Shiftwork and Eating Behaviour

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Glossary

ABS	Australian Bureau of Statistics
ACCV	Anti-Cancer Council of Victoria
A-H	anger-hostility
ANOVA	analysis of variance
BMI	body mass index
C-B	confusion-bewilderment
CCDQ	Cancer Council Dietary Questionnaire
CI	confidence interval
D-D	depression-dejection
EEG	electroencephalogram
EMG	electromyogram
EOG	electrooculogram
FD	forced desynchrony
FFQ	food frequency questionnaire
F-I	fatigue-inertia
GEE	Generalised Estimating Equation
GHQ	general health questionnaire
ghrelin	an appetite stimulating hormone
GI	glycaemic index
GIQ	General Information Questionnaire
h	hours
HDL	high-density lipoprotein
kcal	calorie or kilocalorie
kJ	kilojoules
LDL	low-density lipoprotein
leptin	an appetite reducing hormone
LOC	left outer canthi
NREM	non rapid eye movement
POMS	Profile of Mood States
PSG	polysomnography/polysomnographic
REM	rapid eye movement
ROC	right outer canthi
SD	standard deviation
SSI	Standard ShiftWork Index
SWA	slow wave activity
SWS	slow wave sleep
T-A	tension-anxiety
TMD	total mood disturbance
V-A	vigour-activity
VAS	visual analogue scales
WHO	World Health Organisation

Contextual statement

Style and format of thesis

This thesis is submitted as a 'Thesis Containing Published Research' in accordance with the University of South Australia's Academic Regulations for Higher Degree by Research Clause 16.1.1.b. This presentation method allows students to submit a combination of conventional chapters and publications. It is required that publications be produced, published or accepted for publication in peer reviewed journals or conference proceedings during the student's candidature. The requirements of a 'Thesis Containing Published Research' are as follows:

- Publications must be peer reviewed and must be published or accepted for publication in significant journals, books and/or conference proceedings relevant to the discipline.
- The candidate must be the principal author.
- Where the publications are co-authored a statement by the candidature will be included describing the contribution of each author to each publication. The statements must be signed by each author (see 'Overview of Author's Contributions' and 'Written Permission of Co-Authors').
- The publications should form part of an integrated project and form a cohesive narrative.
- The publications must be compliant with copyright law and intellectual property requirements of the University of South Australia.
- Accepted or published publications must have been completed during the degree at the University of South Australia. Publications completed at another University must not be included within the thesis.

Explanation of how published works included within the thesis are critically placed within the area and the field of study, and the context of the thesis as a whole

The three publications within this thesis form Chapters 3, 4 and 5. These publications have been submitted, accepted and published in conference proceedings (Chapters 3 and 5) and in an international journal (Chapter 4) relevant to the field of sleep and chronobiology.

Chapter 3

Heath G., Dorrian J., Kosmadopoulos A., & Sargent C. (2011). Food consumption and food choice following one week of sleep restriction: A pilot study. In: Kennedy G A, Sargent C (Eds.). *Little clock, big clock: Molecular to physiological clocks.* Australasian Chronobiology Society, Melbourne, Australia, 17–21. (Appendix A)

The above publication was presented initially at the 8th Annual Meeting of the Australian Chronobiology Society in Melbourne Australia (September, 2011). The chapter was then submitted and published as a conference proceeding for the Australasian Chronobiology's Society's publication *Little clock, big clock: Molecular to physiological clocks* (2011). Prior to acceptance for publication the manuscript was reviewed by two researchers in the field of sleep and chronobiology.

Chapter 4

Heath G., Roach G., Dorrian, J, Ferguson S., Darwent D., & Sargent C., (2011). The effect of sleep restriction on snacking behaviour during a week of sImulated shiftwork. *Accident Analysis & Prevention 45*, 62–67. (Appendix B)

The above paper was published in the journal *Accident Analysis and Prevention*, an international peer reviewed journal that accepts articles covering a variety of general fields. The journal has a wide audience and has published a number of articles in relation to sleep restriction and shiftwork. The submitted manuscript was peer reviewed by two international independent peers and accepted for publication in August, 2011. According to Google Scholar and Scopus, this article has been cited 21 and nine times respectively.

Chapter 5

Heath G., Sargent C., Darwent D., Ferguson S. A., Kennaway D. J., Hampton L. K., Matthews R. W., & Roach G. D. (2010). Subjective mood is influenced by sleep-related and circadian processes in a forced desynchrony protocol with severe sleep restriction. In: Sargent C, Darwent D, Roach GD (Eds). *Living in a 24/7 world: The impact of circadian disruption on sleep, work and health*. Australasian Chronobiology Society, Adelaide, Australia, 7–11. (Appendix C)

The above paper was originally presented at the 7th Annual Meeting of the Chronobiology Society in Adelaide in September 2010. A manuscript was then submitted as a conference proceeding for the Australasian Chronobiology Society's publication *Living in a 24/7 world: The impact of*

circadian disruption on sleep work and health (2010). The submitted manuscript was peer reviewed by two researchers in the area of sleep and chronobiology prior to publication. This paper has been cited once according to Google Scholar. Similar to Chapter 3, the presentation of this paper gave the candidate the opportunity to present the findings at an international conference and provided exposure of the candidate's work to researchers in the field of sleep and chronobiology.

Overview of author's contributions

The following section describes the author's contributions to the papers included within this thesis.

Chapter 3: Study 1

Study design and data collection

Study 1 was conducted as part of pre-existing grants from the Australian Technology Network Centre for Metabolic Fitness and the University of South Australia.

I was responsible for designing the methodology within this study to answer my research question. I researched suitable methods for the measurement of eating behaviour and as a result I designed the buffet meal. I was responsible for investigating the kilojoule and macronutrient content of the food, purchasing, preparing, weighing and measuring the buffet meals before and after consumption. In addition, I planned all of the participant's meals within this study to ensure they met the required daily energy intake and the appropriate macronutrient distribution. Prior to each data collection phase I screened and recruited participants. This involved ensuring individuals met the requirements of the study. I also assessed their dietary requirements prior to participation and ensured these could be met by adjusting and altering meal plans if necessary.

I was responsible for setting up the laboratory (including the equipment used within the study). I also organised necessary paperwork and was responsible for training and rostering students and staff working on the study. Data collection was carried out over a period of approximately eight months, including the preparation and running of four data collection phases. Each data collection phase ran for 11 days. During each of the study phases, I was responsible for supervising students and staff, collecting data and the management of data. I used my expertise in eating behaviour to assist two Psychology Honours students with their projects. I was involved in all aspects of data collection (e.g. running test batteries, supervising participants). In addition, I was specifically responsible for preparing all of the participant's meals within the study. The preparation of meals

included weighing, measuring and cooking all food consumed by participants along with analysing any left-over portions to determine macronutrient and kilojoule content of food consumed. This was a large study that required participants to live in the laboratory for the entire 11 days of each data collection phase. Therefore, Dr Charli Sargent and Psychology Honours students assisted with data collection.

This study produced a large amount of data to answer my research question along a series of additional research questions proposed by Dr Charli Sargent and Psychology Honours students. Due to the large volume of data, I entered data from the study with assistance from the Psychology Honours students working on the project. Following data entry, I decided on the statistical tests that would best suit my research question, ran the tests and interpreted the data.

Publication of manuscript

I drafted the manuscript for publication. Dr Charli Sargent and my current principal supervisor, Associate Professor Jillian Dorrian, assisted with the data analysis and interpretation of data. Dr Charli Sargent, Associate Professor Jillian Dorrian and Anastasi Kosmadopoulos (Psychology Honours student) assisted with the drafting and development of the manuscript for publication. I submitted the publication to the Australian Chronobiology Society as the corresponding author. Reviewers' comments were received following submission and I was responsible for making the requested revisions and resubmitting the article for publication.

Chapters 4 and 5: Study 2

Study design and data collection

Study 2 was conducted as part of a pre-existing grant from the Australian Research Council and the Australian Technology Network Centre for Metabolic Fitness. Study 2 was a large project which ran over a number of years. The project was designed to answer a number of research questions. Due to the large amount of time involved in preparing and conducting this study, a team of three PhD candidates (including myself) worked as a team to prepare for and run each data collection phase. As part of my role within this team I was responsible for screening and recruiting participants, setting up the laboratory and required paperwork (for test batteries and payment of participants). In addition, I helped to train Psychology Honours students working on the study and utilised my expertise in eating behaviour and mood to assist one of these students with their project. My data was collected over a period of approximately one year, which included preparing for and running seven data collection phases. Each data collection phase ran for a period of 14 days.

During each study phase I was responsible for data collection and various tasks involved with running the study (for example running test batteries, organising snacks and checking and setting up equipment for test batteries, along with the supervision of participants). Similar to study 3, participants were required to live in the laboratory for the entire 14 days, and therefore a team of staff and students were required to run each study. Dr Charli Sargent and Associate Professor Gregory Roach assisted with data collection during this study, along with the team of PhD candidates, Psychology Honours students and paid research staff. Due to the large volume of data collected, all data was entered by the team of PhD students along with Honours students and paid research staff. I analysed the snacking and mood data to answer my research questions. This included deciding which statistical tests would best answer my research questions, running the appropriate tests and interpretation of the data.

Publication of manuscript

I drafted the two manuscripts that form part of this thesis for publication. Dr Charli Sargent, Associate Professor Jillian Dorrian and Dr David Darwent assisted with data analyses and interpretation of the data associated with Chapter 4 (Heath et al., 2011). Dr Charli Sargent and Dr Darwent assisted with the data analysis and interpretation of the data associated with Chapter 5 (Heath et al., 2010).

Dr Charli Sargent, Associate Professor Gregory Roach, Dr David Darwent and Professor Sally Ferguson assisted with the drafting and the development of the manuscript associated with Chapters 4 and 5. Additionally, Associate Professor Jillian Dorrian, Professor David Kennaway, Laura Hampton (Honours student) and Raymond Matthews (PhD candidate) assisted with the drafting and development of the manuscript associated with Chapter 5 (Heath et al., 2010). Reviewers' comments were received for both of these manuscripts, and I was responsible for addressing these comments and resubmitting the articles for publication.

