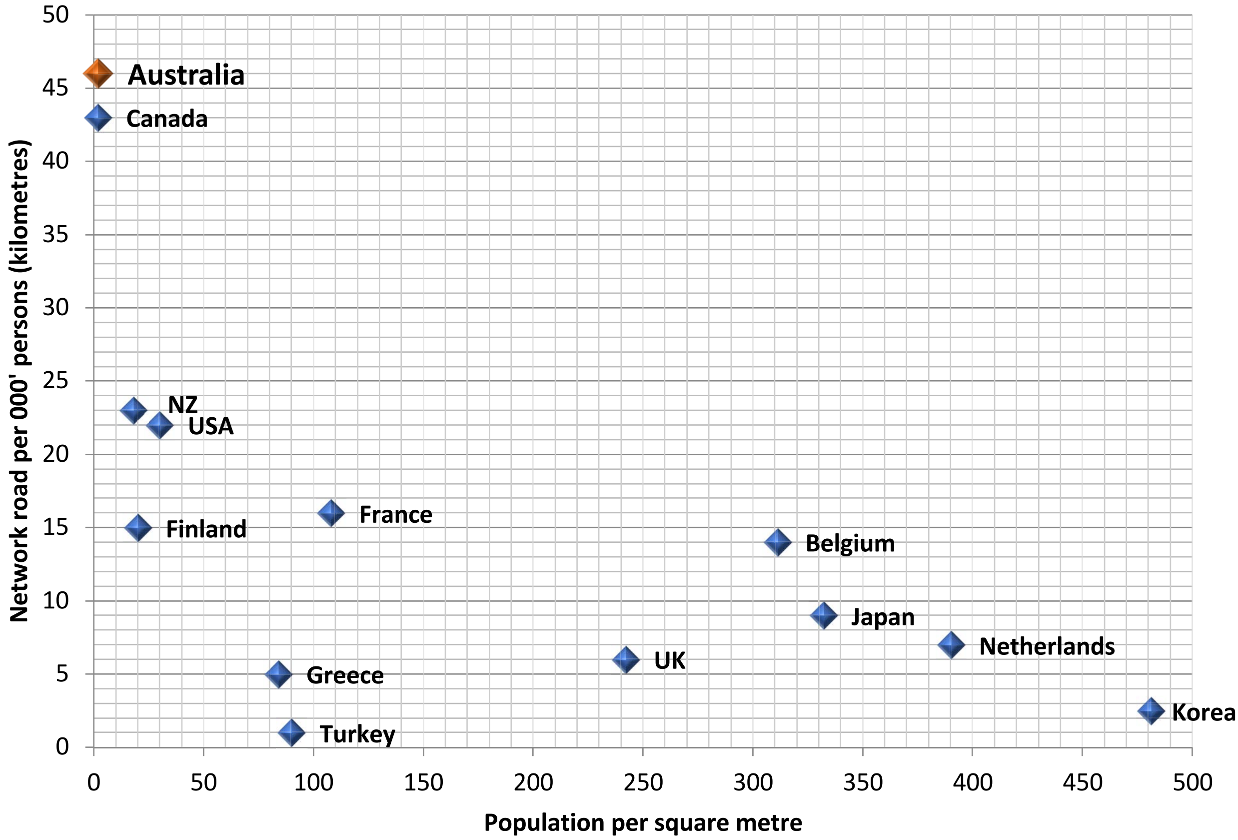


Figure 1 presents the kilometer-per-capita ratio of thirteen countries. Note that Australia has the lowest person per kilometer of road ratio in the world. Adapted from pg. 3, Tasman (2004).

Key:

NZ = New Zealand

UK = United Kingdom

USA = United States of America

Figure 2 Road freight tonne-km per capita

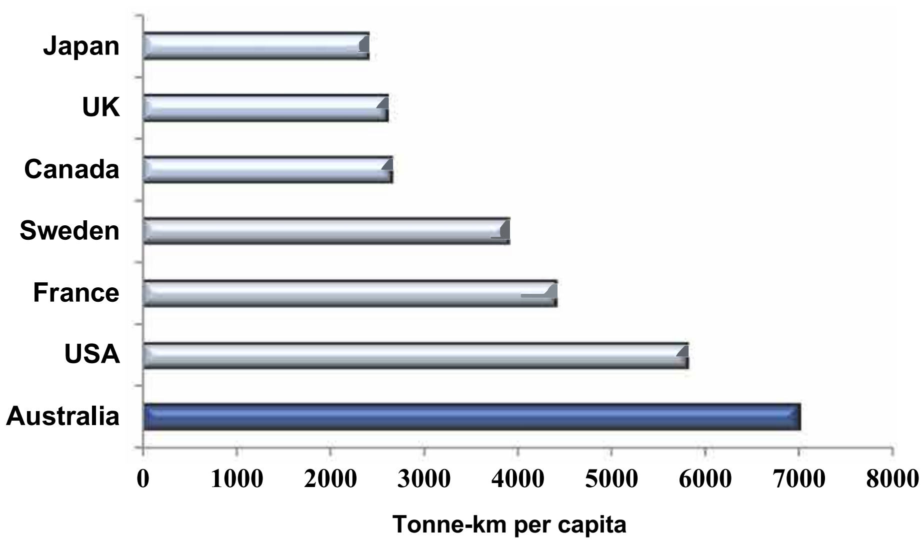


Figure 2 depicts a graphical representation of the road freight tonne-kilometre per capita ratios of the seven highest ratio countries in the world; Australia, United States of America, France, Sweden, Canada, the United Kingdom and Japan. Note that Australia has the highest tonne-km per capita ratio in the world. Adapted from pg. 2, Austroads (2000).

Key:

km = kilometres

UK = United Kingdom

USA = United States of America

The road transport sector commands the 'transport and storage' industry within Australia, employing 131,920 individuals which accounts for 48.7 percent of the total employment in the 'transport and storage' sector (IBISWorld, 2020, Australian Bureau of Statistics, 2012a).

The utilisation of road freight has dramatically increased in recent decades, with a growth from 27 billion tonne kilometres in 1971 to 184 billion tonne kilometres in 2006 (Figure 3) (Bureau of Infrastructure Transport and Regional Economics, 2011). New South Wales remains the largest employer of interstate road freight (totalling 33% of state allocated road freight), however Queensland utilises the greatest intrastate road freight transport (24.4%) within Australia (Table 1) (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2010).

Figure 3 Total road freight by commercial vehicle type, 1971 - 2006

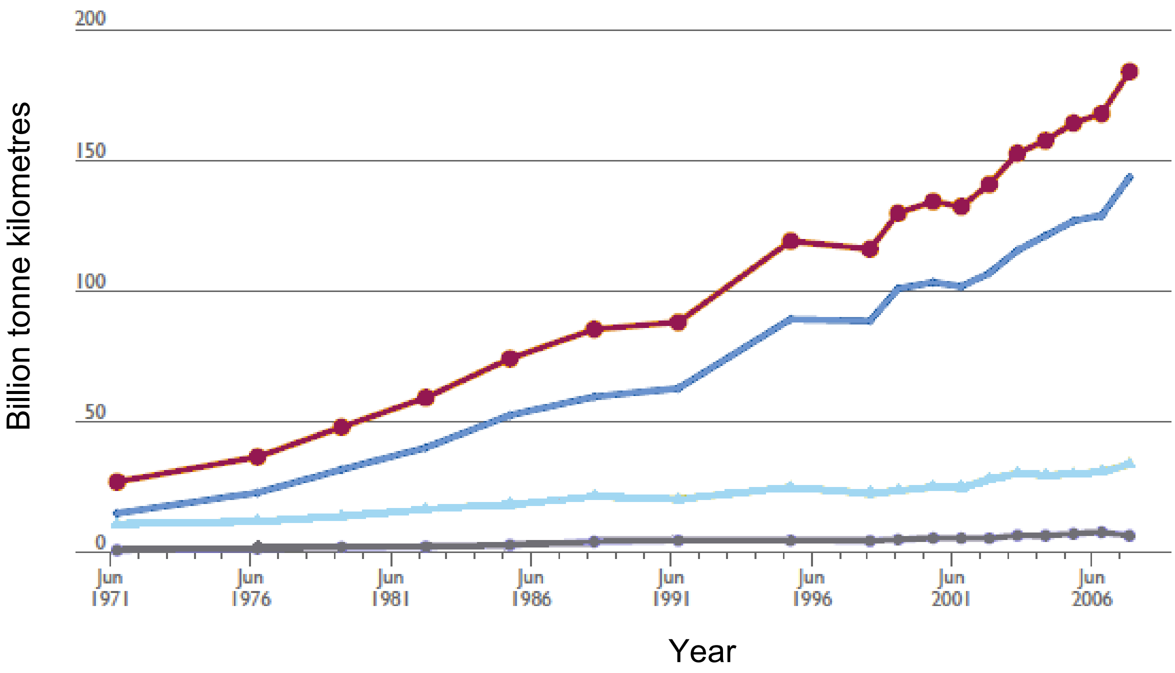


Figure 3 presents billion tonne per kilometre of freight moved by commercial vehicle type between the years 1971 and 2006. Note that all road freight has increased from 27 billion tonne kilometres in 1971 to 184 billion tonne kilometres in 2006. Adapted from Bureau of Infrastructure Transport and Regional Economics (2011). Statistics elucidated from Australian Bureau of Statistics (2008).

Key:

- = All road freight
- = Articulated trucks
- = Rigid trucks
- = Light vehicles

Table 1 Road freight by Australian state measures in billion tonne kilometer for 2011.

	Interstate				Intrastate	Total
	From	To	Through	Total		
NSW	15.89	14.69	9.02	39.60	27.18	66.78
Victoria	8.60	9.07	0.69	18.37	24.19	42.56
Queensland	3.32	3.04	0.00	6.36	29.41	35.77
SA	3.31	3.46	1.06	7.83	7.92	15.75
WA	2.19	1.52	0.00	3.72	26.58	30.30
Tasmania	0.00	0.00	0.00	0.00	3.50	3.50
Australia				77.00	120.30	197.30

Table 1 presents the road freight movements in 2011 by Australian state. Note that New South Wales (NSW) controls the most total freight. Adapted from Bureau of Infrastructure, Transport and Regional Economics (2010).

Road freight within Australia, although concentrated around metropolitan hubs, does extend between cities and states. Figure 4 depicts Australia's major domestic road freight movements in 2006-07 (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2010).

Figure 4 Australia's major domestic road freight movements 2006-07

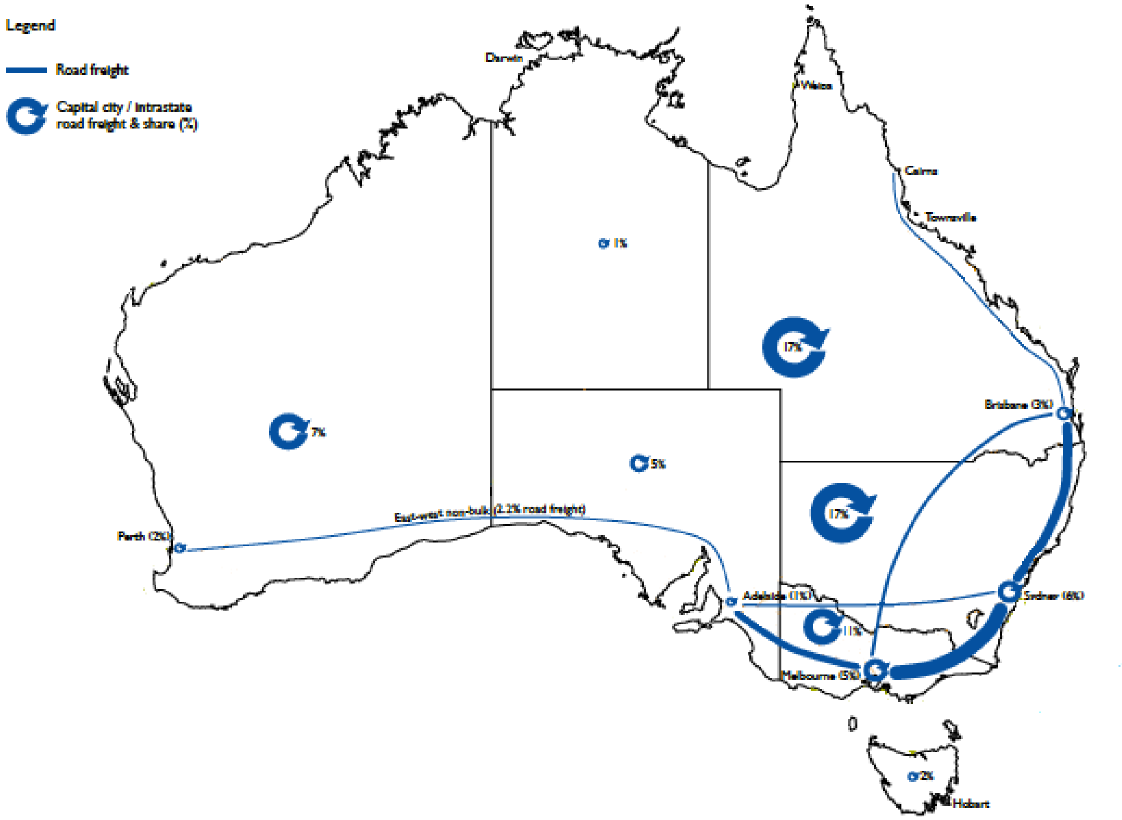


Figure 4 depicts Australia's major road domestic freight movements in 2006-07. Note that the line widths are relative to the freight volume (tonnes) and percentages indicate the share of the total modal-specific mass-distance freight task. Adapted from Bureau of Infrastructure Transport and Regional Economics (2011). Information elucidated from Bureau of Infrastructure Transport and Regional Economics (2010).

A recent ABS release found road freight vehicles on Australian roads totalled 4,047,667, accounting for 20.4% of vehicles on Australian roads (Australian Bureau of Statistics, 2020). The trucking industry, as a whole, represents an acute gender bias, as 97.5% of truck drivers in Australia are male (Table 2) (Australian Government, 2012a).

Table 2 The statistically typical Australian truck driver in comparison with a statistically typical Australian employee

	Truck Driver	All Occupations
Average age	43 years	39 years
Average hours work per week	46.8 hours	39.7 hours
Percentage full-time	92.6%	71.3%
Percentage male	97.5%	54.9%

Table 2 depicts a statistically typical Australian truck driver in comparison with a statistically typical Australian employee averaged from all other occupations. Note that a typical Australian truck driver works 7.1 hours longer per week than the average weekly hours worked in all other occupations and 97.5 percent of truck driver are male. Adapted from pg. 14, Australian Government (2012a).

Studies have found that one in every five persons injured in a workplace environment in Australia is employed as a truck driver (Safe Work Australia, 2011). The occupational fatality rate is fourteen times greater than Australia's average industry occupational deaths (Table 3) (Safe Work Australia, 2011).

Table 3 Working fatalities: fatality numbers by occupation, Australia, 2003–08

Occupation	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Truck drivers	**58**	**49**	**50**	**71**	**71**	**59**
Farm, forestry & garden workers	26	22	17	17	26	21
Automotive & engineering workers	10	12	12	9	10	20
Construction trades workers	10	7	9	25	11	16
Farmers & farm managers	35	34	28	9	30	20
Professionals	22	18	27	25	27	21
Community & personal service	7	18	9	11	6	11
Clerical & administrative workers	1	3	4	5	6	8
Sales workers	8	2	7	5	9	8
TOTAL *	264	252	288	300	293	286

Table 3 displays the industry allocation of occupational fatalities for the years 2003 through to 2009 and includes fatalities where occupation was not stated. Note that truck drivers have the highest number of fatalities for all years stated. Adapted from SafeWork (2011).

Key:

*** =** Includes deaths where occupation was not stated

1.1.2 Train Driving in Australia

The Australian Rail industry provides a vital mechanism by which goods, services and individuals are transported between cities and metropolitan centres. Contributing over $9 billion dollars to Australia's Gross Value Added (GVA), the Australian Rail industry is also responsible for the employment of over 480,000 individuals each year (Australian Bureau of Statistics, 2018). This industry is also experiencing steady employment growth, with an increase in overall employment of almost 4.1% between 2008-09 and 2009-10 (Australian Bureau of Statistics, 2012a). During the 2009-10 year, approximately 770 million journeys were undertaken in Australia using the rail system (Australian Bureau of Statistics, 2012a), and given that Australia has one of the lowest person per square kilometre ratios in the world (Australian Bureau of Statistics, 2017a) there is a well-documented inherent reliance of Australia's Rail system (Table 4).

Table 4 Australia's rail passenger journeys (million) and passenger kilometers (billion) 2005-10

Year	Passenger Journeys (million)	Passenger-Kilometres (billion)
05-06	643.36	11.36
06-07	677.09	12.31
07-08	724.70	13.27
08-09	773.11	13.95
09-10	769.95	14.13

Table 4 depicts both the passenger journeys (million) and passenger-kilometers (billion) within Australia from 2005-10. Note that passenger-kilometres are the aggregate of the product of the number of passengers carried over each journey and the journey distance. Adapted from Australian Bureau of Statistics (2012b).

Rail within Australia, although concentrated around metropolitan hubs, does extend between cities and states. Figure 5 depicts Australia's major domestic rail movements in 2006-07 (Bureau of Infrastructure Transport and Regional Economics (BITRE), 2010).

Figure 5 Australia's major domestic rail movements 2006-07

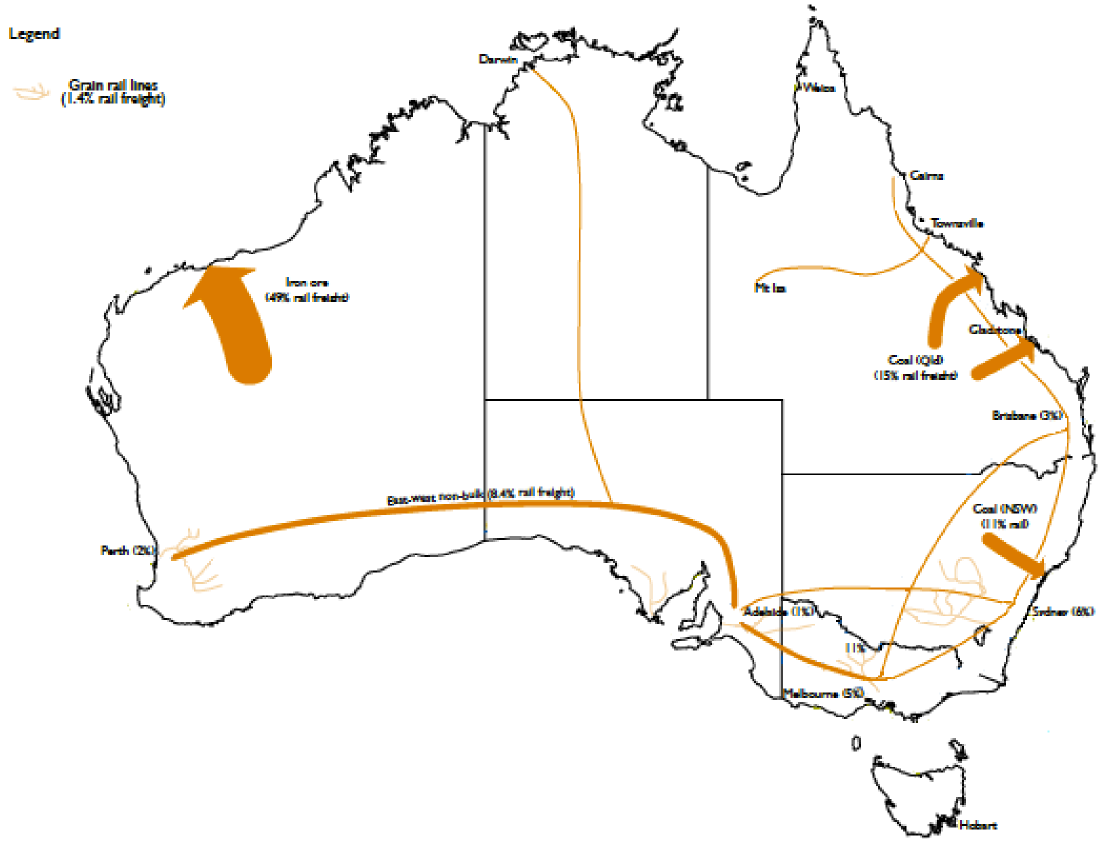


Figure 5 depicts Australia's major rail movements in 2006-07. Note that the line widths are relative to the freight volume (tonnes) and percentages indicate the share of the total modal-specific mass-distance freight task. Adapted from Bureau of Infrastructure Transport and Regional Economics (2011).

Comparable to the demographic profile of Australian truck drivers, a recent Australian study has suggested that approximately 97.4% of the industry is male, indicating an extreme gender bias in this industry (Mina and Casolin, 2007).

1.2 Cardiovascular disease in Australia

Cardiovascular disease (CVD) is the primary cause of death in Australia, with CVD resulting in approximately 45,000 deaths annually (Australian Heart Foundation, 2012). Cardiovascular disease is responsible for the death of one Australian every 12 minutes (Australian Heart Foundation, 2012). Cardiovascular disease is one of Australia's principal health implications. Despite improvements in medical fields over recent decades, it is still one of the principal burdens on the Australian health economy.

Cardiovascular disease includes stroke as well as diseases of the heart and blood vessels, and affects one in six Australians or approximately 3.7 million people annually (Australian Heart Foundation, 2012). Cardiovascular disease resulted in 482,000 hospitalisations in 2009-10 and was attributed to have had a secondary role in almost 800,000 hospitalisations, resulting in 45,600 fatalities in Australia (31% of all deaths) in 2011. Those within lower socioeconomic groups, Aboriginal and Torres Strait Islander people and those living in geographically remote areas report the greatest rate of hospitalisations and fatalities resulting from CVD in Australia (Australian Heart Foundation, 2012).

Coronary heart disease affects around 1.4 million Australians each year and was implicated in 14% of all Australia deaths in 2011. Heart attacks are estimated to affect approximately 380,000 Australians at some point in their lifetime, claiming the lives of 9,811 Australian in 2011 (Australian Heart Foundation, 2012).

1.2.1 Cardiovascular Disease in Truck Drivers

Heavy vehicle drivers experience frequent occupational stress to adhere to challenging delivery schedules, and experience a range of concerning health implications that directly relate to the inherent stressors of their professional industry (Boyd, 2003), such as diabetes (Marcinkiewicz and Szosland, 2010), cancer (Young et al., 2009), lower back pain (Village et al., 1989), fatigue (Sabbagh-Ehrlich et al., 2005), affective disorders such as depression (Hilton et al., 2009a) and cardiovascular disease (Hartvig, 1983b). Consequently, the association between truck driving and cardiac health has been investigated numerous times. Cardiovascular diseases (Hartvig, 1983a), such as myocardial infarction (Bigert et al., 2003) and ischemic heart disease (Robinson and Burnett, 2005), have been recognised as significant health implications within the truck driving industry. An American study by the National Transportation Safety Board (1990) established that 9.2% of truck driver fatalities involved some form of cardiovascular incident. Additionally, a recent Australian institution has attained statistical evidence to suggest that a collapse from a cardiovascular incident accounts for approximately 15% of all crashes where the driver unexpectedly becomes unwell (VicRoads, 2012).

Numerous studies have supported the notion that professional drivers find themselves at an elevated risk of hypertension and cardiovascular disease, when compared with other drivers from both the working or general population (Belkić et al., 1996, Van Amelsvoort, 1995). Of further concern is the prevalence of premature cardiovascular disease, whereby long-haul truck drivers find themselves overrepresented in the demographic grouping of young individuals who have suffered a heart attack. For instance, in a study conducted by Villarem and associates, of the 38 consecutive heart attack patients examined from the general public, almost 20% were long-haul truck drivers (Villarem et al., 1982). Supporting this, an analysis of disease rates within United States workers found that truck drivers were ranked amongst the highest for prevalence of cardiovascular disease and heart attacks (Leigh, 1997). Gustavsson and team (1996) also found of the professional drivers (aged 30-74) that were assessed, the long-distance truck drivers (n=220) exhibited an increased relative risk (RR) of myocardial infarction for both geographical locations assessed (Stockholm RR= 1.31, Uppsala RR=1.24). Similarly, a recent retrospective study of trucking industry workers (using computerized records from 1985) examined 54,319 men and 4,007 women within the industry (Hart et al., 2013). This study assessed the associations between increasing years of employment in the industry and risk of ischemic heart disease. The study found that there was a positive correlation between years employed in the industry, and identification of ischemic heart disease as the underlying cause of death.

High rates of driver obesity have been frequently reported within this industry (Marcinkiewicz and Szosland, 2010, Korelitz, 1993, Turner and Reed, 2011), which is of concern when coupled with high rates of cardiovascular disease. Supporting these findings, Marcinkiewicz and Szosland (2010) found the incidence of obesity in the professional driving industry to be significantly greater than in the general population, with 45.3% and 17.4% of drivers being recorded as overweight (body mass index of 25-30) and obese (body mass index of >30) respectively. Similarly, a study that was conducted in America (Korelitz, 1993) employing a cross-sectional survey of male (n=2,945) and female (n=353) truck drivers, found that a high percentage were overweight (50%), did not participate in frequent exercise (92%), smoked cigarettes (54%), had hypertension (66%) and engaged in alcohol dependent behaviour (23%) (Figure 6). Furthermore, a recent study conducted by Whitfield Jacobson and team

(2007) examined 92 long-haul truck drivers in America. The study found despite an overall positive attitude towards nutrition (as measured by the Nutrition Attitude Survey), only 17 of the 92 assessed consumed an adequate dietary intake of fruit and vegetables.

Further, many truck drivers lead comparatively sedentary lifestyles (Korelitz, 1993), and find themselves subjected to a number of occupational factors, such a exposure to exhaust fumes (Hart et al., 2013) and an increased consumption of saturated fats and cholesterol (Gill and Wijk, 2004), which collectively contribute to the development of cardiovascular issues within this occupational field (Hartvig, 1983a, Siu et al., 2012, Robinson and Burnett, 2005, Korelitz, 1993).

Figure 6 Physiological characteristics from a United States study comparing truck drivers to the general male population

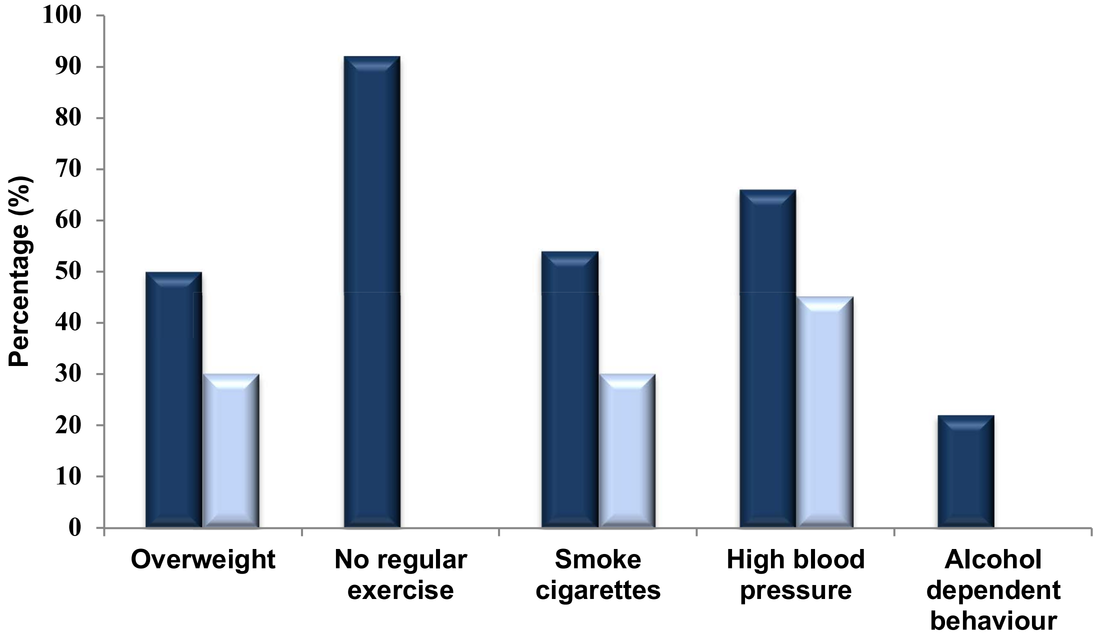


Figure 6 depicts a graphical representation of the percentage of truck drivers in America who; are overweight, do not engage in regular exercise, smoke cigarettes, have high blood pressure and engage in alcohol dependent behaviour. The navy columns represent the assessed male truck drivers (n=2,945) and the light blue columns represent the corresponding percentage rates in the male United States population. Note that 92% of truck drivers engage in no regular exercise, and rates of smoking and high blood pressure are significantly elevated, highlighting an increased risk of a cardiovascular event within this industry in comparison to the general United States male population. Adapted from pg. 120-121, Korelitz (1993).

1.2.2 Cardiovascular Disease in Train Drivers

The prevalence of pre-existing cardiovascular disease or cardiovascular risk factors within the train driving industry of Australia is also of concern. Mina and Casolin (2007) assessed 743 train drivers between June and August 2005, on the basis of physiological and psychological health parameters. Cardiovascular disease risk factors, and cardiovascular disease itself, emerged as the primary health issues affecting train drivers' fitness to work. Risk factors such as smoking (25.2%) were higher in the train driver population tested, than in the general Australian public (20.1%). Similarly, the presence of pre-existing heart conditions (3.1%) and hypertension (43.8%) were higher in the train driver population, than the general Australian population (2.4% and 32% respectively). In the study, cardiovascular disease (both diagnosed and suspected) resulted in 43 drivers being classified as unfit for work, with diabetes (a significant cardiovascular risk factor) being associated with 22 drivers being graded as unfit for work. It should also be noted that rates of obesity (as measured by body mass index of ≥ 30) was found to be significantly higher in the train driver population (39.7%) than the general Australian population (19.3%) (Table 5).

Table 5 Prevalence of health conditions within Australian train drivers (n = 743)

	Number (%) of drivers	Population prevalence in Australian adults (prevalence in males)
Smoking	187 (25.2%)	19.5% (2.4%)
Body mass index (kg/m^2)		
< 25.0	143 (19.2%)	40.2% (32.5%)
25.0 – 29.9	305 (41.0%)	39.0% (48.2%)
≤ 30.0	295 (39.7%)	20.8% (19.3%)
Pre-existing cardiovascular disease	23 (3.1%)	1.9% (2.4%)
Hypertension	326 (43.8%)	28.6% (32.0%)

Table 5 presents the prevalent health conditions and risk factors within the Australian train driving community in comparison with the general Australian public. Note that a higher percentage of Australian train drivers exhibit a body mass index of greater than 30, when compared with the general Australian population (39.7% versus 19.3%). Also, higher rates of hypertension and pre-existing cardiovascular disease are greater in the Australian train driving community when compared to the general Australian public Mina and Casolin (2007).

This study was the first of such a scale to be conducted in Australia and presents a worrying snapshot of the health of train drivers in our country. Subsequently, the only other study to have been conducted to assess the cardiovascular health of train drivers in Australia was conducted by Ng and team (2013). This was a retrospective, observational study assessing 317 train drivers from a private, de-identified South Australian train company. The study found that a number of cardiovascular risk factors were significantly higher in the train driver population that in the control group. These included higher resting systolic blood pressure ($p<0.002$) and smoking rates ($p<0.001$). Additionally, high density lipoprotein cholesterol (which plays a role in removing low density lipoproteins from the cardiovascular system (American Heart Association, 2013)) was significantly lower in the train drivers than in the control population

($p<0.003$). Although not distinctly assessing the rates of cardiovascular disease within this population, these results do provide statistics on the high rates of a number of risk factors for CVD within this population.

Similar to Australia, the cardiovascular health of train drivers in other countries has been somewhat overlooked, with only one study having been conducted in recent years. This study, conducted by Loukzadeh and team (2013) in Iran, found that of the 152 train drivers assessed, 13 had diabetes, 20 had hypertension and 2 were suffering from ischemic heart disease. Additionally, the study revealed that 133 (88%) did not engage in optimal levels of physical activity. Collectively, these two studies provide a concerning snapshot of the cardiovascular heath of individuals within this occupational field, and additionally are of concern in and of themselves, being the only two studies having been conducted to assess the health of train drivers. Another health issue within the truck and train driving industries that has received minimal attention is the affective disorder, depression.

1.3 Depression in Australia

Depression is a prominent health issue, which The World Health Organisation defines as a mood disorder that manifests with depressed moods, feelings of guilt or low self-worth, disturbed sleep or appetite, low energy, and poor concentration (World Health Organisation, 2012). Depressive disorder is the primary cause of disability worldwide when assessed using Years Lived with Disability (World Health Organisation, 2012). In 2000, depression was the fourth greatest contributor to the global burden of disease, and it has been forecast that by the end of the year 2020, it will be the second greatest contributor to this burden (World Health Organisation, 2012). Depression affects approximately 264 million individuals worldwide, and 11.6% of the Australian population (World Health Organization, 2020). Studies have shown that without effective treatment, depressive symptoms will reoccur in 50% of individuals (Bear et al., 2007).

The most popular neurophysiological model of depression is the monoamine theory (Figure 7). Initially proposed by Joseph Schildkraut (1965), the theory states that depression is the result of underactive monoamines, in particular, serotonin and norepinephrine. This theory evolved from the early treatments of certain disorders with pharmaceuticals. In particular, the depression-eliciting effects of the drug Reserpine, which is a monoamine antagonist which was used to treat high blood pressure. Depression was observed as a common side effect of this drug, and as such, led to the biological conclusion that depression may result due to the reduced activity of monoamines, such as serotonin and norepinephrine (Goodwin and Bunney, 1971). One of these monoamines in particular, serotonin, is generally accepted to regulate mood and plays a part in policing social interactions (Young and Leyton, 2002) . As such, reduced levels of this monoamine may play a role in the development of depressive behaviour.

Figure 7 Monoamine theory of depression

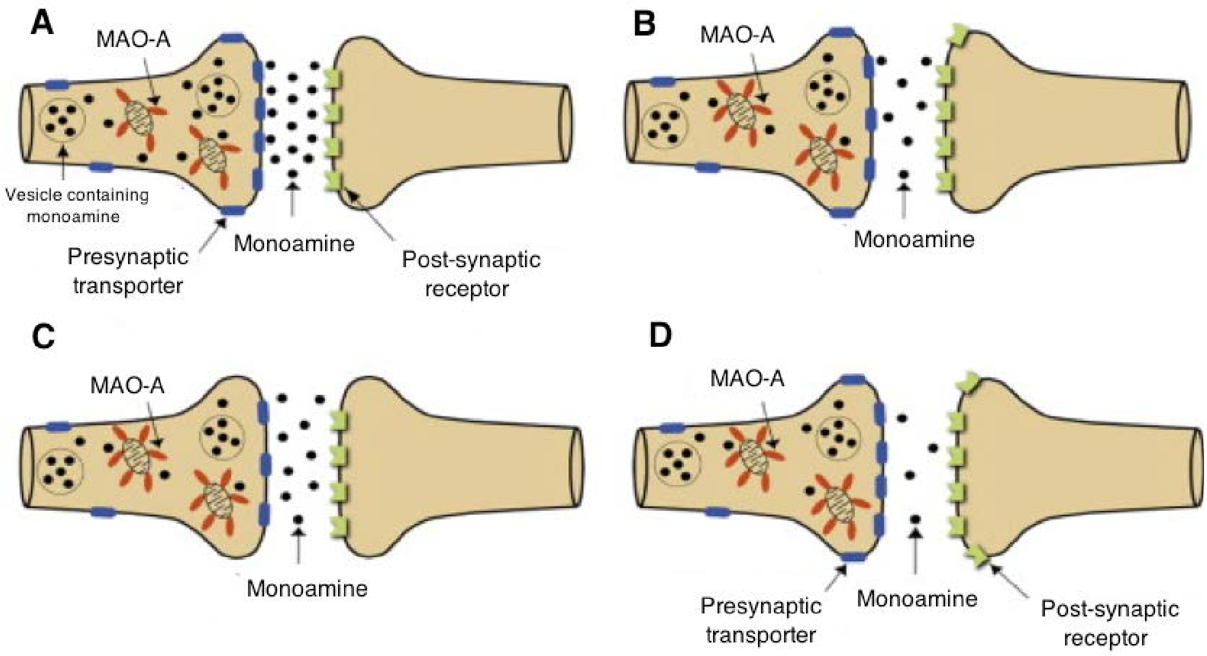


Figure 7 depicts the process of monoamine loss in a depressed patient. (A) Depicts healthy monoamine release in an individual exhibiting no depressive symptoms. (B) During a major depressive episode, monoamine oxidase A density is raised, which results in an increased metabolism of monoamines. Outcomes include down regulation of presynaptic transporters, resulting in reduced synaptic transmission of monoamines (C) or increased presynaptic degradation of monoamines leading to reduced release from synapses despite unchanged presynaptic transporter density (D). Adapted from pg. 295, Meyer (2008).

Key:

MAO-A: Monoamine oxidase-A

A second theory of depression is the diathesis-stress theory (Nemeroff, 1998). This hypothesis originated through the notion that genetic vulnerabilities (diatheses) prejudice an individual to developing depression, when concomitant with a traumatic life event (Figure 8) (Abela and D'Alessandro, 2002, Monroe and Simons, 1991). It has been proposed that as a result of the attenuated effect of early childhood stressors and/or genetic diatheses, biological adaptations to the hypothalamic-pituitary-adrenal axis (HPA axis) occur, which results in altered activation of the hippocampal glucocorticoid receptors, leading to reduced inhibition of cortisol release (Bear et al., 2007).