Written permission of co-authors

The co-authors listed below contributed to the publications included within this thesis. The signatures provided below confirm each author's contributions and acknowledge my input into the two studies described in the overview of author's contributions.

Associate Professor Jillian Dorrian



Dr Charli Sargent



Associate Professor Gregory Roach



Professor David Kennaway



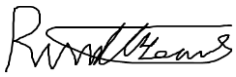
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Dr David Darwent



Raymond Matthews



Laura Hampton



Anastasi Kosmadopoulos



Summary

Many health disorders associated with shiftwork may result from alterations in eating behaviour. This thesis hypothesises that mood (fatigue and stress), sleep-wake related variables (sleep duration, sleep efficiency, prior wake) and shift-related variables (shift schedule, type) predict eating behaviour. Measurements of eating behaviour include hunger, food consumption, and food choice. This thesis contains a series of studies—two laboratory-based, and two field studies.

Study 1 investigated the effect of sleep duration on eating behaviour. Twelve males participated in a laboratory study where they were assigned to either a sleep restriction (4-hour sleep opportunity) or a control condition (8-hour sleep opportunity) for one week. Participants were provided with the same buffet meal both at baseline and following the experimental period. Hunger was measured prior to each meal, with food consumption and choice analysed for energy and macronutrient content.

Study 2 investigated the effect of sleep restriction, prior wake and circadian disruption on eating behaviour and mood. Twenty-four males participated in a laboratory study employing a forced desynchrony design protocol for 12 days. Participants were assigned to either a moderate sleep restriction condition (the equivalent of a 6-hour sleep opportunity per 24 hours) or a severe sleep restriction condition (the equivalent of 4-hour sleep opportunity per 24 hours). Mood analyses were conducted on the severe sleep restriction participants (n = 12) using the Profile of Mood States questionnaire. Eating behaviour was measured by observing snack consumption and choice.

Study 3 examined the impact of sleep duration, shift schedule, mood, and various demographic and work-related factors on eating behaviour. Shiftworkers (n = 118) on various schedules participated in a survey-designed field study. A food frequency questionnaire measured energy and macronutrient content of food consumed on average over the previous year. All other variables were measured using a modified version of the Standard ShiftWork Index.

Study 4 investigated the effect of sleep-related variables, shift type, mood and demographic variables on eating behaviour (energy and macronutrient intake). Shiftworking nurses (n = 42) employed on various shift types participated in a repeated measures field study for 14 days. Actigraphy was used to measure sleep. All other variables were measured using questionnaires and diaries.

Results showed shorter sleep durations resulted in increased hunger (Study 1) and increased snack consumption, in particular increased consumption of sweet snacks (Study 2). Shiftworkers who had less sleep (Study 3), and lower sleep efficiency (Study 4) reported a higher percentage of carbohydrate in their diet. Mood deteriorated with long durations of prior wake, mood was more disturbed around the circadian nadir, and snacks were less likely to be consumed around the circadian nadir (Study 2). Night shifts were associated with higher energy and carbohydrate intakes, and a lower intake of protein and alcohol (Study 4). Permanent night-shiftworkers had a higher consumption of saturated fat (Study 3). Twelve-hour rotating shifts were associated with lower carbohydrate intakes (Study 3). Higher levels of stress and feelings of tiredness were associated with night shift, and high stress predicted greater energy intake (Study 4). Long durations of prior wake were associated with greater mood disturbance, and mood was worse around the circadian nadir (Study 2).

There has been limited research investigating predictors of eating behaviour in shiftworkers. In particular, no prior research has examined relationships between sleep-wake variables, mood and eating behaviour in shiftworkers. Overall findings showed that mood, sleep-wake related factors and shift-related factors affected hunger, and predicted food consumption and food choice. Therefore, shiftworkers are at increased risk of developing health conditions associated with altered eating behaviour.

Declaration

I declare that:

This thesis presents work carried out by myself and does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university.

To the best of my knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text; and all substantive contributions by others to the work presented, including jointly authored publications, is clearly acknowledged.

_____

Georgina Heath

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This thesis could not have been possible without the help and support from many people. I would like to sincerely thank the following people.

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Special thanks to Dr Charli Sargent for supervising me over the first two years of my candidature. I would like to thank Charli for helping me design my overall thesis, run the laboratory studies and for sharing her knowledge and skills with me. Charli provided her guidance not only during the years of supervision, but also continued to support me after supervision had officially finished.

A big thank you to the 'sleep girls' at the Centre for Sleep Research. Thank you so much Gabby, Millie, Steph, Cassie, Crystal, Alex, Diana, Rachael and Gemma for being there for me through the tough times, and also helping me enjoy the good times (and we had plenty of those!). Thanks also goes to all other PhD students I have worked with at the centre for your support and friendship (especially Amy and Ray).

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Chapter 1

Introduction and review of the literature

The demand for a 24-hour (h) society over the past few decades has led to a vast increase in shiftwork worldwide (Australian Bureau of Statistics, 2010; Harrington, 2001; United States Department of Labor, 2005). Typically, shiftworkers are employed to work outside of normal (9am–5pm Monday to Friday) working hours (Åkerstedt, 2003). (See Section 1.4 for a more detailed description of shiftwork). As the trend toward shiftwork rises, attention has been focussed on the safety and performance of shiftworkers (Banks & Dinges, 2007; Dorrian, Baulk, & Dawson, 2011; Folkard & Tucker, 2003). In recent years however, there has been growing concern over the long-term health of shiftworkers. Numerous health disorders have been linked to shiftwork, such as cardiovascular disease, metabolic syndrome, gastrointestinal disorders and type 2 diabetes (Kim et al., 2013; Lowden, Moreno, Holmbäck, Lennernäs, & Tucker, 2010; Pan, Schernhammer, Sun, & Hu, 2011; Pietroiusti et al., 2010; Yong et al., 2014). A wide body of research has demonstrated behavioural and lifestyle differences between shiftworkers and day workers that may place shiftworkers at a greater risk of developing these conditions (Baker, Ferguson, & Dawson, 2003; Kivimäki, Kuisma, Virtanen, & Elovainio, 2001; Knutsson & Nilsson, 1998). It is well documented that shiftworkers are subject to sleep restriction. Sleep restriction refers to the curtailment of sleep. Sleep restriction occurs when an individual delays or advances their bed and wake up time. Shiftworkers are also likely to experience disruption to their circadian rhythm. Circadian rhythms are internal timing systems which oscillate at a period of just over 24h (Åkerstedt, 2003; Dorrian et al., 2008; Knauth et al., 1980; Paech, Jay, Lamond, Roach, & Ferguson, 2010). Circadian disruption is common in shiftworkers (Folkard, 2008) as they are often sleeping, eating and working at hours that directly oppose their internal circadian system (Costa, 2010; Rajaratnam & Arendt, 2001). Sleep and the circadian system is discussed in more detail in Section 1.3.

Sleep restriction and circadian disruption can lead to a number of disturbances in the daily lives of shiftworkers. There is evidence to suggest that circadian disruption and sleep restriction experienced by shiftworkers may alter eating behaviour. In particular, poor food choices have been demonstrated in shiftwork populations (Harada et al., 2005; Puttonen, Härmä, & Hublin, 2010; Reinberg et al., 1979). This is concerning, as obesity and weight gain that occur as a result of a poor diet place individuals at high risk of developing the abovementioned health disorders (Hill & Peters, 1998). A number of studies have been conducted to investigate the eating behaviour of shiftworkers and thus far results have been varied. Some studies suggest shiftworkers consume more food than day workers (Suwazono et al., 2008), other studies have demonstrated no differences in food intake for shiftworkers on various shift types (de Assis, Kupek, Nahas, &

Bellisle, 2003) and some studies show shiftworkers eat fewer meals (Geliebter, Gluck, Tanowitz, Aronoff, & Zammit, 2000).

It is difficult to compare shiftwork studies, as the definition of shiftwork often varies and shiftwork involves a variety of shift types (e.g. morning, afternoon or night shift) and shift schedules (e.g. rotating or permanent schedules). Shift schedules and shift type are discussed in further detail in Section 1.4.1. Each shift type and shift schedule has varying impacts on a shiftworker's life. Of particular relevance for this thesis, the shift schedule or type of shift an individual works may alter factors that predict eating behaviour. Therefore, it is important to understand what these predictors are and the impact differing shift schedules have on these predictors.

Each shift schedule and shift type comes with a varying level of circadian disruption and sleep restriction. Circadian disruption and sleep restriction have both been demonstrated to affect eating behaviour. For example, shiftworkers may consume foods at times when the body is not designed to eat (during the night) (Waterhouse, Buckley, Edwards, & Reilly, 2003), with evidence suggesting that the body is not designed to consume food during the night (Glenn Stanley, Schwartz, Hernandez, Hoebel, & Leibowitz, 1989; Strubbe & van Dijk, 2002). Additionally, sleep restriction may alter appetite hormones and this may result in increased hunger (Schmid, Hallschmid, Jauch-Chara, Born, & Schultes, 2008; Spiegel, Tasali, Penev, & Van Cauter, 2004). Studies examining responses in the brain following sleep restriction suggest that activation is increased in areas associated with motivation and desire when individuals are shown food images (Benedict et al., 2012). Therefore, shiftworkers not obtaining enough sleep may be more likely to seek for food for reasons other than hunger. Overall, the research thus far suggests shiftworkers on shift types or schedules resulting in circadian disruption and sleep restriction may be at greater risk of alterations in eating behaviour.