Figure 8 The diathesis-stress theory of depression according to Nemeroff (1998)

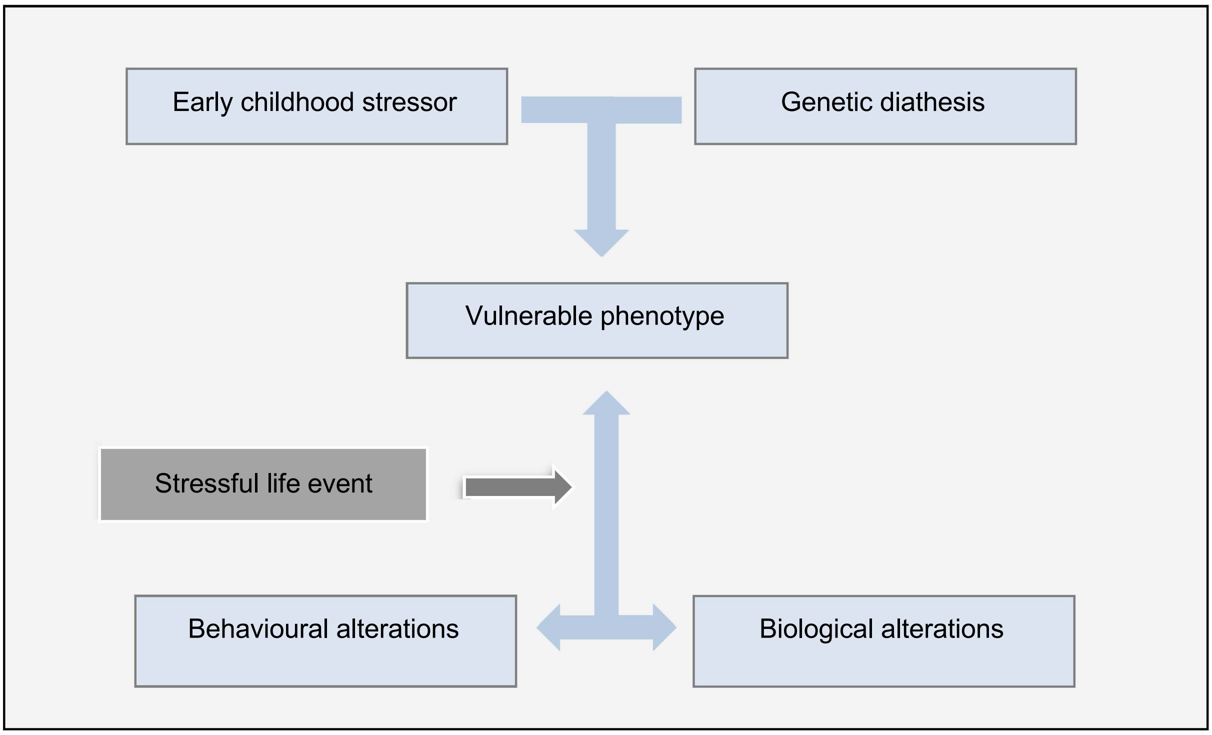


Figure 8 depicts the Diathesis-stress theory of depression. Early childhood stressors and/or genetic diatheses result in an increased vulnerability to lifetime stressors, which can result in biological and behavioural alterations. Adapted and modified from pg. 212, Barlow and Durand (2005).

1.3.1 Depression and Truck Driving

A recent study by Hilton and his team (2009a) assessed 1324 heavy goods vehicle drivers for symptoms of psychological distress. The study found that 13.3% of Australian heavy vehicle truck drivers demonstrated some form of depression. This number is distinctly greater than the nation-wide rate of 11.6% (World Health Organization, 2020). Comparably, a study conducted by da Silva-Junior (2009) found that truck drivers were at a significantly greater risk of developing depressive symptoms (13.6%). The study also found that truck drivers who were “wage earners” had a significantly increased odds ratio (OR) of developing depression than those who were considered “self-employed” (2.72 compared to 1.0 respectively). Supporting this, a 2007 study found that 14.5% of truck drivers felt “more depressed” since beginning work within this occupational field (Wong et al., 2007). Recently, work stress has been profoundly implicated as an independent predictor of depressive symptoms (Wang, 2005). As mentioned in earlier sub-chapters, truck drivers are regularly exposed to long working hours, intermittent work/rest cycles, workplace solitude and extreme occupational pressure. These commonplace occupational stress factors can result in individuals within this industry being viewed as a depression vulnerable population. Long working hours have recently been implicated in the development of depression, with a study conducted by Virtanen and colleagues (2012) assessing individuals who worked more than 11 hours a day. The study found that those who did work more than 11 hours per day had a significantly higher OR of developing depression (2.52 compared to 1.0).

A major concern is the paucity of literature regarding the incidence of depression in the Australian truck driving industry. Excluding the aforementioned Hilton study (2009a), the incidence of depression in Australian truck drivers has been overlooked in recent literature. Furthermore, the statistics regarding the probability of seeking the advice of a medical professional for the treatment of depression in Australia are of concern. A recent household survey administered by the Australian Bureau of Statistics (Australian Bureau of Statistics (ABS), 2007) found that only 35% of individuals in Australia who had experienced a psychological disorder in the prior 12-months had accessed appropriate medical services. Despite a higher incidence of depression amongst females in comparison with males in Australia (14.5% and 8.8% respectively (ABS, 2007)), a seemingly entrenched social stigma, which deters males from obtaining the advice of medical professionals, has resulted in significantly lower diagnostic rates of affective disorders among males (Klint and Weikop, 2004, van Praag, 1980). Due to the extreme gender bias of the Australian trucking industry (97.5% male), an underlying incidence of undiagnosed affective disorders may be present, further supporting the exploration and investigation of this primary health concern within this occupational field. These combined facts suggest a significant health issue, when the number of trucks on Australian roads, the possibility of high rates of undiagnosed depression in this male dominated occupational field and the social and economic burden of heavy vehicle road accidents to this country are considered.

1.3.2 Depression and Train Driving

Despite the previously mentioned, well-documented high rates of depression amongst professional truck drivers, at present, there have been no epidemiological studies regarding the presence and effects of depression within Australia’s train driving industries. Although a National Standard for Health Assessment of Rail Workers (National Transport Commision, 2012) has been implemented within the rail industry, which assesses psychological disorders amongst a range of health conditions, the true prevalence of depression within this industry remains somewhat unclear. With train drivers in Australia frequently subjected to comparable working conditions to that of truck drivers (such as long working hours, monotonous driving conditions, etc.), it would stand to reason that there may be an elevated risk of depression in this profession. As such, elucidating the rates and effect of depression within this industry remains a priority in Australia.

In Australia, rail suicide accounts for 6-8% of the nation’s death by suicide, totalling approximately 150 deaths per annum (Lifeline, 2012). This is a serious issue that has been known to result in extreme psychological distress that can progress in a number of psychological conditions such as depression (Cothereau et al., 2004b). A study conducted by Cothereau and associates in France (2004b) assessed 388 train drivers, either those having been exposed (n=202) and non-exposed (n=186) to a rail suicide whilst operating a train. The study found that those individuals in the exposed cohort had significantly higher rates of post-traumatic stress symptoms ($p<0.0001$), somatic symptoms ($p<0.0001$), anxiety and insomnia ($p<0.001$). 1.5% of the assessed drivers exhibited severe depression; with other affective disorders also being observed, such as generalised anxiety disorder (4.0%), dysthymia (1.0%), panic disorder (0.5%) and manic episodes (0.5%). Collectively, these statistics provide a unique insight into the acute occupational stressors encountered by train drivers, and the psychological effects of these stressors on the individuals within this field.

Another study, assessing the psychological health of train drivers, conducted by Loukzadeh and associates (2013), found that 15% of the 152 train drivers assessed exhibited scores on the Kessler Psychological Distress Scale (Anderson et al., 2013) of greater than 19, indicating that they were likely to have a mild, moderate or severe mental disorder. Although this study did not assess depression specifically, it does provide some evidence for the impaired psychological health of individuals within this field.

It should be noted that the presence and effect of depression within the train driving industry has only been examined twice in recent years and has yet to be examined in Australia. When we consider the acute and chronic effects of depression on the quality of life on an individual, it is clear that elucidating the true prevalence of this affective disorder within this industry is vital to preserving the health of these individuals.

1.3.3 Depression and Driver Performance

Depression has been increasingly correlated to a reduction in driver performance. A study by Hilton and associates (2009a) found that severe and extremely severe depression in truck drivers resulted in a significantly increased odds ratio (OR) (4.4 and 5.0 respectively) for an accident or near miss. This study also found that driving performance (reaction time and steering control) was decreased by 5.7% in drivers suffering from depression in comparison to those experiencing no depressive symptoms. Furthermore, Blumash and team (2006b) found that individuals suffering from major depressive disorder demonstrated distinct decreases in steering reaction time, and a total reduction in driver performance when compared to a control sample. These collective findings provide substantiation for both the detection and management of depression in both the train and truck driving industries of Australia.

1.4 Depression and links to cardiovascular disease

Behavioural cardiology is an emerging field of clinical practice, founded on the understanding that adversative lifestyle behaviours, emotional factors, and chronic stress, can all contribute to atherosclerosis and unfavourable cardiovascular events (Rozanski et al., 2005). The Australian Heart foundation also recognised depression as a modifiable biomedical risk factor for CVD, and has proposed that the associations between depression and impaired cardiovascular functioning warrant additional investigation (Australian Heart Foundation, 2008b). The associations between depression and cardiovascular impairments have been progressively examined in recent years. However, variable results have been attained regarding the effect of this psychological disorder on cardiovascular functioning and its impact on the development of cardiovascular disease. Penninx and team (2001) undertook a four-year longitudinal study of 2,397 men and women who were free from cardiovascular diseases at baseline measurement. This study found that individuals who were experiencing minor and major depression at baseline displayed a greater relative risk of cardiovascular mortality (1.5 and 3.9 respectively) in comparison with non-depressed controls. Supporting the findings of this study, Ariyo and team (2000) investigated 4,493 males and females who were free from cardiovascular impairment at baseline, for six years. The study found that the hazard ratio (HR) of developing coronary heart disease was greater in individuals experiencing depression (HR=1.15) than in those without depressive symptoms.

There have been numerous mechanisms proposed to account for the potential cardiovascular vulnerability related to depression, including higher levels of circulating cortisol, hyperactivity of the hypothalamic-pituitary-adrenal axis (Nemeroff, 1996), decreased efficacy of glucocorticoid receptors (Pariante and Miller, 2001) leading to reduced biological sensitivity to the inhibitory effects of the glucocorticoid dexamethasone on the production of adrenocorticotropic hormone and cortisol, augmented platelet activation (Roy et al., 1988) and variations in autonomic function (Figure 9). Patients suffering from depression frequently demonstrate alterations to the variability of their heart rate as assessed using an electrocardiogram (Gorman and Sloan, 2000).

Figure 9 Depression and the heart

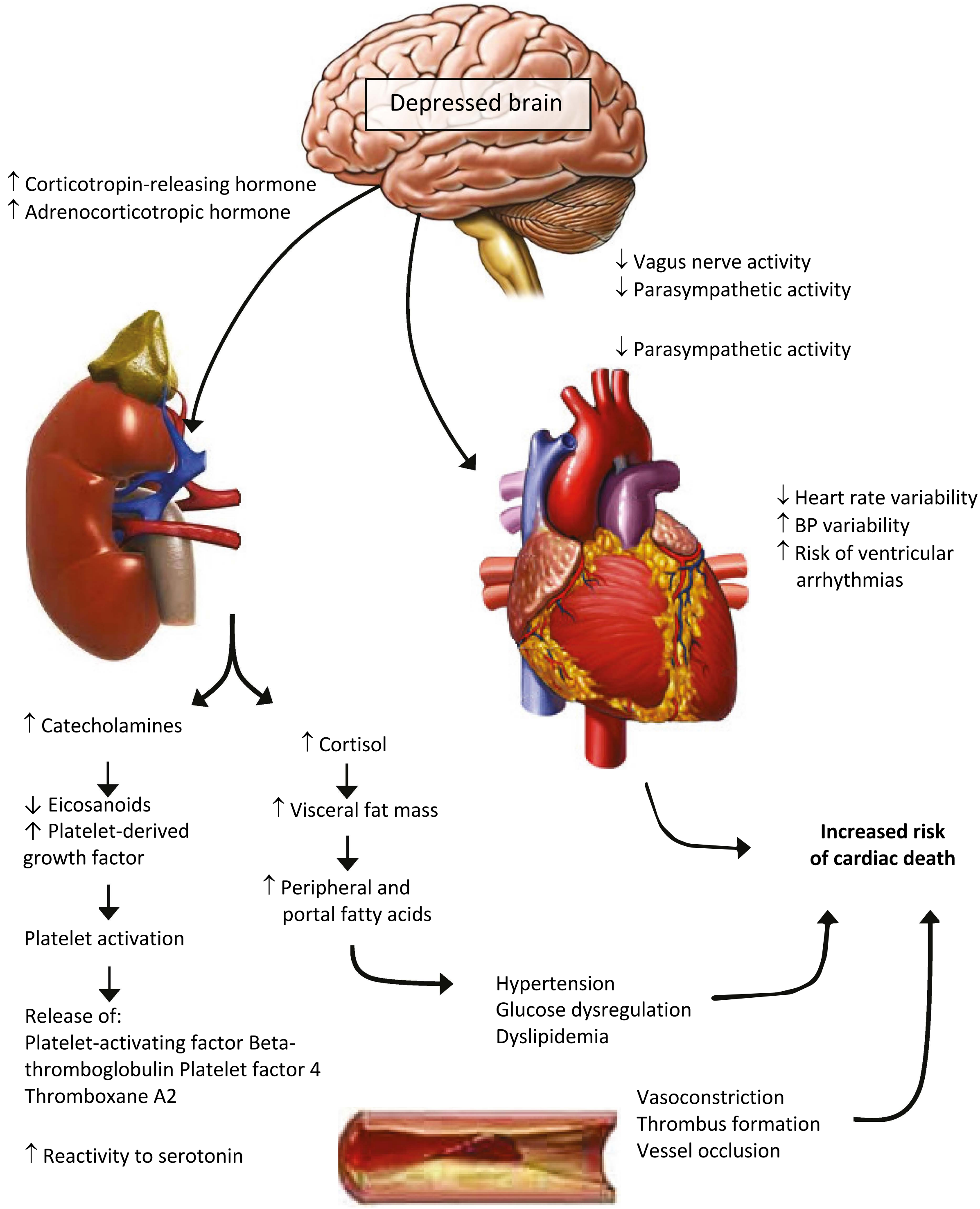


Figure 9 depicts the suggested mechanisms for cardiac vulnerability seen in depressive patients. Adapted from pg. 749, Kemp (2003).

Key:

↓ : Decreased

↑ : Increased

1.5 Heart rate variability

The utilisation of the electrocardiogram as both a diagnostic and predictive cardiovascular instrument for the identification of depression has developed in recent years. Relying on the autonomic function of the peripheral nervous system, the utilisation of the electrocardiogram as a quantitative assessment of depression continues to be investigated in a clinical setting (Gorman and Sloan, 2000).

The autonomic nervous system (ANS) of the human body is a division of the peripheral nervous system, which can be further classified into the sympathetic and parasympathetic branches (Figure 10). These two divisions of the ANS act synchronously and autonomously to preserve homeostatic bodily function in response to internal and external stimuli (Pumprla et al., 2002a, Robertson et al., 2012). The homeostatic effects of these subdivisions incorporate a broad range of visceral components, including cardiac control, secretory gland regulation and organ metabolic function (Furness, 2009).

Figure 10 Subdivisions of the human nervous system

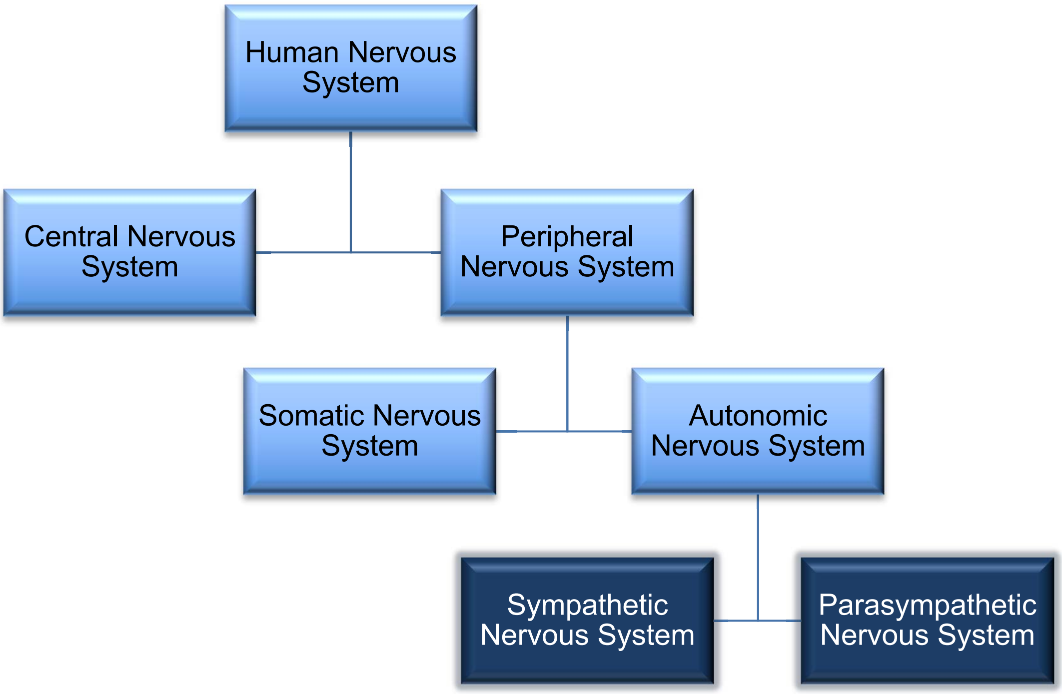


Figure 10 illustrates the subdivisions of the human nervous system; of particular interest (appearing in navy) are the subdivisions of the autonomic nervous system – the sympathetic and parasympathetic nervous system. These complimentary components act autonomously to maintain homeostatic bodily function. Adapted from pg. 61, Nicholas (2008).

Colloquially referred to as the “fight or flight” response, the function of the sympathetic nervous system (SNS) is to accommodate for abrupt requirements of metabolic stores (Raven and Johnson, 2008). Resulting physiological adjustments, such as the initiation of the stress response, dilation of the pupils, increased heart rate, adrenaline release, decreased digestive processes, depressed immune function and the dilation of the bronchioles, prepare the body for activity and reduce non-vital processes (Raven and Johnson, 2008).

Known as the “rest and digest” response, the parasympathetic nervous system (PNS) is principally associated with digesting food, relaxing and sleeping (Raven and Johnson, 2008). It involves the reduction of metabolic rates and increasing the secretions and activities of digestive organs (Raven and Johnson, 2008). The parasympathetic nervous system also acts to reduce the heart rate (Raven and Johnson, 2008).

These two subdivisions of the ANS (SNS and PNS) can be examined using spectral analysis of heart rate variability (HRV) (Pumprla et al., 2002a). This non-invasive technique involves comprehensive and meticulous analysis of time fluctuations between sequential heart beats, and can be used to indirectly quantify autonomic control of the heart (Acharya et al., 2008). HRV is attained via a three-step sequence, the first of which involves attaining an electrocardiogram (ECG) recording (Figure 11). The period between sequential heartbeats is generally measured from one R peak on the ECG to the next. Variability in this heart rate has been shown to be indicative of the dynamic interaction between the SNS and the PNS (Acharya et al., 2008).

Figure 11 The electrocardiogram tachogram

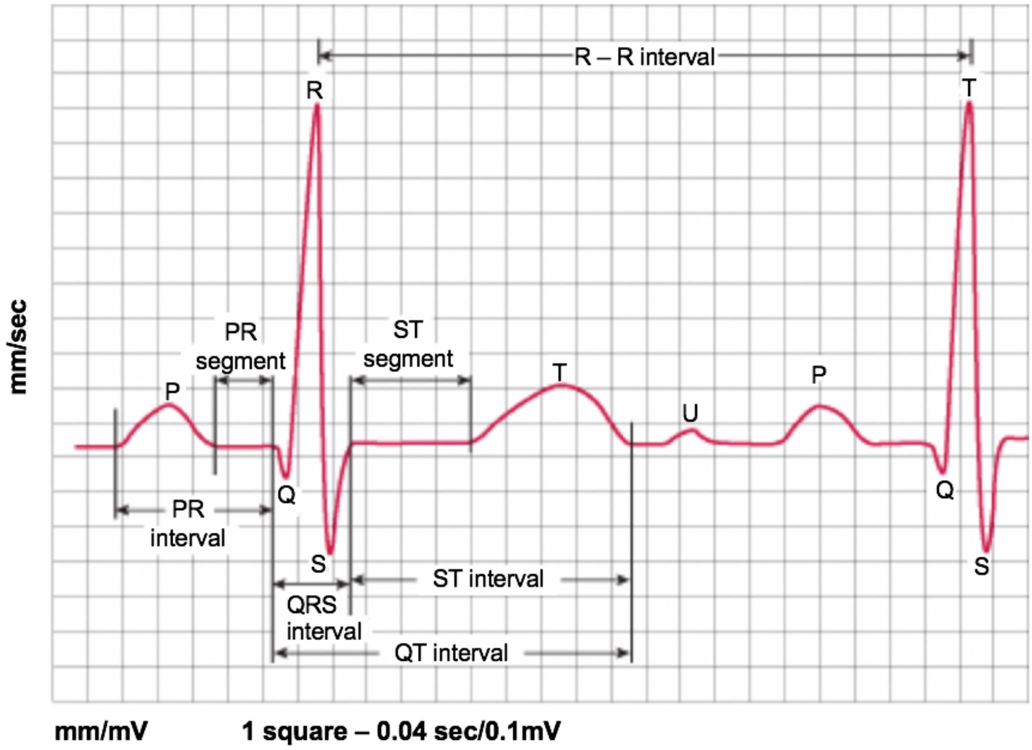


Figure 11 depicts a typical electrocardiogram recording. Heart rate variability is derived from the R-R interval. Adapted from pg. 223, Beers and Porter (2006).

Key:

P: Atrial depolarisation

Q: Depolarisation of the interventricular septum

R: Ventricular depolarisation

S: Ventricular depolarisation

T: Ventricular repolarisation

U: Atrial repolarisation

PR interval: The interval of time required for the impulse to reach the atrioventricular node from the sinoatrial node

PR segment: This interval represents the time between the onset of atrial depolarization and the onset of ventricular depolarization

QRS interval: The duration of the ventricular depolarization

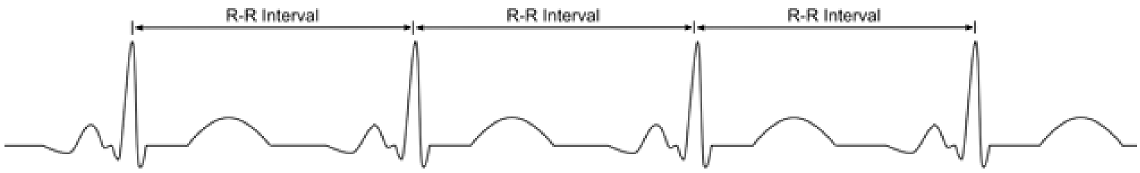
mm/mV: Millimetres per millivolt

mm/sec: Millimetres per second

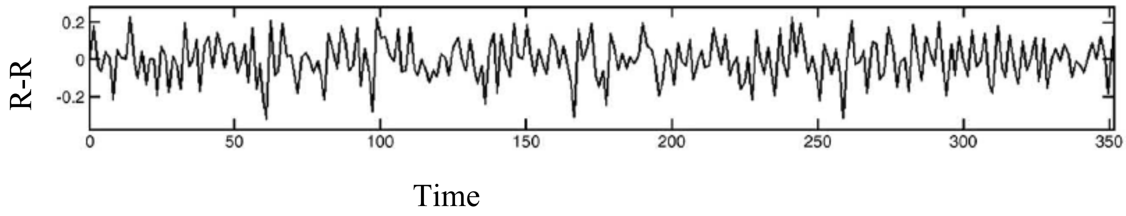
Figure 12 illustrates the 3-step method of deriving HRV parameters. The measurement of HRV is initially derived from the R-R intervals of an electrocardiogram (Figure 12a). Variances in the time interval between sequential R waves are then plotted on a time series graph (Figure 12b). A spectrogram is then derived from this time series graph using a non-parametric algorithm (the Fast Fourier Transform) and the total cyclical variability present at different frequencies can then be quantified (Figure 12c) (Malliani et al., 1991).

Figure 12 The method of deriving heart rate variability data from an electrocardiogram

a) ECG recording



b) Time series



c) Spectrogram with frequency domains

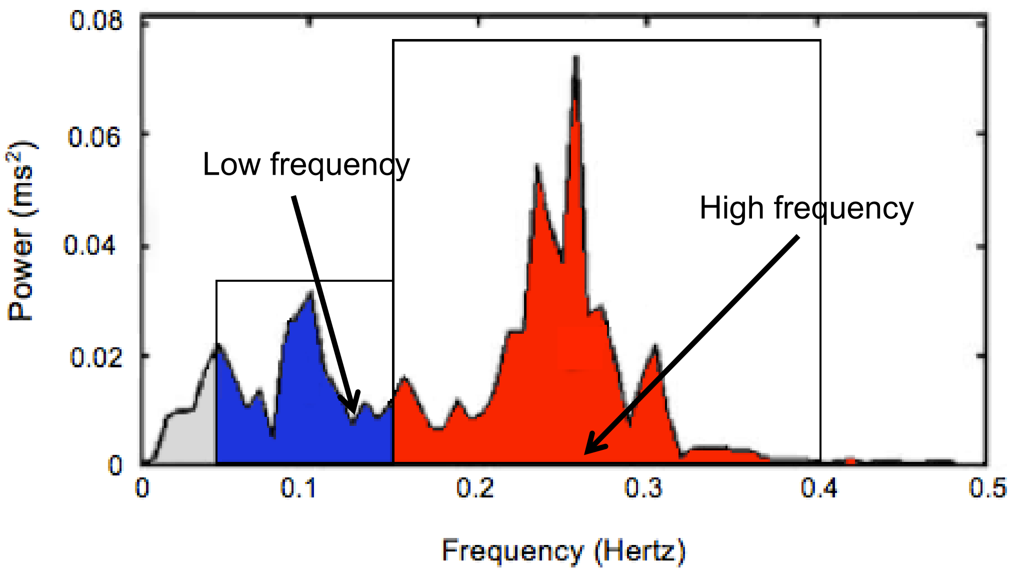


Figure 12 displays the method of deriving heart rate variability from an electrocardiogram, modified from pg. 32, Pichon et al. (2006).
a) A simplified electrocardiogram recording
b) Time series data reflecting the length of time between consecutive R-R intervals.
c) Time interval transformed using a fast Fourier Transform algorithm to produce the spectrogram.
Low Frequency = **Blue.** High Frequency = **Red.**

Key:
ECG: Electrocardiogram
Hz: Hertz
ms^2: Milliseconds squared
s: Seconds

The sinus node of the heart, an intrinsic pacemaker that regulates the rhythm and rate of cardiac contraction, is innervated by both the SNS and the PNS (Figure 13) (Pumprla et al., 2002a). Each of these subdivisions employs unique innervation mechanisms, providing the basis for their complimentary action and the foundation of HRV analysis. Parasympathetic innervation of the heart is facilitated by the synaptic release of acetylcholine, which then acts upon the vagus nerve (Raven and Johnson, 2008, Pumprla et al., 2002a). This acetylcholine employs a uniquely short latency period and a fast rate of metabolism. Contrarily, sympathetic innervation is modulated by the synaptic release of noradrenaline, which employs a comparatively slow metabolism rate (Raven and Johnson, 2008, Pumprla et al., 2002a). As a result of these distinctive metabolism rates, variations in heart rate frequencies are observed, providing the foundation for HRV analysis (Pumprla et al., 2002a). Standards for bandwidth frequencies have further been recognised in order to provide quantitative frequencies at which each of these autonomic branches are innervated (Malik, 1996).

Figure 13 The electrical conduction pathways of the heart

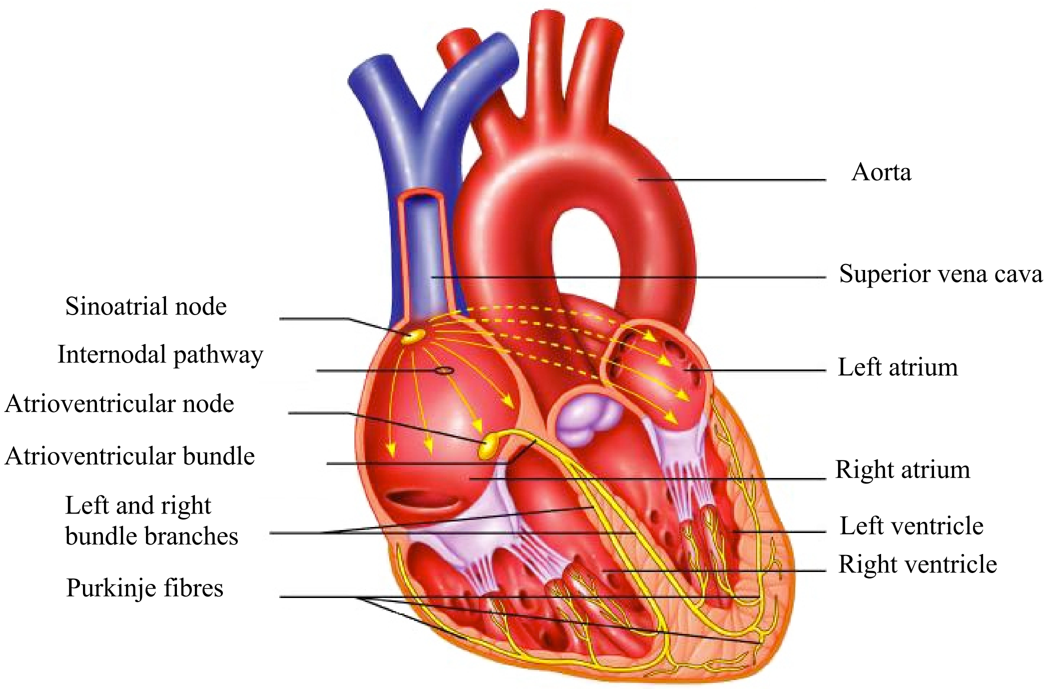


Figure 13 depicts a diagrammatic representation of the electrical conduction pathways of the heart. Adapted from pg. 249, Belk (2009).

The two primary bandwidths of the HRV frequency domains are high frequency (HF) and low frequency (LF), indicating parasympathetic activity and sympathetic activity respectively (Table 6) (Tulppo and Huikuri, 2004). The bandwidth ranges for HF are 0.15-0.40 Hertz (Hz) and 0.04-0.15 Hz for LF (Table 6) (Thayer et al., 2010). Minute cyclical variations in HRV are also detected at HF (generally around 0.25 Hz) in response to normal resting respiration (Pagani et al., 1986). Similarly, endogenous BP variances at rest have been shown to exert a minimal effect on HRV data, the effects of which have been observed predominantly at 0.10 Hz (Sleight et al., 1995). The ratio of LF to HF is reflective of the sympathovagal balance, which has been employed as a significant assessor of irregularities in autonomic activity (Pumprla et al., 2002a).

Table 6 Heart rate variability bandwidths in association with autonomic activity

Bandwidth	Frequency	Associated autonomic activity
Low frequency (LF)	0.04-0.15 Hz	Sympathetic
High frequency (HF)	0.15-0.40 Hz	Parasympathetic
LF:HF		Sympathovagal balance

Table 6 presents the frequency ranges for each of the heart rate variability parameters. The ratio of LF to HF denotes the balance between sympathetic and parasympathetic activity (sympathovagal balance). Modified from pg. 821, Malik (1996).

Key:

HF: High frequency

Hz: Hertz

LF: Low frequency

LF:HF: Low frequency to high frequency ratio (sympathovagal balance)

The employment of HRV as an indicative measurement in clinical settings has provided the foundation for the practical functionality of this assessment. HRV is utilised in many clinical settings. A study conducted by Acharya and associates (2008) assessed 352 patients for cardiac abnormalities using analysis of HRV. The study found that using the Fast Fourier Transform to analyse HRV resulted in the correct classification of cardiac classes for chronic heart failure, complete heart block and preventricular contraction 91.6%, 100% and 91.7% of the time respectively. The correct classification of a left bundle branch block and ischemic/dilated cardiomyopathy was determined in 83.3% and 81.8% of the cases respectively. It should be noted, however, that reduced accuracy was identified for some cardiac conditions, as atrial fibrillation, ventricular fibrillation and sick sinus syndrome were only correctly classified using FFT analysis of HRV in 66.7%, 58.3% and 63.6% of the cases respectively.

Additionally, the prognostic value of HRV after myocardial infarction has been identified. A prospective study was conducted by La Rovere and team (1998), assessing 1,284 patients who had suffered a recent (<28 days) myocardial infarction. A follow up was completed, with individuals being reassessed every 4 months for a minimum of 1 year and a maximum of 21 months. It was found that the univariate relative risk of cardiac mortality after a myocardial infarct when an individual presented low HRV was 5.3, providing evidence for the prognostic value of HRV analysis in determining relative risk of cardiac mortality in myocardial infarct patients. These varied applications emphasise the clinical significance of this important predicative measure based on cardiac activity.

HRV is decreased when sympathetic influence dominates parasympathetic influence (Klein et al., 1995, American College of Cardiology Cardiovascular Technology Assessment Committee, 1993, van Ravenswaaij-Arts et al., 1993). Reduced heart rate variability has been associated with a greater risk of ventricular arrhythmias and sudden death (van Ravenswaaij-Arts et al., 1993).

This association between depression and an increased risk of developing CVD is of serious concern, especially when we consider the increased incidence of depression within the truck and train driving industries. Additionally, the Australian Heart Foundation has indicated that additional research is required to assess the cardiac effects of depression (Australian Heart Foundation, 2008b).

1.5.1 Heart Rate Variability and Depression

The link between heart rate variability (see section 1.5 for a detailed explanation of heart rate variability) and depression has been investigated increasingly in recent years. Despite numerous recent studies, the results attained from these have yielded varied results. The association between depression and an increased risk of developing CVD is of concern, especially when we consider the paucity of literature surrounding the topic. Depression has been linked to increased risk of cardiovascular mortality, however to exact mechanism is somewhat unclear. Furthermore, the Australian Heart Foundation has indicated that additional research is required to assess the cardiac effects of depression, and whether it may be possible to link biomarkers such as HRV to the degree of depressive symptomology being experienced by the individual (Australian Heart Foundation, 2008a).

Agelink and co-workers (2002) associated time and frequency domain HRV indices throughout a 5-min rest, deep breathing and Valsalva test, in 32 patients with suffering from major depression and 64 controls who exhibited no depressive symptoms. The Valsalva manoeuvre comprises forced exhalation against a closed glottis, resulting in an increase in intrathoracic pressure (Opotowsky et al., 2010). This clinical technique is used to assess cardiovascular health. The study found that individuals with severe depression displayed reduced HRV, specifically, a significantly reduced modulation of cardiovagal activity, when compared to non-depressed controls. The increase in cardiovascular mortality observed in patients exhibiting symptoms of severe depressive disorder may be somewhat attributed to the dislocation of the sympathovagal balance in favour of sympathetic modulation. Furthermore, severity of depressive symptoms and cardiovagal activity were found to be inversely correlated, indicating that as depressive symptoms increased, cardiovagal activity decreased.

Furthermore, a study by Koschke and associates (2009), supportive of these findings, compared 75 individuals experiencing recurrent major depressive disorder to 75 age and gender matched controls. HRV frequency domain results exhibited a significant shift of autonomic balance towards sympathetic dominance and a reduction in parasympathetic modulation. There was, however, no evidence to support prior studies that suggest the degree of autonomic imbalance relates to the severity of depressive symptoms.

A study by Kemp and team examined 73 patients diagnosed with Major Depressive Disorder and 94 age- and sex- matched controls (Kemp et al., 2012). The Hamilton Depression Rating Scale was used to assess the severity of clinical depression. The study found that HRV was reduced in patients diagnosed with Major Depressive Disorder when compared to their age- and sex-matched controls. An interesting identification was noted, in that patients exhibiting comorbid Generalised Anxiety Disorder were found to have a greater reduction in HRV than those exhibiting Major Depressive Disorder alone.

Supporting these findings, Udupa and associates (2007) conducted a study, which found that individuals suffering from major depressive disorder exhibited higher sympathovagal balance (the ratio of low frequency (LF) to high frequency (HF) HRV) than non-depressed controls suggesting sympathetic predominance. The study assessed 40 individuals experiencing major depression when compared with 40 gender and age matched controls. Resting HRV was obtained whilst individuals were seated for fifteen minutes in a relaxed position. Active HRV was then obtained during a deep breathing and Valsalva test (see above for an explanation of the Valsalva manoeuvre). Results indicated that individuals with severe depression presented a reduction in HRV, indicative of an increase in sympathetic and decrease in parasympathetic modulation.

In contrast, a study led by Henje Blom (2010) identified significant reductions in sympathetic modulation in female patients with major depressive disorder (n=11) when compared to their age and location matched controls (n=53). In contrast, a study by Bar and associates (2004) found no deviation in HRV when comparing patients exhibiting depressive symptoms (n=18) to their physiologically matched controls (n=18). This study associated HRV during a five-minute rest period with HRV data attained during a deep breathing exercise. There were no perceptible variations in HRV between the depressed and non-depressed control groups, although this could be attributed to artifacts during the short length of the HRV recording (5 minutes). HRV requires an adequate period of time (a minimum of 5 minutes of good quality ECG data) to allow for the detection of subtle autonomic variations that accompany depression (Berntson et al., 1997). Supporting this, a study by Yeragani (1991) found no significant variation in HRV between depressed individuals (n=19) and a control sample (n=20), although the study employed a small sample size, which may have skewed the obtained results. Table 7 summarises depression and HRV results from the various studies.

Table 7 Summaries of studies reporting changes in the components of heart rate variability in depressed subjects when compared with healthy controls

Study	Sample size	LF	HF	LF:HF	Relationship between depression and HRV
Henje Blom et al., 2010	11	↓	n/c	-	Yes
Bar et al., 2004	18	n/c	n/c	n/c	No
Yeragani et al., 1991	19	n/c	n/c	n/c	No
Agelink et al., 2002	32	↑	↓	↑	Yes
Udupa et al., 2007	40	↑	↓	↑	Yes
Koschke et al., 2009	75	-	↓	-	Yes

Table 7 depicts heart rate variability data from different studies. The table compares sample size, effects on low and high frequency components of heart rate variability, LF:HF ratio and the presence of a relationship between severity of depressive symptoms and autonomic alterations. Each of the studies compared depressed patients with age-matched controls. Varied results are apparent, with two of the six studies reporting an increase in LF (sympathetic influence) (Agelink et al., 1991; Udupa et al., 2009), one reporting a decrease in LF (Henje Blom et al., 2010) and two reporting no change (Yeragani et al., 1991; Bar et al., 2004). Similarly, the effects on HF (parasympathetic influence) were varied, with three studies reporting a decrease (Agelink et al., 2002; Udupa et al., 2007; Koschke et al., 2009) and three reporting no change (Yeragani et al., 1991; Bar et al., 2004; Henje Blom et al., 2010). Agelink (2002) was the only study to find a correlation between the severity of depressive symptoms and HRV. In the studies that tested more than 30 participants (Red) (Agelink et al., 2002; Udupa et al., 2007; Koschke et al., 2009), similar results were attained (decreased parasympathetic activity, increased sympathetic activity) providing some evidence of the impact of small sample sizes.

Key:
↑ = Higher
↓ = Lower
HF = High frequency
LF = Low frequency
LF:HF = Low frequency to high frequency ratio (sympathovagal balance)
n/c = No change
- = no data

Studies that have examined the associations between HRV and depression have obtained varied results. Whilst some studies have reported a reduction in parasympathetic modulation (Rechlin et al., 1994, Guinjoan et al., 1995) others have reported no apparent variation (Yeragani et al., 1991, Moser et al., 1998, Bar et al., 2004). Likewise, inconsistent results have been obtained concerning the influence of depression on the sympathetic branch of the ANS, with studies reporting an increased (Guinjoan et al., 1995, Udupa et al., 2007), decreased (Tulen et al., 1996) and unchanged (Moser et al., 1998) sympathetic control in individuals with depression. Of those that did report a confirmatory link between HRV and depression, there remains some ambiguity regarding the impact of the severity of symptoms on autonomic control. Some studies have suggested that cardiovagal modulation is conditional to symptom severity (Agelink et al., 2002), whilst others have reported that there is no evident association between the degree of autonomic imbalance and the acuteness of depressive symptoms (Koschke et al., 2009). Variations in the heterogeneity, sample size, exclusion criteria, length of ECG recording, and experimental design have all contributed to these inconsistencies.

1.6 Basis for Research

1.6.1 Research question

The distinct discrepancies in literature concerning the effects of depression and depressive symptomology on heart rate variability (refer to previous section 1.5) provides the basis for this study, leading to the aims and hypotheses detailed below. Additionally, the paucity of literature regarding the incidence of depressive symptomology in the trucking and train driving industries in Australia is concerning. A high incidence of both depression and impaired cardiovascular function within the truck and train driving industries presents a substantial health issue for Australia. Although epidemiological studies have yet to be conducted on the train driver population of Australia, it remains a serious concern as train drivers in Australia find themselves exposed to similar occupational factors that may also predispose them to high rates of depression. This study intends to address this scarcity of current literature regarding the incidence of depressive symptomology within these two cohorts, and the effects of depressive symptomology on HRV, in order to quantitate cardiovascular risks in the drivers in the train and trucking industry.

Udupa and team (2007) have postulated that cardiac autonomic factors, including heart rate variability, associate depression with cardiovascular imbalance. Literature concerning these associations has tended to place emphasis principally on individuals experiencing cardiovascular impairment at baseline (Carney et al., 2001, Krittayaphong et al., 1997, Carney and Freedland, 2009, Carney et al., 2005). Of the studies that have examined the effects of depressive symptoms on heart rate variability in healthy cohorts, there have been inconsistent results (Agelink et al., 2002; Bar et al., 2004; Koschke 2009). Moreover, the association between depression and heart rate variability is yet to be explored within the population of truck and train drivers and elucidating the links between these parameters may provide the foundation for improved management of depression within these occupations, and as such, a possible reduction in cardiac health implications. Previous studies have displayed limitations in experimental design, including small sample sizes (Yeragani et al., 1991; Bar et al., 2004; Henje Blom et al., 2010) and short HRV recording times (Bar et al., 2004).

To examine the association between depressive symptomology and altered cardiac function, an electrocardiogram was obtained in 60 truck drivers and 60 train drivers during a baseline resting and active driver simulator task. The electrocardiogram was analysed to derive heart rate variability parameters. Depressive symptomology (affective state) measures were obtained using the Profiles of Mood States Questionnaire (Beck et al., 1996a) and the Beck Depression Inventory Scale-II (Beck et al., 1996a). The incidence of depressive symptomology was assessed using the POMS and BDI, and potential contributing workplace factors identified using the SmartData Driver Package (Kanvanagh, 2007). Associations between cardiovascular function, occupational factors and affective measures were examined to the bio-psycho-social-occupational relationship between affective states, workplace conditions and cardiovascular health (Figure 14). Assessing the prevalence of depressive symptomology, and its associations with impaired cardiovascular function in the previously unobserved population of train and truck drivers in Australia may provide quantitative evidence for the improved management of this prevalent disorder within these high-risk occupational industries.

Figure 14 The bio-psycho-social-occupational relationship to be examined.

Figure 14 depicts a diagrammatic representation of the bio-psycho-social-occupational relationships to be examined in the present study.

1.6.2 Hypothesis

1. There will be a higher incidence of depressive symptomology within the cohort of professional drivers than in the general population.

2. There will be associations between depressive symptomology and cardiovascular risk factors in train and truck drivers.

1.6.3 Aims

1. To assess the incidence of depressive symptomology in truck and train drivers.

2. To assess the links between depressive symptomology and altered cardiovascular function in train and truck drivers.

1.6.4 Conclusion

Literature has presented evidence to suggest that depression may impair cardiovascular modulation and increase the risk of developing cardiac impairment in a previous healthy cohort. There have been numerous mechanisms proposed to account for the potential cardiovascular vulnerability related to depression, most of which centre around an increase in sympathetic dominance reported in individuals suffering from depression. Given the reportedly high incidence of both negative mood states and cardiovascular disease within the professional driving community, investigation of the links between the two is of significant interest. Further, steps to improve the management of depression may in turn decrease cardiovascular risk within these industries. This study will provide statistical data regarding the prevalence of depressive symptomology within a cohort of professional drivers, and the occupational factors that may contribute to this disorder. Further, this research will examine the association between depressive symptomology and cardiac risks in truck and train drivers. Finally, early driver safety intervention schemes could potentially be employed if depression can be conclusively associated with impaired HRV, and consequentially, reduced cardiovascular function. This will facilitate the potential reduction in the health, emotional and socioeconomic implications of both depression and CVD within the truck and train driving industries in Australia.

Chapter Two - Methodology

2.1 Ethics Approval

This study was granted University of Technology Sydney Human Research Ethics Committee approval (HREC: 2007-55A). Prior to the commencement of the study, participants were provided with a consent form, which comprehensively outlined the purpose and methods of the study (see section 2.4). The individual was advised that they may, at any time, leave the study without a need to provide a reason. The consent form also contained information regarding contact details of both the lead research and supervisor, and the HREC number. Finally, the participant was advised that full anonymity was provided, with all recorded information being stored under case numbers, which were only accessible by the lead researcher. If signed consent was given, the participant signed two copies of the consent form, one of which was retained by the researcher, and the other by the volunteer.

2.2 Participant Recruitment

Participants were recruited through local advertisement via a poster, recruitment though contacts established independently to this research, online forums and with the aid and endorsement of Australia Post Transport division, the Transport Workers Union, the Australian Trucking Association and Sydney Trains.

2.3 Participant Selection Criteria

2.3.1 General requirements

After an initial expression of interest from potential participants, a pre-study email was sent to the individual. This email provided information on a number of exclusion criteria, some of which were drawn from the Lifestyle Appraisal Questionnaire (LAQ) (Craig et al., 1996b). Participants were screened via email with the following exclusionary questions; “Do you take any drugs or medication other than tea, coffee and nicotine (such as sleeping tablets, anti-anxiety drugs such as Valium, antidepressants, hallucinogens, barbiturates, pain-killers, etc.?)”, which was adapted from question 8 of the LAQ. If the participant replied yes to this question, they were excluded from the study. This reduced the risk of known drugs or medication affecting the results attained from this study, as many drugs and medications have been associated with alterations to BP and heart rate variability. These include anti-depressants (Licht et al., 2010, Licht et al., 2011), anti-psychotics (Henderson et al., 2004), antihypertensive medication (Pavithran et al., 2010), anxiolytics (Papadopoulos et al., 2010) and steroids (Payne et al., 2004). If the participant answered no to question 8, they were then asked, “Do you, at present, suffer from any chronic disease or illness (such as cancer, heart disease, asthma, diabetes, arthritis, etc.?)”, which was adapted from question 18 of the LAQ. If the participant answered yes to this question, they were excluded from the study. This reduced the risk of known disease states affecting results. Furthermore, this exclusion criterion was in agreement with the University of Technology Sydney Human Research Ethics Committee (UTS HREC) requirements. Finally, drivers were permitted into the study only if they were not rostered to work on the day of testing, in order to reduce the impacts of varied shift work on physiological and psychometric data.

Upon preliminary inclusion in the study, the participant was invited to visit the University of Technology Sydney, where the study was to be conducted. Upon arrival, and after permitting consent, three pre-study BP readings were recorded. If systolic and diastolic BP readings were greater than or equal to 160/100 mmHg respectively, the participant was advised that they were unable to participate in the study, and the individual was offered assistance to visit the nearest medical centre. If a BP reading was recorded at greater than 140/90 mmHg and less than 160/100 mmHg, the participant was included in the study, however, they were advised to seek medical advice from their general practitioner. These steps were in accordance with the National Heart Foundation of Australia BP guidelines (2010) and the UTS HREC approved emergency protocol (see appendices).

Finally, it was a requisite that participants smoke less than 10 cigarettes per day and not consume more than 16 alcoholic beverages per day. This information was obtained via part one of the LAQ. This was to reduce the possible confounding variables that may influence heart rate and BP readings.

2.3.2 Requirement for Professional Drivers

Specific inclusionary criteria for drivers were as follows; drivers were required to be employed full time, and heavy vehicle drivers were required to drive a vehicle over 4.5 gross vehicle mass (the lower limit of GVM required to be classified as a heavy vehicle driver). Finally, drivers were only permitted participate in the study if they were not rostered to work on the day of testing.

2.4 Experimental Protocol

The study was conducted in a controlled laboratory environment, with temperature, auditory and visual interference being reduced as much as viably possible. Light sources were controlled, with laboratory blinds being drawn to reduce the impact of external light sources influencing physiological measurements. The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions being presented. Upon confirmation of written consent, the study was commenced.

2.4.1 Laboratory methodology

Initially, a participant who had met the inclusion criteria was seated for five minutes of quiet relaxation. Three pre-study blood pressure measurements were obtained, with two minutes of seated rest between each reading. Following this, the participant was asked to complete a number of questionnaires. These included the Lifestyle Appraisal Questionnaire (Craig et al., 1996b) (assessing lifestyle behaviour and habits), the Beck Depression Inventory Scale-II (Beck et al., 1996a), the Beck Anxiety Inventory (Beck et al., 1988b), the Profile of Mood States questionnaire (McNair et al., 1971), the Professional Drivers Package (developed specifically for this study to assess driving history and information) and the Likert Fatigue scale (Lal and Craig, 2002). Next the participant was fitted with a three-lead electrocardiogram (ECG), attached to their chest. The measurement of the participants ECG was obtained using the FlexComp Infinity ECG (Thought Technology Ltd, Canada) along with the BioGraph Infinity computer software program (Thought Technology Ltd, Canada). According to Berntson and associates (1997), a three lead ECG recording is adequate to obtain well-defined R-R intervals, which are necessary for the analysis of HRV.

Following this, the individual was seated and undertake the baseline phase of testing, which involved 20 minutes of quiet sitting, with their eyes open. Following this, the participant began the active phase of testing. For the truck drivers, this involved the participant being seated in the driving simulator, using the Logitech G7 Racing wheel to manoeuvre around the Standard Street One course of the Scania Truck Driver Simulator for twenty minutes whilst the ECG was used to collect heart rate data (Figure 15). The train drivers were seated at the computer and commenced twenty minutes of stimulated train driving using the Trainz Classics (N3V Games, Queensland, Australia) driving simulator program. After this, the ECG electrodes were removed from the participant and three post-study BP readings were obtained with two-minute interval in between (as described in section 2.4.1.2). This research is based on a within-subject design, as participants serve as their own control by providing individual baseline scores prior to the stress intervention. This concluded the laboratory study. See Figures 16 and 17 for diagrammatic representations of the laboratory protocol.

Figure 15 Laboratory Truck Driving simulator

Figure 15 depicts the laboratory setup for the active truck driving simulator using a Logitech G7 Racing wheel and the Standard Street One course of the Scania Truck Driver Simulator. Note that the driving simulator includes a driving seat comparable to common truck and car seats, accurate pedals and a steering wheel. Permission obtained from participant to reproduce image.

Figure 16 Flowchart of experimental protocol

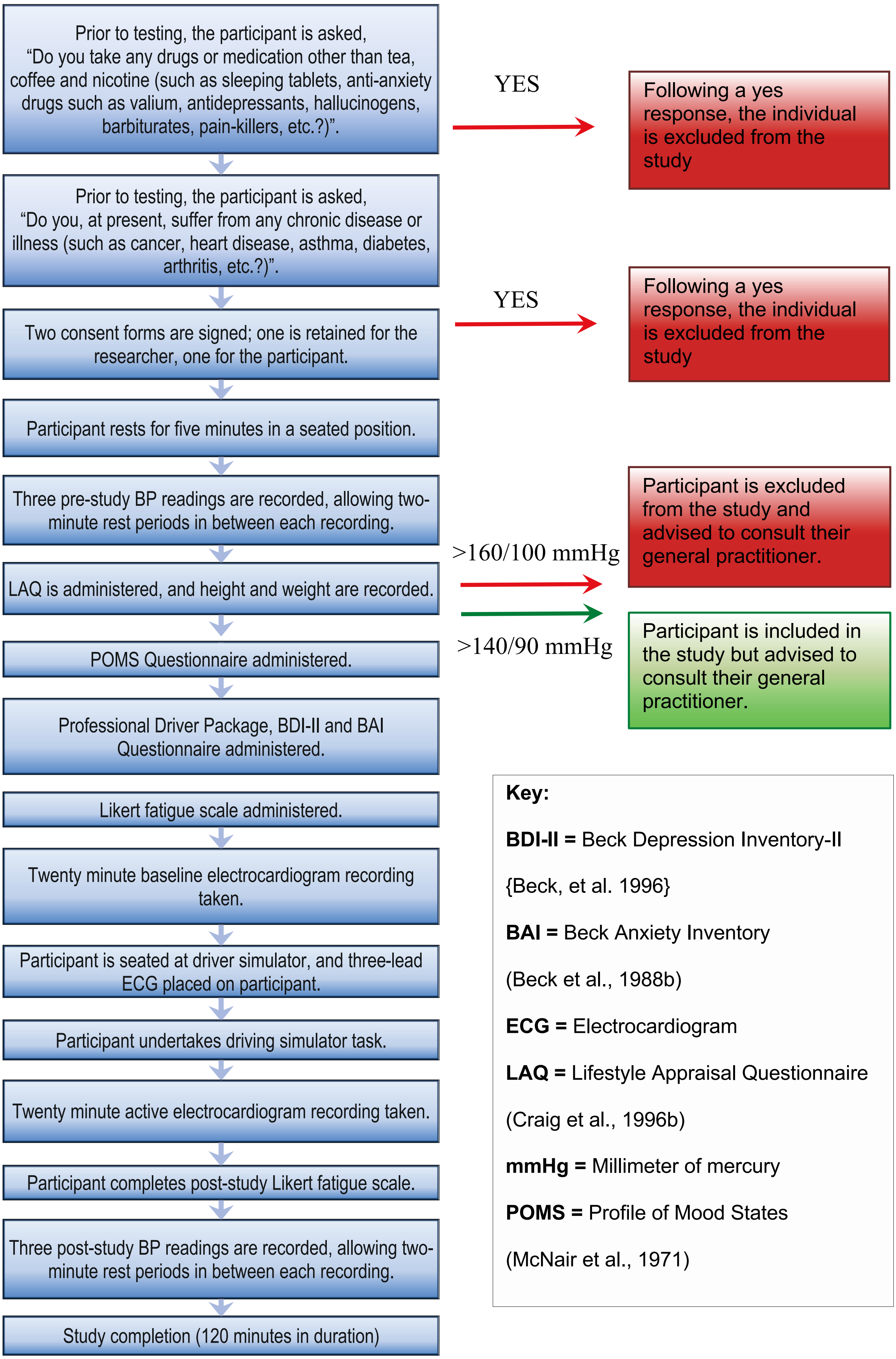
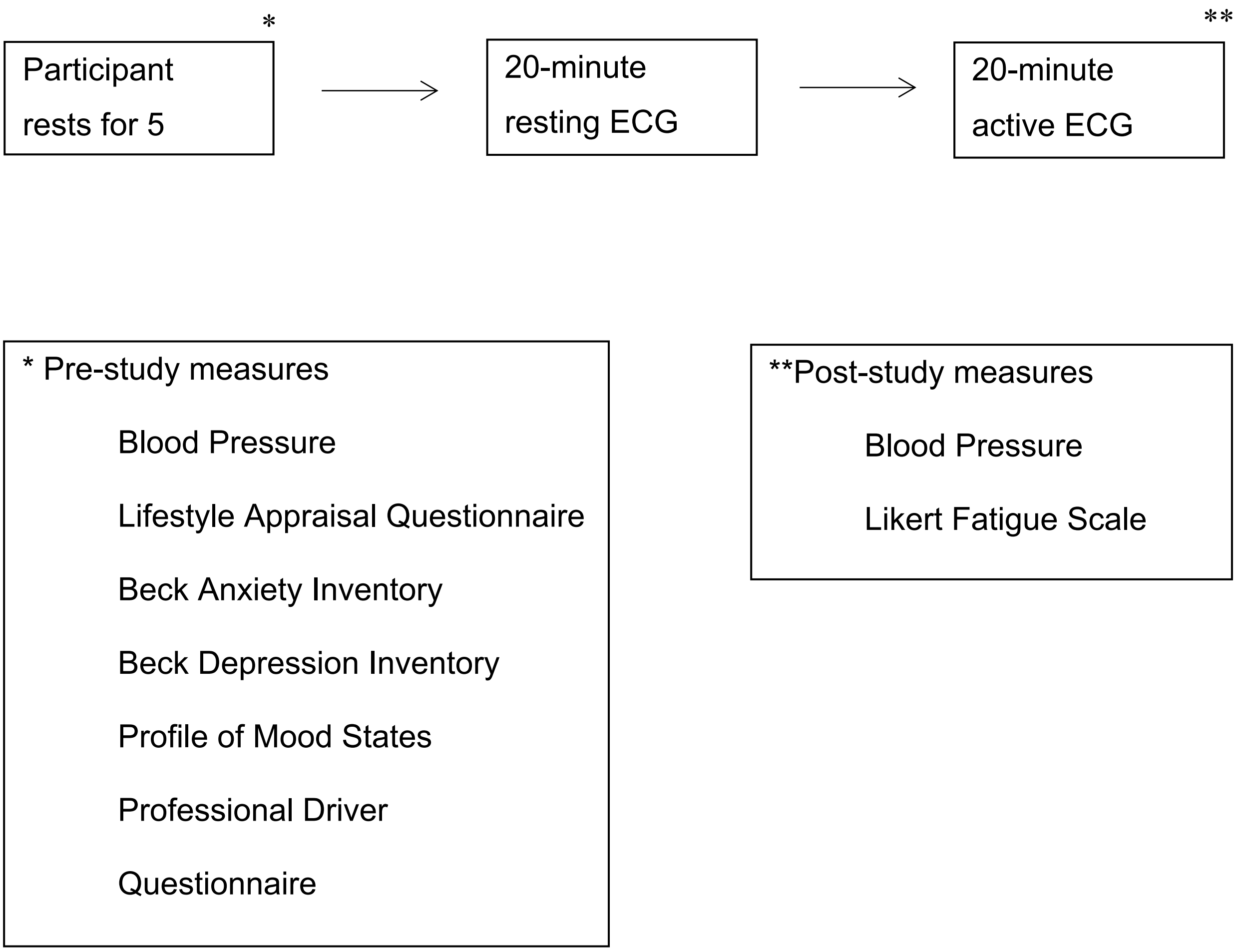


Figure 17 Study Protocol



2.4.2 Measurements of cardiovascular function

Cardiovascular function was assessed using electrocardiogram and blood pressure measurements. Electrocardiogram data was used to derive heart rate variability parameters.

2.4.2.1 Blood Pressure

Upon commencement of the study, three pre-study BP readings were obtained. The volunteer was required to remain seated for five minutes prior to the BP readings being recorded, with a two-minute seated interval between each of the measurements. In accordance with the National Heart Foundation of Australia BP guidelines (2010) and the UTS Human Research Ethics Committee approved emergency protocol, a BP reading of greater than 160/100 mmHg resulted in the participant being excluded from the study. Furthermore, the participant was advised to seek urgent medical advice, and the offer was made to escort the individual to the nearest medical facility. A participant with a pre-study BP reading greater than 140/90 mmHg but lower then 160/100 mmHg, whilst included in the study, was advised to consult their general practitioner regarding their elevated BP reading (Figure 18).

Figure 18 Stages of blood pressure readings from normal to hypertension

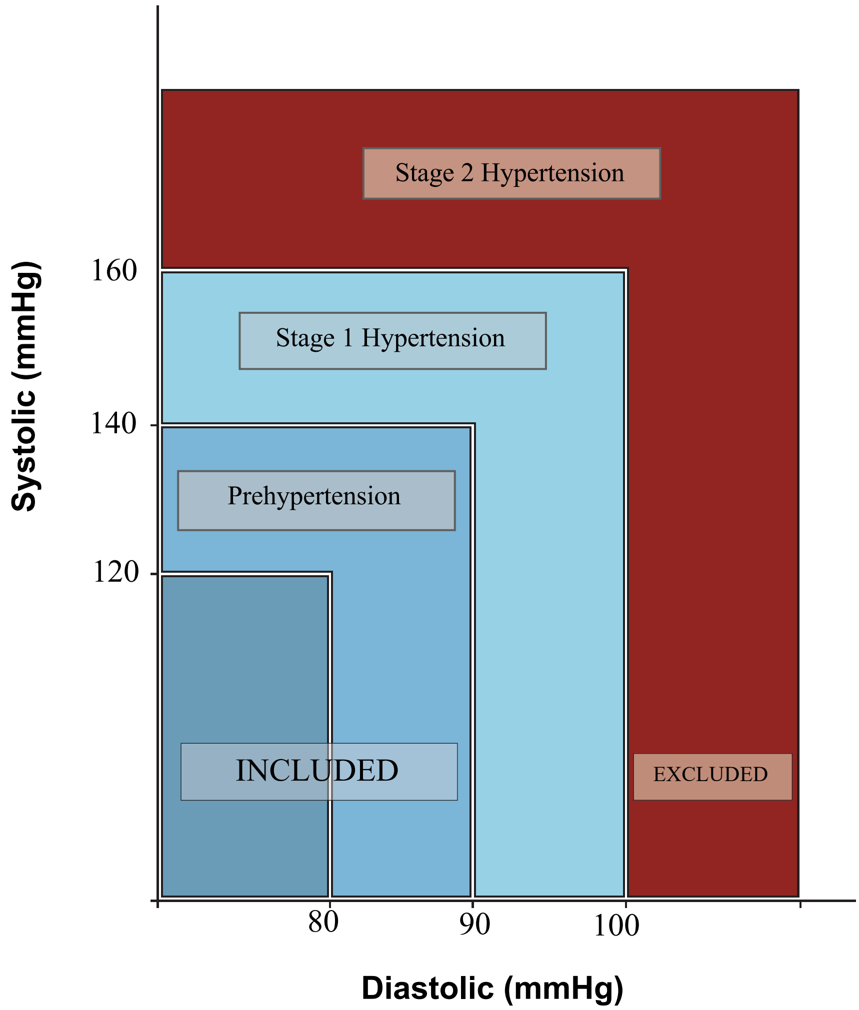


Figure 18 presents a graphical representation of the systolic and diastolic blood pressure readings that denote the stages of hypertension. Adapted from the National Heart Foundation of Australia BP guidelines (2010).

BP was recorded three times using a validated and reliable BP monitor, the Livingstone OMRON IA1 (Japan) (Figure 19). The BP reading was taken from the left arm, as per the provided product instructions. Due to the known acute variability of BP (Hansen et al., 2009), the average of three BP readings was obtained. Heart rate, the number of heart beats per minute, was also recorded using the Livingstone OMRON IA1 (Japan). After satisfying the aforementioned inclusion criteria for BP assessment, the participant was then included in the study.

Figure 19 The Livingstone BP monitor and measurement instructions

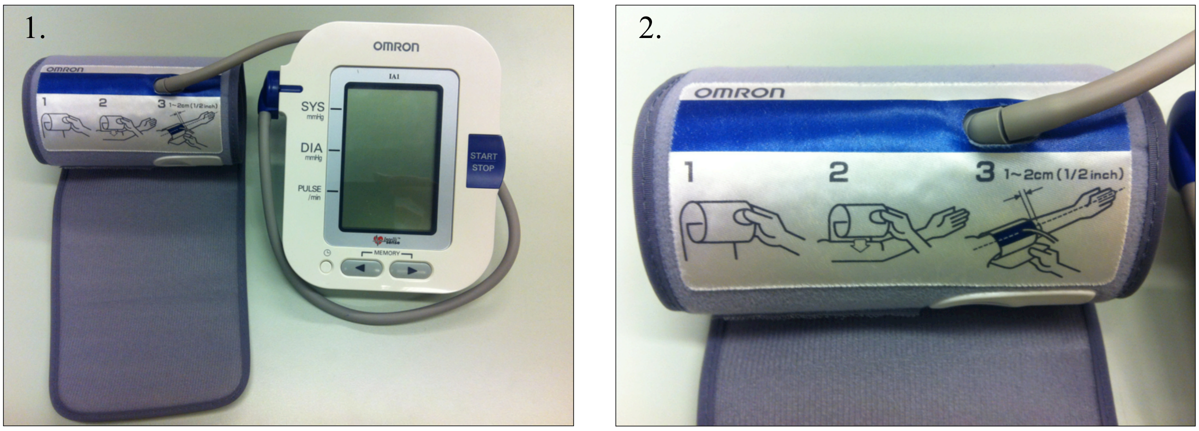


Figure 18 depicts 1. The Livingstone Omron IA1 BP monitor used during the laboratory experiment. 2. BP was measured using the standardised method displayed on the cuff of the BP monitor Livingstone OMRON IA1 (Japan).

2.4.2.2 Electrocardiogram and Heart Rate Variability

The measurement of the participants ECG was obtained using the FlexComp Infinity ECG (Thought Technology Ltd, Canada) along with the BioGraph Infinity computer software program (Thought Technology Ltd, Canada). According to Berntson and associates (1997), a three lead ECG recording is adequate to obtain well-defined R-R intervals, which are necessary for the analysis of HRV.

Initially, the adhesion sites of the ECG on the participant's skin were cleaned using an alcohol wipe (Liv-Wipe alcohol swab, 70% isopropyl alcohol, Livingstone International Pty Ltd Australia) in order to remove surface dirt and decrease the noise associated with an ECG signal. See Figure 15 for diagrammatic representation of the ECG lead placement sites. Following this, the ECG cup electrodes were loaded with highly conductive, multi-purpose electrode gel (Signa Gel, Parker Laboratories Inc, USA) using a 5mL syringe (BD Ltd, Singapore). The blue and yellow electrodes (active) were positioned at the intercostal space between the 4^{th} and 5^{th} ribs, two centimeters laterally from each side of the sternum (Figure 20). These two active electrodes were then secured to the chest, using microporous surgical tape (Liv-Pore microporous surgical tape, Livingstone International Pty Ltd Australia). The final reference electrode (black) was then secured underneath the shoulder.

Figure 20 Electrode placement (three-lead ECG)

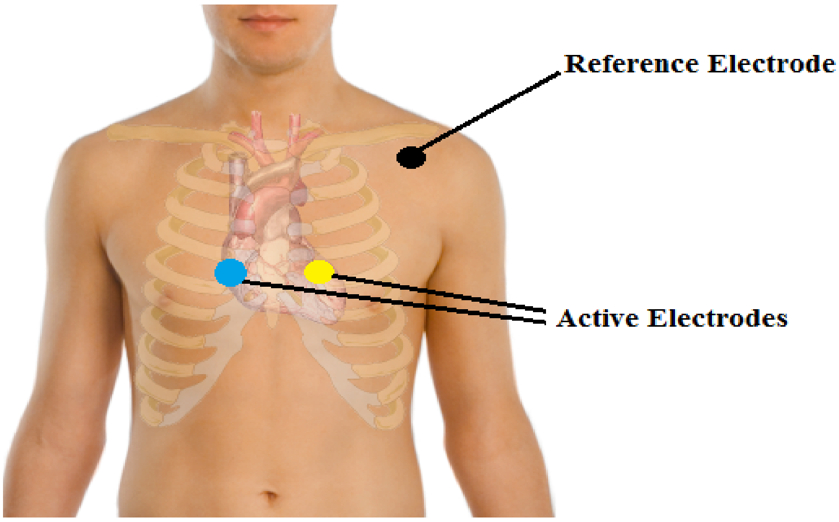


Figure 19 depicts the electrode placement for the three-lead electrocardiogram. The two active electrodes (blue and yellow) are placed two centimeters laterally of each side of the sternum, at the intercostal space between the 4th and 5th ribs. The reference electrode (black) is place underneath the distal end of the left clavicle. Adapted from Linggo (2012).

Once the electrodes were successfully attached, the participant undertook the baseline and active phases of testing (see 2.4.1 for a detailed explanation of phases), whilst a concurrent ECG was recorded (Figure 21).

Figure 21 Labelled screenshot of the ECG recording

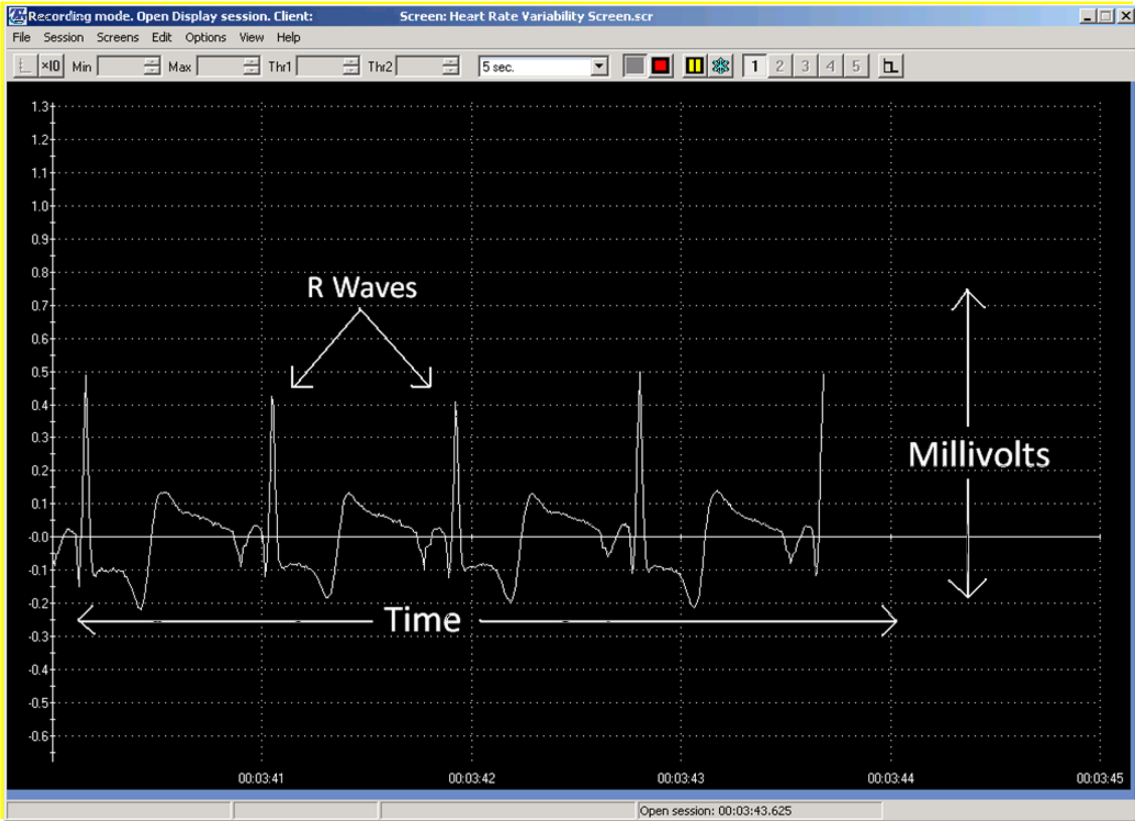


Figure 21 depicts a screenshot obtained during the baseline resting electrocardiogram using Biograph Infiniti software (Thought Technology Ltd, Canada), with labels indicating R waves against the time and millivolts axes. The clear R-R intervals are sufficient for accurate HRV analysis.

Key: ECG = Electrocardiogram; HRV = Heart rate variability

Initially, using the QRS detector, the pre-processing step of HRV analysis included band pass filtering to decrease power line noise, baseline wander, muscle noise and any other interference components. The pass band at approximately 5 – 30 Hz is sufficient to cover most of the frequency content of QRS complex. After this pre-processing had occurred, a set of decision rules were applied to define if a QRS complex had occurred. The decision rules included the average heartbeat period as well as the amplitude threshold, which were amended adaptively as the detection process continued. The fiducial point was selected to be the R-Wave, and the time at which the R-Wave occurs was logged. Post R-Waves identification, and time of R-Wave occurrence was determined, the HRV time series was derived. The R-R intervals were determined as the variances between successive R-Wave occurrence time periods. A power spectrum density (PSD) estimate was then used to calculate the R-R interval series. The PSD estimation is performed using the Fast Fourier Transform based Welch's periodogram method (Hann window was used). In the Welch's periodogram method, the HRV sample is separated into overlapping segments (50% overlap). The spectrum was then acquired by calculating the average spectra of these segments. This method reduces the amount of variance of the FFT spectrum. The frequency bands derived for short-term HRV recordings were low frequency (LF, 0.04 – 0.15 Hz) and high frequency (HF, 0.15 – 0.4 Hz). The absolute power values for each frequency band were derived through integration of the spectrum over the band limits.

Other HRV time domain methods, geometric measures and non-linear methods require lengthier recording sectors than 20 minutes (such as 24-hour readings) (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996, Heart Rate Variability: Standards of Measurement and Use, 1996) and thus were inappropriate to include in the analysis. HRV data is inherently skewed (Macfarlane et al., 2011). In order to ensure statistical validity, logarithmic transformations were applied to frequency parameters (LF, HF, LF/HF, TP) (Tarkiainen et al., 2005, Macfarlane et al., 2011).

2.4.3 Mood Scales

Affective and anxious states were assessed using a number of validated and reliable mood state questionnaires as detailed below.

2.4.3.1 Profile of Mood States Questionnaire

The Profile of Mood States questionnaire (POMS) (McNair et al., 1971) is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigour-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia and confusion-bewilderment scales minus the score on the vigour-activity scale. The depression-dejection subscale has been shown to be strongly predictive of the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996a), which is often used in clinical practice to diagnose depression. The depression-dejection subscale of the POMS is consequently considered a useful short alternative to the BDI-II, since it also investigates other components of mood such as anxiety and aggression (Griffith et al., 2005).

The POMS questionnaire is a subjective measurement of well-being and is an assessment of an individual's mood state during the previous week, including the day of participation. This questionnaire is a reliable, low cost, ergonomic mood state tool that has been highly validated by numerous previous studies (Norcross et al., 1984). The participant was asked to tick the box that corresponded to the intensity of each feeling stated, from "Not at all" to "Extremely" through a five-point progression from 0 to 4. For example, next to the feeling “Angry”, a participant may either mark “Not at all”, “A little”, “Moderately”, Quite a bit” or “Extremely”. After the completion of this questionnaire, the scores for each subscale, and a total mood disturbance score, were calculated. Table 8 displays the number of items included in each subscale of the Profile of Mood States Questionnaire and the possible ranges for each of these subscales. Numerous previous studies have utilised the POMS questionnaire to assess mood states within cohorts of professional divers (Xianglong et al., 2018, Feng et al., 2020, McGough, 2011, Angelika, 2018, Tamrin et al., 2014). Further, the POMS questionnaire has often been employed in studies assessing mood states and heart rate variability (Oldham, 2020, Fazackerley et al., 2019, Hattori et al., 2020, Farrow and Washburn, 2019, Bourdillon et al., 2021, Azam et al., 2019, Carrera Arias et al., 2019).