Circadian disruption and sleep restriction have a negative effect on many factors such as performance, alertness and mood (Boivin et al., 1997; Cohen et al., 2010; Dinges et al., 1997; Zhou et al., 2011). For example, laboratory studies manipulating the sleep-wake cycle have demonstrated mood disturbances when participants are totally deprived of sleep or when sleep is restricted (Brendel et al., 1990; Dinges et al., 1997; Paterson et al., 2011). Furthermore, mood has been shown to exhibit a circadian rhythm such that mood is worse during the early hours of the morning (Boivin et al., 1997; Koorengevel, Beersma, den Boer, & van den Hoofdakker, 2003) Therefore, shiftworkers working through the early hours of the morning may be more likely to experience negative moods at work. Indeed, shiftworkers often report mood disturbances such as

fatigue, anxiety and depressive disorders (Cavallo, Jaskiewicz, & Ris, 2002; Scott, Monk, & Brink, 1997).

Mood can impact on various aspects of daily living and mood is an important motivator of food choice. Studies have demonstrated that specific mood states can result in alterations in eating behaviour. For example, a study investigating the influence of mood on food choice found that depression resulted in a preference for junk foods, whereas individuals who were happy preferred healthy foods (Lyman, 1982). Depressive moods have also been associated with the eating of comfort foods (Benton & Donohoe, 1999) and cravings for chocolate, confectionary and sweet foods increased with feelings of anxiety (Hill, Weaver, & Blundell, 1991).

Section 1.1 presents an overview of eating behaviour. Eating behaviour is the main outcome variable within this thesis. Sections 1.2–1.4 overview factors that have been demonstrated to predict eating behaviour: mood, sleep and the circadian system, and shiftwork. Sections 1.5 reviews the literature suggesting that these factors predict eating behaviour. Section 1.6 reviews the literature suggesting that sleep and shift-related factors predict mood. Section 1.7 discusses how shift-related factors predict sleep. Section 1.8 outlines the research aims of this thesis.

1.1 Eating behaviour

Shiftworkers are at risk of developing serious health conditions. Often these health conditions develop as a result of lifestyle-related disorders such as obesity. Indeed, studies investigating shiftworkers have found they are more likely to be overweight or obese when compared to day workers (Kivimäki et al., 1997; Marqueze, Ulhôa & Moreno, 2012 Morikawa et al., 2007; Suwazono et al., 2008). There are many factors that lead to weight gain and obesity, and mechanisms are often complicated (Marqueze et al. 2012). However, one of the principal behaviours that results in weight gain and obesity is alterations in eating behaviour (increased food consumption and poor food choice) (Hays et al., 2002). This section begins with a discussion of nutrition to allow for an understanding of nutrients and their functions. An overview of factors impacting on food consumption and food choice, and a summary of eating behaviour measures follow.

1.1.1 *Nutrition and the macronutrients*

Nutrition is a broad term covering the science of food and its relationship with health (Wardlaw & Smith, 2011). Nutrients and substances obtained from food are important for maintenance of the

human body. There are six classes of nutrients: carbohydrates, fats, proteins, vitamins, minerals and water. Carbohydrates, fats and proteins (known as macronutrients) provide energy for use or storage within the body and help with the building of tissues. Vitamins, minerals and water have been found to facilitate numerous bodily activities. For example, vitamins assist with releasing energy from macronutrients and producing DNA. Minerals help maintain fluid balance in the body and assist with bone growth. Water assists with the transport of waste products and nutrients throughout the body, regulates body temperature and helps to maintain blood volume (Whitney & Rolfes, 2013).

Essential nutrients are those obtained from foods that body cannot produce sufficient quantity of these nutrients for physiological needs. Energy provided by the macronutrients (carbohydrate, fat and protein) is measured in joules, and the amount of energy provided by a food will depend on its macronutrient profile. In Australia, kilojoules (kJ) is the preferred measurement of food energy (1,000 joules equals one kilojoule). However, some countries measure food in kilocalories (often abbreviated to calories or kcal). One hundred kcal is equivalent to 420 kJ (Australian National Health and Medical Research Council & the New Zealand Ministry of Health, 2006; Whitney & Rolfes, 2013).

The amount of energy contained in a food depends on the breakdown of carbohydrate, fat and protein. For example, one gram of carbohydrate or protein contains about 17 kJ of energy. However, one gram of fat yields approximately 37 kJ of energy. Therefore, fat is more energy dense than carbohydrate or protein. Another substance that contributes to energy, while not a macronutrient, is alcohol. Alcohol yields 29 kJ per gram. As alcohol can be detrimental to the maintaining, repairing and growth of the body it is not considered a nutrient (Whitney & Rolfes, 2013).

Most foods consumed consist of fats, carbohydrate and protein along with water, vitamins, minerals and other substances. Energy released from nutrients are used to fuel bodily activities. If nutrients are not used as energy the body will reorganise them into storage compounds (e.g. body fat and glycogen). They are then used when fresh energy supplies are low (e.g. overnight). However, if energy consumption exceeds energy expenditure weight gain will occur. Conversely, if less energy than consumed is expended then weight loss will occur due to a decrease in energy stores (World Health Organisation, 2015).

1.1.1.1 Carbohydrates

Carbohydrates are a major energy source for the human brain in the form of glucose (Australian National Health and Medical Research Council & the New Zealand Ministry of Health, 2006) and are important for the maintenance of glycaemic, homeostatic and gastrointestinal health (Stylianopoulos, 1999a). They are also important for supplying muscles with fuel to allow for participation in physical activity (Wardlaw & Smith, 2011). Carbohydrates are obtained from foods such as cereals, fruits, legumes and vegetables (Stylianopoulos, 1999a). It is recommended that diets should be high in complex carbohydrates (e.g. starches and fibres), however, simple sugars should be avoided (Krauss et al., 2000).

As all of the cells in the body are dependent on glucose supplied from carbohydrates it is useful to understand how blood glucose responds to foods (Whitney & Rolfes, 2013). Glycaemic index (GI) (the blood glucose response to carbohydrate consumption) can be used represent the quality and quantity of the carbohydrate (Salmerón et al., 1997). The type of carbohydrate consumed and the physical determinates of digestion rate (i.e. cooked or uncooked food) will determine the GI. For example, sugars are absorbed by the body easily and raise blood glucose levels (Whitney & Rolfes, 2013). Additionally, consuming protein and fat at the same time as carbohydrate ingestion can reduce the GI of the meal (Jenkins et al., 1981; Stylianopoulos, 1999b). Ideally, individuals should aim to consume foods with lower GI as low GI foods have been found to reduce the risk of heart disease, improve blood lipids, and potentially help with weight management (Cade, Burley, & Greenwood, 2004; National Institutes of Health, 2001).

There are a number of health effects associated with the different types of carbohydrates. First, high intakes of sugar may be harmful to health. Foods high in sugar are energy dense and therefore may increase the risk of obesity due to increased energy intake (Schulze et al., 2004; Stylianopoulos, 1999b). Some individuals may increase their intakes of sugary carbohydrates to improve their mood as carbohydrates increase the levels of serotonin (a brain neurotransmitter) (Wurtman et al., 1981); for further information see Section 1.5.1. Furthermore, high intakes of refined sugar have been found to increase the risk of cardiovascular disease (Stylianopoulos, 1999b).

Second, a diet high in complex carbohydrates may be beneficial to health in various ways. Dietary fibre can reduce the risk of obesity, as such foods are typically lower in fat and sugars. Furthermore, satiety is increased as dietary fibres absorb water from digestive juices causing them to swell (Stylianopoulos, 1999b; Whitney & Rolfes, 2013). In addition, the consumption of

complex carbohydrates has been found to protect against chronic diseases (Brown, Rosner, Willett, & Sacks, 1999; Davis, Rifkind, Brenner, & Gordon, 1990)

The Australian Dietary Guidelines recommend that adults consume approximately half of their diet (45–65%) from carbohydrates; however, there are no specific recommendations on the daily amounts. The guidelines suggest eating a variety of carbohydrate-rich foods such as vegetables, legumes, beans, fruit and grains. Further, it is recommended that women consume 25 grams of dietary fibre per day and men consume 30 grams per day (National Health & Medical Research Council, 2013).

1.1.1.2 Fats

Lipids are the category of nutrients known as fat. Lipids include triglycerides (fats and oils), phospholipids and sterols. Triglycerides are the main form of fat in the diet and the body. They are important for providing the body with energy, insulation, protecting against shock, and helping the body to use carbohydrate and protein efficiently. Fatty acids can be saturated, mono-unsaturated or polyunsaturated depending on the number of double bonds they contain. The chemistry of the fatty acid (i.e. short or long, saturated or unsaturated) affects the physical characteristics of the food and the impact it has on health (Lichenstein, 1999)

Dietary fats can be beneficial or detrimental to health (Lichenstein, 1999; Nestel et al., 2005). Elevated blood cholesterol is a risk factor for cardiovascular disease as cholesterol can accumulate in the arteries causing them to become blocked, restricting blood flow and raising blood pressure (Corbin, Welk, Corbin, & Welk, 2001; Malloy & Kane, 2000). In particular, saturated fats from foods such as red meat and full-fat dairy products are a major contributor to raised concentrations of low-density lipoprotein (LDL) cholesterol (Siri-Tarino, Sun, Hu, & Krauss, 2010). In addition to saturated fats, trans fats contained in deep-fried foods and bakery products have also been associated with heart disease (Mozaffarian, Katan, Ascherio, Stampfer, & Willett, 2006) as they raise LDL cholesterol and lower high-density lipoprotein (HDL) cholesterol. Trans fatty acids may also increase inflammation and insulin resistance. It is therefore important to limit the intake of foods containing trans fats, such as deep-fried foods, chips, meat and dairy. There is also evidence to suggest an association between fat and some types of cancer (Giovannucci et al., 1993).

The Australian Dietary Guidelines recommend that 20–35 % of energy intake is consumed from fat, as this percentage of fat in the diet is congruent with lower rates of health conditions such as

heart disease, diabetes, obesity and cancer (National Health & Medical Research Council, 2013). In particular, individuals should maintain a diet low in saturated fat, trans fat, and replace these fats with mono-unsaturated and polyunsaturated fat (Dayton, Pearce, Hashimoto, Dixon, & Tomiyasu, 1969; Turpeinen, Pekkarinen, Miettinen, Elosuo, & Paavilainen, 1979). Further, 8–10% of energy in the diet should come from saturated fats and trans fats together (National Health & Medical Research Council, 2013).

1.1.1.3 Protein

Protein is the most satiating of the macronutrients (Brennan et al., 2012). Protein has many functions, such as supporting growth and maintenance of the body, helping regulate body processes and facilitating chemical reactions. Proteins are more complex than carbohydrates or lipids. Proteins are also made up of approximately 20 amino acids, nine of which cannot be made by the body. Protein in food does not become body protein directly, rather, it allows the body to make its own protein through the supply of amino acids. Therefore, it is important to consume a diet of high-quality proteins that contain the essential amino acids required to support the body. If energy intake exceeds the body's needs and carbohydrate intake is adequate, amino acids can be used to make fat, thus protein can contribute to weight gain (Whitney & Rolfes, 2013).

Diets high in protein may be detrimental to health, as some high protein diets have been linked to chronic diseases such as heart disease and some types of cancer (Giovannucci et al., 1994; Kelemen, Kushi, Jacobs, & Cerhan, 2005). High-protein diets often consist of increased intake of protein from animals. Meat is not only high in protein but also high in saturated fat. Therefore, high protein diets can contribute to heart disease and cancer in the same way described above in the section on fats. However, if animal proteins are replaced with vegetable protein, blood lipids are generally improved and heart disease mortality is decreased (Tai et al., 2005). As protein can help reduce appetite, diets higher in protein may promote weight loss (Weigle et al., 2005).

The Australian Dietary Guidelines recommend that protein intake should fall within 10–35% of the diet. Females should consume 0.75 grams of protein per kilogram of their body weight, and males should consume 0.84 grams per kilogram of their body weight per day (Australian National Health and Medical Research Council and the New Zealand Ministry of Health, 2006).

In summary, this section provided a brief overview of the macronutrients in food, and a brief outline of their importance and health benefits. Following the recommendations provided by the Australian Dietary Guidelines is important for the maintenance of health (i.e. protection against

disease). Conversely, a poor diet may place an individual at risk of obesity and lead to the development of life-threatening health conditions such as cardiovascular disease, diabetes and cancer. When examining eating behaviour, it is important to understand the determinants of food consumption and choice, and the following section provides an overview of the reasons people have for consumption and food choice.

1.1.2 *Food consumption and choice*

Maintaining a healthy diet is important; however, individuals have various reasons for choosing to eat, and in particular why they choose specific foods. The types of food consumed have implications for an individual's health, with food choice determining the nutritional benefits the body receives. Therefore, it is important to understand the factors that may influence food choice. A number of factors such as sensory characteristics of the food, attitudes of the consumer, and social, cultural and environmental factors have been found to influence food choice. This section briefly summarises these factors. Figure 1.1 illustrates the factors that influence food consumption and food choice.

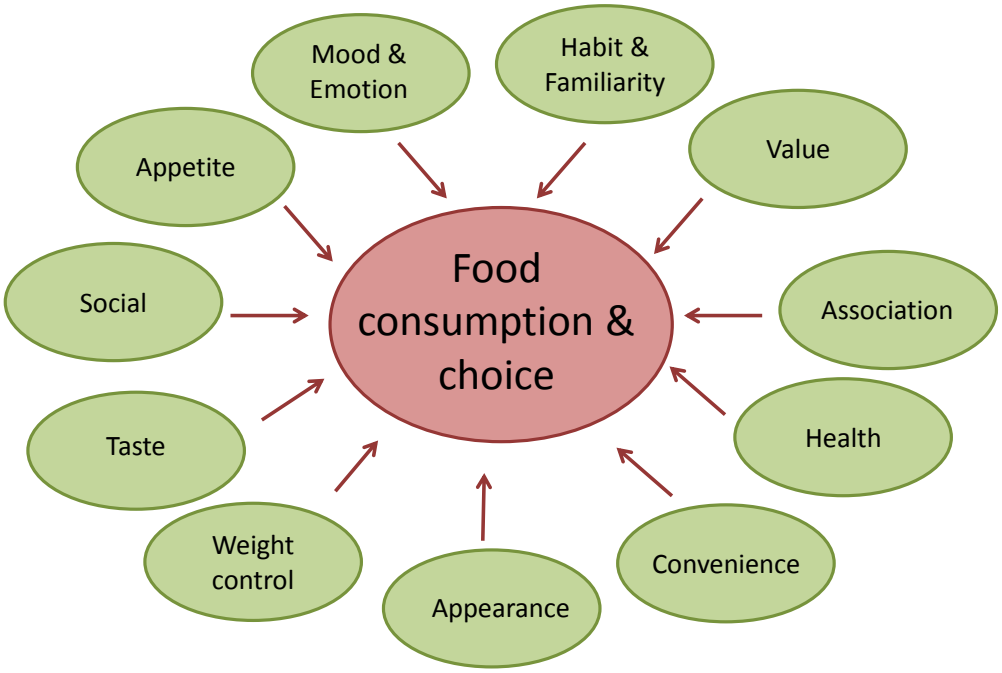


Figure 1.1 Factors that influence food consumption and food choice

1.1.2.2 Appetite: hunger and satiety

One of the major influences of eating behaviour is appetite, which includes both hunger and satiety (Whitney & Rolfes, 2013). Hunger refers to the physical biological drive to eat. For

example, when an individual is hungry they are motivated to seek and consume food. In contrast, satiety refers to the feeling of satisfaction derived from the consumption of food that ceases the desire to eat (Insel, 2011). Neural, nutritional and psychological processes interact to control appetite. Nutrients are absorbed by the stomach and small intestine following the consumption of food. Signals are then sent to the liver and the hypothalamus in the brain to decrease further food intake. Hormones such as ghrelin (hunger increasing hormone) and leptin (satiety increasing hormone) are also involved in appetite (Arora, 2006). For a detailed discussion on appetite hormones and their role in relation to appetite and obesity, see the review conducted by Arora (2006).

1.1.2.3 Taste

The flavour of food is one of the most common reasons for choosing a particular food (Glanz, Basil, Maibach, Goldberg, & Snyder, 1998). Typically individuals prefer foods that are sweet (i.e. foods high in sugar) as they are highly palatable (Steptoe, Pollard, & Wardle, 1995; Stylianopoulos, 1999b). Studies have suggested a preference for sweet foods is innate, as a preference for sweetness has been demonstrated in newborns by measuring facial expressions (Desor, Maller, & Andrews, 1975). Additionally, the savoury taste of salty foods is commonly enjoyed (Steptoe et al., 1995). High-fat foods are also often preferred by many individuals, as fats contribute to the texture and aroma of foods (Drewnowski & De Roos, 1992).

1.1.2.4 Habit/familiarity

Habit or familiarity is another common reason for choosing foods. Individuals often choose foods they may have grown up eating or foods typical of their country, heritage or religion. Furthermore, familiar foods are often considered comforting (Whitney & Rolfes, 2013). It is estimated that 75% of an individual's food intake results from about 100 basic food items (Wardlaw & Smith, 2011).

1.1.2.5 Social

Meals are often social occasions or occur as part of social interaction, and food is typically enjoyed when shared with others. In some circumstances, foods may be consumed to indicate social status as certain foods are considered prestigious (Sanjur, 1982).

1.1.2.6 Convenience

Often foods are chosen because they are readily available or because they are quick and easy to prepare. Indeed, convenience is often a major priority for many individuals, and research suggests

more than 50% of food budgets are spent on meals that require limited preparation (e.g. eating out, foods delivered to the home and foods that can be prepared in 20 minutes or less) (Tillotson, 2002). Meals are often consumed outside of the home (Blisard, Lin, Cromartie, & Ballenger, 2002; Kant & Graubard, 2004) and these meals often contain more kcals and saturated fat than food prepared at home (Guthrie, Lin, & Frazao, 2002). Whilst food that is quick and easy can be nutritious (e.g. fruit), many convenience foods provide little nutrition (e.g. chocolate bars) (Whitney & Rolfes, 2013).

1.1.2.7 Associations (positive and negative)

Food is often associated with events or occasions (e.g. cake at birthday parties), and the positive association with these foods may be why a specific type of food is chosen. Conversely, aversions to food can develop if foods are forced, or if nausea, illness or other negative outcomes occur as a result of consuming a particular food. Additionally, food used as a reward or punishment in childhood may result in likes or dislikes for particular foods (Scaglioni, Arrizza, Vecchi, & Tedeschi, 2011).

1.1.2.8 Emotions and mood

Food choice is often based on emotions or moods. For example, particular foods may be consumed to relieve depression, stress and anxiety (Ioakimidis et al., 2011). Food can influence the chemistry of the brain (e.g. carbohydrates and alcohol can be calming; however, caffeine and protein can activate the brain) (Whitney & Rolfes, 2013). Food choice as a result of emotions or mood are discussed in detail in Section 1.5.1.

1.1.2.9 Values

Religious beliefs, political views and ethical or environmental concerns are frequent reasons for food choice. These views or concerns may also lead to certain foods being excluded from the diet (Lau, Krondl, & Coleman, 1984). These factors may not only play a role in the food chosen, but also in how food is prepared.

1.1.2.10 Weight control, appearance and health

Individuals often report consuming particular foods they believe may enhance their physical appearance (Hayes & Ross, 1987). Alternatively foods can be avoided at times for the same reason (Furst, Connors, Bisogni, Sobal, & Falk, 1996). These types of food choices may be beneficial to the individual (e.g. resulting from sound nutritional advice by a qualified professional). On the other hand, making food choices based on controlling weight or physical

appearance can at times be detrimental to health (e.g. resulting in eating disorders) (Whitney & Rolfes, 2013). In addition, food may be chosen and consumed based on the benefits they provide for an individual's health, or to prevent diseases such as heart disease or cancer (Furst et al., 1996).