Table 8 The number of items included in each subscale of the Profile of Mood States Questionnaire and the possible ranges for each of these subscales

Subscale	Number of items	Range	Normative values (adult population)
Tension-anxiety	9	0 – 36	7.1 ± 5.8
Depression-dejection	15	0 – 60	7.1 ± 7.3
Anger-hostility	12	0 - 48	7.3 ± 5.9
Vigour-activity	7	0 - 32	7.5 ± 9.2
Fatigue-inertia	8	0 – 28	5.6 ± 4.1
Confusion-bewilderment	7	0 - 28	19.8 ± 6.8
Total Mood Disturbance	58	-24 to 177	14.8 ± 32.9

Table 8 summarises the six mood subscales of the Profile of Mood States questionnaire (McNair et al., 1971). Listed is the number of items in each mood subscale, the possible ranges for each of these subscales, and the normative data based on an adult population Nyenhuis, 1999

2.4.3.2 Beck Depression-Inventory II

The Beck Depression Inventory Scale (BDI-II) is a 21-item self-reported tool used to assess the severity of depression in adults and adolescents (aged >13) (Beck et al., 1996a). This tool is widely used in the psychiatric profession, and take approximately 5-10 minutes to complete (Ball et al., 1994). Scores range from 0-63, with 0-13 indicating minimal depression, 14-19 indicating mild depression, 20-28 indicating moderate depression and 29-63 indicating severe depression (Beck et al., 1996a). The coefficient alpha of the BDI-II was found to be 0.93, indicating high internal consistency. The test-retest correlation of the BDI-II was found to be 0.93, which was significant (p=<0.001). As such, the BDI-II is a suitable mood state tool for the assessment of depressive symptoms within this study. Although a multitude of studies have suggested different cut-off scores for depression, the normative data that will be used throughout this study comes from research by Sprinkle and associates, who determined the cut-off score to be 16 (Sprinkle et al., 2002). This cut-off score was determined to have a sensitivity rate of 84% and a false-positive rate of 18% in identifying depressed mood. Numerous previous studies have utilised the Beck Depression Inventory to assess mood states within cohorts of professional divers (da Silva-Júnior et al., 2009b, Miyata et al., 2018, Bulmash et al., 2006a, Vakili et al., 2010a, Kaul et al., 2019). Further, the Beck Depression Inventory has been frequently employed in research examining association between mood states and heart rate variability (Frasure-Smith et al., 2009, Karavidas et al., 2007, Pizzi et al., 2008, Su et al., 2010, Song et al., 2011, Walter et al., 2019, Gao et al., 2019, Lesnewich et al., 2019).

2.4.3.3 Beck Anxiety Inventory

The Beck Anxiety Inventory (Steer and Beck, 1997) is a 21 question, self-reported inventory that is utilized to assess anxious symptomology. It's internal consistency is high (alpha = .92) (Steer et al., 1993), and it is used clinically to assess true clinical anxiety, and reduce the overlap with depressive symptoms. A total score of 0 - 7 is interpreted as a "Minimal" level of anxiety; 8 - 15 as "Mild"; 16 - 25 as "Moderate", and; 26 - 63 as "Severe" (Steer and Beck, 1997).

2.4.4 Other Questionnaires

2.4.4.1 Lifestyle Appraisal Questionnaire

The Lifestyle Appraisal Questionnaire (LAQ) (Craig et al., 1996a), a validated and clinically reliable questionnaire, was used to record demographic, lifestyle and psychological stress information from participants. The LAQ consists of two parts, with Part I consisting of 22 questions, with the highest obtainable score being 73. This information included family history of disease, smoking status, alcohol intake, exercise and diet regime, etc. Items in Part I are scored for level of risk. Most item scoring ranges from 0 (little or no risk) to 4 (high risk) whilst some are dichotomous (yes/no). Higher scores are associated with higher risks of chronic disease. Part II of the LAQ consists of 27 items, each assessed on a four-point Likert scale ranging from 0 (almost never) to 3 (almost always) is used to assess the person's cognitive appraisal of life pressures and demands. Items are added directly, and high scores indicate higher perceived levels of stress (Craig et al., 1996a).

2.4.4.2 SmartData questionnaire

The SmartData questionnaire [29] provides demographical information regarding licensing, trucking history, employment status, nutrition, accident history and working conditions. This questionnaire was utilised as a basis for possible stratification of data, and to ascertain common conditions of truck driving in Australia. Following the administration of the SmartData questionnaire, the Likert Fatigue scale was completed.

2.4.4.3 Likert Fatigue Scale

The Likert scale is used to measure fatigue levels both prior and post the electrocardiogram (ECG) study [30]. The measure employs a rating scale of four points: not at all, slightly, moderately or markedly fatigued, and the participant circles the appropriate response, scored 0 – 3 respectively. The Likert scale of fatigue is scored 0 – 3 and produces a fatigue score (maximum score 3, with 0 indicating the participant is not at all fatigued, and 3 indicating marked fatigue). Fatigue has been shown to impact upon heart rate variability (HRV) and as such, this confounder is measured pre- and post-study to provide adequate information to allow for thorough identification of any areas of possible inter-individual variability.

2.5 Statistical methods

The data that was analysed within this study included:

- Lifestyle Appraisal Questionnaire (Craig et al., 1996)
- SmartData Questionnaire (Kavanagh, 2007)
- Profile of Mood States Questionnaire (McNair et al., 1971)
- Likert (fatigue levels) (Lal and Craig, 2002)
- Beck Depression Inventory (Beck et al., 1996b)
- Beck Anxiety Inventory (Beck et al., 1988a)
- Blood pressure and heart rate (HR) readings pre- and post-study
- ECG recording and subsequent HRV-parameters linked to active and baseline phases

2.5.1 Power analysis

Power analysis was applied to determine the minimum sample size required to produce statistically reliable data (Thomas and Krebs, 1997). The minimum sample size required to undertake a multiple regression with 8 predictors, based on moderate effect, was 108 (Cohen, 2013, Soper, 2015). Statistical power increases with increasing sample size (Lachin, 1981, Thomas and Krebs, 1997). As such, with a total sample size of 120, sufficient power for statistical analysis was obtained.

2.5.2 Statistical Analysis

The statistical analyses was conducted using the software program SPSS Version 22.0 (IBM Corp., Released 2013) and comprised of dependent sample t-tests, Pearson's correlations and regression analyses. Associations of significance are presented at a p value of <0.05. Detailed explanations of the statistical analysis performed are presented in the following subsections.

2.5.2.1 Dependent and Independent sample t-test

In this study, dependent sample t-tests were utilised to identify significant differences in heart rate and blood pressure data obtained both before and after the experimental session. Additionally, dependent sample t-tests were also used to assess the differences in HRV values between the baseline resting and active driving task. Further, independent sample t-tests were utilised to determine if there were significant differences in demographic variables, LAQ scores, POMS, BAI and BDI scores between the truck and train driving cohorts.

2.5.2.2 Pearson's Correlation

Pearson's correlation was applied to evaluate the relationship between mood states (derived from the part two of the LAQ, POMS questionnaire, BDI and BAI), lifestyle and workplace factors and BP and HRV data. A Pearson's correlation is used to assess the strength of the linear relationship between two variables, by producing an r (*rho*) value that ranges from -1 to 0. This value is indicative of the strength of the relationship between these two variables, with 0 indicating no relationship, and either -1 or 1 indicating a perfectly synchronised relationship. An r-value of 1 indicates that as one variable increases, the other variable increases by an identical amount. This is known as a direct relationship. Conversely, an r-value of -1 indicated that as one variable increases, the other decreases by an identical amount. This is known as an inverse relationship.

2.5.2.3 Regression analysis

In the present study, multiple regression analysis was used to identify the most significant predictors of cardiac health (assessed by BP and HRV) and negative mood states (assessed by POMS, BDI and BAI). Extrapolating from the correlations performed, if three or more significant predictors were associated with a dependent (cardiovascular) variable, regression analysis was applied in order to assess the strongest predictors of cardiovascular function. Linear regression models were used. BDI score was examined as a numerical value. Confounders (age, BMI, gender, smoking) were controlled for in correlation and regression models, as discussed in the methods. Regression analysis is used to examine the nature of the linear relationship between dependent and independent variables (Peacock and Peacock, 2011).

2.5.2.4 Bonferroni Correction

Bonferroni corrections were applied to all correlations where two or more independent variables were correlated to a dependant variable. The Bonferroni correction technique involves dividing the p-value by the number of variables being examined to make the p-value more conservative and reduces the risk of type 1 errors (false positives) (Bland and Altman, 1995). Three or more independent variables were required to fall equal to or less than the Bonferroni adjusted p-value to perform the linear regression. Correlations that did not fall equal to or below the Bonferroni-adjusted p value were not displayed in data tables.

Chapter Three – Results

The following is a summary of the main findings of the study. This section presents key findings related to the aims and hypotheses. Expanded results are presented in each of the published papers in the following chapters.

3.1 Subject Characteristics

A total of 60 truck drivers and 60 train drivers were recruited for the present study, aged 21-56. The following section reports on the epidemiological and physiological results that were obtained.

Table 9 depicts the general demographics for the truck drivers (n=60), train drivers (n=60), total sample (n=120).

Table 9 General characetristics for the truck drivers (n=60), train drivers (n=60), total sample (n=120).

	Truck Drivers (n=60)	Train Drivers (n=60)	Total Sample (n=120)
Age	35.8 ± 9.1	38.2 ± 10.1	37.0 ± 9.5
BMI	28.3 ± 3.4	28.9 ± 5.3	28.6 ± 4.3
% Male	91.67	95	93.34

Table 9 reports the mean values attained for age, body mass index and percentage male for all participants; truck drivers (n=60), train drivers (n=60) and total sample (n=120).

Key:
BMI: Body mass index
n: Sample size

The average age recorded for the truck driver sample was 35.8 ± 9.1 years, which was younger than the national average age of truck drivers (48 years) (Australian Government, 2017). The mean BMI was reported as 28.3 which is within the overweight category (25 – 30) (Heart Foundation of Australia, 2010). The present cohort of truck drivers was 91.67% males, which reflects the male dominance of the industry.

The average age recorded for the train driver sample was 37.0 ± 9.5 years, which was younger than the national average age of train drivers (41 years). The mean BMI was reported as 28.9 which is within the overweight category (25 – 30) (Heart Foundation of Australia, 2010). The present cohort of truck drivers was 95% males, which reflects the male dominance of the industry.

The average age recorded for the total sample was 35.8 ± 9.1 years, which was younger than the national average age of truck drivers (43 years). The mean BMI was reported as 28.6 ± 4.3 which is within the overweight category (25 – 30) (Heart Foundation of Australia, 2010).

The truck driving, train driving and total sample all reported a BMI within the overweight category, and a higher BMI than the national average for males, which is 27 (Cancer Council Victoria, 2012).

Using the LAQ, smoking status and frequency of smoking was recorded, and is presented in Table 10.

Table 10 Smoking rate for the present cohort of truck drivers (n=60), train drivers (n=60), total sample (n=120) and national percentage.

Smoking status	Truck drivers	Train drivers	Total sample	Australian population
No	57%	70%	63%	83%
Yes	43%	30%	33%	19%

Table 10 reports the percentage of the present cohort of truck drivers that were smokers, when compared with the percentage of the Australian population who presently smoke (AIHW, 2008a).

Within the present cohort, 43% of truck drivers, 30% of train drivers, and 33% of the total sample currently smoked cigarettes, when compared with the 19% of the Australian population who smoke (AIHW, 2008a).

3.2 Mood disturbances

3.2.1 Profile of Mood States

The mean test scores of each of the six respective mood subscales (tension-anxiety, anger-aggression, fatigue-inertia, depression-dejection, confusion-bewilderment and vigor-activity) of the POMS questionnaire, a total mood disturbance scores, along with the normative values (Nyenhuis et al., 1999) are listed in Table 11.

Table 11 The average scores attained for the six mood subscales, the total mood disturbance score in truck drivers (n=60), train drivers (n=60), total sample (n=120) and the normative values for an adult male sample (Nyenhuis et al., 1999).

Sub-scale	Truck Driver mean score	Train Driver mean score	Total Sample mean score	Normative values (Nyenhuis et al., 1999)
Tension-Anxiety	12.0 ± 5.5	7.3 ± 6.5	9.5 ± 6.5	7.1 ± 5.8
Anger-agression	10.1 ± 6.6	7.3 ± 7.8	8.7 ± 7.4	7.1 ± 7.3
Fatigue-inertia	11.7 ± 6.5	8.8 ± 6.3	10.3 ± 9.5	7.3 ± 5.7
Depression-dejection	13.5 ± 9.9	7.0 ± 7.7	10.3 ± 9.5	7.5 ± 9.2
Confusion-bewilderment	9.4 ± 5.0	4.6 ± 3.2	7.0 ± 4.9	5.6 ± 4.1
Vigor-activity	11.8 ± 5.7	16.6 ± 5.2	14.4 ± 5.9	19.8 ± 6.8
TOTAL MOOD DISTURBANCE	44.9 ± 28.4	18.4 ± 28.3	31.4 ± 31.9	14.8 ± 32.7

Table 11 presents the average test scores attained for the six mood subscales, the total mood disturbance score and the possible ranges and normative values (Nyenhuis et al., 1999).

For the truck driving sample, the highest mean scores attained of the six possible mood subscales were the depression-dejection subscale (13.5 ± 9.9) followed by vigour-activity (11.8 ± 5.7) and fatigue-inertia (11.7 ± 6.5). The mean test score attained for the total mood disturbance score was 44.6 ± 32.0.

For the train driving sample, the highest mean scores attained for the six possible mood subscales were the vigor-activity subscale (16.6 ± 5.2) followed by fatigue-inertia (8.8 ± 6.3). The mean test score attained for the total mood disturbance score was 16.5 ± 25.6.

Tension-anxiety (p=<0.001), anger-aggression (p=0.002), fatigue-inertia (p=0.001), depression-dejection (p=<0.001), confusion-bewilderment (p=0.023) and total mood disturbance (p=<0.001) were all significantly higher in the truck driving sample than the train driving sample. Further, all negative mood states in the truck driving sample were higher than the normative data (Nyenhuis et al., 1999).

3.2.2 Beck Depression Inventory

The mean BDI-II test score for the truck (n=60), train (n=60) and total sample (n=120) are presented in Table 12, along with the cut-off for mild to moderate depression (Beck et al., 1996b). 31.6% of truck drivers (n=19) and 11.7% of train drivers (n=7) scores above the cut-off for mild to moderate depression (Beck et al., 1996b).

Table 12 Beck Depression Inventory scores for the truck drivers, train drivers and total sample.

	Truck Drivers (n=60)	Train Drivers (n=60)	Total Sample (n=120)	Cut-off for mild to moderate depression (Beck et al., 1996b)
BDI Score	12.2 ± 9.3	7.5 ± 5.6	9.7 ± 7.9	10

Truck drivers reported significantly higher scores on the BDI than both the train driving sample ($p<0.001$) and higher scores than the advised cut-off score for mild to moderate depression (Beck et al., 1996b).

3.2.3 Beck Anxiety Inventory

The mean BAI test score for the truck (n=60), train (n=60) and total sample (n=120) are presented in Table 13, along with the cut-off for mild anxiety (Beck et al., 1988a). 38% of truck drivers (n=23) and 18% of train drivers (n=11) scored above the cut off for mild anxiety.

Table 13 Beck Anxiety Inventory scores for the truck drivers, train drivers and total sample.

	Truck Drivers (n=60)	Train Drivers (n=60)	Total Sample (n=120)	Cut-off for mild anxiety (Beck et al., 1988a)
BAI Score	11.2 ± 9.6	7.5 ± 5.6	4.3 ± 4.1	8

Truck drivers reported significantly higher scores on the BAI than both the train driving sample ($p<0.001$) and higher scores than the advised cut-off score for mild anxiety (Beck et al., 1988a).

3.3 Cardiac parameters

3.3.1 Blood pressure

BP was recorded before and after the study for each volunteer. Table 14 reports the mean pre- and post-study systolic BP, diastolic BP and HR for the truck (n=60), train (n=60) and total sample (n=120).

Table 14 The mean pre and post study blood pressure and heart rate for each sample group.

		Truck Drivers (n=60)	Train Drivers (n=60)	Total Sample (n=120)
Pre-study	**SBP (mmHg)**	135.9 ± 13.0	123.5 ± 10.8	128.8 ± 12.7
	DBP (mmHg)	82.7 ± 6.4	78.7 ± 7.6	80.4 ± 7.3
	HR (bpm)	70.7 ± 6.8	71.8 ± 10.6	71.2 ± 9.0
Post-study	**SBP (mmHg)**	139.8 ± 12.4	125.5 ± 11.0	129.9 ± 12.1
	DBP (mmHg)	87.4 ± 5.7	79.9 ± 6.8	81.1 ± 7.0
	HR (bpm)	72.9 ± 8.6	71.2 ± 10.2	71.8 ± 9.2

Table 14 reports the sample means for the pre and post study blood pressure and heart rate readings.

Key:
DBP: Diastolic blood pressure
HR: Heart rate
SBP: Systolic blood pressure
SD: standard deviation
mmHg: millimeters mercury
bpm: beats per minute

Using an independent sample t-test, it was found that truck drivers exhibited signifcantly higher pre ($p<0.001$) and post ($p<0.001$) SBP than the train driving sample. It was also found that truck drivers exhibited signifcantly higher pre ($p=0.01$) and post ($p=0.003$) DBP than the train driving sample.

3.3.2 Heart rate variability

3.3.2.1 Baseline phase

The mean HRV (LF, HF, TP and LF:HF) for the truck (n=60), train (n=60) and total sample (n=120) during the baseline phase is displayed in Table 15. Refer to methods section 2.4.1 for detailed description of the baseline laboratory setup.

Table 15 Mean HRV parameters for truck, train and total sample during the baseline task.

HRV parameter	Truck Drivers (n=60)	Train Drivers (n=60)	Total Sample (n=120)
LF (ms^2)	3.0 ± 2.8	3.5 ± 3.8	3.2 ± 3.2
HF (ms^2)	2.6 ± 2.6	3.2 ± 3.7	2.9 ± 3.3
Low Total power (ms^2)	3.5 ± 3.3	3.8 ± 4.2	3.7 ± 3.8
LF:HF	1.6 ± 0.4	1.1 ± 0.5	1.4 ± 0.5

Table 15 depicts the mean HRV parameters (low frequency, high frequency, total power) for the baseline task.

Key:
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
ms^2: Milliseconds squared

Truck drivers were found to have significantly higher sympathovagal balance (LF:HF) than the train driving sample (p=0.002). Total power was also found to be significantly lower in the truck driving sample than the train driving sample (p=0.03).

Partial correlations, when controlling for gender, smoking status, age and BMI, were undertaken to assess associations between baseline HRV parameters, depression-dejection scores and BDI scores are displayed in Table 16 (truck drivers) and Table 17 (train drivers).

Table 16 Correlations between Depression scores (Depression-dejection and BDI) and HRV parameters in cohort of truck drivers (n=60) during a baseline task.

	HRV parameter	r	p
Depression-Dejection	**LF**	0.34	0.043
	HF	0.35	0.036
	TP	0.35	0.038
	Ratio	0.43	0.009
BDI	**LF**	0.09	0.57
	HF	0.08	0.51
	TP	0.07	0.58
	Ratio	0.23	0.11

Table 16 displays depression-dejection and BDI correlations with HRV parameters during the baseline phase in truck drivers. Statistically significant correlations are seen in red.

Key:
BDI: Beck Depression Inventory
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
TP: Total HRV power
p: Level of statistical significance
r: Correlation coefficient

A number of statistically significant correlations between depression scores and HRV parameters (seen in red) were identified during the baseline task in truck drivers. Depression-dejection (as measured by the POMS) was found to be correlated with all HRV parameters. No signifcant correlations were identified between the BDI and HRV parameters.

Table 17 Correlations between Depression scores (Depression-dejection and BDI) and HRV parameters in cohort of train drivers (n=60) during a baseline task.

	HRV parameter	r	p
Depression-Dejection	**LF**	0.05	0.71
	HF	0.03	0.81
	TP	0.59	0.000
	Ratio	0.13	0.34
BDI	**LF**	0.13	0.36
	HF	0.14	0.37
	TP	0.41	0.02
	Ratio	0.17	0.23

Table 17 displays depression-dejection and BDI correlations with HRV parameters during the baseline phase in train drivers. Statistically signifiant correlations are seen in red.

Key:
BDI: Beck Depression Inventory
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
TP: Total HRV power
p: Level of statistical significance
r: Correlation coefficient

A number of statistically significant correlations between depression scores and HRV parameters (seen in red) were identified during the baseline task in train drivers. Depression-dejection (as measured by the POMS) was found to be correlated with total power (r = 41, p = 0.02). The BDI was found to be correlated with total power (r = 0.59, p = <0.001).

3.3.2.2 Active phase

The mean HRV (LF, HF, TP and LF:HF) for the truck (n=60), train (n=60) and total sample (n=120) during the active phase is displayed in Table 18. Refer to methods section 2.4.1 for detailed description of the active laboratory setup.

Table 18 Mean HRV parameters for truck, train and total sample during the active task.

HRV parameter	Truck Drivers (n=60)	Train Drivers (n=60)	Total Sample (n=120)
LF (ms^2)	3.4 ± 3.1	3.5 ± 3.8	3.4 ± 3.5
HF (ms^2)	3.0 ± 3.4	3.5 ± 4.0	3.2 ± 3.7
Low Total power (ms^2)	3.6 ± 3.8	4.0 ± 4.4	3.8 ± 4.0
LF:HF	1.2 ± 0.3	1.0 ± 0.7	1.1 ± 0.5

Table 18 depicts the mean HRV parameters (low frequency, high frequency, total power) for the active task.

Key:
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
ms^2: Milliseconds squared

Truck drivers were found to have significantly lower HF than the train driving sample (p=0.001). Total power was also found to be significantly lower in the truck driving sample than the train driving sample (p=0.004).

Partial correlations, when controlling for gender, smoking status, age and BMI, were undertaken to assess associations between baseline HRV parameters, depression-dejection scores and BDI scores are displayed in Table 19 (truck drivers) and Table 20 (train drivers).

Table 19 Correlations between Depression scores (Depression-dejection and BDI) and HRV parameters in cohort of truck drivers (n=60) during an active task.

	HRV parameter	r	p
Depression-Dejection	**LF**	0.18	0.19
	HF	0.17	0.22
	TP	0.004	0.98
	Ratio	0.25	0.075
BDI	**LF**	0.28	0.048
	HF	0.24	0.08
	TP	0.04	0.79
	Ratio	0.33	0.02

Table 19 displays depression-dejection and BDI correlations with HRV parameters during the active phase in truck drivers. Statistically signifiant correlations are seen in red.

Key:
BDI: Beck Depression Inventory
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
TP: Total HRV power
p: Level of statistical significance
r: Correlation coefficient

A number of statistically significant correlations between depression scores and HRV parameters (seen in red) were identified during the active task in truck drivers. BDI score was found to be low frequency heart rate variability (r = 0.28, p = 0.048) and ratio (r = 0.33, p = 0.02).

Table 20 Correlations between Depression scores (Depression-dejection and BDI) and HRV parameters in cohort of train drivers (n=60) during an active task.

	HRV parameter	r	p
Depression-Dejection	**LF**	0.26	0.73
	HF	0.45	0.001
	TP	0.46	0.001
	Ratio	0.31	0.029
BDI	**LF**	0.17	0.23
	HF	0.17	0.23
	TP	0.22	0.13
	Ratio	0.21	0.14

Table 20 displays depression-dejection and BDI correlations with HRV parameters during the active phase in train drivers. Statistically signifiant correlations are seen in red.

Key:
BDI: Beck Depression Inventory
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
TP: Total HRV power
p: Level of statistical significance
r: Correlation coefficient

A number of statistically significant correlations between depression scores and HRV parameters (seen in red) were identified during the active task in train drivers. Depression-dejection (as measured by the POMS) was found to be correlated with high frequency (r = 0.45, p = 0.001), total power (r = 0.46, p = 0.001) and sympathovagal balance (ration) (r = 0.31, p = 0.029). No signifcant correlations were identified between the BDI and HRV parameters.

3.2.3.3 Comparisons between baseline and active HRV

Comparison between baseline and active mean HRV (LF, HF, TP and LF:HF) for the truck (n=60) and train (n=60) driving sample is displayed in Tables 15 and 16.

Table 21 Comparison between baseline and active HRV for the truck driving sample (n=60).

	Baseline	Active	p
LF (ms^2)	3	3.4	0.024
HF (ms^2)	1.8	3	0.013
Total power (ms^2)	3.5	3.6	0.215
LF:HF	1.6	1.2	0.029

Table 21 present a comparison between baseline and active HRV in the truck driving sample (n=60).

Table 22 Comparison between baseline and active HRV for the train driving sample (n=60).

	Baseline	Active	p
LF (ms^2)	3.5	3.5	0.982
HF (ms^2)	3.2	3.5	0.974
Low Total power (ms^2)	3.8	4	0.086
LF:HF	1.1	1	0.327

Table 21 present a comparison between baseline and active HRV in the train driving sample (n=60).

This results section provides a brief overview of the findings of the present study. A more comprehensive analysis of findings can be found in each of the individual results chapter papers.

Chapter Four – Discussion Papers

4.1 Affective States in Professional Drivers

As discussed in section 1.1, professional drivers in Australia experience a myriad of workplace factors that result in these individuals being viewed as depression vulnerable. The following chapter comprises of original research articles based on the prevalence of negative mood states within a population of Australian truck and train drivers. All of the following articles are published in press, have been accepted, or are currently under review.

4.1.1 Depression in Professional Truck drivers – Short Communication

Under Review – Workplace Health and Safety

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The purpose of this review was to elucidate the incidence of depression or depressive symptomology among individuals employed as professional truck drivers. At present, no review has been conducted to explore the prevalence of depression within this occupational group. The aim of this review was to first, identify previous literature that has reported the incidence of depression within this industry, and second, to identify gaps in literature which may provide the basis for future research. This review encompasses a number of subject areas, including the unique workplace conditions within this occupational field, the unique male dominance of this industry and its impacts upon appropriate access to medical services for affective disorders, and the consistently reported high levels of depression within this largely unexplored occupational population. This review will provide critical discussion of previous literature concerning depression within this industry, with the discussion geared towards emphasising the need for future directions and studies, as well as provide insights into the unique workplace conditions that may contribute to high levels of depression within this industry.

Introduction

Many countries rely on heavy vehicles for the transportation of good and services between metropolitan hubs. The industry is a vital contributor to all aspects of logistics and transportation and can be a key determinate in a nation's economic development. Recently, Boyce suggested that the health and wellbeing of truck drivers deserved more attention, due to a number of reasons including inefficient or ineffective supply chains, a shortage of truck drivers due to the perceived negative health effects associated with the industry, and the consistently high rates of illness and injury within this field (Boyce, 2016a). The health of these truck drivers is not only important for drivers themselves, but also for ensuring safe work practices, public safety and efficient operational functioning. Often, the physiological health of drivers is well quantitated and reported; however, to date the mental health of professional heavy vehicle drivers remains poorly investigated. It is well understood that workplace conditions can have adverse effects on mental health (Huntington et al., 2008). Despite a shifting perception in the understanding, awareness and acceptance of mental health issues within the collective social psyche, it has been shown that males are less likely to divulge information that may infer vulnerability (Courtenay, 2000b, Courtenay, 2000a). The heavy vehicle trucking industry is largely male dominated, which when considered alongside the paucity of literature regarding mental health in this field, is of concern, considering that males are less likely to seek appropriate medical advice regarding mental illness. The focus of this review is the affective disorder depression within the occupational fields of heavy vehicle truck and train driving.

Depression

Depression is defined by The World Health Organisation (WHO) as a mood disorder that manifests with depressed moods, feelings of reduced self-esteem, impaired sleep, altered appetite, reduced energy and impaired concentration, and is a pressing global health issue (World Health Organisation, 2012). Depressive disorder is the leading cause of disability worldwide when assessed using Years Lived with Disability (World Health Organisation, 2012). In 2000, depression was the fourth greatest contributor to the global burden of disease, and it has been predicted that by the year 2020, it will be the second greatest contributor to this burden (World Health Organisation, 2012). Depression affects approximately 350 million individuals worldwide and studies have shown that without effective treatment, depressive symptoms will reoccur in 50% of individuals (Bear et al., 2007).

Depression and driver performance

Motor vehicle accidents have been identified as a leading cause of disability and premature mortality worldwide (World Health Organisation, 2009). Direct empirical evidence has identified numerous factors that may have a contributory impact on motor vehicle accidents risk, however the effects of mental illnesses, such as depression, on driving ability and risk, have received limited attention.

A 2006 study assessed 4,448 Norwegian drivers who had reported a motor vehicle accident to their insurance company (Sagberg, 2006). The study assessed the relative crash involvement risk associated with diagnosed medical conditions, based on a self-reported questionnaire. Relative risk was derived by comparing the odds of the driver being at fault, with the presence or lack of various medical conditions. When adjusted for age and annual driving distance, the study found that drivers who reported feeling depressed had an increased odds ratio (OR=2.43) of being at fault in the accident. This indicated that drivers suffering from depression had a 2.5 times increased likelihood of being at fault in a motor vehicle accident than other drivers who reported no depression. The limitations of the study, however, were that the self-reported questionnaire was completed several months after the accident and required participants to retrospectively report the presence of depression. Furthermore, the response rate was only 30%, which may lend itself to some reporting bias.

Hilton and associates conducted a survey of Australian heavy vehicle drivers, assessing the correlation between the presence and severity of depression and driver performance (Hilton et al., 2009a). The study found that severe and extremely severe depressive symptomology was associated with a four times greater risk (OR=4.4) of being involved in an accident whilst driving.

Similarly, Bulmash and colleagues (Bulmash et al., 2006b) conducted a simulation study, in which the simulated driving performance of 29 control and 18 out-patients diagnosed with Major Depressive Disorder were compared in driving performance. Compared to the control group, the study determined that after controlling for age and sleepiness, the unmedicated out-patient group demonstrated reduced steering reaction time and an increased number of accidents.

A case-control study by Meuleners (2015) examined health conditions of 100 Australian heavy vehicle truck drivers who were involved in an accident during the study period, versus 100 heavy vehicle truck drivers who were not involved in an accident in the previous year. The study found that drivers who had reported being diagnosed with depression were almost seven times as likely to have been involved in a crash as those who had not (OR=6.59).

Collectively this evidence suggests that the driving performance of individuals suffering from depression may be negatively impacted. Research suggests that these individuals exhibit slower reaction times and problems with commonplace vehicular tasks such as divided attention.

Depression: impact on economics in the workplace

A recent Australian PricewaterhouseCoopers report estimated that Australian businesses will lose $10.9 billion each year for failing to appropriately manage mental health issues in the workplace (PricewaterhouseCoopers. beyondblue, 2014). However, corporations that take steps to manage mental health will, on average, see a return of $2.30 for every $1 invested in initiatives that promote improved mental health in the workplace. The transport industry was found to have an even higher return, with an average of $2.80 returned for every $1 invested (PricewaterhouseCoopers. beyondblue, 2014). Mental health in the workplace is not unique to Australia, with over 350 million individuals worldwide suffering from depression (World Health Organisation, 2012). In the US, lost productivity due to depression costs between $31-$52 billion annually (Stewart et al., 2003, Greenberg et al., 2003).

Workplace risk factors for depression

Truck drivers are regularly exposed to unique workplace conditions including long working hours, intermittent work/rest cycles, low job satisfaction (Ulhoa et al., 2010), workplace solitude, shift work, fatigue (Sabbagh-Ehrlich et al., 2005) and extreme occupational pressure. These commonplace occupational stress factors can result in individuals within this industry being viewed as a depression vulnerable population. Long working hours have recently been implicated in the development of depression, with a study conducted by Virtanen and colleagues (2012) assessing employees who worked for greater than 11 hours each working day. The study found that those workers who were employed for more than 11 hours each day had a significantly higher OR of developing depression (2.52 compared to 1.0). It has been estimated that up to 26% of rotating shift workers will develop shift work disorder (Drake et al., 2004), which in turn, has been shown to increase the risk of developing depression (Kalmbach et al., 2015). Overall, studies have shown that shift workers report poorer mental health and reduce quality of life (Axelsson et al., 2004, Bambra et al., 2008, Bjorvatn et al., 2012).

Depression in the professional truck driving industry

A study conducted in 2001, of 91 male truck drivers in Australia, used the Major Depression Inventory (Bech et al., 2001) to assess typical symptoms depression and the Externalising Symptoms Scale (adapted from the Masculine Depression Scale (Magovcevic and Addis, 2008)) to assess atypical depression symptoms. The study found that 21.97% of drivers met the retrospective criteria for a major depressive episode.

Wong and associates conducted a cross-sectional survey of 193 cross-border (China and Hong Kong border) truck drivers in 2004 (Wong et al., 2007). The study employed a 47-item multifaceted questionnaire and found that 14.51% reported feeling depressed.

A recent study by Hilton and his team (2009a) assessed 1324 Australian heavy goods vehicle drivers for symptoms of psychological distress. The study used the well validated Depression, Anxiety and Stress Scale (Lovibond and Lovibond, 1995) to assess negative emotional states of depression, anxiety and stress. Using this scale, the study found that 13.3% of Australian heavy vehicle truck drivers exhibited some form of depression (mild (5.6%), moderate (4.4%), severe (1.5%) or extremely severe (1.8%).

Comparably, da Silva-Junior (2009) conducted a descriptive-exploratory, cross-sectional investigation examining risk factors for depression in truck drivers in Fortaleza, Brazil. The study assessed 300 licensed truck drivers after a minimum period of 12 hours rest. The study used the Major Depressive Episode section of the Mini International Neuropsychiatric Interview, and the Beck Depression Inventory Short Form to assess the incidence of depression. Statistical analysis revealed that 13.6% of the truck drivers exhibited depression. The study also found that truck drivers who were “wage earners” had a significantly increased odds ratio (OR) of developing depression than those who were considered “self-employed” (2.72 compared to 1.0 respectively). Multivariate analysis indicated that use of stimulants, low level of education and low wages, increased the risk for depression.

Vakili and team conducted a cross-sectional study of 400 male truck drivers in Yazd Province, Iran (Vakili et al., 2010b). The study used the Beck Depression Inventory Short Form to assess the prevalence of depression amongst the sample. The study found that 70.3% of drivers exhibited some form of depression, with 14.8% reporting major depression, 25.4% reporting moderate depression and 30.1% reporting mild depression.

A population based random-digit-dialled survey of non-institutionalised Washington States workers ages 18 years and older was conducted in both 2006 and 2008 (Fan et al., 2012). The study used the Patient Health Questionnaire 8 (Kroenke et al., 2009) to measure current depression, and the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (American Psychiatric Association, 1994). 20.560 Washington State workers were surveys, being stratified into 20 occupational groups. Of the 153 truck drivers assessed, 11.9% reported current depression.

Shattell and associates (2012a) undertook a quantitative, cross-sectional, descriptive study to assess mental health disorders within a sample of 316 male truck drivers in North Carolina. The study employed the Healthy Trucker Survey (Apostolopoulos and Sonmez, 2010) to assess eight sections, including; “demographics, professional history, health, substance use, work, health care access and treatment history, attitudes toward health, and health information and promotion” (2012a). The study found that 26.9% of the truck drivers assessed reported either past or current depression.

A case-control study of 100 long-haul heavy vehicle drivers who were involved in a police reported crash in Western Australia, and 100 long haul heavy vehicle drivers recruited from Western Australia truck stops, who were not involved in a crash in the previous year was conducted by Meuleners and associates (2015). The study found that 12% of the case drivers, and 3% of the control drivers reported depression as diagnosed by a doctor under self-reported health conditions.

Conclusion

A major concern is the paucity of literature regarding the incidence of depression in the truck driving industry. The aforementioned impacts of depression on driving performance, and the high rates of depression reported amongst truck drivers in the few studies that have been conducted present a worrying snapshot of the industry at large. The consistency of high rates of depression within a truck-driving sample spans many countries, indicating that this is a ubiquitous global issue. This collective evidence suggests a significant health issue, when the number of trucks on roads worldwide, the possibility of high rates of undiagnosed depression in this male dominated occupational field and the social and economic burden of heavy vehicle road accidents are considered. Collectively, the few studies that have assessed the prevalence of depression amongst truck drivers have found consistently high rates of this mental illness. In order to adequately address and manage this debilitating mental illness, further research is warranted.

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4.1.2 Prevalence of affective states in Australian Truck and Train Drivers

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Abstract

Within this exploratory preliminary study, data is presented regarding the prevalence of specific mood states within a sample of Australian truck and train drivers. A total of 49 heavy vehicle truck drivers and 58 train drivers were recruited from the local community. Subjects completed a mood state questionnaire. Numerous mood states (tension-anxiety, depression-dejection, anger-aggression, fatigue-inertia, confusion-bewilderment and total mood disturbance score) were found to be significantly higher ($p<0.05$) in the truck-driving sample than the train driving sample, and higher than the advised normative values.

Keywords

Depression, Truck driving, Train driving, Mental illness, Mood states

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Introduction

The professional driving industry plays a vital role in the movement of people and goods and in the prosperity of Australia. A combination of extensive distances between industries and a low population density has resulted in a large reliance upon road and rail freight. Occupational conditions within Australia's heavy vehicle and train driving industries are often comparable, frequently requiring both physiological and psychological demands. Long hours spent sitting, workplace isolation, sporadic rest and work cycles, monotonous driving conditions, the pressure to meet delivery schedules and the need for continuous alertness are some of the common inherent occupational demands of these two industries, some of which may contribute to impaired driver health. Mood or affective disorders such as depression have been frequently reported in overseas epidemiological studies of mental health within the professional driving industries (da Silva, 2009), however the paucity of literature regarding the incidence of depressive symptomology within an Australian sample of professional drivers is concerning. Depression has been increasingly correlated to a reduction in driver performance, with recent studies having found that severe and extremely severe depression in truck drivers resulted in a significantly increased odds ratio (4.4 and 5.0 respectively) for an accident or near miss (Hilton, 2009). Studies have also found links between self-reported negative mood states and electroencephalography fatigue indicators (Lal, 2002). It is important to ascertain accurate statistics regarding the incidence of depression and other negative mood states within these professional drivers in order to provide the foundation for the improved management of these illnesses within these occupational fields.