In summary, this section outlined factors that influence eating behaviour. Food may be consumed for homeostatic reasons (hunger); however, there are many non-homeostatic reasons specific foods may be chosen, such as taste, or to align with religious beliefs or environmental concerns. In addition, food choice may differ depending on the mood an individual is experiencing. Therefore it is important to remain aware that pathways to eating behaviour are multifaceted. This overview on eating behaviour concludes with a discussion outlining the various methods of measuring eating behaviour, and their strengths and weaknesses.

1.1.3 *Measurement of eating behaviour*

There are several tools available to measure dietary intake as a measure of eating behaviour. These tools differ in time frame (average intake over a period of time or current intake), administration method (interview, questionnaire, observation), measurement of foods consumed (weighing or estimation) and conversion into food components (nutritional database) (Van Staveren, Ocke, & De Vries, 2012).

There are two main categories of dietary intake recording: assessments that record food consumed at the time of eating (prospective methods), and those that collect data retrospectively over a period of time (retrospective methods). Prospective methods include measures such as diaries of food intake that can be weighed or estimated. Prospective methods usually cover several days of recording. Retrospective methods can cover recent diet history (e.g. 24h food recalls) or habitual diet (e.g. food frequency questionnaires [FFQ]) (Van Staveren et al., 2012). The following section briefly describes the various methods and discusses their strengths and weaknesses.

1.1.3.1 Dietary records

Dietary records are weighed or estimated recordings of current food intake. Dietary records are considered 'gold standard', as foods are described in detail and it is less likely that a participant will forget portion sizes of foods consumed. Dietary records allow for an estimation of typical food intake of a population if recording occurs for two or more days within and between participants (Erdman Jr, MacDonald, & Zeisel, 2012).

The weighed record technique involves the participant weighing and recording food consumed. The participant describes information such as the brand name of the food, preparation method (e.g. boiling or frying) and recipe details (Thomson & Subar, 2001). If it is not practical to weigh the food, the participant may describe food consumed (e.g. restaurant meals) and the researcher will estimate weights. Estimated dietary records involve the participant reporting portion sizes of foods consumed. Portion sizes are described using measurement utensils commonly found in homes, such as cups and tablespoons (Erdman Jr et al., 2012).

Dietary records have weaknesses. For example, participants need to be literate to complete the diary, and need to maintain motivation across the study period (Thomson & Subar, 2001). Additionally, if the records are kept for longer periods of time validity is likely to decrease due to participant burden (Gersovitz, Madden, & Smiciklas-Wright, 1978). Researchers also need to be aware that dietary records may result in a response bias, as studies are often over represented by participants with a high level of education. Additionally, participants choosing to take part in studies involving dietary intake may have an interest in nutrition and health. Accuracy in the recording process can also reduce when recording occurs away from the home. Furthermore, participants may change their typical eating pattern over the recording period (Rebro, Patterson, Kristal, & Cheney, 1998). Under-reporting is common in participants recording food intake using dietary records (Black et al., 1993; Goris, Westerterp-Plantenga, & Westerterp, 2000; Taren et al., 1999). In particular, some populations, such as those with a high body mass index (BMI), are more likely to under-report food intake (Lichtman et al., 1992). Women are more likely to under-report than men (Johnson, Goran, & Poehlman, 1994; Lafay et al., 1997).

Typically, dietary records are kept over a number of days (Erdman Jr et al., 2012). Whilst some studies choose to record data over consecutive days, other researchers have suggested that non-consecutive days are preferable. Dietary patterns on consecutive days are correlated and non-consecutive days will capture the variability of an individual's diet (Hartman et al., 1990). Analysing dietary records, which is typically conducted on dietary assessment software, can be time consuming and costly (Thomson & Subar, 2001).

1.1.3.2 Twenty-four hour food recall

The 24h recall method is one of the most common recalling methods of recording dietary intake. In this method the participant recalls the intake of food and beverages for a proceeding period of time (typically 24h). Food consumption is measured using household measurements. Additionally, food models or photographs may be used (Erdman Jr et al., 2012). This method may be conducted

via a personal interview (Thomson & Subar, 2001), telephone interview (Buzzard et al., 1996; Casey, Goolsby, Lensing, Perloff, & Bogle, 1999) or computer assisted interview (Conway, Ingwersen, Vinyard, & Moshfegh, 2003; Slimani et al., 1999). Interviewers must be trained to ask probing questions (e.g. 'Did you have butter on your toast?') (Erdman Jr et al., 2012).

The 24h recall method is generally used to describe the mean intakes of a group of individuals (Beaton et al., 1979). Literacy is not required if an interviewer is used, and administration time is short (typically around 30–45 minutes) (Erdman Jr et al., 2012). Coding of data can occur during the interview, which helps to reduce costs and ensure data are unlikely to be missed (McDowell et al., 1990). Response rates are also higher using this method as participant burden is minimal. However, as with most methods of measuring food intake, 24h recalls also have limitations. For example, recalls are often not estimated correctly as intakes (particularly portion sizes) can be difficult to remember. If the record is only taken for only one day, within-individual variation cannot be determined (Erdman Jr et al., 2012; Thomson & Subar, 2001). Similar to dietary records, there is a tendency for participants to under-report during 24h food recalls (Bathalon et al., 2000; Kroke et al., 1999). Under-reporting appears to be related to factors such as weight, gender, education and social desirability. (Ballard-Barbash, Graubard, Krebs-Smith, Schatzkin, & Thompson, 1996; Hebert, Clemow, Pbert, Ockene, & Ockene, 1995; Klesges, Eck, & Ray, 1995; Krebs-Smith et al., 2000).

1.1.3.3 Diet history

A diet history examines food intake over a period of time (e.g. 6 or 12 months). Originally 'diet histories' (a term coined by Burke) collected information about the frequency of intake and the usual makeup of meals (Burke, 1947; Burke & Stuart, 1938). Currently, there are numerous variations of the original diet history and they are applied in various ways (Jain, Howe, & Rohan, 1996; Kohlmeier, Mendez, McDuffie, & Miller, 1997; Van Staveren, De Boer, & Burema, 1985). Diet histories usually include an interview regarding the participant's typical daily pattern of food intake and a cross-check via a detailed list of foods (Erdman Jr et al., 2012). Typically, diet histories are more detailed than FFQs (see below) (Kohlmeier, 1994; Kohlmeier et al., 1997). Portion sizes are measured using household measurements. The diet history is suitable for studies that wish to assess patterns of food intake. If the history is administered by an interviewer, literacy is not required. However, accuracy can be limited. For example, participants may be influenced by current food consumption. Additionally, they are not useful if the participant does not have a set eating pattern, and responses may be biased towards social desirability (Erdman Jr et al., 2012;

Thomson & Subar, 2001). Studies have suggested that nutrient estimates are higher in diet histories compared to other tools such as dietary records or recalls (Jain et al., 1996).

1.1.3.4 Food frequency questionnaires

FFQs are typically administered in larger epidemiological studies and are used to estimate the food intake of individuals or group. The FFQ requires respondents to estimate their habitual consumption and frequency of consumption from a list of foods for a specific period (e.g. 6 or 12 months (Willett, 1994; Zulkifli & Yu, 1992). This method puts less burden on the participant and the research team compared to collecting a diet history via interview (Erdman Jr et al., 2012). In their review of FFQ, Molag et al. (2007) conclude that results were more accurate when the FFQ was longer (e.g. 200 vs 100 items); however, longer questionnaires may result in increased participant burden and participants may not complete the questionnaire. Longer lists and longer time frames may also lead to overestimation of dietary intake. However, participant burden is usually low (e.g. questionnaires are usually self-administered and take around 30–60 minutes to complete), with response rates typically high. In addition, the cost of using this technique is low (usually data can be scanned), and interviewer variation is reduced when food lists are standardised. Similar to previously described methods, accuracy may be reduced as it is difficult to remember food intake over longer periods of time and this method cannot be used to investigate day to day variation. It is also difficult to measure all details of dietary intake as many foods are not included on the questionnaire, and FFQs may be inaccurate due to portion sizes often differing across eating occasions (Erdman Jr et al., 2012; Thomson & Subar, 2001).

In summary, all methods of collecting dietary intake involve error to some extent. Although dietary records are considered the gold standard for collecting dietary intake, they may not be suitable for some studies. It is therefore important to determine the design and use of the dietary method when considering a method of measurement. For example researchers need to take into consideration factors such as cost, participant burden (e.g. time participants have available to complete the study), and specifics of the group to be studied (e.g. literacy, a group known to under-report).

The following sections (Sections 1.2–1.4) provide an overview of the predictors of eating behaviour examined in the current thesis: mood, sleep and circadian related factors, and shiftwork.

1.2 Mood

Research has demonstrated that shiftworkers often report experiencing mood disturbances (see Section 1.6.3). Mood appears to be influenced by factors related to shiftwork, such as sleep restriction and circadian disruption (see Section 1.6.3). This chapter argues that mood is likely to be a predictor of eating behaviour in shiftworkers, therefore the following section provides an overview of this construct.

1.2.1 *Features of mood*

The terms 'mood' and 'emotion' are often used interchangeably to describe an individual's transient episodes of affect, feeling or emotional state (Thayer, 2000; Watson, 2000). Research to date has demonstrated that mood and emotion are similar, yet separate, constructs (Siemer, 2005). These two constructs are compared in order to understand the differences.

It is widely accepted that cause is the most distinguishing feature between mood and emotion (Beedie, Terry, & Lane, 2005). Emotions are caused by external stimuli and circumstances (Beedie et al., 2005; Watson, 2000). For example, participants exhibited emotional responses such as disgust, amusement and pleasure in direct response to clips from feature films (Hewig et al., 2005). In contrast to emotions, moods are often reported as having no direct cause (Beedie et al., 2005). However, moods have been demonstrated to occur not only as a result of external stimuli and circumstances, but also due to internal processes such as metabolism (Izard, 1991). Primarily due to the influence of internal processes, moods have been found to display cyclic variation (Thayer, 2000; Watson, 2000). Moods vary across the day (i.e. they display a circadian rhythm) (Boivin et al., 1997), moods vary across the month (e.g. menstrual cycle) (Davydov, 2004) and mood may fluctuate across the year (e.g. seasonal affective disorder) (Thayer, 2000). Changes in mood have also been demonstrated as a response to biological conditions such as sleep, nutrition and health. For example, individuals participating in a sleep restriction study reported higher levels of depression, anxiety, fatigue and confusion when sleep was restricted to 4h sleep per night for one week compared to individuals who were provided with an 8h sleep opportunity per night for the same period of time (Dinges et al., 1997).

Another important variation between mood and emotion is duration. As moods are milder than emotions, moods are longer, lasting for hours, days or even months. For instance the average duration of depressed mood disturbances in a population of college students who completed a mood checklist twice weekly was approximately six days (Santor & Patterson, 2004). In contrast,

emotions are intense and highly reactive, and are thus brief, typically lasting for only seconds or minutes (Thayer, 2000; Watson, 2000; Watson & Clark, 1997). Unlike emotion, moods in one form or another are constantly experienced by individuals throughout the waking day (Watson, 2000).

In addition to cause and duration, mood has also been found to differ in consequence. For example moods result in alterations in cognition (i.e. information processing and memory), which in turn influences behaviour (Gendolla, 2000). On the other hand, emotions are more likely to prepare an individual for action, similar to the fight or flight response (Frijda, 1994). Additionally, it is thought that moods may occur as a consequence of emotion (Beedie et al., 2005). For example, Frijda (1994) suggests an irritable mood may occur as a result of a brief intense emotion such as anger. Mood and emotion also appear to differ in intentionality. Unlike moods, emotions are typically directed at specific objects (Beedie et al., 2005; Watson, 2000).

1.2.2 *Dimensions of mood*

Research thus far suggests mood consists of two broad dimensions: positive and negative. Positive and negative moods appear to operate independently of one another rather than existing as a unidirectional construct fluctuating between positive and negative (Costa & McCrae, 1980; Watson, Clark, & Tellegen, 1988). Both positive and negative moods can be experienced at the same time. For example, someone who is cheerful (positive mood) may be concurrently nervous (negative mood) (Watson, 2000). Brain imaging studies have demonstrated that a there is some overlap between neurological pathways for the two dimensions. However, there is also evidence to suggest that there are neurological pathways that are unique to each dimension (Lane et al., 1997). Within each dimension, moods are often inter-correlated (e.g. depression is highly correlated with anxiety) (Watson & Clark, 1997). However, positive and negative moods produce different consequences for the psychological and physical well-being of individuals.

1.2.2.1 Positive mood

Positive mood is associated with favourable outcomes for individuals. Adjectives such as enthusiasm, alertness and joy describe positive mood (Watson, 2000). Positive mood may be beneficial for health. For example, higher daily positive mood ratings such as vigour and happiness have been associated with fewer colds and symptoms in healthy adults exposed to a virus similar to the common cold (Cohen, Doyle, Turner, Alper, & Skoner, 2003). It has been suggested that there are various pathways that may explain how positive mood affects health. For example, positive mood may reduce blood pressure and lower heart rate. Positive mood may also

have the potential to decrease hormones such as cortisol (Pressman & Cohen, 2005). An additional pathway may be that positive mood has influence over favourable health-related behaviours (such as diet and exercise) and increases the likelihood of engagement in social activities that may protect health (Das, Vonkeman, & Hartmann, 2012). Furthermore, Pressman and Cohen (2005) propose that positive mood may buffer stress by facilitating resistance, optimism and coping.

In addition to the health benefits of maintaining a positive mood, positive mood has been found to be advantageous in the workplace due to its direct and indirect impact on behaviour. For example, positive mood may improve productivity by enhancing task performance in areas such as decision making (Morgan, Jones, & Harris, 2012). Additionally, positive mood can improve motivation in the workplace. A large sample of 745 students set higher goals for themselves in a performance task when a positive mood was experienced following performance feedback (Ilies & Judge, 2005). Moreover, positive mood can impact on social relationships in the workplace, such as increased employee cooperation (George & Jones, 1996) and helpfulness (Carlson, Charlin, & Miller, 1988).

1.2.2.2 Negative mood

Negative mood is described by adjectives such as fear, anger, anxiety and depression (Watson, 2000). In contrast to positive mood, negative mood states can be harmful to health and detrimental to the workplace. Negative mood can increase vulnerability to illness and intensity of health complaints (Salovey & Birnbaum, 1989). Furthermore, negative mood states such as anxiety, stress and depression have been associated with unfavourable health-related behaviours, such as heavy alcohol consumption, smoking and decreased physical exercise (Steptoe, Wardle, Pollard, Canaan, & Davies, 1996). Additionally, negative mood has clear influences over eating behaviour (Jeffery et al., 2009; Willner et al., 1998); these are discussed in further detail in Section 1.5.1. Negative mood states may also impact on mental health, as they may be precursors of more severe psychological disorders (Kessing, 2007).

As opposed to positive mood, which has benefits for the workplace, negative mood is associated with unfavourable outcomes, such as lower levels of engagement (Bledow, Schmitt, Frese, & Kühnel, 2011) and performance (Jordan, Lawrence, & Troth, 2006), emotional exhaustion, and lower levels of job satisfaction and organisational commitment (Thoresen, Kaplan, Barsky, Warren, & de Chermont, 2003). Evidence from studies shows that negative mood impacts health. This has important consequences for the workplace as it may lead to time off work due to illness.

Negative mood states such as depression and fatigue can lead to psychological distress, and thus result in absences from the workplace, work disability and reduced workplace productivity (Bültmann et al., 2005; da Silva-Junior & Fischer, 2014; Janssen, Kant, Swaen, Janssen, & Schroer, 2003). For example, a large study of fatigue at work involving 45 organisations found that fatigue was associated with future absence from work (Janssen et al., 2003). Similarly, high levels of psychological distress and disorders have been found to predict a larger number of absentee days and long-term absences from the workplace (Hardy, Woods, & Wall, 2003; da Silva-Junior & Fisher, 2014). Even milder symptoms of depression and anxiety (e.g. feeling down and worrying), which have not reached clinical significance, have been associated with absence from the workplace (Terluin, van Rhenen, Anema, & Taris, 2011). Therefore, it is important to understand the causes of negative mood states—not only may they result in absence from the workplace, they may be precursors of more severe psychological disorders.

In summary, whilst mood and emotion are similar, they are separate constructs that can be differentiated by cause, duration and consequence. There are two main mood dimensions: positive mood and negative mood. These two dimensions impact differently on areas such as health, work and productivity. Of particular relevance to this thesis, mood has significant influence on health-related behaviours such as eating. The effect of mood on eating behaviour is discussed further in Section 1.5.1. The following section provides an overview of sleep, which is another predictor of eating behaviour examined in the current thesis.

1.3 Sleep

A number of studies suggest that shiftwork impacts sleep duration and sleep quality. Sleep is described as 'a reversible behavioural state of perceptual disengagement from and unresponsiveness to the environment' (Carskadon & Dement, 2005, p. 16). Sleep is associated with characteristics such as a recumbent postural position, stillness and closed eyes.

1.3.1 *States and stages of human sleep*

Sleep is measured visually and according to specific criteria. A criterion for the scoring of sleep was developed by Rechtschaffen and Kales (1968). More recently, these criteria have been revised by the American Association of Sleep Medicine (Silber et al., 2007). Three polysomnographic (PSG) measures are typically used to determine the state and stage of sleep. Brain-wave activity is measured by the electroencephalogram (EEG); eye movements are measured by the electrooculogram (EOG); and muscle tension is measured by the

electromyogram (EMG) (Carskadon & Dement, 2005; Curie & Franken, 2012; Rechtschaffen & Kales, 1968). Human sleep has been classified into two distinct states: non rapid eye movement (NREM) and rapid eye movement (REM) sleep. By analysing these states, the amount, distribution and quality of sleep episodes can be examined (Curie & Franken, 2012). NREM sleep was traditionally sub-classified by Rechtschaffen and Kales (1968) into four stages (Stages 1, 2, 3 and 4). More recently, Stages 3 and 4 have been coupled together and classified as slow wave sleep (SWS) (Silber et al., 2007). SWS is acknowledged as the most restorative stage of sleep as it is thought that muscles rest and recuperate during this stage (Shapiro & Flanigan, 1993; Spiegel, Köberle, & Allen, 1986).

Sleep onset begins in Stage 1 of NREM (NREM-1) and then progresses through the stages of NREM. NREM-1 is relatively short (usually lasting between one and seven minutes) and can be described as a transitional stage between wake and sleep. The arousal threshold during NREM-1 is quite low, and therefore sleep can be easily terminated during this stage (e.g. by calling the sleeping person's name or touching the sleeping person softly) (Carskadon & Dement, 2005). The transition from wake to NREM-1 is typically characterised by slow rolling eye movements, slower theta waves on the EEG and slower breathing. NREM-2 lasts for approximately 10–25 minutes and is identified on the EEG by low amplitude wave forms known as sleep spindles, and high amplitude wave forms known as K-complexes (Rechtschaffen & Kales, 1968; Silber et al., 2007). As the sleep episode progresses from NREM-2 to SWS, slow wave activity (SWA) begins and slow rhythmic waves (delta waves) identify this stage of sleep. During SWS the muscles relax, respiration decreases and body temperature lowers slightly. In the first cycle of sleep, SWS lasts approximately 20–40 minutes; however, SWS decreases across the sleep episode (Carskadon & Dement, 2005; Rechtschaffen & Kales, 1968; Silber et al., 2007).