There is an increased incidence of the affective disorder, depression within the professional driving industry. A study conducted by Hilton and associates (Hilton,

2009) found that 13.3% of Australian heavy vehicle truck drivers demonstrated at least a mild form of depression (as measured by the Depression, Anxiety and Stress Scale (Lovibond, 2002) in contrast to the national rate of 11.6% (World Health Organisation, 2009). In comparison, a study by da Silva-Junior and team (da Silva, 2009) found that 13.6% of the truck drivers (n=300) suffered from depression (as diagnosed through the section Major Depressive Episode in the Mini International Neuropsychiatric Interview (Sheehan, 1998). Supporting this, Wong and team found that 14.5% of truck drivers felt more depressed once commencing work within the truck driving industry (Wong, 2007). Recently, work stress has been heavily implicated as an independent predictor of depression (Wang, 2005). The common workplace conditions mentioned previously imply that truck drivers can be viewed as a depression vulnerable population. Furthermore, the association of long working hours with increased incidence of depression has been supported by a study by Virtanen and colleagues which found that working more than 11 hours per day demonstrated an increased odds ratio for developing depressive symptomology (Virtanen, 2012).

Despite the previously mentioned, well-documented high rates of depression amongst professional truck drivers, at present, there have been few epidemiological studies regarding the presence and effects of depression within truck and train drivers in Australia. Although a National Standard for Health Assessment of Rail Workers (National Transport Commission, 2012) has been implemented within the rail industry, which assesses psychological disorders amongst a range of health conditions, the true prevalence of depression within this industry remains somewhat unclear. With train drivers in Australia frequently subjected to comparable working conditions to that of truck drivers (such as long working hours, monotonous driving conditions, etc.), it would stand to reason that there may be an elevated risk of depression in both professions. As such, elucidating the rates and effect of depression in drivers within these transport industries is an important safety issue in Australia.

In Australia, rail suicide accounts for 6-8% of the nation's death by suicide, totalling approximately 150 rail-related deaths per annum (Lifeline, 2012). Witnessing rail-suicide is a serious issue that has been known to result in extreme psychological distress that can progress into a number of psychological conditions such as depression (Cothereau, 2004). A study conducted by Cothereau and associates in France (Cothereau, 2004) assessed 388 train drivers, either those having been exposed ($n=202$) or not-exposed ($n=186$) to a rail suicide whilst operating a train. The study found that those individuals in the exposed cohort had significantly higher rates of post-traumatic stress symptoms ($p<0.0001$), somatic symptoms ($p<0.0001$), anxiety and insomnia ($p<0.001$). A total of 1.5% of the assessed drivers exhibited severe depression; with other affective disorders also being observed, such as generalised anxiety disorder (4.0%), dysthymia (1.0%), panic disorder (0.5%) and manic episodes (0.5%). Collectively, these findings provide a unique insight into the acute occupational stressors encountered by train drivers, and the psychological effects of these stressors. Another study, assessing the psychological health of train drivers, conducted by Loukzadeh and associates (Loukzadeh, 2013), found that 15% of the 152 train drivers assessed exhibited scores of greater than 19 on the Kessler Psychological Distress Scale (Anderson, 2013), indicating that they were likely to have a mild, moderate or severe mental disorder. Although this study did not assess depression specifically, it does provide some evidence for the impaired psychological health of individuals within this field.

When we consider the acute and chronic effects of depression on the quality of life of an individual, it is clear that elucidating the true prevalence of affective disorder within the rail and truck industries is vital to preserving the health of drivers in these industries. The effect of managing depression in these drivers would not only benefit the drivers but will also be beneficial to employers who employ these drivers. A recent PricewaterhouseCoopers report estimated that Australian businesses will lose $10.9 billion annually for neglecting to address mental health in the workplace (PricewaterhouseCoopers, 2014). However, businesses that take action will, on average, experience a return of $2.30 for every $1 invested in initiatives that promote improved mental health in the workplace. The transport industry boasts an even higher return, with an average of $2.80 returned for every $1 invested (PricewaterhouseCoopers, 2014).

However, of concern is the scarcity of studies regarding depression in the trucking and train driving industries in Australia. Aside from the aforementioned study conducted by Hilton and associates (Hilton, 2009), the rate of depression in Australian heavy vehicle drivers has been somewhat overlooked. Of further concern are the statistics regarding the adverse effects of depression on driver performance. Furthermore, the likelihood of seeking appropriate medical advice for the management of depression in Australia is disturbing; with a recent Australian Bureau of Statistics survey finding that only 35% of Australians who had experienced a mental illness in the prior 12-month period had sought to access appropriate medical assistance. Despite a higher incidence of depression amongst females when paralleled with males in Australia (14.5% and 8.8% respectively), (Australian Bureau of Statistics, 2007), a well-established social perception, which discourages males from seeking medical assistance, has resulted in lower diagnostic rates of affective disorders among males (Klint, 2004). Due to the severe gender bias of the truck and train driving industries, an underlying incidence of undiagnosed affective disorders may be present, supporting the investigation of this mental disorder within drivers in this occupation.

Therefore, the aim of the present exploratory, preliminary study was to assess the presence of mood (affective) states within the Australian trucking and train driving community. By understanding and evaluating the presence and effect of depression in the Australian truck and train driver community, we would be able to provide the quantitative information required for management practices geared towards reducing the effects of these disorders on driving ability, and thus, contribute towards improving road safety in Australia, as well as extrapolate the benefit internationally.

Methods

Participants

A total of 60 truck drivers (mean age 36.5 ± 9.67, n=45 males, n=4 females) and 60 train drivers (mean age 39.16 ± 10.51, n=53 males, n=5 females) were recruited. Participants were recruited through local advertisement via a poster, recruitment through contacts established independently to this research, online forums and with the aid and endorsement of Australia Post Transport Division, Sydney Trains and the Australian Trucking Association. Participants were required to be employed as a truck driver, regularly driving a truck with a gross vehicle mass of over 4.5 tonne, or a currently employed train driver.

Procedure

The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions being posed. Upon receipt of written consent, the study was commenced. The following questionnaires were administered in the study.

SmartData questionnaire

The SmartData questionnaire (modified from a questionnaire developed in-house (Kavanagh, 2007) helps obtain demographical information regarding licensing, trucking history, employment status, nutrition, accident history and working conditions. This questionnaire was utilised as a basis for possible stratification of data, and to ascertain common conditions of professional driving in Australia.

Profile of Mood States questionnaire

The Profile of Mood States questionnaire (POMS) (McNair, 1971) is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigour-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia and confusion-bewilderment scales minus the score on the vigour-activity scale. The depression-dejection subscale has been shown to be strongly predictive of the Beck Depression Inventory-(BDI-II) (Beck, 1996), which is often used in clinical practice to diagnose depression. The depression-dejection subscale of the POMS is consequently considered a useful short alternative to the BDI-II, since it also investigates other components of mood such as anxiety and aggression (Griffith, 2005). The POMS questionnaire is a subjective measurement of well-being and is an assessment of an individual's mood state during the previous week, including the day of participation. This questionnaire is a reliable, low cost, ergonomic mood state tool that has been highly validated by numerous previous studies (Norcross, 1984). The participant was asked to tick the box that corresponded to the intensity of each feeling stated, from “Not at all” to “Extremely” through a five-point progression from 0 to 4. For example, next to the feeling “Angry”, a participant may either mark “Not at all”, “A little”, “Moderately”, Quite a bit” or “Extremely”. After the completion of this questionnaire, the scores for each subscale, and a total mood disturbance score, were calculated. Normative values for the POMS questionnaire were obtained from a study conducted by Nyenhuis and associates which prepared normative adult values using a sample of 400 individuals (Nyenhuis, 1999), who were age-, gender-, and race-stratified according to 1990 census data.

Results

Using independent sample t-tests, it was ascertained that the train and truck driving samples were age ($p = 0.12$) and body mass index (BMI) matched ($p = 0.28$) (Table 1).

Table 1. Descriptive statistics of current sample

Sample Group	Mean BMI	Mean Age (years)
Train Drivers	29.1 ± 4.86	39.16 ± 10.51
Truck Drivers	28.5 ± 3.40	36.50 ± 9.67

BMI = Body mass index (weight (kilograms)/height (m2))

Truck drivers presented significantly higher levels of negative mood states than train drivers (Table 2). Tension-anxiety (p = <0.0001), anger-aggression (p = 0.004), fatigue-inertia (p = 0.023), depression-dejection (p = <0.0001), confusion-bewilderment (p = <0.0001) and total mood disturbance (p = <0.0001) were all significantly higher in the truck driving sample than in the train driving sample. It should also be noted that through single sample t-tests, it was ascertained that scores were higher for all negative mood states and lower for vigour activity in the truck driving sample than the advised normative values (Nyenhuis, 1999). The train driving sample presented scores comparative to normative values for all mood states, other than confusion-bewilderment and vigour-activity, which were significantly lower than advised normative values.

Table 2. The average scores attained for the six mood subscales, the total mood disturbance score in truck (n=49) and train drivers (n=58) and normative values.

Sub-scale	Truck driver mean score	Train driver mean score	Normative values (adult population)
Tension-anxiety	12.8 ± 5.4*#	7.2 ± 6.3	7.1 ± 5.8
Anger-aggression	10.2 ± 6.3*#	7.0 ± 7.1	7.1 ± 7.3
Fatigue-inertia	13.0 ± 6.4*#	8.3 ± 6.2	7.3 ± 5.9
Depression-dejection	15.3 ± 10.2*#	6.9 ± 7.3	7.5 ± 9.2
Confusion-bewilderment	10.0 ± 4.9*#	4.4 ± 3.1#	5.6 ± 4.1
Vigour-activity	11.1 ± 5.3*#	17.1 ± 4.7#	19.8 ± 6.8
Total Mood Disturbance	50.2 ± 27.5*#	16.7 ± 25.3	14.8 ± 32.7

***Key**:*
** = significantly different to train driving sample (p<0.05)*
 # = significantly different to advised normative values (p<0.05)

Discussion

The present preliminary study identified a concerning trend of high levels of negative mood states within the Australian truck driving sample. Levels of all negative mood states in the truck drivers were both higher than the advised normative values, and the train driving sample scores. High levels of negative mood states have been consistently linked with a decrease in driver performance (Hilton, 2009; Lal, 2002), which when considered alongside the high levels of negative mood states reported within the truck driving sample, raises concerns about driving safety and warrants further investigation.

Tension-anxiety, anger-aggression, fatigue-inertia, depression-dejection, confusion bewilderment and total mood disturbance were all found to be significantly higher in the truck drivers compared to the train drivers. Impaired mental health in the workplace elicits negative impacts on both employees and employers and can compromise work performance and safety. From increased absenteeism (PricewaterhouseCoopers, 2014), to high numbers of approved compensation claims for mental or stress related illnesses (Safe Work Australia), neglecting to appropriately address psychological based illness can impact negatively on all parties involved. As previously mentioned, Australian businesses will lose $10.9 billion annually for neglecting to address mental health issues in the workplace (PricewaterhouseCoopers, 2014). However, the return for industries that invest in mental health schemes is both economically beneficial, and valuable to ensure employee health and transport safety.

Conclusion

Collectively, the findings from the present preliminary study provide a novel perspective on the mental health of Australian truck and train drivers. The present study addressed the gaps in research by assessing a number of mood states (tension-anxiety, depression-dejection, anger-aggression, fatigue-inertia, confusion-bewilderment and total mood disturbance score) within these understudied occupational industries. The preliminary study found that multiple mood states were significantly higher in the truck-driving sample than both the train driving sample, and the advised normative scores. This provides evidence for future research into the incidence of these negative mood states within these understudied industries.

There are a number of limitations within the current preliminary study. Sample size, whilst large enough to provide adequate sample power, should be increased for each sample group (truck and train drivers) in order to provide a representative distribution of the population, and ensure that results are able to be generalised across each of the occupations. Furthermore, drivers were recruited from the Sydney area, and thus, may not be representative of the entire Australian driver population for each sample. Future studies may benefit from recruitment of drivers from a number of suburbs and states across Australia.

Drawing from preceding literature, reducing the incidence of these negative mood states could work to improve mental health within the truck driving industry, and in turn, increase driver performance, thereby improving road safety in Australia. It is vital, however, that future studies use larger sample populations and recruit professional truck and train drivers from a number of different suburbs and states across Australia to ensure an accurate representation of each of the occupational populations.

These preliminary findings provide evidence for further investigation into the incidence of negative mood states within these two occupational fields. Considering that heavy vehicle accidents reportedly cost Australia approximately $2 billion each year (Bureau of Infrastructure Transport and Regional Economics, 2009), quantitating the presence of mental disorders, and improving the mental health profile of these individuals may, in turn, reduce the effects of disorders such as depression on driving ability. Road safety in Australia is a vital aspect of the transport industry that requires a holistic, well-researched management approach. By incorporating mental health and psychological management schemes, the safety advantages in terms of improved driver ability and performance, and reduction in both absenteeism and psychological disorders, would be highly beneficial.

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4.2 Workplace factors and mental health

As discussed previously (sections 1.1.1 and 1.1.2), workplace factors within the professional driving industry are unique, and pose distinctive challenges to the workforce. The purpose of the following original research articles is to elucidate workplace factors that may contribute to negative mental states such as depression, stress and anxiety, in a population of Australian truck and train drivers. All of the following articles are published in press, have been accepted, or are currently under review.

4.2.1 Assessing associations between workplace factors and Depression and Anxiety in Australian heavy vehicle truck drivers

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In Press: Chalmers, T., Maharaj, S., & Lal, S. (2021). Associations between workplace factors and depression and anxiety in Australian heavy vehicle truck drivers. *Annals of work exposures and health*, *65*(5), 581-590.

Abstract: Introduction: A number of health issues have been identified as prevalent within the Australian heavy vehicle driving population. Mental illnesses, such as depression and anxiety, are among those disorders that have been regularly reported, however, the contributing factors are yet to be elucidated. Methods: This study aimed to assess the associations between workplace factors such as years of employment, social interaction and shift length, with depressive and anxious symptomology in a cohort of 60 Australian heavy vehicle drivers. Results: Significant positive associations were identified between depression and alcohol use ($p = 0.044$), coffee consumption ($p = 0.037$), number of accidents during career ($p = <0.004$), and number of hours driving per shift ($p = <0.001$). Anxiety was found to be positively associated with number of hours driving per week ($p = <0.001$), and the number of accidents or near misses during driving career ($p = 0.039$). Conclusion: Several workplace factors were identified as being correlated to depression or anxiety within this cohort, suggesting potential changes to rostering systems and education regarding alcohol use may benefit the mental health of this driver population.

Keywords: Heavy vehicle, depression, anxiety, workplace factors, workplace, occupational safety, occupational health, mental health, safety, truck driver.

Introduction:

Countries with significant distances between metropolitan hubs, such as Australia, rely heavily on road freight for the movement of goods and people between major cities. Currently, heavy vehicles account for 19.5% of the total vehicles on Australian roads, and the freight and logistics sector accounts for 8.6% of the Australian Gross Domestic Product (Australian Bureau of Statistics, 2017b, Department of Infrastructure Regional Development and Cities, 2018). The demands within the trucking industry are vast, encompassing both physical and psychological stressors. Further, the average heavy vehicle driver is older and works longer hours than the average working population, and the industry is heavily male-dominated (Australian Government, 2012b). These factors alone place heavy vehicle drivers at risk of developing numerous health issues, including mental illnesses. There are also a number of industry-specific workplace factors, such as monotonous driving conditions, intermittent rest and work cycles (Platek et al., 2016), long hours spent driving and workplace isolation (Mishra et al., 2018) that have been implicated in the development of health concerns such as anxiety and depression (Chalmers and Lal, 2016).

Depression is a common mood disorder, affecting 9.3% of the Australian population. The links between depression and the heavy vehicle trucking industry have been examined previously, with studies supporting a positive association between the two. Studies have found that truck drivers exhibit higher rates of depression that the general population (Hilton et al., 2009b), with additional occupational and lifestyle factors such as concomitant stimulus use, low educational level, and wage-earning further increasing the likelihood of depression within this occupational group (da Silva-Júnior et al., 2009a). Anxiety is the most common behavioural condition, with 11.2% of the Australian population being diagnosed with this disorder (Australian Bureau of Statistics, 2015). Anxiety has been linked with heavy vehicle truck driving, with a recent large-scale study in Brazil finding that 14.5% of truck drivers exhibited anxiety (Shattell et al., 2012b). There appears to be, however, a paucity of literature regarding the prevalence and impact of anxiety within the heavy vehicle driving industry.

Given that the literature reports a high incidence of depression and anxiety within this cohort, it is important to understand the risks associated with these mental health disorders within the truck driving industry. Anxiety and depression have been linked with impaired driving ability and increased risk of crashes and near misses (Long and Ruosong, 2019, Hill et al., 2017, Cunningham and Regan, 2016, Alavi et al., 2017). In fact, a diagnosis of severe depression has been associated with a four times greater risk of a motor vehicle accident (Hilton et al., 2009b).

Collectively, the reportedly high baseline levels of depression and anxiety within this cohort, and the subsequent potential impacts of these disorders on driving ability and quality of life, presents a concerning profile of risk within the heavy vehicle industry. Further, it provides evidence for the necessity of interventions to ameliorate this risk. Considering the implication of potentially high levels of anxiety and depression among heavy vehicle drivers, it is important to elucidate the potential workplace factors that may contribute to the development of these diseases within this population, in particular in the context of risk reduction and harm minimization. Recent studies have implicated workplace factors such as intermittent rest and work cycles (Zhai et al., 2015), shift work, and long working hours (Virtanen et al., 2011) in the development of mental illnesses. There remains, however, a lack of literature surrounding workplace factors that may contribute to the development of these disorders. This exploratory study aimed to examine the relationship between workplace factors and depression and anxiety in a population of Australian heavy vehicle drivers. We hypothesize that factors such as shift length, accidents during career and alcohol use will be associated with higher depressive symptomology. We hypothesize that factors such as shift length, interaction during work and alcohol use will be associated with higher anxious symptomology. By elucidating modifiable contributing factors, and providing foundations for legislative and company policy changes, we may be able to reduce the impact of these factors on the development of anxiety and depression, in turn reducing their impact on road accidents.

Materials and Methods:

Study Design:

This study was conducted as a part of a larger study analysing the cardiovascular health of professional drivers, and associations between affective states and autonomic cardiovascular impairment. Upon commencement of the study, the participant completed the inclusion and exclusion criteria questionnaire which determined their inclusion in the study. If requirements were met, participants were explained the study in detail, and were asked to complete a consent form. One copy was retained by the researcher, another by the participant.

Participants:

A total of 60 heavy vehicle truck drivers, aged between 18 – 69 years, were recruited from the local Sydney community. Participants were recruited through local advertisement via a poster, through contacts established independently to this research, online forums and with the aid and endorsement of Australia Post Transport division and the Transport Workers Union. The inclusion criteria were as follows; current employment as a truck driver, driving a truck with a gross vehicle mass of greater than 4.5 tonne, and fluent English literacy. The exclusion criteria were as follows; those currently consuming any prescription or non-prescription drugs (excluding caffeine and nicotine) or suffering from any chronic disease or illness were excluded from the study. Participants were required to abstain from food for 2 hours, nicotine and caffeine for 4 hours, and alcohol for 12 hours before the study. Blood pressure was obtained three times prior to, and post the administration of the questionnaires, in accordance with the HREC approved protocol. A participant with a pre-study BP reading greater than 140/90 mmHg but lower than 160/100 mmHg, whilst included in the study, was advised to consult their general practitioner regarding their elevated BP reading. Participants with blood pressure readings of greater than 160/100 mmHg were excluded from the study and were offered to be accompanied by a researcher to the University medical clinic or advised to consult a general practitioner. 4 participants were excluded from the study for reasons as follows; prescription drug use (carvedilol, 12.5mg OD), recent nicotine ingestion (<4 hours prior to study), type 2 diabetes and alcohol less than 12 hours prior.

The average age of participants was 35.8 years ± 9.1 years (Table 1). The cohort was 95% male, reflecting the male dominance of the heavy vehicle truck driving industry. The mean BMI was 28.3 ± 3.4. The study was conducted in a precise laboratory environment, with light sources being controlled and consistent across all participants. The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions being presented. Upon obtaining written consent, the study was commenced.

Instruments:

The questionnaire package included the Professional Driver Package, adapted from the SmartData Questionnaire (Kanvanagh, 2007), Lifestyle Appraisal Questionnaire (Craig et al., 1996a), the Beck Depression Inventory (Beck et al., 1996b), the Beck Anxiety Inventory (Steer and Beck, 1997) and the Profile of Mood States Questionnaire (McNair, 1971). The Professional Driver Package provides demographical information regarding licensing, employment length, employment status, nutrition, accident or near-miss history and working conditions. The Lifestyle Appraisal Questionnaire (LAQ), a validated and clinically reliable questionnaire, was used to record demographic, lifestyle and psychological stress information from the participant. The LAQ consists of two parts, with Part I consisting of 22 questions, with the highest obtainable score being 73. This information included family history of disease, smoking status, alcohol intake, exercise and diet regime, etc. The higher the score obtained from Part I of the LAQ, the greater the risk of developing a chronic illness later in life. Part II of the LAQ consists of 27 items and assessed an individual's "*cognitive appraisal of pressure and demands*"(Craig et al., 1996a).

The Beck Depression Inventory Scale (BDI-II)(Beck et al., 1996b) is a 21-item self-reported tool used to assess the severity of depression in adults and adolescents (aged

>13). Scores range from 0-63, with 0-13 indicating minimal depression, 14-19 indicating mild depression, 20-28 indicating moderate depression and 29-63 indicating severe depression (Beck et al., 1996a). The coefficient alpha of the BDI-II was found to be 0.93, indicating high internal consistency. The test-retest correlation of the BDI-II was found to be 0.93, which was significant ($p = <0.001$). As such, the BDI-II is a suitable mood state tool for the assessment of depressive symptoms within this study. The Beck Anxiety Inventory (Steer and Beck, 1997) is a 21 question, self-reported inventory that is utilized to assess anxious symptomology. It's internal consistency is high (alpha = .92) (Steer et al., 1993), and it is used clinically to assess true clinical anxiety, and reduce the overlap with depressive symptoms. The Profile of Mood States questionnaire (POMS) (McNair, 1971) is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigour-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, and confusion-bewilderment scales minus the score on the vigour-activity scale. The depression-dejection subscale is strongly predictive of the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996a), which is often used in clinical practice to diagnose depression. The depression-dejection subscale of the POMS is consequently considered a useful short alternative to the BDI-II, since it also investigates other components of mood such as anxiety and aggression (Griffith et al., 2005).

Data Analysis:

Statistical analysis was performed using SPSS, with partial correlations being performed after controlling for covariates (age, gender, smoking status, and body mass index). The variables entered into the correlation analysis were Length of employment (years), Number of accidents during career, Number of accidents during previous 12 months, Hours spent driving per shift, Social interaction during shift, Alcohol consumption, Coffee consumption. Multiple linear regressions were run for dependent variables - BDI, BAI, Depression/Dejection, and Tension/Anxiety. Cases were excluded pairwise, and significance was set at $p<0.05$. All regressions were run using SPSS for Windows (version 23; SPSS Inc; Chicago, IL, USA).

Ethics:

All subjects provided informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the UTS HREC (HREC number 2014000110).

Results:

3.1. Demographics

Average years employed as a heavy vehicle driver was 12.3 ± 8.4, and the average hours driving a work vehicle each week was 42.2 ± 10.3. Drivers reported 1.3 ± 1.7 accidents or near misses in the previous 12 months, and 7.9 ± 9.7 accidents or near misses in their career (Table 1).

Table 1: Demographics of truck driving sample

	Mean ± SD or %
Age	35.8 ± 9.1
Gender (Males)	91.67

BMI	28.3 ± 3.4
Years Employed	12.3 ± 8.4
Hours Driving	42.2 ± 10.3
Accidents in Previous Year	1.3 ± 1.7
Accidents per Career	7.9 ± 9.7

BMI: Body Mass Index

SD: Standard deviation

3.2. Depression and Anxiety associations to Workplace and Lifestyle factors

A number of significant partial correlations were identified between workplace/lifestyle factors and depression assessment scores, when controlling for covariates (age, gender, smoking status and body mass index). The depression/dejection subscale of the Profile of Mood States questionnaire identified significant positive correlations to the number of accidents or near misses during career (R = 0.29 p = 0.04), and the number of hours driving per week (R = 0.35, p = 0.012).

The Beck Depression Inventory scores were positively correlated with the amount of coffee consumed each day (R = 0.29, p = 0.04), the number of accidents or near misses during career (R = 0.32, p = 0.0004), and the number of hours driving per week (r = 0.48, p = <0.000).

A number of significant correlations were identified between workplace/lifestyle factors and anxiety assessment scores. The tension anxiety subscale of the Profile of Mood States questionnaire was significantly positively correlated to the amount of alcohol consumed each day (R = 0.28, p = 0.04), the number of hours driving per week (R =

0.43, p = 0.0001), and negatively correlated to the amount of human interaction a person perceived they had during working hours (R = -0.32, p = 0.03). The Beck Anxiety Inventory scores were positively correlated with the number of hours driving per week (R = 0.43, p = 0.001). No further significant correlations were identified.

Table 2: Depression and Anxiety partial correlations to Workplace and Lifestyle factors

Variable	POMS D/D		BDI		POMS T/A		BAI	
	r	p	r	p	r	p	r	p
Alcohol	0.21	0.135	0.17	0.223	0.28	0.044*	0.19	0.183
Coffee	0.24	0.085	0.29	0.037*	0.25	0.08	0.21	0.137
Years Driving	0.07	0.606	0.13	0.349	0.09	0.54	0.05	0.735
Accidents during career	0.29	0.039*	0.40	0.004*	0.10	0.055	0.13	0.365
Accidents in previous 12 months	0.17	0.221	0.21	0.135	0.27	0.463	0.10	0.481
Hours Driving	0.35	0.012*	0.48	<.0001*	0.43	0.001*	0.43	0.001*
Interaction	-0.24	0.099	-0.26	0.082	-0.32	0.03*	-0.15	0.477

p: Level of statistical significance
POMS D/D: Depression/Dejection subscale of the Profile of Mood States Questionnaire
POMS T/A: Tension/Anxiety subscale of the Profile of Mood States Questionnaire
r: Correlation coefficient
*: Indicates significance (p = <0.05)

To determine which workplace variables uniquely contributed to depressive symptomology, only those variables that correlated significantly with the Beck Depression Inventory scores were entered into a multiple regression analysis. Table 3 shows that this regression was significant (R .50, R^2 .25, adjusted R^2 .20, F 3,49, = 5.37, p = 0.002) for three workplace variables (coffee, accidents during career and number of hours driving a work vehicle each week), which together explained 25% of the variance depressive symptomology, as measured by the Beck Depression Inventory score. However, the only individual factor that was significant in the regression was the number of hours driving a work vehicle each week (p = 0.004).

Table 3: Standard multiple regression BDI score and workplace variables

	β	SE of β	B	SE of B	t	p
(Constant)			-12.81	6.06	-2.11	0.039
Coffee	0.14	0.14	3.44	3.47	0.99	0.327
Accidents during career	0.04	0.13	0.28	0.79	0.35	0.73
Hours Driving	0.42	0.14	0.44	0.15	3.01	0.004*

β = Standardised coefficient
B = Unstandardised regression coefficient
p = Level of statistical significance
R = Correlation coefficient
SE of β = Standard error of standardised regression coefficient
SE of B = Standard error of unstandardised regression coefficient
Std. = Standard
t = t statistic
*: Indicates significance (p = <0.05)

To determine which workplace variables uniquely contributed to depressive symptomology as measured by the Depression/Dejection subscale of the POMS, only those variables that correlated significantly with the Depression/Dejection variable were entered into a standard multiple regression analysis. Table 4 shows that this regression was significant (R .44, R^2 .19, adjusted R^2 .16, F 2,51 = 6.112, p = 0.004) for two workplace variables (number of accidents during career and number of hours driving a work vehicle each week), which together explained 16% of the variance in depressive symptomology (as measured by the Beck Depression Inventory score). However, the only individual factor that was significant in the regression was the number of hours driving a work vehicle each week (p = <0.000).

Table 4: Standard multiple regression – Depression/Dejection score and workplace variables

	β	SE of β	B	SE of B	t	p
(Constant)			-2.80	5.30	-0.53	0.599
Accidents during career	<0.00	0.13	0.01	0.71	0.01	0.994
Hours Driving	0.44	0.13	0.42	0.12	3.49	<0.000

β = Standardised coefficient
B = Unstandardised regression coefficient
p = Level of statistical significance
R = Correlation coefficient
SE of β = Standard error of standardised regression coefficient
SE of B = Standard error of unstandardised regression coefficient
Std. = Standard
t = t statistic
*: Indicates significance (p = <0.05)

In order to determine which workplace variables uniquely contributed to anxious symptomology as measured by the Tension/Anxiety subscale of the POMS, only those variables that correlated significantly with the Tension/Anxiety variable were entered into a standard multiple regression analysis. Both the model, and each individual variable were insignificant.

Discussion:

The present study identified a number of positive correlations between negative workplace or lifestyle factors, such as long working hours and regular alcohol consumption, and depression and anxiety. Historically, there has been a scarcity of literature surrounding the impact of the unique workplace conditions on heavy vehicle truck drivers' mental health, despite a myriad of evidence suggesting that truck drivers are a depression vulnerable population.

When we examine the factors associated with high depression scores, the number of hours driven each week showed positive correlations across both the Profile of Mood states and the Beck Depression Inventory, indicating that as an individual spent more time driving their work vehicle, their level of depressive symptomology also increased. This parallels recent literature, with da Silva-Junior and team reporting an increased odds ratio (OR = 1.28) of depression in truck drivers who report work overload (long working hours) (da Silva-Júnior et al., 2009a). Research has also suggested that there is an inverse relationship between the number of hours spent driving a work vehicle, and job satisfaction (Raggatt, 1991). Some recent studies have suggested that the adjusted odds ratio of depression in individuals who work long hours each week may be as high as 9.9 (Tomioka et al., 2011). Long working hours may designate the unfavorable effects of work exposures and stress. There is some research to suggest that occupational overload is particularly associated to anxiety symptoms while reduced decision autonomy is more commonly correlated with depression (Broadbent, 1985).

Prolonged working hours have also been associated with raised salivary cortisol (Lundberg and Hellström, 2002), and there is a strong body of literature to suggest that raised cortisol levels may be associated with the depression (Handwerger, 2009). It has been hypothesized that the relationship between long working hours and anxiety and depression is due to self-selection, rather than causation; namely, employees with pre-existing affective and anxious disorders tend to work or have to work longer; or employees with mental disorders are forced to stay in unsatisfactory jobs, including those with longer working hours, because their potential for finding alternative employment is limited (Kleppa et al., 2008; Waghorn & Chant, 2005).

Similar to the number of hours spent driving, the number of accidents throughout an individual's career was found to be higher as depressive symptomology increased. This is a novel finding among Australian heavy vehicle truck drivers. This supports previous literature from other countries, which suggests that depression is linked to a reduction in driver performance (Bulmash et al., 2006a), increased accident risk (Mann et al., 2010), greater risk-taking behaviour (Yu et al., 2004) and reduced reaction times (Bulmash et al., 2006a). It has been hypothesized that drivers with depressive symptoms exhibit more difficulty in attention division between competing driving related tasks (Deery and Fildes, 1999). Further, studies have shown that individuals with depression exhibit reduced arousal and activation of the somatic nervous system, which may translate to reduced driving performance as a result of lower central nervous system arousal (Wingen et al., 2006). Current Australian guidelines recommend commercial vehicle drivers are not to work more than 60 hours in a single week (Government of Western Australia, 2020). However, recent Australian studies have found that mental health begins to decline after 39 hours of work per week (Dinh et al., 2017). Given the disparity between these findings and the permitted 60 hours of weekly work allowed under current WHS guidelines, this population may benefit from a reduction in permitted weekly hours of work.

Coffee consumption was also found to increase with increased depressive symptomology. Interestingly, a recent meta-analysis regarding the associations between coffee consumption and depression found that coffee may have a protective effect against the development of depression (Wang et al., 2016). The meta-analysis analysed the data from 330,677 participants from seven studies and found that coffee consumption reduced the relative risk of depression. The conflict between the present findings of this study and the data obtained from the meta-analysis may have been influenced by the link between coffee consumption and hours spent driving a work vehicle. The amount of coffee consumed was positively correlated to hours spent driving a work vehicle, and due to the strong positive correlation between hours spent driving and depression, this may have masked the reported protective depression effects of coffee. Further, coffee consumption may be linked to fatigue, which has been shown to be linked with depressive symptoms (Jacobsen et al., 2003).

When we examine the factors associated with high anxiety scores, alcohol consumption, and the number of hours spent driving a work vehicle each week were both positively correlated to an increase in anxious symptomology. Interestingly, perceived social interaction was found to be negatively correlated to anxiety scores, indicating that the more social interaction an individual experienced in the workplace, the lower their reported anxiety scores. Literature supports the positive association identified between alcohol and anxiety scores, with the “self-medication hypothesis” suggesting that the pharmacological and psychological effects of alcohol may be perceived to mediate anxiety symptoms, and thus is used as a coping mechanism in those individuals who experience anxious symptoms (Quitkin et al., 1972). Further, literature has also suggested a possible causal link between alcohol consumption and the promotion of anxiety disorders. Literature has suggested that the development of anxiety disorders may be a bio-psycho-social consequence of significant alcohol consumption (George et al., 1990). Mitigation of alcohol misuse in the professional driving industry in Australia has historically revolved around voluntary policy implementation by employers. Although commercial drivers must have a BAC of either 0.00% or 0.02% (dependent on their state of employment), policies surrounding alcohol misuse outside of work have been largely sporadic in the past. There has, however, been some progression in recent years, with alcohol awareness policies within commercial driving workplaces becoming more common. Further, VicRoads has created a free drug and alcohol policy builder for companies to utilize, in order to reduce and liabilities. By continuing to discuss alcohol use not only in the context of work BAC, but also 'health at home', companies may see an improvement in the psychosocial welfare of their employees.

When we examine the factors associated with high anxiety scores, the number of hours driven each week showed positive correlations across both the Profile of Mood states tension/anxiety subscale and Beck Anxiety Inventory, indicating that as an individual spent more time driving their work vehicle, their level of anxious symptomology also increased. This parallels recent literature, with Virtanen and team reporting an increased odds ratio (OR = 1.74) of anxiety in truck drivers who report working for greater than 55 hours each week (Virtanen et al., 2011). One suggested mechanism for this relationship is the limbic-behavioural pathway, which suggests that as individuals work longer hours, they engage in more negative behaviours such as excessive alcohol use, a known contributor to the development of anxiety (Van der Hulst, 2003). Further, research suggests that the longer the working hours, the greater the stress placed on a worker, and as such, the greater the propensity to develop anxiety disorders (Warr, 1990). Long working hours are associated with reduced time periods spent with social support, which in itself is a predictor of anxious symptomology (White et al., 2003). Once again, it is clear that long working hours are implicated in negative mental health outcomes, and given these, the current limits of 60 hours work per week for individuals in the heavy vehicle driving industry should be modified in order to promote the biopsychosocial health of these individuals.

Finally, workplace social interaction was found to be inversely related to anxious symptomology, indicating that as an individual experienced greater social interaction at work, their levels of anxiety lowered. This parallels recent literature, which suggests that as social interaction increases, there is a biological suppression of the hypothalamic-pituitary-adrenal axis, resulting in a dampened cortisol effect, thus reducing the systemic effects of cortisol (Heinrichs et al., 2003). Further, long term social support has been found to have a significant anxiolytic effect, resulting in increased oxytocin release, and reduced cortisol release, thus providing evidence for the causal link between greater social support and reduction in anxious symptomology (Heinrichs et al., 2003). Currently, Australian companies are utilising a number of support initiatives aimed at increasing social interaction within the workplace. Toolbox talk training packages, delivered by the mental health service Beyond Blue, aim to "encourage conversations about mental health in the workplace, reduce workplace stigma and support staff who may be experiencing a mental health condition" (Heads Up, 2020). Studies have shown significant improvements in perceived morale, self-reported mental health, and reductions in stress, subsequent to the introduction of socialisation initiatives such as these toolbox talks (Oakman et al., 2018, Bowers et al., 2018, Hanna et al., 2020, Campbell and Gunning, 2020). Given that this study is the first in Australia to identify social interaction as a potential contributory factor to anxious and depressive symptomology within a cohort of heavy vehicle drivers, these findings may provide the foundation for further employment of social interaction strategies in the workplace.

There are some limitations of the present study. The use of self-reported mood state questionnaires may introduce some response bias; however, the effects of this bias were ameliorated through the use of participant identification numbers for all responses, providing anonymity for the participant. While common in medical science analysis, univariate analysis has some limitations in predictive power, in particular as workplace variables rarely occur alone. However, we believe that a reasonable and commonly employed initial step is evaluating univariate associations, which allows the variables to be quantified prior to their inclusion in the later model. The initial objective is to include the "best" grouping of variables that increase predictive ability, whilst circumventing unnecessary complexity. Finally, it has been shown that males are less likely to divulge information that may infer vulnerability (Courtenay, 2002). The study design attempted to address this potential reporting bias by utilising multiple mood state questionnaires with high internal validity to allow for the assessment of congruency between questionnaires, and their validity and reliability ensure an accurate response.