Following the first cycle of NREM sleep an individual will briefly ascend back through to NREM-2, subsequently the first cycle of REM sleep will begin. REM sleep is characterised most commonly by bursts of rapid eye movements. Muscle activity ceases during REM sleep, pulse and blood pressure rise and respiration becomes rapid and irregular (Carskadon & Dement, 2005). In contrast to NREM sleep, which is associated with limited mental activity, brain activity is apparent in REM sleep. The brain activity that occurs during REM sleep is quite similar to that seen in wake, and has been linked to dreaming (Dement & Kleitman, 1957). REM sleep is relatively short during the first sleep cycle (approximately one to five minutes); however, it becomes longer across the sleep episode. As a result SWS becomes shorter and may eventually disappear completely. The

stages of sleep continue to rotate throughout the sleep episode cyclically, with the first sleep cycle of REM and NREM sleep lasting approximately 70–100 minutes. Later cycles of NREM and REM are typically 90–120 minutes in duration (Carskadon & Dement, 2005).

1.3.2 *Sleep regulation*

Human sleep is regulated by an interaction of processes (described below) and factors, including age, ambient temperature, drugs and sleep disorders (Carskadon & Dement, 2005). One of the most widely accepted models of sleep regulation is the two-process model described by Borbèly (Borbèly, 1982). This model suggests that sleep is regulated by a sleep-dependent homeostatic process (Process S) and a circadian process (Process C), as illustrated in Figure 1.2, and outlined below.

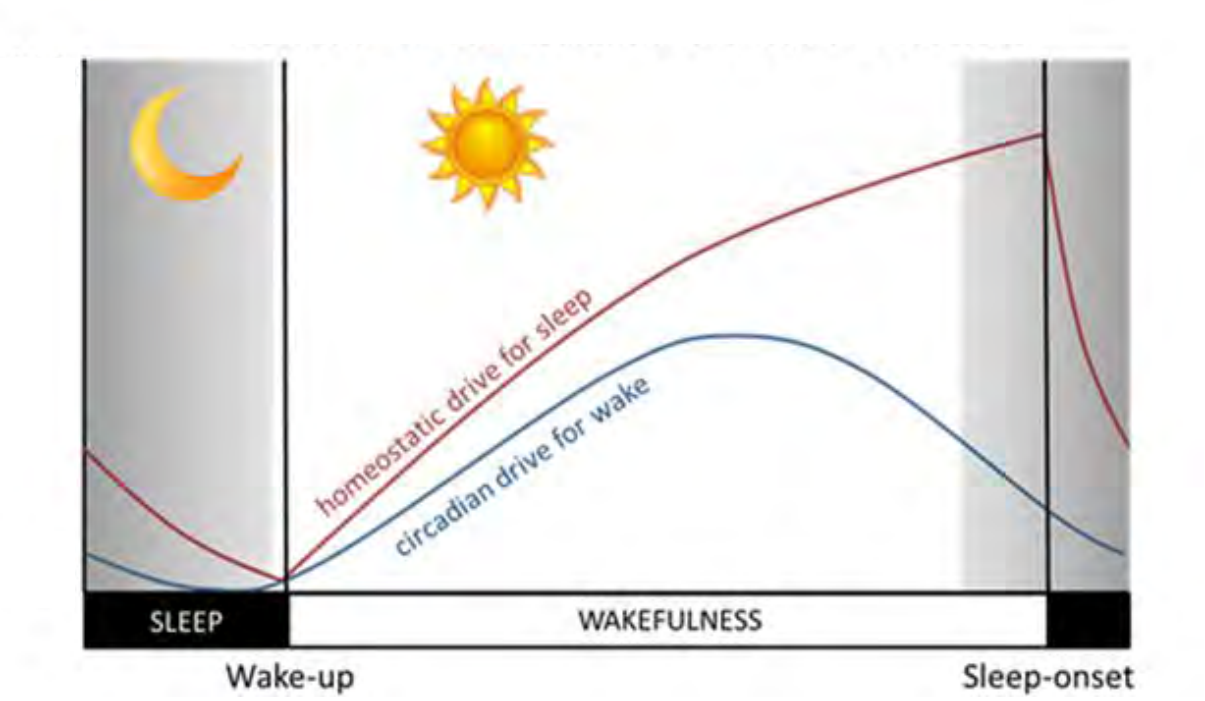


Figure 1.2 Interaction of homeostatic and circadian processes

Note: The homeostatic process is represented by the red line; sleep propensity increases with increasing duration of prior wake (indicated as the red line throughout wakefulness on the y-axis). Sleep propensity decreases during a sleep episode (indicated by the red line through the sleep period shown on the x-axis). The circadian drive for sleep and wakefulness is represented by the blue line demonstrating that sleep propensity varies depending on time of day. Sleep propensity is highest during the biological night (grey shading).

1.3.2.2 The circadian regulation of sleep (Process C)

This circadian system is an internal timing system in humans and animals that oscillates at a period slightly below or above 24h. Circadian rhythms have been observed in many physiological

bodily functions, such as core body temperature, blood pressure and hormonal secretions (Czeisler & Dijk, 2001; Moore-Ede, Sulzman, & Fuller, 1982; Wright, Hull & Czeisler, 2002). Physiological measures such as core body temperature are often used to determine the circadian phase of an individual. The maximum core body temperature (acrophase) occurs around 17:00. Following the acrophase, body temperature begins to decrease, which typically results in the onset of sleep (as demonstrated in Figure 1.2). Core body temperature reaches its minimum (nadir) around 05:00 which usually coincides with sleep. As demonstrated in Figure 1.2, wake tends to occur shortly after the circadian nadir. Melatonin, a hormone secreted by the pineal gland, is also a reliable marker of the circadian phase. In humans, melatonin is secreted at night (maximum ˜04:00) and signals the onset of sleep, whereas the minimum melatonin level occurs around 16:00 (Åkerstedt, 2003; Rajaratnam & Arendt, 2001).

The circadian system regulates the initiation, duration and ability to maintain sleep (Czeisler, Weitzman, Moore-Ede, Zimerman, & Knauer, 1980; Dijk & Cajochen, 1997; Dijk & Czeisler, 1995). For example, studies have demonstrated that the time it takes to fall asleep (sleep latency) shows a circadian rhythm, and appears to have a close relationship with other circadian markers such as body temperature and melatonin levels. Sleep latency is shorter around the early hours of the morning (around 06:00) in line with the circadian nadir when core body temperature and melatonin levels are higher (Czeisler et al., 1980; Dijk & Cajochen, 1997; Dijk, Duffy, & Czeisler, 1992; Paech, Ferguson, Sargent, Kennaway, & Roach, 2012; Sargent, Darwent, Ferguson, Kennaway, & Roach, 2012). Conversely, when sleep is attempted around the early hours of the evening (around 18:00–20:00h), close to the maximum of the temperature curve (circadian acrophase) and when melatonin levels are low, sleep is difficult to initiate (Dijk & Czeisler, 1994; Dijk, Duffy, Riel, Shanahan, & Czeisler, 1999; Wyatt, Ritz-De Cecco, Czeisler, & Dijk, 1999). The difficulties in the initiation of sleep around this time are evident even following long periods of wakefulness (Dijk & Cajochen, 1997). Indeed, this time of day is often referred to as the 'wake maintenance zone' (Cajochen, Knoblauch, Kräuchi, Renz, & Wirz-Justice, 2001) or 'forbidden zone for sleep' (Beersma, 1998). In some studies an increase in the ability to initiate sleep has also been observed around mid-afternoon (Lack & Lushington, 1996); however, the likelihood of falling asleep at this time of day is not as strong as it is around the circadian nadir (Dijk & Cajochen, 1997).

Studies have shown sleep duration is influenced by circadian processes. For example, a recent study showed that when the midpoint of the sleep occurred just before the circadian nadir

(˜01:00) sleep episodes were longer in duration. However when the midpoint of a sleep episode occurred around or the circadian acrophase (around 17:00), sleep episodes were shorter in duration (Sargent et al., 2012). The ability to maintain sleep (sleep consolidation) is most likely at or just after the circadian nadir. Following the circadian nadir, sleep consolidation will gradually decrease until the circadian acrophase. Subsequent to the acrophase, sleep consolidation will increase rapidly (Dijk & Czeisler, 1994).

A large body of research provides evidence to suggest that sleep composition is also influenced by circadian factors. The sleep state that appears to be most regulated by circadian factors is REM sleep. Similar to sleep initiation and duration, REM sleep demonstrates a close relationship with body temperature and shows a clear circadian rhythm. The maximum amount of REM sleep occurs around the circadian nadir whereas the minimum amount of REM sleep occurs around the acrophase (Dijk & Czeisler, 1995; Zulley, 1980).

1.3.2.3 The homeostatic regulation of sleep (Process S)

The homeostatic process (Process S) is often referred to as sleep pressure (Rajaratnam & Arendt, 2001; Rechtschaffen & Kales, 1968). Sleep pressure depends on prior sleep-wake history. As demonstrated in Figure 1.2, sleep propensity increases in line with the duration of time spent awake. In contrast, following a sleep episode sleep propensity decreases (Borbèly, 1982). Evidence for the homeostatic regulation of sleep has been provided by total sleep deprivation studies in which participants are deprived of sleep for a certain period of time (e.g. one to two nights) (Bonnet, 2005; Kales et al., 1970). Similar findings have been demonstrated when sleep is partially restricted (e.g. sleep is curtailed to as little as 2h per sleep episode) (Åkerstedt & Gillberg, 1986; Brunner, Dijk, & Borbély, 1993). Research has established that the time taken to fall asleep is shorter when homeostatic pressure for sleep is high (Brunner, Dijk, Tobler, & Borbély, 1990; Carskadon & Dement, 1981; Dinges et al., 1997). For example, time taken to fall asleep (sleep latency) can be as short as <5 minutes following a period of total sleep deprivation (Bonnet, 2005; Lamond et al., 2007). Similar findings of very short sleep latencies have been demonstrated when sleep is partially restricted (Lamond et al., 2007; Paech et al., 2012; Sargent et al., 2012).