Conclusions

Collectively, the findings from the present study support previous literature, which suggest that Australian heavy vehicle truck drivers find themselves at an increased risk of depression and anxiety and that there may be modifiable causative workplace factors that contribute to this increased incidence of mental health disorders. The findings of this study are highly pertinent to the safety and health of this industry and provide a unique insight into the workplace factors that may contribute to affective states. Given the high rates of depression and anxiety consistently reported within this population, and the impacts of these mood disorders on driving ability and overall wellbeing, the contributing factors must be elucidated and modified where possible. Acceptable reductions in shift length, and the introduction of the buddy-driving system may improve mental health within this field and have the added benefit of reducing accidents and near misses. Research has shown the buddy system to be an effective management technique to reduce collisions and given this study found social interaction to be negatively related to depression and anxiety, this would also improve socialisation on-shift. Further, policies that prevent suppliers demanding unachievable timelines for deliveries may reduce occupational stress and the need for excessive shift length durations.

Alcohol consumption was also shown to be associated with depressive symptomology. Further research is needed to elucidate the true relationship of these two variables, however, given previous research which suggests alcohol misuse can have a range of negative biopsychosocial impacts, workplace facilitated discussions surrounding alcohol use, and on-site, or subsidised counselling services, may prove beneficial in this cohort.

The heavy vehicle trucking industry is vital to the prosperity of Australia, with 72% of the freight in this country conveyed via the road system. The heavy vehicle industry employs over 200,000 individuals each year, and the health and safety of this sector extends far beyond the individual workers. Safe work practices and a ubiquitous commitment to improving mental health within this sector are paramount to not only safe roads, but a healthy economy.

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curation, Chalmers, T., Lal, S., and Maharaj, S.; writing—original draft preparation and writing, Chalmers, T.; review and editing, Chalmers, T, Lal S., supervision, Lal, S.

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4.2.2 Evaluating associations between workplace factors and stress, depression and anxiety in Australian train drivers

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Under Review – Industrial Health

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Running Head:

Workplace factors, stress and depression in Train Drivers

Abstract:

Objectives: Australia's unique landscape, and large distances between metropolitan hubs, has resulted in a heavy reliance of rail freight. Train drivers experience a myriad of unique workplace conditions that may predispose them the mental health conditions such as depression. This study aimed to assess associations between workplace factors and stress, depression and anxiety in a cohort of Australian train drivers. **Methods:** 60 full time train drivers were recruited to participate in the present study. A battery of lifestyle, workplace risk factor and mental health questionnaires were administered. **Results:** Stress and depression were linked with accidents or near misses during the previous 12 months, accidents or near misses across the participants career, and inversely correlated with social interaction during shift. The strongest predictor of stress and depression, as determined by regression analysis was social interaction during shift. **Conclusion**: This study highlights important workplace factors that may be linked with negative mental states, and their potential implications within the workplace. The promotion of improved mental health within this occupation would not only improve the health of the individual drivers but may also reduce mental health associated absenteeism and improve commuter safety.

Keywords: Train driver, depression, anxiety, workplace factors, occupational safety, mental health.

Introduction:

Rail freight in Australia remains a primary means of moving goods and people between suburbs, cities and states (Australian Bureau of Statistics, 2018). Given the large distances between major municipalities, and low person-per square kilometre ratio in Australia, rail freight has persisted as an important contributor to both the economic and societal stability of this country (Australian Bureau of Statistics, 2018). Train drivers present a unique workforce profile, one which is highly male dominated and largely older than the national population working average (Chalmers and Lal, 2016). Further, drivers find themselves subjected to a myriad of occupational conditions which, in combination, are unique to this industry. These include long hours spent sitting (Chang and Ju, 2008), monotonous driving conditions (Lees et al., 2018), intermittent rest and work cycles, shift work, the necessity of strict mental alertness, and consistent cabin vibrations (Forsberg, 2016).

Further, train drivers find themselves at risk of experiencing unique negative psychological occurrences, such as 'person-under-train' events. International research has shown that almost 16% of drivers who experience a person under train event will develop post-traumatic stress disorder, and over 30% will develop an anxious or affective disorder such as depression or anxiety (Farmer et al., 1992). Mental illnesses such as anxiety and depression are common, not only in the general population, but also within professional driving industries. Studies have shown higher prevalence of depression (Tranah and Farmer, 1994, Chalmers and Lal, 2016) , anxiety (Chalmers and Lal, 2016) and posttraumatic stress disorder (Lemos and Patrão, 2018) among train drivers when compared with the general population.

Although the physical health of train drivers has been increasingly investigated in recent years, the psychological health of these drivers remains somewhat elusive, as studies have generally focused on the assessment of drivers after a 'person-under-train' event, rather than the general mental health of these individuals (Cothereau et al., 2004a, Limosin et al., 2006, Mehnert et al., 2012, Theorell et al., 1994). Further, in order to guide beneficial changes to workplace factors and policies, it is important to elucidate those workplace factors, outside of 'person-under-train' events, that may contribute to negative mental health states within this population. Hence, this study aimed to assess workplace factors linked to depression and anxiety in a population of Australian professional train drivers.

Materials and Methods:

Study Design:

This study was conducted as a part of a larger study analysing the cardiovascular health of professional drivers, and associations between affective states and autonomic cardiovascular impairment. Upon commencement of the study, the participant completed the inclusion and exclusion criteria questionnaire, the lifestyle appraisal questionnaire part 1 (LAQP1) (Craig et al., 1996a), which determined their inclusion in the study. If inclusion requirements were met, participants were explained the study in detail, and were asked to complete a consent form, a copy of which was retained by the researcher, another by the participant.

Participants:

A total of 60 professional train drivers, aged between 18 – 69 years, were recruited from the Sydney Trains. Participants were recruited through advertisement via a poster which was displayed in the tearoom of the Central Station depot in Ultimo, New South Wales (NSW). This research was undertaken with the aid and endorsement of Sydney Trains. The inclusion criteria were as follows; current employment as a train driver, and fluent English literacy. The exclusion criteria, as determined by the LAQP1, were as follows; those currently taking any prescription or non-prescription drugs (excluding caffeine and nicotine) or suffering from any chronic disease or illness, were excluded from the study. Participants were required to abstain from food for 2 hours, nicotine and caffeine for 4 hours, and alcohol for 12 hours before the study; to avoid influencing the physiological measures. Blood pressure was obtained three times prior to, and post the administration of the questionnaires, in accordance with the institute's ethics approved protocol. Participants with pre-study BP reading < 140/90 mmHg were included in the study. Participants with a pre-study BP (either systolic or diastolic or both) reading of greater than 140/90 mmHg, but lower than 160/100 mmHg, whilst included in the study, were advised to consult their general practitioner regarding their elevated BP reading. Participants with blood pressure readings of greater than 160/100 mmHg were excluded from the study and were offered to be accompanied by the researcher to the University medical clinic or advised to consult a general practitioner. Three participants were excluded from the study for reasons as follows; 2 participants for prescription drug use (diazepam, 5mg, PRN/metformin 500mg, BD), and 1 participant was excluded for having ingested nicotine less than 12 hours prior to the study. After excluding the three participants, 60 drivers were included in the final analysis (n = 63 – 3, = 60).

The average age of participants was 38.2 years ± 10.1 years (Table 1). The cohort was 95% male, reflecting the male dominance of the train driving industry. The mean BMI was 28.9 ± 5.3. The study was conducted in a controlled laboratory environment, with light sources and temperature being consistent across all participants. The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions were presented. Upon obtaining written consent, the study was commenced.

Instruments:

The questionnaire package included the Professional Driver Package, adapted from a in-house developed SmartData Questionnaire (Kanvanagh, 2007), Lifestyle Appraisal Questionnaire (Craig et al., 1996a), the Beck Depression Inventory (Beck et al., 1996b), the Beck Anxiety Inventory (Steer and Beck, 1997) and the Profile of Mood States Questionnaire (McNair, 1971). The Professional Driver Package provides demographical information regarding licensing, employment length, employment status, nutrition, accident or near-miss history and working conditions. The Lifestyle Appraisal Questionnaire (LAQ), a validated and clinically reliable questionnaire, was used to record demographic, lifestyle and psychological stress information from the participant. The LAQ consists of two parts, with Part I consisting of 22 questions, with the highest obtainable score being 73. This information included family history of disease, smoking status, alcohol intake, exercise and diet regime, etc. Items in Part I are scored for level of risk. Most item scoring ranges from 0 (little or no risk) to 4 (high risk) whilst some are dichotomous (yes/no). Higher scores are associated with higher risks of chronic disease. Part II of the LAQ consists of 27 items, each assessed on a four-point Likert scale ranging from 0 (almost never) to 3 (almost always) is used to assess the person's cognitive appraisal of life pressures and demands. Items are added directly, and high scores indicate higher perceived levels of stress (Craig et al., 1996a).

The Beck Depression Inventory Scale (BDI-II) (Beck et al., 1996b) is a 21-item self-reported tool used to assess the severity of depression in adults and adolescents (aged >13). Scores range from 0-63, with 0-13 indicating minimal depression, 14-19 indicating mild depression, 20-28 indicating moderate depression and 29-63 indicating severe depression (Beck et al., 1996a). The coefficient alpha of the BDI-II was found to be 0.93, indicating high internal consistency. The test-retest correlation of the BDI-II was found to be 0.93, which was significant (p = <0.001). As such, the BDI-II is a suitable mood state tool for the assessment of depressive symptoms within this study. The Beck Anxiety Inventory (Steer and Beck, 1997) is a 21 question, self-reported inventory that is utilized to assess anxious symptomology. It's internal consistency is high (alpha = .92) (Steer et al., 1993), and it is used clinically to assess true clinical anxiety, and reduce the overlap with depressive symptoms. The Profile of Mood States questionnaire (POMS) (McNair, 1971) is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigour-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, and confusion-bewilderment scales minus the score on the vigour-activity scale. The depression-dejection subscale is strongly predictive of the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996a), which is often used in clinical practice to diagnose depression. The depression-dejection subscale of the POMS is consequently considered a useful short alternative to the BDI-II, since it also investigates other components of mood such as anxiety and aggression (Griffith et al., 2005).

Data Analysis:

Statistical analysis was conducted using SPSS for Windows (version 23; SPSS Inc; Chicago, IL, USA), with partial correlations being performed after controlling for covariates (age, gender, smoking status, and body mass index). The variables entered into the correlation analysis were Length of employment (years), Number of accidents during career, Number of accidents during previous 12 months, Hours spent driving per shift, Social interaction during shift, Alcohol consumption and Coffee consumption. Multiple linear regressions were run for dependent variables - BDI, BAI, Depression/Dejection, and Tension/Anxiety, based on significant correlations with these dependent variables. Cases were excluded pairwise, and significance was set at $p<0.05$.

Ethics:

All subjects provided informed consent for inclusion before they participated in the study. The study was approved by the UTS HREC (HREC number 2014000110).

Results:

3.1. Demographics

Average years employed as a train driver was 7.5 ± 6.1, and the average hours driving a train as a worker each week was 33.7 ± 7.9. Drivers reported 0.9 ± 1.4 accidents or near misses in the previous 12 months, and 4.2 ± 6.7 accidents or near misses in their career (Table 1).

Table 1: Demographic data of the train driving sample (n = 60)

	Mean ± SD or %
Age	38.2 ± 10.1
Gender (Males)	95
BMI	28.9 ± 5.3
Years Employed	7.5 ± 6.1
Hours Driving	33.7 ± 7.9
Accidents/near misses in Previous Year	0.9 ± 1.4
Accidents/near misses per Career	4.2 ± 6.7

Table 1 present demographic data for the train driving sample (n=60).

Key:

BMI: Body Mass Index

SD: Standard deviation

The mean test scores of each of the six respective mood subscales (tension-anxiety, anger-aggression, fatigue-inertia, depression-dejection, confusion-bewilderment and vigor-activity) of the POMS questionnaire, a total mood disturbance scores, along with the normative values (Nyenhuis et al., 1999) are listed in Table 2. No individual mood subscales were significantly higher than the advised normative scores.

Table 2 The average scores attained for the six mood subscales, the total mood disturbance score in train drivers (n=60) and the normative values for an adult male sample (Nyenhuis et al., 1999) of the Profile of Mood States Questionnaire.

Sub-scale	Train Driver mean score	Normative values (Nyenhuis et al., 1999)
Tension-Anxiety	7.3 ± 6.5	7.1 ± 5.8
Anger-agression	7.3 ± 7.8	7.1 ± 7.3
Fatigue-inertia	8.8 ± 6.3	7.3 ± 5.7
Depression-dejection	7.0 ± 7.7	7.5 ± 9.2
Confusion-bewilderment	4.6 ± 3.2	5.6 ± 4.1
Vigor-activity	16.6 ± 5.2	19.8 ± 6.8
TOTAL MOOD DISTURBANCE	18.4 ± 28.3	14.8 ± 32.7

Table 2 presents the average test scores attained for the six mood subscales, the total mood disturbance score and the normative values (Nyenhuis et al., 1999)

3.2. Stress, Depression and Anxiety associations to Workplace and Lifestyle factors

A number of significant partial correlations were identified between workplace/lifestyle factors and perception of stress scores (as measured by LAQ-P2), when controlling for covariates (age, gender, smoking status and body mass index). Perception of stress scores were positively correlated with the number of accidents or near misses during the previous 12 months (r = 0.33, p = 0.021), the number of accidents or near misses during career (r = 0.29, p = 0.042), and negatively correlated with social interaction during working shift (r = -0.31, p = 0.028).

A number of significant partial correlations were identified between workplace/lifestyle factors and depression assessment scores, when controlling for covariates (age, gender, smoking status and body mass index). The Beck Depression Inventory scores were positively correlated with the number of accidents or near misses during the previous 12 months (r = 0.30, p = 0.0035), the number of accidents or near misses during career (r = 0.36, p = 0.011), and negatively correlated with social interaction during working shift (r = -0.28, p = <0.05). The Beck Anxiety Inventory scores were positively correlated with the amount of alcohol consumed each week (r = 0.33, p = 0.02). No further significant correlations were identified. Refer to table 3 for a list of these associations.

Table 3: Depression and Anxiety partial correlations to Workplace and Lifestyle factors

Variable	LAQ P2		POMS D/D		BDI		BAI		POMS T/A	
	r	p	r	p	r	p	r	p	r	p
Alcohol	0.192	0.186	0.175	0.229	0.184	0.207	0.331	0.020*	0.092	0.529
Coffee	0.108	0.460	-0.022	0.883	0.004	0.980	0.048	0.742	0.008	0.957
Years Driving	0.161	0.270	0.093	0.525	0.150	0.304	0.13	0.372	0.037	0.800
Accidents/CR	0.291	0.042*	0.156	0.284	0.360	0.011*	0.217	0.134	0.245	0.089
Accidents/YR	0.330	0.021*	0.240	0.097	0.302	0.035*	0.203	0.161	0.233	0.108
Hours Driving	0.161	0.268	0.038	0.739	0.083	0.569	0.069	0.637	0.104	0.479
Interaction	-0.314	0.028*	-0.241	0.095	-0.282	0.050*	-0.246	0.088	-0.273	0.058

Table 3 present partial correlations between depression, anxiety and workplace and lifestyle factors.

p: Level of statistical significance
POMS D/D: Depression/Dejection subscale of the Profile of Mood States Questionnaire
POMS T/A: Tension/Anxiety subscale of the Profile of Mood States Questionnaire
r: Correlation coefficient
*: Indicates significance (p <0.05)

To determine which workplace variables uniquely contributed to the perception of stress scores, as measured by the LAQ-P2, only those variables that correlated significantly were entered into a multiple regression analysis; to identify the strongest predictors. Table 4 shows that this regression was significant (R = .60, R^2 = .35, adjusted R^2 = .30, F = 6.9, df = 3,59, p = <0.001) for three variables (accidents during previous 12 months, accidents during career and social interaction during work shift), which together explained 35% of the variance in perception of stress scores. However, the only individual variable that was significant in the regression was the number of accidents during the previous 12 months (p = 0.048), making it the strongest predictor of perception of stress.

Table 4: Standard multiple regression, perception of stress and workplace/lifestyle variables

	β	SE of β	B	SE of B	t	p
(Constant)			20.1	3.08	6.5	<0.001
Accidents during previous 12 months	0.433	0.14	3.15	1.53	2.06	0.047
Accidents during career	0.061	0.18	0.13	0.45	0.29	0.77
Social interaction during shift	-0.272	0.11	-1.01	0.50	-2.04	0.048*

β = Standardised coefficient
B = Unstandardised regression coefficient
p = Level of statistical significance
R = Correlation coefficient
SE of β = Standard error of standardised regression coefficient
SE of B = Standard error of unstandardised regression coefficient
Std. = Standard
t = t statistic
*: Indicates significance (p = <0.05)

To determine which workplace variables uniquely contributed to depressive symptomology as measured by the Beck Depression Inventory, only those variables that correlated significantly with the BDI scores were entered into a standard multiple regression analysis. Table 5 shows that this regression was significant (R =.47, R^2 =.22, adjusted R^2 =.18, F = 5.2, df = 3,56, p = 0.003) for three variables (accidents during previous 12 months, accidents during career and social interaction during work shift), which together explained 22% of the variance in depression, as measured by the BDI. However, the only variable that was significant in the regression was social interaction during shift (p = 0.025).

Table 5: Standard multiple regression – Depression/Dejection score and workplace variables

	β	SE of β	B	SE of B	t	p
(Constant)			9.07	1.53	-5.93	<0.001
Accidents during previous 12 months	0.16	0.12	0.66	0.63	1.04	0.302
Accidents during career	0.24	0.14	0.20	0.13	1.53	0.133
Social interaction during shift	-0.27	0.17	-0.57	0.25	-2.30	0.025*

β = Standardised coefficient
B = Unstandardised regression coefficient
p = Level of statistical significance
R = Correlation coefficient
SE of β = Standard error of standardised regression coefficient
SE of B = Standard error of unstandardised regression coefficient
Std. = Standard
t = t statistic
*: Indicates significance (p = <0.05)

Discussion:

A number of lifestyle and workplace variables were found to be linked to negative mood states such as perception of stress, depression and anxiety. When examining the variables associated with stress, the number of accidents across both the previous 12 months and throughout career were found to be positively correlated to stress scores. Stress is a known risk factor for the development of other mental health conditions, such as anxiety and depression, in particular when chronic (Plieger et al., 2015). Stress has also been linked with reduced driver performance and an increase risk of accidents or near misses (Matthews et al., 1998, Taylor and Dorn, 2006, Matthews et al., 1991). Chronic stress is well accepted to interfere with normal bodily stress responses, those responses that would generally be considered advantages in times of stress. During times of chronic stress, an acute on chronic stress response results in impaired memory retrieval (Roozendaal, 2002, Kuhlmann et al., 2005), fine motor skills (Mancini et al., 2018, Mancini et al., 2019) and higher-order cognitive processes (Budsankom et al., 2015). As such, stress is known to be a contributing factor to reduced driver performance, and thus crash risk (Klauer et al., 2006). This study is the first of its kind to link stress to increased crash or near miss risk in a population of Australian train drivers. Given this, further research would benefit from identifying stress inducing factors that have the potential to be mitigated within the workplace, thus reducing the potential contribution of stress to this risk. Further, social interaction during shift was found to be inversely related to stress. That is, the greater the social interaction reported by drivers during their shift, the lower the average stress levels. Social interaction is well recognized as a protective factor against stress levels. A study by Ozebay and team (2007) found that as social interaction increased, both acute and chronic stress reduced. The biopsychosocial theories behind socialisation as a protective factor for stress stem from the necessity of interaction as an evolutionary advantage. Social support may mitigate genetic and environmental vulnerabilities and provide resilience to stress, conceivably via its hormonal effects on the hypothalamic-pituitary-adrenocortical (HPA) axis, the noradrenergic system, and systemic oxytocin pathways (Ozbay et al., 2007). Given the identified links between stress, accidents throughout career and interaction that were elucidated in this study, further research is needed to identify factors that may mitigate stress within this population.

Similar to perception of stress, depression was positively correlated with accidents or near misses, both in the previous 12 months and throughout career, and inversely correlated with social interaction during shift. Much like stress, depression has been strongly linked to a reduction on driver performance, with studies finding that individuals suffering from depression exhibit reductions in reaction times, steering control (Bulmash et al., 2006a) and attentive awareness (Vedhara et al., 2000). Given not only the implications of train carriage accidents, but the potential for large scale commuter danger should an accident occur, it is evident that further research must be undertaken to elucidate the direction of the relationship between accidents and near misses, and depression. While the present study did not identify levels of depression within this population that were higher than advised normative values, it is clear that the implications of this mental illness may be significant with regards to driver performance. Further, the inverse relationship identified between depression and social interaction during shift provides a unique insight into a possible contributory, or protective, aspect of this occupation. That is, increased social interaction may be a protective factor for the development of depression, just as social isolation during shift may contribute to the development of this mental health disorder. There may, however, be some selection bias regarding this association. That is, individuals who experience depression are more likely to avoid social interaction that those who do not. All the same, workplace procedures which encourage social interaction at work, such as ToolBox talks (Campbell and Gunning, 2020), regular mental health forums (Nexø et al., 2018) and buddy systems (Clark-Hitt et al., 2012) have been shown to improve employee mental health in many other industries.

There are some limitations of the present study. Response bias may be present due to the use of self-reported questionnaires; however, we attempted to mitigate this bias by conveying to participants that all responses were deidentified and thus, anonymous. While common in psychometric studies, univariate analysis has limitations in its predictive power, in particular as workplace variables rarely occur in isolation of one another. However, we believe that a rational and well recognised preliminary step is to investigate univariate associations, which allows the variables to be quantified preceding their insertion into a later predictive model. The primary objective is to include the "best" group of variables that increase predictive capability, whilst ensuring no unnecessary complexity.

Conclusion:

The population of Australian train drivers has rarely been studied, in particular, the biopsychosocial health of these individuals remains elusive. This study aimed to assess workplace factors that may be linked with depression and anxiety within this population. Accident history was identified as an independent predictor of both stress and depression within this population. Further, reduced social interaction on shift was found to be the strongest predictor of both stress and depression. This study highlights important workplace factors that may be linked with negative mental states, and their potential implications within the workplace. The promotion of improved mental health within this occupation would not only improve the health of the individual drivers but may also reduce mental health associated absenteeism and improve commuter safety. Buddy driving systems (Clark-Hitt et al., 2012), regular workplace ToolBox talks and forums (Campbell and Gunning, 2020), and a commitment to mental awareness (Nexø et al., 2018) are strategies that have been successfully employed in other industries. Given the societal responsibility of passenger train drivers, protecting and promoting the psychosocial health of these individuals is paramount to not only a healthy workforce, but a safe community.

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4.3 Cardiovascular links to affective states

The links between depression and reduced cardiovascular health is well identified in the literature. The Australian Heart foundation has also recognised depression as a modifiable biomedical risk factor for CVD, and has proposed that the associations between depression and impaired cardiovascular functioning warrant additional investigation (Australian Heart Foundation, 2008b). The following original research articles aim to address the gaps in literature surrounding the potential links between depression and impaired autonomic cardiovascular functioning in a cohort of Australian train and truck drivers. All of the following articles are published in press, have been accepted, or are currently under review.

4.3.1 Heart rate variability and depression: a general review

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Under Review: *Psychopathology*

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The autonomic nervous system (ANS) of the human body is a division of the peripheral nervous system, which can be further classified into the sympathetic and parasympathetic branches. These two divisions of the ANS act synchronously and autonomously to preserve homeostatic bodily function in response to internal and external stimuli (Pumprla et al., 2002a, Robertson et al., 2012, Pumprla et al., 2002b). The homeostatic effects of these subdivisions incorporates a broad range of visceral components, including cardiac control, secretory gland regulation and organ metabolic function (Grassi, 1998)

Colloquially referred to as the “fight or flight” response, the function of the sympathetic nervous system (SNS) is to accommodate for immediate requirements of metabolic stores (Raven and Johnson, 2008). Resulting physiological adjustments, such as the initiation of the stress response, dilation of the pupils, increased heart rate, adrenaline release, decreased digestive processes, depressed immune function and the dilation of the bronchioles, prepare the body for activity and reduce non-vital processes ((Raven and Johnson, 2008)

Known as the “rest and digest” response, the parasympathetic nervous system (PNS) is principally associated with digesting food, relaxing and sleeping (Raven and Johnson, 2008). It involves the reduction of metabolic rates and increasing the secretions and activities of digestive organs (Raven and Johnson, 2008). The parasympathetic nervous system also acts to reduce the heart rate (Raven and Johnson, 2008).

These two subdivisions of the ANS (SNS and PNS) can be examined using spectral analysis of heart rate variability (HRV) (Pumprla et al., 2002a). This non-invasive technique involves comprehensive and meticulous analysis of time fluctuations between sequential heart beats, and can be used to indirectly quantify autonomic control of the heart (Acharya et al., 2008). HRV is attained via a three-step sequence, the first of which involves attaining an electrocardiogram (ECG) recording. The period between sequential heartbeats is generally measured from one R peak on the ECG to the next. Variability in this heart rate has been shown to be indicative of the dynamic interaction between the SNS and the PNS (Acharya et al., 2008, Andrade et al., 2003).

The employment of HRV as an indicative measurement in clinical settings has provided the foundation for the practical functionality of this assessment. HRV is utilised in many clinical settings. A study conducted by Acharya and associates assessed 352 patients for cardiac abnormalities using analysis of HRV (2008). The study found that using the Fast Fourier Transform (FFT) to analyse HRV resulted in the correct classification of cardiac classes for chronic heart failure, complete heart block and preventricular contraction 91.6%, 100% and 91.7% of the time respectively. The correct classification of a left bundle branch block and ischemic/dilated cardiomyopathy was determined in 83.3% and 81.8% of the cases respectively. It should be noted, however, that reduced accuracy was identified for some cardiac conditions, as atrial fibrillation, ventricular fibrillation and sick sinus syndrome were only correctly classified using FFT analysis of HRV in 66.7%, 58.3% and 63.6% of the cases respectively.

Additionally, the prognostic value of HRV after myocardial infarction has been identified. A prospective study was conducted by La Rovere and team (1998) assessing 1,284 patients who had suffered a recent (<28 days) myocardial infarction. A follow up was completed, with individuals being reassessed every 4 months for a minimum of 1 year and a maximum of 21 months. It was found that the univariate relative risk of cardiac mortality after a myocardial infarct, when an individual presented low HRV was 5.3, providing evidence for the prognostic value of HRV analysis in determining relative risk of cardiac mortality in myocardial infarct patients. These varied applications emphasise the clinical significance of this important predicative measure based on cardiac activity. HRV is decreased when sympathetic influence dominates parasympathetic influence (Klein et al., 1995, American College of Cardiology Cardiovascular Technology Assessment Committee, 1993, van Ravenswaaij-Arts et al., 1993). Reduced heart rate variability has been associated with a greater risk of ventricular arrhythmias and sudden death (van Ravenswaaij-Arts et al., 1993).

The link between heart rate variability and depression has been investigated increasingly in recent years. Despite numerous recent studies, the results attained from these have yielded varied results. Depression is a burdensome affective disorder, affective between 8-12% of the population worldwide. Depressive disorder is the primary cause of disability worldwide when assessed using Years Lived with Disability (World Health Organisation, 2012). In 2000, depression was the fourth greatest contributor to the global burden of disease, and it has been forecast that by the year

2020, it will be the second greatest contributor to this burden (World Health Organisation, 2012). Depression has been linked to an increase in cardiovascular mortality, with studies suggesting this risk may be as high as 400% in patients suffering from Major Depressive Disorder.(Nicholson et al., 2006)

This association between depression and an increased risk of developing CVD is of serious concern, especially when we consider the paucity of literature surrounding the topic. Depression has been linked to increased risk of cardiovascular mortality, however to exact mechanism is somewhat unclear. Furthermore, the Australian Heart Foundation has indicated that additional research is required to assess the cardiac effects of depression, and whether it may be possible to link biomarkers such as HRV to the degree of depressive symptomology being experienced by the individual (Australian Heart Foundation, 2008b).

Agelink and co-workers (2002) associated time and frequency domain HRV indices throughout a 5-min rest deep breathing and Valsalva test, in 32 patients with suffering from major depression and 64 controls who exhibited no depressive symptoms. The Valsalva manoeuvre comprises of forced exhalation against a closed glottis, resulting in an increase in intrathoracic pressure (Opotowsky et al., 2010). This clinical technique is used to assess cardiovascular health. The study found that individuals with severe depression displayed reduced HRV, specifically, a significantly reduced modulation of cardiovagal activity, when compared to non-depressed controls. The increase in cardiovascular mortality observed in patients exhibiting symptoms of severe depressive disorder may be somewhat attributed to the dislocation of the sympathovagal balance in favour of sympathetic modulation. Furthermore, severity of depressive symptoms and cardiovagal activity were found to be inversely correlated, indicating that as depressive symptoms increased, cardiovagal activity decreased.

A study by Koschke and associates (2009) supports these findings, compared 75 individuals experiencing recurrent major depressive disorder to 75 age- and gender-matched controls. HRV frequency domain results exhibited a significant shift of autonomic balance towards sympathetic dominance and a reduction in parasympathetic modulation. There was, however, no evidence to support prior studies that suggest the degree of autonomic imbalance relates to the severity of depressive symptoms.

A study by Kemp and team examined 73 patients diagnosed with Major Depressive Disorder and 94 age- and sex- matched controls (Kemp et al., 2012). The Hamilton Depression Rating Scale was used to assess the severity of clinical depression. The study found that HRV was reduced in patients diagnosed with Major Depressive Disorder when compared to their age- and sex-matched controls. An interesting identification was noted, in that patients exhibiting comorbid Generalised Anxiety Disorder were found to have a greater reduction in HRV than those exhibiting Major Depressive Disorder alone. Supporting these findings, Udupa and associates conducted a study (2007) which found that individuals suffering from major depressive disorder exhibited higher sympathovagal balance (the ratio of low frequency (LF) to high frequency (HF) HRV) than non-depressed controls suggesting sympathetic predominance. The study assessed 40 individuals experiencing major depression when compared with 40 gender- and age- matched controls. Resting HRV was obtained whilst individuals were seated for fifteen minutes in a relaxed position. Active HRV was then obtained during a deep breathing and Valsalva test (see above for an explanation of the Valsalva manoeuvre). Results indicated that individuals with severe depression presented a reduction in HRV, indicative of an increase in sympathetic and decrease in parasympathetic modulation. In contrast, a study led by Henje Blom identified significant reductions in sympathetic modulation in female patients with major depressive disorder (n=11) when compared to their age and location matched controls (n=53) (2010).

In further contrast, a study by Bar and associates (2004) found no deviation in HRV when comparing patients exhibiting depressive symptoms (n=18) to their physiologically matched controls (n=18). This study associated HRV during a five-minute rest period with HRV data attained during a deep breathing exercise. There were no perceptible variations in HRV between the depressed and non-depressed control groups, although this could be attributed to artifacts during the short length of the HRV recording (5 minutes). HRV requires an adequate period of time (a minimum of 5 minutes of good quality ECG data) to allow for the detection of subtle autonomic variations that accompany depression (Berntson et al., 1997). Supporting this, a study by Yeragani (1991) found no significant variation in HRV between depressed individuals (n=19) and a control sample (n=20) although the study employed a small sample size, which may have skewed the obtained results.

Studies that have examined the associations between HRV and depression have obtained varied results. Whilst some studies have reported a reduction in parasympathetic modulation (Rechlin et al., 1994, Guinjoan et al., 1995), others have reported no apparent variation (Yeragani et al., 1991, Moser et al., 1998, Bar et al., 2004). Likewise, inconsistent results have been obtained concerning the influence of depression on the sympathetic branch of the ANS, with studies reporting an increased

(Guinjoan et al., 1995, Udupa et al., 2007), decreased (Tulen et al., 1996), and unchanged (Moser et al., 1998) sympathetic control in individuals with depression. Of those that did report a confirmatory link between HRV and depression, there remains some ambiguity regarding the impact of the severity of symptoms on autonomic control. Some studies have suggested that cardiovagal modulation is conditional to symptom severity (Agelink et al., 2002), whilst others have reported that there is no evident association between the degree of autonomic imbalance and the acuteness of depressive symptoms (Koschke et al., 2009). Variations in the heterogeneity, sample size, exclusion criteria, lengths of ECG recording and experimental design have all contributed to these inconsistencies.

Author Contributions

Conceived and designed the experiments: SL, TC. Analysed the data: TC. Wrote the first draft of the manuscript: TC. Contributed to the writing of the manuscript: TC. Agree with manuscript results and conclusions: SL. Jointly developed the structure and arguments for the paper: TC, SL. Made critical revisions and approved final version: TC, SL. All authors reviewed and approved of the final manuscript.

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4.3.2 Assessing cardiovascular associations to affective states in Australian truck drivers

In Press: Chalmers, T., & Lal, S. (2014). Assessing cardiovascular associations to affective states in Australian truck drivers. *Journal of the Australasian College of Road Safety*, *25*(3), 23.

Abstract

Within this exploratory study, data is presented regarding occupational and lifestyle factors that contribute to cardiovascular disease and depression within the truck driving industry, and subsequently contribute to reduced road safety in Australia. The study assessed associations between mood parameters, heart rate variability (HRV) and blood pressure in the unstudied population of Australian truck drivers. A total of 35 heavy vehicle truck drivers were recruited from the local community. Electrocardiogram recordings were obtained during a baseline quite sitting, and active driving simulator task. HRV low and high frequency parameters were obtained from the ECG. Subjects completed the Profile of Mood States questionnaire and the Lifestyle Appraisal Questionnaire. Blood pressure was recorded before and after the study. Numerous mood states (anger-aggression, total mood disturbance score) were correlated to an increase in sympathetic activity ($p<0.05$). Diastolic blood pressure was positively correlated to a number of mood states, the most significant correlation being depression-dejection ($p<0.001$).

Introduction

The trucking industry plays a fundamental role in the affluence of Australia. A combination of long distances between industries and a low population density results in a heavy dependence upon road freight. Working conditions in the truck driving industry commonly involve both physiological and psychological demands. Intermittent work and rest cycles, loading and unloading of heavy freight [1], intense cabin vibrations, irregular meal schedules, occupational stress [1], monotonous driving conditions and the necessity of intense mental alertness [2], all contribute to impaired truck driver health. As a result of these occupational lifestyle factors, truck drivers potentially elevate their risk of many physiological and psychological health conditions such as diabetes [3], cancer [4], pain [1], sleep apnoea [5], cardiovascular disease (CVD) [2, 6], and affective disorders such as depression [7]. Between June 2010 and June 2011, 211 deaths resulted from 185 crashes involving heavy rigid or articulated trucks in Australia [8]. Despite accounting for only 2.47% of the total vehicles on Australian roads, heavy vehicles have been implicated in 17.96% of the fatal road accidents [9]. The economic implications of these accidents are significant, reportedly costing Australia approximately $2 billion each year [10]. It has also been shown that approximately one in every five individuals who are injured in the workplace in Australia is a truck driver [11]. This fatality rate is fourteen times that of all other occupational deaths in Australia [11].

Globally, CVD is the leading cause of premature death [12]. Cardiovascular disease [2], myocardial infarction and ischemic heart disease [6] have all been identified as serious health issues within the trucking industry. A study conducted by the National Transportation Safety Board [13] found that 9.2% of fatalities involving truck drivers in America involved some form of cardiac incident. Furthermore, a recent study found that in Australia, a collapse from heart disease accounts for as much as 15% of all crashes where the driver suddenly becomes ill [14]. High rates of obesity, sedentary lifestyles [15], cigarette smoking [15], hypertension [15], saturated fat and alcohol dependent behaviour [15] have all been consistently reported within this occupational field, and as such, contribute to the development of cardiovascular disease within the trucking industry.

Depression is a common affective disorder, which has been previously linked to the truck driving industry. A recent study conducted by Hilton and his team [7] found that 13.3% of Australian heavy vehicle truck drivers exhibited at least a mild form of depression (as measured by the Depression, Anxiety and Stress Scale) in comparison to the reported national rate of 11.6% [16]. Similarly, a study by da Silva-Junior and associates [17] found that 13.6% of the sample cohort of truck drivers (n=300) suffered from depression (as diagnosed through the section Major Depressive Episode in the Mini International Neuropsychiatric Interview). Supporting these findings, a study in 2007 found that 14.5% of truck drivers felt more depressed since beginning work within this occupation [18]. Recently, work stress has been heavily implicated as an independent predictor of depression [19]. As previously mentioned, truck drivers are frequently subjected to long hours, irregular work/rest cycles, isolation and intense occupational pressure. These common work stressors result in truck drivers being viewed as a depression vulnerable population. Additionally, the implication of long working hours in the development of depression has been further supported by a study conducted by Virtanen and colleagues [20], in which individuals who worked more than 11 hours per day were at a significantly increased odds ratio (OR) of developing depression (2.52 compared to 1.0). Depression has been consistently associated with a decrease in driver performance. A recent study conducted by Hilton and his team [7] found that severe and extremely severe depression in heavy vehicle truck drivers resulted in a significantly higher OR (4.4 and 5.0 respectively) for an accident or near miss. The study also found that self-reported performance at work was reduced by 5.7% in drivers experiencing severe depression when compared to those with no depressive symptoms. Supporting this, Blumash and associates [21] found that individuals with major depressive disorder exhibited marked decreases in steering reaction time and an increased number of crashes when compared to a control sample. These findings provide evidence for the detection and management of depression in heavy vehicle truck drivers in Australia.

Of concern is the scarcity of literature regarding depression in the trucking industry in Australia. Aside from the aforementioned study conducted by Hilton and associates [7], the rate of depression in Australian heavy vehicle drivers has been somewhat overlooked. Of further concern are the statistics regarding the adverse effects of depression on driver performance and the role of CVD in road accidents. Furthermore, the likelihood of seeking medical advice for the treatment of depression in Australia is worrisome, with a recent survey conducted by the Australian Bureau of Statistics [22] ascertaining that only 35% of Australian individuals who had suffered from a mental disorder in the previous 12-month period had accessed appropriate medical services. Despite a higher prevalence of depression amongst females when compared with males in Australia (14.5% and 8.8% respectively [22]), a seemingly entrenched social perception, which dissuades males from seeking medical advice, has resulted in significantly lower diagnostic rates of affective disorders among males [23]. Due to the extreme gender bias of the truck driving industry (97.5% male [24]), an underlying prevalence of undiagnosed affective disorders may be present, supporting the investigation of this health implication within this occupation.

Behavioural cardiology is a developing field of clinical practice based on the understanding that adversative lifestyle behaviours, emotive factors and chronic stress can collectively contribute to atherosclerosis and adverse cardiovascular events. The Australian Heart Foundation has recently identified depression as a modifiable biomedical risk factor for CVD and has suggested that the link between depression and cardiovascular impairment warrants further investigation [25]. At present, there have been varying results regarding the impact of this disorder on cardiac activity and the development of cardiovascular disease. The present study aimed to assess the presence and effect of a number of adverse lifestyle and mood states on the cardiovascular system in order to identify possible behavioural and environmental factors within the Australian trucking community that may contribute to the development of CVD. By understanding and evaluating the presence and effect of depression and cardiovascular disease in the Australian truck driving community, we may be able to provide the foundation for the implementation of management procedures to reduce the effects of these disorders on driving ability, and thus, improve road safety within Australia.

Methods

Participants

A total of 35 heavy vehicle truck drivers were recruited from the local Sydney City community, aged between 18 and 69 inclusive. The ratio of males to females reflected the male dominance (97.5%) in the Australian trucking industry, with 33 males and 2 females being recruited to participate. Participants were recruited through local advertisement via a poster, recruitment though contacts established independently to this research, online forums and with the aid and endorsement of Australia Post Transport division and the Transport Workers Union. Participants were required to be employed as a truck driver, regularly driving a truck with a gross vehicle mass of over 4.5 tonne, not be consuming any prescription or non-prescription drugs (excluding tea, coffee and nicotine) and not be suffering from any chronic disease or illness. Participants were required to abstain from food for two hours, nicotine and caffeine for four hours, and alcohol for 12 hours prior to the study.

Procedure

Participants were tested between 9.30 am and 3 pm in order to negate the variations in heart rate between 8 - 9am and 4 – 8pm recently identified by Chen [26]. Furthermore, by ensuring participants abstained from consuming food for two hours prior to testing, the effect of the post-prandial blood pressure dip was negated. The study was conducted in a controlled laboratory environment, with auditory and visual interference being reduced as much as viably possible. Light sources were controlled, with laboratory blinds being drawn to reduce the impact of external light sources influencing physiological measurements. The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions being presented. Upon confirmation of written consent, the study was commenced.

Blood pressure

Upon commencement of the study, three pre-study blood pressure (BP) readings were obtained. The volunteer was required to remain seated for five minutes prior to the BP readings being recorded, with a two-minute seated interval between each of the measurements. In accordance with the National Heart Foundation of Australia BP guidelines [27] and the UTS HREC approved emergency protocol, a BP reading of greater than 160/100 mmHg resulted in the participant being excluded from the study. Furthermore, the participant was advised to seek urgent medical advice and the offer was made to escort the individual to the nearest medical facility. A participant with a pre-study BP reading greater than 140/90 mmHg but lower then 160/100 mmHg, whilst included in the study, was advised to consult their general practitioner regarding their elevated BP reading. Three post-study BP readings were also obtained, again in accordance with the National Heart Foundation of Australia BP guidelines [27] and the UTS HREC approved emergency protocol.

Lifestyle Appraisal Questionnaire

The Lifestyle Appraisal Questionnaire (LAQ) [28], a validated and clinically reliable questionnaire, was used to record demographic, lifestyle and psychological stress information from participants. The LAQ consists of two parts, with Part I consisting of 22 questions, with the highest obtainable score being 73. This information included family history of disease, smoking status, alcohol intake, exercise and diet regime, etc. The higher the score obtained from Part I of the LAQ, the greater the risk of developing a chronic illness later in life [28]. Part II of the LAQ consists of 27 items and assessed an individual's "*cognitive appraisal of pressure and demands*" [28]. Following this, body mass index was objectively measured in the laboratory.

SmartData questionnaire

The SmartData questionnaire [29] provides demographical information regarding licensing, trucking history, employment status, nutrition, accident history and working conditions. This questionnaire was utilised as a basis for possible stratification of data, and to ascertain common conditions of truck driving in Australia. Following the administration of the SmartData questionnaire, the Likert Fatigue scale was completed.

Likert Fatigue Scale

The Likert scale is used to measure fatigue levels both prior and post the electrocardiogram (ECG) study [30]. The measure employs a rating scale of four points: not at all, slightly, moderately or markedly fatigued, and the participant circles the appropriate response, scored 0 – 3 respectively. The Likert scale of fatigue is scored 0 – 3 and produces a fatigue score (maximum score 3, with 0 indicating the participant is not at all fatigued, and 3 indicating marked fatigue). Fatigue has been shown to impact upon heart rate variability (HRV) and as such, this confounder is measured pre- and post-study to provide adequate information to allow for thorough identification of any areas of possible inter-individual variability.

Profile of Mood States Questionnaire

The Profile of Mood States questionnaire (POMS) [31] is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigour-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia and confusion-bewilderment scales minus the score on the vigour-activity scale. The POMS questionnaire is a subjective measurement of well-being and is an assessment of an individual's mood state during the previous week, including the day of participation. This measurement is not used in this study to clinically diagnose depression in individuals, but rather, to elucidate mood states that may impact physiological parameters. This questionnaire is a well-validated, reliable, low cost, ergonomic mood state tool.

Heart rate variability

Standardised attachment of a three-lead electrocardiogram was performed, with the active electrodes being positioned at the intercostal space between the fourth and fifth ribs, two centimetres laterally from each side of the sternum and the reference electrode being secured underneath the shoulder. Following this, the individual was seated and undertake the baseline phase of testing, which involved 20 minutes of quiet sitting, with their eyes open. Following this, the participant began the active phase of testing which involved the participant being seated in the driving simulator, using the Logitech G7 Racing wheel to manoeuvre around the Standard Street One course of the Scania Truck Driver Simulator for twenty minutes whilst the ECG was used to collect heart rate data. The driving simulator was employed in order to elicit a physiological stress response, and it should be noted that subjects were familiarised with the program prior to ECG recordings being obtained. Heart rate variability (HRV) data was then obtained from the R-R intervals of the ECG recordings using a non-parametric algorithm (Fast Fourier Transform) and used as a quantitative measurement of the sympathetic (Low Frequency HRV) and parasympathetic nervous systems (High Frequency HRV).

Heart rate variability analysis

Initially, using the QRS detector, the pre-processing step of HRV analysis included band pass filtering to decrease power line noise, baseline wander, muscle noise and any other interference components. The pass band at approximately 5 – 30 Hz is sufficient to cover most of the frequency content of QRS complex [32]. After this pre-processing had occurred, a set of decision rules were applied to define if a QRS complex had occurred. The decision rules included the average heartbeat period as well as the amplitude threshold, which were amended adaptively as the detection process continued. The fiducial point was selected to be the R-Wave, and the time at which the R-Wave occurs was logged. Post R-Waves identification, and time of R-Wave occurrence was determined, the HRV time series was derived. The R-R intervals were determined as the variances between successive R-Wave occurrence time periods. A power spectrum density (PSD) estimate was then used to calculate the R-R interval series. The PSD estimation is performed using the Fast Fourier Transform based Welch's periodogram method (Hann window was used). In the Welch's periodogram method, the HRV sample is separated into overlapping segments (50% overlap). The spectrum was then acquired by calculating the average spectra of these segments. This method reduces the amount of variance of the FFT spectrum. The frequency bands derived for short-term HRV recordings were low frequency (LF, 0.04 – 0.15 Hz) and high frequency (HF, 0.15 – 0.4 Hz). The absolute power values for each frequency band were derived through integration of the spectrum over the band limits.

Results

Significance testing was conducted using a standard confidence interval of 95%. Correlation analysis identified a number of statistically significant associations between BP and LAQ scores (Table 1). Pre-study systolic BP was positively correlated with both P1 ($r = 0.34$, $p = 0.049$) and P2 ($r = 0.39$, $p = 0.02$) of the LAQ. This positive correlation was also identified for pre-study diastolic BP with respect to P1 ($r = 0.47$, $p = 0.004$) and P2 ($r = 0.38$, $p = 0.024$) of the LAQ. Additionally, an increase in post-study systolic BP was associated with increased P1 ($r = 0.43$, $p = 0.009$) and P2 scores ($r = 0.46$, $p = 0.006$).

A number of statistically significant correlations between pre-study diastolic BP and the scores from the POMS questionnaire were identified. Those who presented with high pre-study diastolic BP readings, also reported higher tension-anxiety (r = 0.34, p = 0.043), fatigue-inertia (r = 0.35, p = 0.038), total mood disturbance (r = 0.38, p = 0.023) and the most significant association; depression- dejection (r = 0.43, p = 0.009) scores.

Table 1. Blood pressure associations with Lifestyle Appraisal Questionnaire

		r	p
Pre-study systolic BP	**LAQ P1**	0.34	0.049
	LAQ P2	0.39	0.020
Pre-study diastolic BP	**LAQ P1**	0.47	0.004
	LAQ P2	0.38	0.024
Post-study systolic BP	**LAQ P1**	0.43	0.009
	LAQ P2	0.46	0.00

The regression analysis for pre-study diastolic BP had an overall significance (F = 2.42, df = 9, 25, p = < 0.039, R = 0.68, R^2 = 0.47, Adjusted R^2 = 0.27) for nine variables (age, BMI, LAQ P1, LAQ P2, tension-anxiety, anger- aggression, fatigue-inertia, depression-dejection, TMD) together accounting for 46% of the variance in pre-study diastolic BP. The regression analysis for post-study systolic BP was significant (F = 3.9, df = 4,30, p = < 0.011, R = 0.59, R^2 = 0.34, Adjusted R^2 = 0.26) for four variables (age, BMI, LAQ P1 and LAQ P2) together accounting for 34% of the variance in post-study systolic BP. The individual variable that was most predictive of post-study systolic BP variability was LAQ P2 (p = 0.03).

A statistically significant positive correlation was identified between LF HRV measured during the active phase and anger-aggression (r = 0.38, p = 0.03) (Table 2). A significant positive correlation between HF and anger-aggression (r = 0.42, p = 0.001) and a negative correlation with the vigour- activity score (r = -0.36, p = 0.004) was also identified.

HF reactivity showed a positive correlation with the anger-aggression subscale (r = 0.38, p = 0.023) and was negatively correlated with vigour-activity (r = -0.34, p = 0.048). No significant correlations were identified between POMS mood subscale scores and HRV data during the passive phase of testing.

Table 2. Mood disturbance associations with HRV during an active task

HRV parameter	POMS mood subscale	r	p
LF (ms^2) (Active)	Anger-aggression	0.38	0.03
	Vigour-activity	-0.31	0.07
	TMD	0.32	0.07
HF (ms^2) (Active)	Anger-aggression	0.42	0.01
	Confusion- bewilderment	0.32	0.06
	Vigour-activity	-0.36	0.04
	TMD	0.33	0.06

Discussion

Although no previous literature has addressed the links between part 1 of the LAQ and BP measurements, the present study identified a positive correlation between adverse lifestyle factors and pre/post-study SBP and pre-study DBP. Collectively, it can be assumed that an individual engaging in a number of undesirable lifestyle habits, such as those assessed in part 1 of the LAQ, is likely to have high BP. High SBP and DBP have been strongly associated with an increased CVD risk [33], and as such, addressing these adverse lifestyle factors that contribute would be beneficial in reducing BP in truck drivers.

Part 2 of the LAQ assesses an individual's cognitive appraisal of pressures and life demands over the previous eight weeks [28]. It is used to assess an individual's own assessment of the psychological pressures they are experiencing and produces a raw score from which their levels of perceived stress can be determined. It is widely accepted that there is a significant positive correlation between psychological stress and BP [34]. The present study supports these findings, with pre- and post-study SBP, and pre-study DBP found to be positively associated with perception of stress in the truck drivers. A number of mechanisms for this increase in BP, as a result of psychological stress, have been suggested. Individuals who experience prolonged periods of psychological stress have been shown to present higher circulating levels of cortisol, an essential glucocorticoid that controls catecholamines and a number of vasoactive agents that regulate vasculature tone [35]. Cortisol acts to enhance SNS activity by increasing the sensitivity of adrenergic receptors to catecholamine activation [36]. Furthermore, it has been suggested that due to the ability of cortisol to shift fluid from intracellular to extracellular compartments of the kidney, circulating blood volume may increase as a result, thereby increasing BP [37]. The hippocampus is the negative feedback mechanism for the control of circulating cortisol. Consistently elevated cortisol levels, such as those seen in times of prolonged and cumulative stress, reduce the hippocampal neuronal integrity, causing dysregulation of the HPA-axis [38]. This altered function of the HPA-axis has been directly linked to elevations in BP [38].

A number of studies found strong positive correlations between anxiety and BP [39]. The present study supports these findings to some degree, with pre-study DBP found to be positively correlated to Tension-anxiety scores attained from the POMS questionnaire. Unlike previous studies, however, no correlation was found between SBP and Tension-anxiety in the sample studied. This could be attributed to the predominantly male sample of the present study, as it has been reported that men will often underreport symptoms and severity of anxiety in surveys in which they are asked to assess their own psychological health [40]. The Tension-anxiety scores attained from the present sample (12.8 ± 5.4) were comparable to the normative values (12.9 ±6.8) [31]. Despite, this, due to the disinclination of men to report anxiety symptoms accurately on surveys, the true incidence of anxiety disorders within this cohort may actually be significantly higher.

The link between fatigue and BP has been comprehensively investigated numerous times. A recent study found that individuals who scored high on the Epworth Sleepiness Scale (ESS) displayed an increased casual SBP and DBP, when compared with those who attained low ESS scores [41]. Furthermore, short sleep durations, an occupational condition that is often reported by truck drivers, has been consistently associated with an increased risk of hypertension [42]. The present study supports these findings, with a positive correlation identified between pre-study DBP and Fatigue-inertia. The mechanisms by which fatigue influences BP can be attributed to the natural diurnal pattern of BP changes. With the onset of sleep and actual sleep, BP progressively decreases until an individual awakens [43]. This awakening is accompanied by a rapid increase in BP [42]. Sleeping fewer hours per night, as is reported by a large percentage of truck drivers would therefore act to increase average 24-hour BP, an issue in truck drivers. Overall, it should be noted that the Fatigue-Inertia mean score reported from participants in the present study was 2.6 points higher than the reported normative scores, which may suggest that fatigue is an issue within the Australian truck driving industry.

There have been a number of studies that have examined the links between depression and BP. While some found a positive association between depressive symptoms and BP [44], others identified a negative correlation [45]. It should be noted, however, that the inverse relationships found to be associated with depression were generally identified in geriatric populations [45]. The present study found that of all the POMS subscales, Depression-dejection scores had the strongest positive correlation with higher pre-study DBP. Furthermore, there was a trend towards significance with post-study SBP and higher Depression-dejection.

As the present truck driver study sample had a highest individual age of 57, results parallel prevalent literature that suggest BP is positively correlated with depression in samples aged >65 years. This finding supports the initial hypothesis of the study, which stated that depression would be linked to increases in blood pressure. A number of mechanisms have been proposed to justify the increase in BP associated with depression and depressive symptoms. An increase in SNS activity, resulting in an exaggerated cardiovascular reactivity response, is one prominent theory [46]. Also, HPA axis dysregulation resulting in variable hypersecretion of cortisol has been hypothesised to result from depression [47]. It should also be noted that individuals within the present study presented an average Depression-Dejection score of 3.2

points higher than the reported normative, indicating that this condition may be of concern within this industry.

The present study identified a positive correlation between low frequency (LF) (sympathetic activity) HRV during the active driving phase, and the Anger-aggression subscale of the POMS questionnaire. In previous studies, anger has been shown to have a positive relationship with LF activity, indicating an increased sympathetic outflow and sympathetic dominance, which has been identified as a predictive factor for the development of CVD [48]. It has been suggested that the increase in LF HRV in individuals exhibiting anger and aggression can be attributed to the sympatho-adrenal system, which, when experiencing high levels of anger or aggressive behaviour, is over-stimulated, resulting in sympathetic dominance [49]. Furthermore, it has been observed that the application of norepinephrine to the paraventricular hypothalamic nucleus resulted in increases in circulating corticosteroids and glucose [50].

It has been hypothesised that the close physical proximity of the hypothalamic regions involved in defence and those that stimulate the sympatho-adrenal system, may provide evidence for a functional interaction between the neural mechanisms for anger and aggression, and the sympatho- adrenal control of the body at the hypothalamic level [51].

Conclusion

A number of psychological states were assessed in relation to blood pressure. Psychological stress was associated with an increase in BP. This finding parallels the literature, which suggests that psychological stress increases the levels of circulating cortisol, thereby increasing vasoconstriction and blood volume, resulting in elevated BP [35]. Within the present study, fatigue was also positively correlated to BP. This finding is well supported by the current literature [42]. Depression was also found to be associated with an increase in DBP. Although current literature has debated the impacts of depression on BP, the present study suggests that this negative mood state may be associated with an increase in BP and may subsequently result in an increased cardiovascular risk. The psychological health of Australian truck drivers has been somewhat overlooked, with only one study having assessed the psychological wellbeing of this cohort [7]. The Hilton study [7] assessed the prevalence of depression, anxiety and stress-related mood impairment within Australian truck drivers, although no comparisons were made to cardiovascular health. The present study assessed a more comprehensive range of mood states within this industry, including depression, anger, psychological stress, anxiety, confusion and fatigue. Findings from the present study suggest that a number of these negative mood states (psychological stress, tension-anxiety, depression- dejection and fatigue-inertia) are correlated to alterations in BP. As such, the identification and managements of these mood states would improve both the psychological and cardiovascular health of individuals within this industry.

There is also varying evidence regarding the effects of a number of mood states on autonomic activity (as assessed by HRV analysis). The current study identified positive associations between LF HRV (sympathetic activity) and anger. In previous studies, anger has been shown to have a positive relationship with LF activity, indicating an increased sympathetic dominance, which has been identified as an indicator for the development of cardiovascular impairment [48].

Collectively, the findings from the present study provide a novel perspective on the physiological and psychological health of Australian truck drivers. The present study is the first assess to the effects of certain lifestyle and mood states on cardiac parameters (such as BP and HRV) in the cohort of Australian truck drivers. The present study addressed the gaps in research by assessing a number of mood states and their relationships with cardiac parameters. The study found that multiple lifestyle and mood parameters (BMI, psychological stress, anger and depression) were associated with altered cardiovascular function. Elucidating from previous literature, reducing the incidence of these factors would work to reduce both CVD and depression, in turn, increasing driver performance, thereby improving road safety in Australia. These findings also suggest that the improved awareness and management of these factors in the male dominated truck driving industry would improve both the short term psychological and long-term cardiovascular health of these individuals, in turn, reducing the socioeconomic burden associated with these affective disorders and cardiovascular disease in Australia. Considering that heavy vehicle accidents reportedly cost Australia approximately $2 billion each year [10], improving the psychological profile of these individuals would, in turn, reduce the effects of disorders such as depression on driving ability. Furthermore, identifying depression as a contributing factor to impaired cardiovascular function would provide the foundation for the management of this disease within the Australian truck driving industry. Road safety in Australia is a vital aspect of this industry that requires a holistic approach. By incorporating both physiological and psychological management schemes, the safety gains in terms of improved driver ability, and reduction in both absenteeism and cardiovascular related road crashes, would be beneficial.

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4.3.3 Assessing cardiovascular links to depression in Australian Professional drivers

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Abstract:

Introduction: Train and truck drivers experience a myriad of unique occupational factors, which have been postulated to contribute to a high incidence of health conditions such as depression anxiety and cardiovascular disease amongst this population. The present study aimed to identify associations between heart rate variability and negative mood states such as depression and anxiety in a cohort of Australian truck and train drivers. Methods: 120 professional drivers (60 truck drivers, 60 train drivers) were recruited from the local community. Participants completed a battery of mood state questionnaires to assess levels of negative mood states such as depression and anxiety. Participants then completed a baseline (resting) and active (driving) task while concurrent ECG data was collected to obtain HRV parameters. Results: Anxiety and depression were found to be associated with increases in low frequency heart rate variability and sympathovagal balance, and a reduction in total power. Conclusion: The present study identified associations between negative mood states and heart rate variability parameters that are unique to this cohort.

Keywords:

Heart rate variability; professional driver; truck driver; train driver; depression; anxiety.

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1. Introduction:

Australia's rail and road freight systems are primary means for the movement of freight and people between cities, states and territories. These industries employees over 1 million individuals each year, and experience annual industry growth of approximately 4% (Australian Bureau of Statistics, 2018). Given that Australia's person per square kilometre of land ratio is amongst the lowest in the world (Australian Bureau of Statistics, 2017a), a reliance on road and rail freight has persevered despite advancements in commuter and transport technology.

Train and truck drivers experience a myriad of unique occupational workplace factors, such as monotonous driving conditions, long hours spent sitting, the necessity of strict mental alertness, workplace social isolation and the potential for "person under vehicle" events. These conditions have been postulated to contribute to a high incidence of health conditions such as depression (Jeon et al., 2014, Farmer et al., 1992, Ro et al., 2013, Ro and Shin, 2016, Zhou et al., 2015, Hatami et al., 2019, Vakili et al., 2010a), anxiety (Hickey and Collins, 2017, Mehnert et al., 2012, Cothereau et al., 2004a, Boyce, 2016b) and cardiovascular disease (CVD) (Mansur et al., 2015, Ronna et al., 2016, Chapman et al., 2019) amongst this population.

Although often occurring independently of one another, the link between depression and cardiovascular risk is well established. The world health organisation recently identified depression as in independent risk factor for heart disease (Australian Institute of Health and Welfare, 2016). Individuals with depression are more likely to suffer from cardiovascular disease and are more likely to die from CVD related diseases than the general population (Hare et al., 2014). The mechanisms by which depression and cardiovascular disease are linked, however, remain somewhat elusive. Various pathophysiological mechanisms have been suggested, including increased inflammatory responses; hypercoagulability as a result of deleterious adaptions of the clotting cascade; upregulation of oxidative stress responses; hyperactivity of the hypothalamic-pituitary-adrenal axis; downregulation of systemic endothelial progenitor cells; decreased heart rate variability; and genetic diatheses (Penninx, 2017, Bucciarelli et al., 2020, Zuzarte et al., 2018, Shao et al., 2020). Recent studies have utilised heart rate variability (HRV), the analysis of minute fluctuations in successive heart beats, as a means of quantifying cardiovascular autonomic control. In particular, HRV can be used to measure parasympathetic nervous system activity and has been utilised as an indirect measure of cardiovascular function. Previous studies assessing the associations between depressive symptomology and HRV have yielded varied results, however limitations in sample size, psychometric assessment and potential reporting bias may have obscured results.

Given the high rates of both depression and cardiovascular disease within the population of Australian truck and train drivers, this study aimed to identify associations between heart rate variability and negative mood states such as depression and anxiety in a cohort of Australian truck and train drivers. Quantitative assessment of the association between depression and cardiovascular function (as measured by HRV) in the Australian professional driving community may provide the foundation for a dual mitigation approach within the workplace to manage both conditions within this community.

2. Methods:

Participants

A total of 60 truck drivers (mean age 36.5 ± 9.67, n=45 males, n=4 females) and 60 train drivers (mean age 39.16 ± 10.51, n=53 males, n=5 females) were recruited. Participants were recruited through local advertisement via a poster, recruitment through contacts established independently to this research, online forums and with the aid and endorsement of Australia Post Transport Division, Sydney Trains and the Australian Trucking Association. Participants were required to be employed as a truck driver, regularly driving a truck with a gross vehicle mass of over 4.5 tonne, or a currently employed train driver.

Procedure:

Participants were tested between 9.30 am and 3 pm in order to negate the variations in heart rate between 8 - 9am and 4 – 8pm (Llinares and Clifford, 2010). The inclusion criteria were as follows; current employment as a full-time truck or train driver, and fluent English literacy. The exclusion criteria, as determined by part one of the Lifestyle appraisal questionnaire (Craig et al., 1996a), were as follows; those currently taking any prescription or non-prescription drugs (excluding caffeine and nicotine) or suffering from any chronic disease or illness, were excluded from the study. Participants were required to abstain from food for 2 hours, nicotine and caffeine for 4 hours, and alcohol for 12 hours before the study; to avoid influencing the physiological measures. The study was conducted in a controlled laboratory environment, with auditory and visual interference being reduced as much as viably possible. Light sources were controlled, with laboratory blinds being drawn to reduce the impact of external light sources influencing physiological measurements. The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions being presented. Upon confirmation of written consent, the study was commenced.

Questionnaires:

The questionnaire package included the Professional Driver Package, adapted from the SmartData Questionnaire (Kanvanagh, 2007), Lifestyle Appraisal Questionnaire (Craig et al., 1996a), the Beck Depression Inventory (Beck et al., 1996b), and the Profile of Mood States Questionnaire (McNair, 1971). The Professional Driver Package provides demographical information regarding licensing, employment length, employment status, nutrition, accident or near-miss history and working conditions. The Lifestyle Appraisal Questionnaire (LAQ), a validated and clinically reliable questionnaire, was used to record demographic, lifestyle and psychological stress information from the participant. The LAQ consists of two parts, with Part I consisting of 22 questions, with the highest obtainable score being 73. This information included family history of disease, smoking status, alcohol intake, exercise and diet regime, etc. The higher the score obtained from Part I of the LAQ, the greater the risk of developing a chronic illness later in life. Part II of the LAQ consists of 27 items and assessed an individual's "*cognitive appraisal of pressure and demands*"(Craig et al., 1996a). The Beck Depression Inventory Scale (BDI-II) (Beck et al., 1996b) is a 21-item self-reported tool used to assess the severity of depression in adults and adolescents (aged >13). Scores range from 0-63, with 0-13 indicating minimal depression, 14-19 indicating mild depression, 20-28 indicating moderate depression and 29-63 indicating severe depression (Beck et al., 1996a). The coefficient alpha of the BDI-II was found to be 0.93, indicating high internal consistency. The test-retest correlation of the BDI-II was found to be 0.93, which was significant ($p = <0.001$). As such, the BDI-II is a suitable mood state tool for the assessment of depressive symptoms within this study. The Profile of Mood States questionnaire (POMS) (McNair, 1971) is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigour-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, and confusion-bewilderment scales minus the score on the vigour-activity scale. The depression-dejection subscale is strongly predictive of the Beck Depression Inventory-II (BDI-II) (Beck et al., 1996a), which is often used in clinical practice to diagnose depression. The depression-dejection subscale of the POMS is consequently considered a useful short alternative to the BDI-II, since it also investigates other components of mood such as anxiety and aggression (Griffith et al., 2005).

Heart rate variability

Standardised attachment of a three-lead electrocardiogram was performed, with the active electrodes being positioned at the intercostal space between the fourth and fifth ribs, two centimetres laterally from each side of the sternum and the reference electrode being secured underneath the shoulder. Following this, the individual was seated and undertake the baseline phase of testing, which involved 20 minutes of quiet sitting, with their eyes open. Following this, the participant began the active phase of testing. For the truck drivers, this involved the participant being seated in the driving simulator, using the Logitech G7 Racing wheel to manoeuvre around the Standard Street One course of the Scania Truck Driver Simulator for twenty minutes whilst the ECG was used to collect heart rate data. The train drivers were seated at the computer and commenced twenty minutes of stimulated train driving using the Trainz Classics (N3V Games, Queensland, Australia) driving simulator program. The driving simulator was employed in order to elicit a physiological stress response, and it should be noted that subjects were familiarised with the program prior to ECG recordings being obtained. Heart rate variability (HRV) data was then obtained from the R-R intervals of the ECG recordings using a non-parametric algorithm (Fast Fourier Transform) and used as a quantitative measurement of the sympathetic (Low Frequency HRV) and parasympathetic nervous systems (High Frequency HRV). HRV reactivity was obtained by calculating the increase from baseline to active states in the various HRV parameters.

Heart rate variability analysis

Initially, using the QRS detector, the pre-processing step of HRV analysis included band pass filtering to decrease power line noise, baseline wander, muscle noise and any other interference components. The pass band at approximately 5 – 30 Hz is sufficient to cover most of the frequency content of QRS complex [32]. After this pre-processing had occurred, a set of decision rules were applied to define if a QRS complex had occurred. The decision rules included the average heartbeat period as well as the amplitude threshold, which were amended adaptively as the detection process continued. The fiducial point was selected to be the R-Wave, and the time at which the R-Wave occurs was logged. Post R-Waves identification, and time of R-Wave occurrence was determined, the HRV time series was derived. The R-R intervals were determined as the variances between successive R-Wave occurrence time periods. A power spectrum density (PSD) estimate was then used to calculate the R-R interval series. The PSD estimation is performed using the Fast Fourier Transform based Welch's periodogram method (Hann window was used). In the Welch's periodogram method, the HRV sample is separated into overlapping segments (50% overlap). The spectrum was then acquired by calculating the average spectra of these segments. This method reduces the amount of variance of the FFT spectrum. The frequency bands derived for short-term HRV recordings were low frequency (LF, 0.04 – 0.15 Hz) and high frequency (HF, 0.15 – 0.4 Hz). The absolute power values for each frequency band were derived through integration of the spectrum over the band limits.

3. Results:

3.1. Demographics

The average age recorded for the professional driver sample was 37.0 ± 9.5 years, which was younger than the national average age of employees (46 years). The mean BMI was reported as 28.6 which is within the overweight category (25 – 30) (Heart Foundation of Australia, 2010). The sample was 93.3% male, which reflects the male dominance of this industry. Average years employed as a professional driver was 9.3 ± 7.4, and the average hours driving a vehicle as a worker each week was 33.8 ± 9.7. Drivers reported 0.9 ± 1.5 accidents or near misses in the previous 12 months, and 4.7 ± 7.3 accidents or near misses in their career (Table 1).

Table 1: Demographic data of the professional driving sample (n = 120)

	Mean ± SD or %
Age	37.0 ± 9.5
Gender (Males)	93.34
BMI	28.6 ± 4.3
Years Employed	9.3 ± 7.4
Hours Driving	33.8 ± 9.7
Accidents/near misses in Previous Year	0.9 ± 1.5
Accidents/near misses per Career	4.7 ± 7.3

Table 1 present demographic data for the professional driving sample (n=120).

Key:

BMI: Body Mass Index

SD: Standard deviation

3.2 Mood State Questionnaires

The mean test scores of each of the six respective mood subscales (tension-anxiety, anger-aggression, fatigue-inertia, depression-dejection, confusion-bewilderment and vigor-activity) of the POMS questionnaire, a total mood disturbance scores, along with the normative values (Nyenhuis et al., 1999) are listed in Table 2. It should be noted that through single sample t-tests, it was ascertained that scores were significantly higher for tension-anxiety (p=0.003) anger-aggression (p=0.03), fatigue-inertia (p=<0.001), depression-dejection (p=0.004) and total mood disturbance (p=<0.001), and significantly lower for vigour-activity (=<0.001) than the advised normative values (Nyenhuis, 1999).

Table 2 The average scores attained for the six mood subscales, the total mood disturbance score in professional driving sample (n=120) and the normative values for an adult male sample (Nyenhuis et al., 1999) of the Profile of Mood States Questionnaire.

Sub-scale	Total Sample mean score	Normative values (Nyenhuis et al., 1999)
Tension-Anxiety	9.5 ± 6.5	7.1 ± 5.8
Anger-agression	8.7 ± 7.4	7.1 ± 7.3
Fatigue-inertia	10.3 ± 9.5	7.3 ± 5.7
Depression-dejection	10.3 ± 9.5	7.5 ± 9.2
Confusion-bewilderment	7.0 ± 4.9	5.6 ± 4.1
Vigor-activity	14.4 ± 5.9	19.8 ± 6.8
TOTAL MOOD DISTURBANCE	31.4 ± 31.9	14.8 ± 32.7

Table 2 presents the average test scores attained for the six mood subscales, the total mood disturbance score and the normative values (Nyenhuis et al., 1999).

The mean BDI-II test score for the professional driving sample (n=120) are presented in Table 3, along with the cut-off for mild to moderate depression (Beck et al., 1996b).

Table 3 Beck Depression Inventory scores for professional driving sample (n = 120)

	Total Sample (n=120)	Cut-off for mild to moderate depression (Beck et al., 1996b)
BDI Score	9.7 ± 7.9	10

Table 3 presents the average test scores attained for the Beck Depression Inventory.

There was no significant differences in BDI scores between the current sample of professional drivers (n=120) and the advised normative cut-off (Beck et al., 1996b).

3.3 Baseline Task

The mean HRV (LF, HF, TP and LF:HF) for the professional driving sample (n=120) during the baseline phase is displayed in Table 4.

Table 4 Mean HRV parameters for the professional driving sample during the baseline task.

HRV parameter	Total Sample (n=120)
LF (ms^2)	3.2 ± 3.2
HF (ms^2)	2.9 ± 3.3
Low Total power (ms^2)	3.7 ± 3.8
LF:HF	1.4 ± 0.5

Table 4 depicts the mean HRV parameters (low frequency, high frequency, total power) for the baseline task.

Key:
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
ms^2: Milliseconds squared

Partial correlations, when controlling for gender, smoking status, age and BMI, were undertaken to assess associations between baseline HRV parameters, profile of mood states scores and Beck Depression Inventory scores. Significant findings are displayed in Table 5.

Table 5 Correlations between Profile of Mood Sates scores, Beck Depression Inventory and HRV parameters in cohort of professional drivers during a baseline task.

	HRV parameter	r	p
Tension-anxiety	**LF**	0.25	0.046
	HF	-0.24	0.044
	Ratio	0.24	0.049
Anger-aggression	**TP**	0.26	0.041
BDI	**LF**	0.17	0.048
	TP	-0.18	0.030

Table 5 displays Profile of Mood States and Beck Depression Inventory correlations with HRV parameters during the baseline phase. Statistically signifiant correlations are seen in red.

Key:
BDI: Beck Depression Inventory
HF: High frequency (normalised units)
HRV: Heart rate variability
LF: Low frequency normalised units)
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
TP: Total HRV power
p: Level of statistical significance
r: Correlation coefficient

A number of statistically significant correlations between depression scores and HRV parameters (seen in red) were identified during the baseline task in professional drivers. Tension-anxiety and anger-aggression (as measured by the POMS) were found to be correlated with LF, HF and Ration, and TP respectively. The BDI was found to be correlated with LF and TP.

3.4 Active phase

The mean HRV (LF, HF, TP and LF:HF) for the professional driving sample (n=120) during the active phase is displayed in Table 6.

Table 6 Mean HRV parameters during the active task.

HRV parameter	Total Sample (n=120)
LF (ms^2)	3.4 ± 3.5
HF (ms^2)	3.2 ± 3.7
Low Total power (ms^2)	3.8 ± 4.0
LF:HF	1.1 ± 0.5

Table 6 depicts the mean HRV parameters (low frequency, high frequency, total power) for the active task.

Key:
HF: High frequency
HRV: Heart rate variability
LF: Low frequency
LF:HF Low frequency to high frequency ratio (sympathovagal balance)
ms^2: Milliseconds squared

Partial correlations, when controlling for gender, smoking status, age and BMI, were undertaken to assess associations between active HRV parameters, profile of mood states scores and Beck Depression Inventory scores. Significant findings are displayed in Table 7.

Table 7 Correlations between Profile of Mood Sates scores, Beck''s Depression Inventory and HRV parameters in cohort of professional drivers during an active task.

	HRV parameter	r	p
Confusion-bewilderment	**LF**	0.32	0.016
	HF	-0.29	0.024
Total Mood Disturbance	**LF**	0.24	0.049
	Ratio	0.27	0.038
BDI	**LF**	0.18	0.030
	HF	-0.19	0.031

Table 7 displays Profile of Mood States and Beck Depression Inventory correlations with HRV parameters during the active phase. Statistically signifiant correlations are seen in red.

Key:

BDI: Beck Depression Inventory

HF: High frequency (normalised units)

HRV: Heart rate variability

LF: Low frequency normalised units)

LF:HF Low frequency to high frequency ratio (sympathovagal balance)

TP: Total HRV power

p: Level of statistical significance

r: Correlation coefficient

A number of statistically significant correlations between depression scores and HRV parameters (seen in red) were identified during the active task. Confusion bewlderment was correlated with LF and HF. Total mood disturbance was correlated with LF and ratio. BDI was correlated with LF and HF.

Discussion:

Previous literature has suggested that professional drivers are at a high risk of a number of health conditions such as depression (Jeon et al., 2014, Farmer et al., 1992, Ro et al., 2013, Ro and Shin, 2016, Zhou et al., 2015, Hatami et al., 2019, Vakili et al., 2010a), anxiety (Hickey and Collins, 2017, Mehnert et al., 2012, Cothereau et al., 2004a, Boyce, 2016b) and cardiovascular disease (CVD) (Mansur et al., 2015, Ronna et al., 2016, Chapman et al., 2019). Given this, the current study aimed to assess associations between mood states and cardiovascular function as assessed by heart rate variability.

Anxiety was found to be higher in the professional driving cohort than the advised normative values. This supports previous literature which suggests the inherent nature of professional driving lends itself to higher rates of anxiety (Hickey and Collins, 2017, Mehnert et al., 2012, Cothereau et al., 2004a, Boyce, 2016b). In particular, perceived job stressors in the professional driving industry remain a primary source of anxiety (Naweed et al., 2017), as do the burden of passenger safety (Cothereau et al., 2004a), employment stability and income (Hege et al., 2019). Anxiety was also found to be positively associated with an increase in low frequency heart rate variability at baseline. Recent research suggests the LF bandwidth, while inclusive of sympathetic activity, may for accurately be describes as a combination of autonomic (PSNS and SNS) system, and the baroreceptor reflex (Bar-Haim et al., 2007). Nonetheless, increased LF has been associated with cardiac impairment, increase risk of cardiac event and mortality (Yadav et al., 2017). The ratio of LF to HF, which has been suggested to reflect sympathovagal balance, was found to be positively correlated to anxiety scores.

This indicates a parasympathetic nervous system withdrawal in the context of high resting anxiety levels. Further, high frequency (HF) HRV was found to be inversely related to anxiety symptoms. It is well accepted that HF is indicative of parasympathetic nervous system activity, and thus states of anxiety facilitate a parasympathetic withdrawal (Carney et al., 2000, Kemp et al., 2012). In times of acute stress, this provides an evolutionary benefit, allowing for the predominance of the sympathetic responses that enable an appropriate stress response. However, in the context of chronic stress, this sympathetic predominance is known to have deleterious effects on the heart. These include increases in circulating ionotropic and chronotropic catecholamines (Goldstein, 2003), suppression of vagal stimulation (Porges, 1995) and prolonged peripheral vasoconstriction resulting in elevated resting total peripheral resistance, and thus elevated blood pressure (Jern, 1991). These findings are novel within a population of Australian professional drivers and provide important insights into the potential associations between anxiety and cardiac health within this cohort. Steps to raise awareness, in particular in these males dominated industries, and the implementation of strategies to mitigate anxiety within this occupational group may improve not only the short-term psychological health of these individuals, but further, may improve their cardiovascular outcomes.

Depression scores were found to be associated with reductions in total heart rate variability, increased low frequency and reduced high frequency values. Given the similarities between anxiety and depression with regards to neurobiological aetiology and the continued scholarly support for the neurovisceral integration theory, it stands to reason that similar biological mechanism may be responsible. Reduced total heart rate variability has been well established as an independent predictor of not only cardiac health, but cardiovascular mortality (Kemp et al., 2010). Reduced total heart rate variability reflects a reduction in parasympathetic vagal outflow. The neurovisceral integration theory suggests efferent outputs from the pre-frontal cortex control vagal nerve inhibition of cardiac automaticity (Thayer and Lane, 2000). A reduction in this top-down control results in reduced cardiac control and is thus cardiopathogenic. The present study, in line with previous research, identified a link between depression and reductions in total HRV at baseline. Given this, steps to address mental health conditions, in particular depression and anxiety, within the population of professional drivers would be beneficial to both psychological outcomes, as well as cardiovascular health. Further, given the hypothesised bidirectionality of this relationship in the literature, interventions that have been shown to improve total HRV, such as exercise, should be encouraged amongst this population.

There are some limitations of the present study. Response bias may be present due to the use of self-reported mood state questionnaires; however, participants were advised that responses were deidentified to provide anonymity and reduce this bias. While common in psychophysiological studies, univariate analysis has limitations in its predictive power, in particular as workplace variables rarely occur in isolation of one another. However, a rational and well recognised preliminary step is to investigate univariate associations, which allows the variables to be quantified preceding their insertion into a later predictive model. The primary objective is to include the "best" group of variables that increase predictive capability, whilst ensuring no unnecessary complexity.

Conclusions:

Mental Health and links to cardiovascular parameters in Australian professional drivers have rarely been studied, which is of concern given the reportedly high levels of negative health states reported within this occupational group overseas. This study is the first to examine associations between mood states and cardiovascular functioning as measured by heart rate variability in Australian professional drivers. Anxiety and depression were both found to be associated with parasympathetic withdrawal, and sympathetic predominance, a known risk factor for cardiovascular disease. This is of major concern and should be considered when adopting holistic workplace health policies within this industry. Given the hypothesised bidirectionality of the relationship between mental health and cardiovascular function in the literature, it stands to reason that improvement of one state would symbiotically improve the other. That is, techniques to improve mental health states such as anxiety and depression may improve cardiovascular risk, and reciprocally, steps to improve cardiovascular variables such as reducing LF HRV may have beneficial effects on mental health. This study is important, as the psychophysiological health of Australia's professional drivers has been somewhat overlooked in the past. Given the large number of workers employed within this industry, and the potential personal and public safety implications of a suddenly unwell driver, it is vital that policies and workplace practices are designed to optimise the health of these individuals.

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Chapter Five – Discussion Summary

The main findings of this research will be discussed in the following chapter, as a summary of the findings of the research papers.

5.1 Links between workplace factors and mood states

5.1.1 Heavy vehicle truck drivers

The present study identified a number of positive correlations between negative workplace and lifestyle factors, such as long working hours and regular alcohol consumption, and negative mood states in truck drivers. Historically, there has been a scarcity of literature surrounding the impact of the unique workplace conditions on heavy vehicle truck drivers' mental health, despite a myriad of evidence suggesting that truck drivers are a depression vulnerable population.

When we examine the factors associated with high depressive symptomology, the number of hours driven each week showed positive correlations across both the Profile of Mood states and the Beck Depression Inventory, indicating that as an individual spent more time driving their work vehicle, their level of depressive symptomology also increased. This parallels recent literature, with da Silva-Junior and team reporting an increased odds ratio (OR = 1.28) of depression in truck drivers who report work overload (long working hours) (da Silva-Júnior et al., 2009a). Research has also suggested that there is an inverse relationship between the number of hours spent driving a work vehicle, and job satisfaction (Raggatt, 1991). Studies have also suggested that the adjusted odds ratio of depression in individuals who work long hours each week may be as high as 9.9 (Tomioka et al., 2011). Long working hours may designate the unfavorable effects of work exposures and stress. There is some research to suggest that occupational overload is particularly associated to anxiety symptoms while reduced decision autonomy is more commonly correlated with depression (Broadbent, 1985).

Prolonged working hours have also been associated with raised salivary cortisol (Lundberg and Hellström, 2002), and there is a strong body of literature to suggest that raised cortisol levels may be associated with the depression (Handwerger, 2009). It has been hypothesized that the relationship between long working hours and anxiety and depression is due to self-selection, rather than causation; namely, employees with pre-existing affective and anxious disorders tend to or have to work longer; or employees with mental disorders are forced to stay in unsatisfactory jobs, including those with longer working hours, as their potential for finding alternative employment may be limited (Kleppa et al., 2008; Waghorn & Chant, 2005).

Similar to the number of hours spent driving, the number of accidents throughout an individual's career was found to be higher as depressive symptomology increased. This is a novel finding among Australian heavy vehicle truck drivers. This supports previous literature from other countries, which suggests that symptoms of depression are linked to a reduction in driver performance (Bulmash et al., 2006a), increased accident risk (Mann et al., 2010), greater risk-taking behaviour (Yu et al., 2004) and reduced reaction times (Bulmash et al., 2006a). It has been hypothesized that drivers with depressive symptoms exhibit more difficulty in attention division between competing driving related tasks (Deery and Fildes, 1999). Further, studies have shown that individuals with depression exhibit reduced arousal and activation of the somatic nervous system, which may translate to reduced driving performance as a result of lower central nervous system arousal (Wingen et al., 2006). Current Australian guidelines recommend commercial vehicle drivers are limited to 60 work hours per week (Government of Western Australia, 2020). However, recent Australian studies have found that mental health begins to decline after 39 hours of work per week (Dinh et al., 2017). Given the disparity between these findings and the permitted 60 hours of weekly work allowed under current WHS guidelines, this population may benefit from a reduction in permitted weekly hours of work.

Coffee consumption was also found to increase with increased depressive symptomology. Interestingly, a recent meta-analysis regarding the associations between coffee consumption and depression found that coffee may have a protective effect against the development of depression (Wang et al., 2016). The meta-analysis analysed the data from 330,677 participants from seven studies and found that coffee consumption reduced the relative risk of depression. The conflict between the present findings of this study and the data obtained from the meta-analysis may have been influenced by the link between coffee consumption and hours spent driving a work vehicle. The amount of coffee consumed was positively correlated to hours spent driving a work vehicle, and due to the strong positive correlation between hours spent driving and depression, this may have masked the reported protective depression effects of coffee. Further, coffee consumption may be linked to fatigue, which has been shown to be linked with depressive symptoms (Jacobsen et al., 2003).

When we examine the factors associated with anxious mental states, alcohol consumption, and the number of hours spent driving a work vehicle each week were both positively correlated to an increase in anxious symptomology. Interestingly, perceived social interaction was found to be negatively correlated to anxiety scores, suggesting the more social interaction an individual experienced in the workplace, the lower their reported anxious symptomology. Literature supports the positive association identified between alcohol and anxious symptoms, with the "self-medication hypothesis" suggesting that the pharmacological and psychological effects of alcohol may be perceived to mediate anxiety symptoms, and thus is often used as a coping mechanism in those individuals who experience anxiety (Quitkin et al., 1972). Further, literature has also suggested a possible causal link between alcohol consumption and the promotion of anxiety disorders. Literature has suggested that the development of anxiety disorders may be a bio-psycho-social consequence of significant alcohol consumption (George et al., 1990). Mitigation of alcohol misuse in the professional driving industry in Australia has historically revolved around voluntary policy implementation by employers. Although commercial drivers must have a BAC of either 0.00% or 0.02% (dependent on their state of employment), policies surrounding alcohol misuse outside of work have been largely sporadic in the past. There has, however, been some progression in recent years, with alcohol awareness policies within commercial driving workplaces becoming more common. Further, VicRoads has created a free drug and alcohol policy builder for companies to utilize, in order to reduce and liabilities. By continuing to discuss alcohol use not only in the context of work BAC, but also 'health at home', companies may see an improvement in the psychosocial welfare of their employees.

When we examine the factors associated with high anxiety scores, the number of hours driven each week showed positive correlations across both the Profile of Mood states tension/anxiety subscale and Beck Anxiety Inventory, indicating that as an individual spent more time driving their work vehicle, their level of anxious symptomology also increased. This parallels recent literature, with Virtanen and team reporting an increased odds ratio (OR = 1.74) of anxiety in truck drivers who report working for greater than 55 hours each week (Virtanen et al., 2011). One suggested mechanism for this relationship is the limbic-behavioural pathway, which suggests that as individuals work longer hours, they engage in more negative behaviours such as excessive alcohol use, a known contributor to the development of anxiety (Van der Hulst, 2003). Further, research suggests that the longer the working hours, the greater the stress placed on a worker, and as such, the greater the propensity to develop anxiety disorders (Warr, 1990). Long working hours are associated with reduced time periods spent with social support, which in itself is a predictor of anxious symptoms (White et al., 2003). Once again, it is clear that long working hours are implicated in negative mental health outcomes, and given this, the current limits of 60 hours work per week for individuals in the heavy vehicle driving industry should be modified in order to promote the biopsychosocial health of these individuals.

Finally, workplace social interaction was found to be inversely related to anxious symptomology, indicating that as an individual experienced greater social interaction at work, their levels of anxious symptoms were lower. This parallels recent literature, which suggests that as social interaction increases, there is a biological suppression of the hypothalamic-pituitary-adrenal axis, resulting in a dampened cortisol effect, thus reducing the systemic effects of cortisol (Heinrichs et al., 2003). Further, long term social support has been found to have a significant anxiolytic effect, resulting in increased oxytocin release, and reduced cortisol release, thus providing evidence for the causal link between greater social support and reduction in anxious symptomology (Heinrichs et al., 2003). Currently, Australian companies are utilising a number of support initiatives aimed at increasing social interaction within the workplace. Toolbox talk training packages, delivered by the mental health service Beyond Blue, aim to "encourage conversations about mental health in the workplace, reduce workplace stigma and support staff who may be experiencing a mental health condition" (Heads Up, 2020). Studies have shown significant improvements in perceived morale, self-reported mental health, and reductions in stress, subsequent to the introduction of socialisation initiatives such as these toolbox talks (Oakman et al., 2018, Bowers et al., 2018, Hanna et al., 2020, Campbell and Gunning, 2020). Given that this study is the first in Australia to identify social interaction as a potential contributory factor to anxious and depressive symptomology within a cohort of heavy vehicle drivers, these findings may provide the foundation for further employment of social interaction strategies in the workplace.

5.1.2 Train drivers

A number of lifestyle and workplace variables were found to be linked to negative mood states such as perception of stress and depressive and anxious symptomology. When examining the variables associated with stress, the number of accidents across both the previous 12 months and throughout career were found to be positively correlated to stress scores. Stress is a known risk factor for the development of other mental health conditions, such as anxiety and depression, in particular when chronic (Plieger et al., 2015). Stress has also been linked with reduced driver performance and an increase risk of accidents or near misses (Matthews et al., 1998, Taylor and Dorn, 2006, Matthews et al., 1991). Chronic stress is well accepted to interfere with normal bodily stress responses, those responses that would generally be considered advantages in times of stress. During times of chronic stress, an acute on chronic stress response results in impaired memory retrieval (Roozendaal, 2002, Kuhlmann et al., 2005), fine motor skills (Mancini et al., 2018, Mancini et al., 2019) and higher-order cognitive processes (Budsankom et al., 2015). As such, stress is known to be a contributing factor to reduced driver performance, and thus crash risk (Klauer et al., 2006). This study is the first of its kind to link stress to increased crash or near miss risk in a population of Australian train drivers. Given this, further research would benefit from identifying stress inducing factors that have the potential to be mitigated within the workplace, thus reducing the potential contribution of stress to this risk. Further, social interaction during shift was found to be inversely related to stress. That is, the greater the social interaction reported by drivers during their shift, the lower the average stress levels. Social interaction is well recognized as a protective factor against stress levels. A study by Ozebay and team (2007) found that as social interaction increased, both acute and chronic stress reduced. The biopsychosocial theories behind socialisation as a protective factor for stress stem from the necessity of interaction as an evolutionary advantage. Social support may mitigate genetic and environmental vulnerabilities and provide resilience to stress, conceivably via its hormonal effects on the hypothalamic-pituitary-adrenocortical (HPA) axis, the noradrenergic system, and systemic oxytocin pathways (Ozbay et al., 2007). Given the identified links between stress, accidents throughout career and interaction that were elucidated in this study, further research is needed to identify factors that may mitigate stress within this population.

Similar to perception of stress, depressive symptomology was positively correlated with accidents or near misses, both in the previous 12 months and throughout career, and inversely correlated with social interaction during shift. Much like stress, depression has been strongly linked to a reduction on driver performance, with studies finding that individuals suffering from depression exhibit reductions in reaction times, steering control (Bulmash et al., 2006a) and attentive awareness (Vedhara et al., 2000). Given not only the implications of train carriage accidents, but the potential for large scale commuter danger should an accident occur, it is evident that further research must be undertaken to elucidate the direction of the relationship between accidents and near misses, and depressive symptomology. While the present study did not identify levels of depressive symptomology within this population that were higher than advised normative values, it is clear that the implications of this mental illness may be significant with regards to driver performance. Further, the inverse relationship identified between depressive symptomology and social interaction during shift provides a unique insight into a possible contributory, or protective, aspect of this occupation. That is, increased social interaction may be a protective factor for the development of depression, just as social isolation during shift may contribute to the development of this mental health disorder. There may, however, be some selection bias regarding this association. That is, individuals who experience depression are more likely to avoid social interaction that those who do not. All the same, workplace procedures which encourage social interaction at work, such as ToolBox talks (Campbell and Gunning, 2020), regular mental health forums (Nexø et al., 2018) and buddy systems (Clark-Hitt et al., 2012) have been shown to improve employee mental health in many other industries.

5.2 Cardiovascular links to affective states

Anxious symptomology was found to be higher in the professional driving cohort than the advised normative values. This supports previous literature which suggests the inherent nature of professional driving lends itself to higher rates of anxiety (Hickey and Collins, 2017, Mehnert et al., 2012, Cothereau et al., 2004a, Boyce, 2016b). In particular, perceived job stressors in the professional driving industry remain a primary source of anxiety (Naweed et al., 2017), as do the burden of passenger safety (Cothereau et al., 2004a), employment stability and income (Hege et al., 2019). Anxiety was also found to be positively associated with an increase in low frequency heart rate variability at baseline. Recent research suggests the LF bandwidth, while inclusive of sympathetic activity, may more accurately be describes as a combination of autonomic (PSNS and SNS) system, and the baroreceptor reflex (Bar-Haim et al., 2007). Nonetheless, increased LF has been associated with cardiac impairment, increase risk of cardiac event and mortality (Yadav et al., 2017). The ratio of LF to HF, which has been suggested to reflect sympathovagal balance, was found to be positively correlated to anxious symptomology. This indicates a parasympathetic nervous system withdrawal in the context of high resting anxious symptoms. Further, high frequency (HF) HRV was found to be inversely related to anxious symptomology. It is well accepted that HF is indicative of parasympathetic nervous system activity, and thus states of anxiety facilitate a parasympathetic withdrawal (Carney et al., 2000, Kemp et al., 2012). In times of acute stress, this provides an evolutionary benefit, allowing for the predominance of the sympathetic responses that enable an appropriate stress response. However, in the context of chronic stress, this sympathetic predominance is known to have deleterious effects on the heart. These include increases in circulating ionotropic and chronotropic catecholamines (Goldstein, 2003), suppression of vagal stimulation (Porges, 1995) and prolonged peripheral vasoconstriction resulting in elevated resting total peripheral resistance, and thus elevated blood pressure (Jern, 1991). These findings are novel within a population of Australian professional drivers and provide important insights into the potential associations between anxious symptomology and cardiac health within this cohort. Steps to raise awareness, in particular in these males dominated industries, and the implementation of strategies to mitigate anxiety within this occupational group may improve not only the short-term psychological health of these individuals, but further, may improve their cardiovascular outcomes.

Depression scores were found to be associated with reductions in total heart rate variability, increased low frequency and reduced high frequency values. Given the similarities between anxiety and depression with regards to neurobiological aetiology and the continued scholarly support for the neurovisceral integration theory, it stands to reason that similar biological mechanism may be responsible. Reduced total heart rate variability has been well established as an independent predictor of not only cardiac health, but cardiovascular mortality (Kemp et al., 2010). Reduced total heart rate variability reflects a reduction in parasympathetic vagal outflow. The neurovisceral integration theory suggests efferent outputs from the pre-frontal cortex control vagal nerve inhibition of cardiac automaticity (Thayer and Lane, 2000). A reduction in this top-down control results in reduced cardiac control and is thus cardiopathogenic. The present study, in line with previous research, identified a link between depression and reductions in total HRV at baseline. Given this, steps to address mental health conditions, in particular depression and anxiety, within the population of professional drivers would be beneficial to both psychological outcomes, as well as cardiovascular health.

Chapter Six - Conclusions

It is estimated that depressive disorder will be the second leading contributor to the global burden of disease by 2020 (World Health Organization, 2020). Affecting 121 million individuals worldwide, and 11.6% of the Australian population (World Health Organization, 2020), depression has been shown to present a high risk of reoccurrence (50%) if untreated (Bear et al., 2007). Males have been shown to consistently underreport depressive symptoms (Pierce and Kirkpatrick, 1992), and as such, the true prevalence of this disorder within the male population is only speculative (Klint and Weikop, 2004, van Praag, 1980). The Australian truck and train driving industries are largely male dominated (Australian Government, 2012a), and due to a number of shared occupational lifestyle factors including intermittent rest and work cycles (Australian Government, 2012a), isolation from family support networks and intense occupational pressure (Koda et al., 2000), individuals within these industry can be viewed as a depression vulnerable population.

Globally, CVD is the leading cause of premature death (Mensah et al., 2019), reportedly costing the Australian Government over $5.9 billion dollars each year (AIHW, 2011). A number of lifestyle factors have been identified within the professional driving industry that contribute to the impaired cardiovascular health these drivers. These include low levels of exercise, high levels of obesity and cigarette smoking, high blood pressure and an increased consumption of saturated fats and cholesterol (Gill and Wijk, 2004).

Studies assessing the associations between depression and an increased rate of cardiovascular disease have been inconclusive. Whilst some report a link between depressive symptoms and cardiovascular impairment (Agelink et al., 2002; Udupa et al., 2007), others have found no significant correlations (Yeragani et al., 1991; Bar et al., 2004). As such, the definitive influences of depression on cardiovascular health are yet to be fully elucidated. Furthermore, the effects of mood states such as depression anxiety are yet to be definitively linked to impairments in cardiovascular health within the population of professional drivers. If depression and other mood states such as anxiety can be definitively identified as cardiovascular risk factors, effective management schemes can be devised and implemented to not only manage and reduce the incidence of these negative mood states in Australia, but also reduce their role in the development of cardiovascular disease.

The present study found a stark disparity in the prevalence of depressive symptomology and other negative mood states between truck and train drivers in Australia. It was identified that the current cohort of truck drivers exhibited significantly higher levels of depressive and anxious symptomology, anger/aggression, fatigue and stress than the train driving sample. Further, smoking rates, and levels of alcohol use were found to be higher in the truck driving sample. A number of workplace factors such as social interaction during shift, and accidents or near misses throughout career, were found to be associated with depressive symptoms across both professional driving cohorts. This study is the first of its kind to assess the prevalence of depressive symptoms, and the associated workplace factors, within a cohort of Australian professional drivers.

This study highlights important workplace factors that may be linked with negative mental states, and their potential implications within the workplace. The promotion of improved mental health within this occupation would not only improve the health of the individual drivers but may also mitigate mental health associated absenteeism and improve commuter safety. Buddy driving systems (Clark-Hitt et al., 2012), regular workplace ToolBox talks and forums (Campbell and Gunning, 2020), and a commitment to mental awareness (Nexø et al., 2018) are strategies that have been successfully employed in other industries. Given the societal responsibility of professional drivers, protecting and promoting the psychosocial health of these individuals is paramount to not only a healthy workforce, but a safe community.

The current study identified associations between stress, depressive and anxious symptomology and impaired autonomic cardiac function. In particular, this study was the first of its kind to show reduced parasympathetic vagal tone to be associated with depressive and anxious symptomology within a cohort of Australian professional drivers. This is of concern and should be considered when adopting holistic workplace health policies within this industry. Given the possible bidirectionality of the relationship between mental health and cardiovascular function in the literature, it stands to reason that improvement of both states would result in a mutual improve of the other. That is, techniques to improve mental health states such as anxiety and depression may improve cardiovascular risk, and reciprocally, steps to increase heart rate variability may have beneficial effects on mental health. This study is important, as the psychophysiological health of Australia's professional drivers has been somewhat overlooked in the past. Given the large number of workers employed within this industry, and the potential personal and public implications of a suddenly unwell driver, it is vital that policies and workplace practices are designed to optimise the health of these individuals.

Collectively, the findings from the present study provide a novel perspective on the physiological and psychological health of Australian professional drivers. The present study is the first assess to the effects of certain lifestyle and mood states on cardiac parameters (such as HRV) in the cohort of Australian professional drivers. Furthermore, comparisons regarding the prevalence and severity of depressive and anxious symptomology within this industry in Australia are scarce and should be further explored in future studies. The present study addressed the gaps in research by assessing a number of mood states, and their effects on cardiac parameters. The study found that multiple lifestyle and mood parameters were linked with HRV parameters that may have deleterious effects on cardiovascular health. These findings suggest that the improved awareness and management of these factors in the male dominated professional driving industry would improve both the short term psychological and long-term cardiovascular health of these individuals, in turn, reducing the socioeconomic burden associated with these mental disorders and cardiovascular disease in Australia.

Chapter Seven - Limitations and future directions

The present study aimed to assess possible links between mood states (such as depression, anxiety, etc.) and cardiac parameters (assessed using heart rate variability (HRV)) in a sample of 120 Australian professional drivers. Presently, a cross-sectional within-subject study was employed, although future studies may benefit from a longitudinal format, as this would provide more thorough information on the changing patterns in cardiac and psychological parameters over a period of time. The present study provided the immediate cardiac and psychological health status of these individuals and not long-term health effects, although the present study did assess psychological states over the previous eight week, as well as BP and HR pre and post study, which provided a more comprehensive assessment of these parameters. It has been noted, however, that BP and HR vary significantly from day to day (Lo et al., 2008, Parati et al., 1995, Bilan et al., 2005, Cygankiewicz et al., 2004). As such, a longitudinal study would allow for a more accurate measurement of the health of these individuals. Further, the normative values cited for the POMS scale are over 20 years old, and despite being the only available general population normative data available, may no longer be as accurate as when first published. Given this, psychological questionnaires with recent normative values would be of benefit in research moving forward, to ensure accurate cohort data for comparison.

Based on the ethics approved guidelines attained for the present study, drivers without any past or present chronic illness or current medication usage were assessed.

Although this was a novel study addressing factors not addressed globally in this sample previously, future studies would benefit from the assessment and comparison in samples with these factors included, as well as clinical samples of patients with varying psychological disorders, such as Major Depressive Disorder and Generalised Anxiety Disorder. This would allow comparisons to be drawn from the general and known diseased population and allow for the elucidation of possible differences in cardiac effects due to these lifestyle factors and psychological disorders. Further, the inclusion on an age and weight matched non-driver control group would further bolster the research findings and allow for comparisons between driving and non-driving professionals. Furthermore, due to the prevalence of medication usage in the professional driving industry, such as sleeping tablets and illicit drugs (Swann, 2002), evaluating the impacts of certain medications on the assessed cardiac parameters may provide the statistical foundation for revised drug management schemes within this industry. Further, the self-reporting of alcohol use may have led to underreporting, however, attempts to reduce this bias were made by ensuring participants were aware that all data collected was to be kept anonymous. this is, however, a consideration for future studies, which may benefit from biological drug screens prior to assessment. The collection of data further data that may contribute to both the dependant and independent factors may also be useful in future studies, such as income bracket, sleep cycles/latency, employment status etc.

While the present study identified links between a number of psychological states and cardiac parameters, the link between depression and HRV was limited. The use of a more comprehensive depression assessment tool in future studies would allow for the true prevalence and severity of depression to be assessed. The prevalence of these symptoms may have also been obscured due to the reliance on autobiographical memory. The present study relied on the individual's ability to accurately recall their psychological state for the previous eight weeks. Autobiographical memory, such as that required for the present study, may be unreliable (Eisenhower et al., 2004). Also, studies have found that individuals suffering from depression presented less specific voluntary memory recall than those with no depressive symptoms (Watson et al., 2012). Finally, it has been shown that males are less likely to divulge information that may infer vulnerability (Courtenay, 2002). The study design attempted to address this potential reporting bias by utilising multiple mood state questionnaires with high internal validity to allow for the assessment of congruency between questionnaires, and their validity and reliability ensure an accurate response. For these reasons, future studies may benefit from the administration of a mood diary that is completed on a daily basis. This would allow for a more accurate assessment of an individual's behavioural state for the weeks preceding the laboratory study. The use of self-reported mood state questionnaires may introduce some response bias; however, the effects of this bias were ameliorated through the use of participant identification numbers for all responses, providing anonymity for the participant. Also, while common in medical science analysis, univariate analysis has some limitations in predictive power, in particular as variables such as workplace and lifestyle factors rarely occur alone. However, a reasonable and commonly employed initial step is evaluating univariate associations, which allows the variables to be quantified prior to their inclusion in the later model. The initial objective is to include the "best" grouping of variables that increase predictive ability, whilst circumventing unnecessary complexity.

Future studies would benefit from increasing the sample size. Although the present study attained a sufficient sample size (n=120) for the statistical comparisons made, assessing a greater number of individuals may increase the significance of the results attained, and allow for the identification of further trends in the data obtained. Finally, the assessment of additional lifestyle and workplace factors may provide information regarding the impact of these parameters on cardiac health. In particular, future assessment of participants during varied shift cycles (i.e., immediately before, during, or after a shift) and sleep parameters (i.e., sleep length, sleep latency, global sleep score, etc) may provide useful information regarding the effects of shift work and sleep on both psychological and cardiovascular parameters.

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Appendices

Poster Advertisement

Truck and Train
WANTED

Help with Research on

'Professional drivers: assessing cardiovascular links
to affective (mood state) measures'

Calling all truck, train and bus drivers aged 18 -69 years to
participate in important research at UTS,

The testing is simple and non-invasive, and will take about 1-1.5 hours of
your time.

Please contact Taryn Chalmers on
ph:

Email: taryn.chalmers@student.uts.edu.au
for more details

This study has the University of Technology Sydney Human Research Ethics
Committee (UTS HREC) approval.
Approval
Number:
2007-55A

General Emergency Protocol

** ALWAYS DIAL SECURITY FIRST**

UTS Contacts
1) Dial/Call UTS Security: dial "6" on an internal UTS phone or 95141192
2) Dial/Call 000
3) Dial/Call Student medical Services (95141177)
4) Dial/Contact supervisor: Sara Lal (95141592) or other authority in the Department

Also, if required:

Contact details for UTS medical center:
Student Services Unit
Tower Building 1, Level 6, UTS
Ph: 95141177

Hours of opening:
Monday: 8:30am-5:30pm
Tuesday: 8:30am- 5:15pm
Wednesday: 8:30am-5:00pm
Thursday: 8:30am-3:45pm
Friday: 8:30am-4:45pm
Saturday and Sunday: Closed

Note: hours of opening are approximations

Contact details for external medical center:
Broadway General Practice
Level 1 Broadway Shopping Center
Ph: 92815085

Hours of opening:
Monday–Wednesday: 8:30am-7pm
Thursday: 8:30-8pm
Friday: 8:30am-7pm
Saturday: 9am-6pm
Sunday: 10am-6pm

Addition to all research study protocols

Student/Researcher protocol

Inclusion criteria

Currently based on lifestyle questionnaire (Craig et al., 1996) per parent ethics approval for the study. That is to qualify for the study (per the lifestyle questionnaire) participants have to meet the following inclusion criteria: no severe concomitant disease, no history of alcoholism and drug abuse and no psychosis, psychological and intellectual problems likely to limit compliance.

Now also add the following:

Before commencement of any human related research study, after the participant/volunteer has had a 10-minute sitting (rest) period, take 3 sitting BP measurements from the arm. A standard sphygmomanometer or a validated and reliable digital BP monitor (Omron etc.) should be used to take BP measurements.

After the measurements, if the average of the 3 BP readings are > 160/100 mmHg or > 160 mmHg for systolic alone or >100 mmHg for diastolic BP alone, the participant will not be included in the research study and will be thanked for their time. **Student/researcher will/must advise participant of their BP and will/must urge them to seek medical attention.**

Similarly, 3 BP readings are to be taken at the end of the study (if the participant qualified and underwent the study.

Grounds for not commencing a study, terminating a study or withdrawing a participant

Accompanying the participant for Medical Assessment

As mentioned above: study will not commence if:

- BP levels outside the criteria stipulated above (if the average of the 3 BP readings are > 160/100 mmHg or > 160 mmHg for systolic alone or >100 mmHg for diastolic BP alone, the participant will not be included in the research)
- or per exclusion criteria based on the Lifestyle questionnaire (Craig et al., 1996).

Prior to any study ask the participants to identify whether they are experiencing any pain, discomfort or not feeling well or have a headache. In all these situations the study will not continue the participant will not be included in the study and will be thanked for their time.

Prior to participation in the study, you must inform the participants that if at any time during the study they experience any discomfort or not feel well or a headache commences, they must inform you (the instructor/researcher) present in the lab and the study will be immediately ceased and not continue and the participant will be thanked for their time. In this situation, you will advise and/or offer to guide (accompanied by the researcher should the participant prefer this) to consult the UTS medical center or the nearest medical center stipulated in the emergency protocol posted in the lab; or consult a medical center of their choice should they prefer the latter. You, the researcher will offer to accompany the participant to the nearest medical center should the above situation arise.

Summary record of the research study

To be completed immediately after each lab study

Date: ___________________

Name of researcher: _________________________________

Name of participant: _________________________________

1. Provide a brief summary of the study (tick one of the following):

the study went smoothly

there were some issues

there were major issues

2. Researchers general account and summary of the study- detail in a few lines or more:

____

____

____

____

____

____

3. Was there any 'out of the ordinary' event or issue in this lab study? Yes/No

Consent Form

UNIVERSITY OF TECHNOLOGY, SYDNEY

CONSENT FORM

I ____________________ *(participant's name)* agree to participate in the research identified as ***'Professional Drivers: assessing cardiovascular links to affective (mood state) measure'*** a sub-study under the SmartData project (Approval no: 2007-55A) being conducted as part of a ___________degree by ___________________ at the University of Technology Sydney, Building 4, Broadway. Funding for this research has been provided by the School of Medical and Molecular Biosciences, Faculty of Science.

I understand the aim of this study is to identify how performance on the road can be improved by monitoring the driver, vehicle and road environments. Information from this research is key to developing smart devices and databases to assist drivers as they and the driving conditions change during a trip. To assesses their current and predicted readiness to respond to unforeseen road incidents. To develop these smart devices and databases the study needs to identify many factors and how best to measure them.

I also understand the study will involve screening for blood pressure and the possibility that I may be found to have high blood pressure. If blood pressure is greater than 140/90 mmHg, I will be advised to consult a doctor. If blood pressure is greater than 160/100 mmHg

Statistical Analysis

The statistical analyses was conducted using the software program SPSS Version 22.0 (IBM Corp., Released 2013) and comprised of dependent sample t-tests, Pearson's correlations and regression analyses. This appendix presents the definitions, assumptions and limitations of these statistical methods in additional detail.

Dependent sample t-test

Dependent sample t-tests were employed in the present study, to identify if the means of two samples were significantly different (Bowers, 2008). This analysis is used to compare the amount of significant change within a parameter, i.e., identifying whether a participant's blood pressure has significantly changed from pre-study to post-study.

Assumptions:

- The sample follows a normal distribution

Note: Non-parametric analysis should be applied if the sample does not follow normal distribution.

t-value: t measures the significance between dependent and independent variables. A t-value that is either greater than +2 or less than -2 is generally acceptable in human based statistical studies. As the t value increases above +2, the coefficient becomes more reliable as a predictive measure. Conversely, as the t value decreases below -2, the reliability of the coefficient as a predicative measure is reduced (Bowers, 2008).

p-value: p is a probability value and as such, it lies between the values of 0 and 1. It represents the potency of evidence for or against the null hypothesis (Peacock and Peacock, 2011). Data is deemed more significant, and the probability of a non-chance finding is reduced when the p value is smaller. a p value of less than 0.05, which equates to a probability of a non-chance finding at less than 5%, is the most commonly used p value for statistical significance.

Pearson's Correlation

Pearson's correlation is an estimation of both the direction and strength of a linear relationship between a dependent and independent variable (Bowers, 2008). Pearson's correlation yields a correlation coefficient, which is represented by an r value. The significance of the Pearson's correlation is directly related to the size of the assessed sample (n). The reliability of results is therefore increased with an increasing sample size, and as such, is more potent as a reflection of an accurate statistical relationship. In the current study, Pearson's correlation was employed to ascertain the relationship between mood states (as assessed by the Profile of Mood States questionnaire) (dependent variable) and age, HRV parameters (LF, HF, TP, LF:HF), workplace factors and blood pressure variables (SBP, DBP, HR) (independent variables).

Assumptions:

- the relationship is linear
- at least one of the variables is normally distributed
- both variables must be normally distributed for confidence intervals

r-value: r (rho) lies between +1 and -1. The closer the r value is to +1 or -1, the higher the correlation between the variables. Calculated r values of -1 or +1 present perfect negative and positive linear correlations respectively. Negative values indicate a negative linear relationship, whereas positive values denote a positive linear relationship. If r=0, no linear relationship applies, and as such, it can be assumed that the variables are not correlated (Bowers, 2008).

Bonferroni Correction

Bonferroni corrections were applied to all correlations where two or more independent variables were correlated to a dependant variable. The Bonferroni correction technique involves dividing the p-value by the number of variables being examined to make the p-value more conservative and reduces the risk of type 1 errors (false positives) (Bland and Altman, 1995). Three or more independent variables were required to fall equal to or less than the Bonferroni adjusted p-value to perform the linear regression. Correlations that did not fall equal to or below the Bonferroni-adjusted p value were not displayed in data tables.

Regression analysis

Multiple regression analysis is utilised to establish the predictive variable with the most significance when numerous independent variables are significant predictors for a particular parameter (Peacock and Peacock, 2011). This multiple regression analysis was utilised in the present study to identify the predictors with the greatest significance for blood pressure (dependent variable) when three or more factors were associated with this factor, after Bonferroni correction.

Assumptions:

- the relationship is linear
- the distribution of residuals is normal
- over all values of each continuous predictor, the standard deviation of the outcome is constant

R: known as the correlation coefficient, R reflects the degree of correlation between two of the variables (Peacock and Peacock, 2011).

R^2: known as the determination coefficient, R^2 reflects the amount of variability between outcomes and their predicted values. This value is equal to the square of the correlation coefficient (Peacock and Peacock, 2011).

Adjusted R^2: The adjusted R^2 is an alternative of R^2 that allows for adjustment of the number of independent variables in a particular model, and allows for the summary of the fit, which considers the number variables in the model. Adjusted R^2 is ≤ R^2 and can be calculated using the method of 1-mean square error divided by the total mean square (Peacock and Peacock, 2011).

F: F is a measure of the probability that the model concedes a relationship that has occurred at random, rather than a true relationship. Similar to the p-value, the lesser the F-value, the higher the chance that the relationships in the model are authentic (Peacock and Peacock, 2011).

B: known as the unstandardised regression coefficient, B reflects the sensitivity of the dependent variable to the independent variable. This represents the totalled effect of the independent variable on the dependent variable, when the residual independent variables in the equation are continuous (Peacock and Peacock, 2011).

β: β is known as the standardised regression beta coefficient and is derived by subtracting the standard deviation from the mean of a specific variable. β is an estimate obtained from standardised variables, with a variance of 1. It signifies the change, with regards to standard deviations, in the dependent variable that result from a change of a standard deviation in an independent variable (Peacock and Peacock, 2011).

Standard error (SE): Standard error is an estimate of the standard deviation of the sample (Crookes and Davies, 1998).

t: t is the coefficient divided by its standard error (see above).

Degrees of freedom (DF): The degrees of freedom represents the number of values in the concluding calculation of a statistical analysis that are free to diverge (Peacock and Peacock, 2011).

Intercept: The intercept is the average of the dependent variables, when all independent variables are equal to zero (Peacock and Peacock, 2011).