In addition to the above, the duration of sleep has been found to be longer when sleep is totally deprived or partially restricted. For example, sleep episodes during a recovery sleep were significantly longer than a baseline sleep episode when sleep was restricted to 2h for one night. (Åkerstedt & Gillberg, 1986). This trend has been shown to increase over multiple nights. For instance, a total sleep deprivation study found that sleep was increased in length for up to two

nights following total sleep deprivation when compared to a baseline sleep episode (Kales et al., 1970). Sleep is also likely to be maintained for longer when sleep pressure is high. For example, young adults can maintain their sleep episode with a high level of sleep quality until around noon or sometimes later, even though the circadian drive for wakefulness is increasing when sleep pressure is high (Dijk & Duffy, 1999).

Similar to sleep latency and sleep duration, sleep composition is altered following total sleep deprivation or partial sleep restriction, suggesting the composition of sleep is a prominent predictor of homeostatic sleep pressure (Åkerstedt, Hume, Minors, & Waterhouse, 1998; Bonnet, 2005; Borbèly, 1982; Czeisler et al., 1980; Paech et al., 2012; Sargent et al., 2012). For example, a study investigating homeostatic influences on sleep found that SWS increased fivefold following one night of total sleep deprivation (Åkerstedt & Gillberg, 1986). Findings are comparable in partial sleep restriction studies over longer durations. For instance, a later study in which participants were given a restricted sleep opportunity of 4h for four nights, found that SWS increased up to 20% for three nights (Brunner, Dijk, & Borbély, 1993). Further evidence that sleep composition is influenced by homeostatic processes is provided by the finding that SWS decreases as sleep pressure lowers. Regardless of circadian phase, SWS declines during the course of a sleep episode (Daan, Beersma, & Borbély, 1984). Furthermore, a reduction is SWS is seen following a nap or an extended sleep episode (Feinberg, Fein, & Floyd, 1980). In contrast to SWS, REM sleep appears to be less affected by homeostatic influences. Even after 40h of total sleep deprivation, REM sleep was not affected in the following sleep episode (Nakazawa, Kotorii, Ohshima, Kotorii, & Hasuzawa, 1978). The decrease in SWS throughout the course of a sleep episode appears to be independent of circadian phase, as this decrease in SWS has been seen when sleep occurs at all circadian phases (Åkerstedt & Gillberg, 1981; Dijk & Czeisler, 1995; Gillberg & Åkerstedt, 1982).

In summary, human sleep is regulated by an interaction of circadian and homeostatic processes. The above section briefly overviewed the role of the homeostatic (Process S) and circadian system (Process C) on sleep. The circadian system controls many physiological functions and behaviours. The above section outlined how both processes influence factors related to sleep (e.g. sleep latency, sleep duration and sleep composition). There are various protocols used to assess the influence of circadian phase on sleep and other variables of interest. A brief overview of these protocols is outlined in the following section.

1.3.3 *Assessing the influence of the circadian phase*

Evidence for the circadian regulation of sleep was originally derived from protocols in which participants were given the opportunity to 'free-run' or self-select their own sleep-wake cycles in an environment free from external *zeitgebers* (German for 'time givers'). *Zeitgebers* synchronise the circadian system to the 24-day, this process is known as *entrainment* (Roenneberg, Daan, & Merrow, 2003; Roenneberg, Hut, Daan, & Merrow, 2010). There are various *zeitgebers,* such as exercise, ambient temperature and meals (Wright & Czeisler, 2002), however, the light-dark cycle is considered to be the most important (Duffy & Wright, 2005). Protocols assessing circadian phase hold exogenous *zeitgebers,* such as lighting and ambient temperature, at a constant level so that the endogenous component of the circadian rhythm is exposed (Duffy & Wright, 2005; Monk et al., 1997; Murray, Allen, & Trinder, 2002; Rajaratnam & Arendt, 2001). Currently, various methods are employed to assess the influence of the circadian phase on variables of interest; these methods are described below.

1.3.3.1 Constant routine protocols

A constant routine protocol attempts to keep the environment constant by reducing or removing changes in behaviour (Duffy & Wright, 2005). Constant routine protocols remove exogenous factors (e.g. sleep-wake cycle and activity) allowing the endogenous circadian rhythm to be assessed. Participants are required to remain in a semi-reclined position to avoid changes in core body temperature due to variation in posture for periods of between 24 and 40 hours (Blatter & Cajochen, 2007; Czeisler et al., 1985; Mills, Minors, & Waterhouse, 1978). However, a major limitation of this protocol is that the sleep-wake cycle and the circadian system are oscillating in synchrony. Therefore, this protocol does not allow for an unconfounded separation of the effects of these two processes on the variable of interest (Blatter & Cajochen, 2007; Brown, Choe, Luithardt, & Czeisler, 2000).

1.3.3.2 Ultra-short sleep-wake cycle protocols

In addition to constant routine protocols, the influence of circadian phase on variables can be measured by implementing an ultra-short sleep-wake cycle. In these protocols the participant is provided with a sleep opportunity for one-third of a sleep-wake cycle which may last for 20, 90, 180 or 240 minutes for 1–10 days. For example, participants may be provided with seven minute sleep opportunities and 13 minute wake periods over a 24-h day (Carskadon & Dement, 1975; Lavie, 1986; Webb & Agnew, 1971; Weitzman et al., 1974). As the range of the circadian pacemaker is between ˜23.5 and˜25.5h (Czeisler, Allan, & Kronauer, 1990), these sleep-wake

cycles fall outside of this range, allowing the circadian pacemaker to run at its intrinsic period. In contrast to constant routine protocols, ultra-short sleep-wake protocols allow for the assessment of circadian phase on variables without the influence of prior wake, as the effect of sleep deprivation is removed. However, due to the short sleep opportunities of the ultra-short sleep-wake cycle protocol, sleep pressure is low and therefore the impact of prior wake cannot be assessed. In order to overcome the limitations of constant routine and ultra-short sleep-wake cycle protocols a forced desynchrony (FD) protocol is used to study the influence of circadian phase on variables.

1.3.3.3 Forced desynchrony protocols

FD studies were developed by Kleitman (1939). Kleitman observed that the endogenous circadian temperature rhythm continued oscillate at around 24h when he imposed a sleep-wake cycle of 28h (9-h sleep opportunity, 19-h wake period). Similarly, Wever (1979) found that in addition to lengthening the sleep-wake cycle, the endogenous circadian temperature rhythm does not become entrained to a sleep-wake cycle of 20h. Therefore, FD studies either reduce the sleep-wake cycle (e.g. 20h) or lengthen the sleep-wake cycle (e.g. 28h) to avoid entrainment of the endogenous circadian temperature rhythm (Dijk & Czeisler, 1994, 1995). Figure 1.3 represents an FD schedule of 28h. Sleep episodes are scheduled to occur 4h later each experimental day. The sleep episodes (black bars) occur at varying phases of the circadian rhythm; however, the duration of prior wake between each sleep episode remains constant. This allows for the separate examination of circadian and homeostatic processes on variables and their interaction.

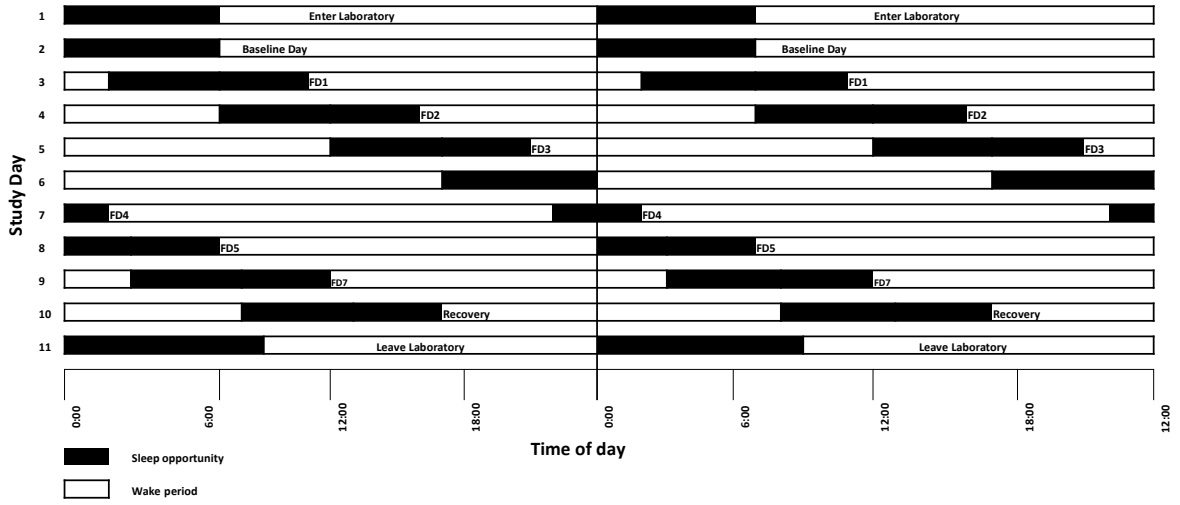


Figure 1.3 Forced desynchrony protocol with 28h sleep-wake schedule (double plotted)

As demonstrated in Figure 1.3, typically sleep episodes in FD studies are scheduled to be one third of the total day length in duration (i.e. the equivalent of approximately 8h sleep per 24h). As mentioned previously, *zeitgebers* can reset circadian rhythm; therefore these are controlled for in FD studies. For example, participants are typically exposed to only dim lighting during wake periods (Boivin, Duffy, Kronauer, & Czeisler, 1996; Czeisler et al., 1999; Dijk & Duffy, 1999; Klerman, Dijk, Kronauer, & Czeisler, 1996). Whilst FD studies have many advantages they can be time consuming as they may require participants to live in a laboratory for up to one month to allow for several repeats of the circadian cycle (Dijk & Czeisler, 1994). This places considerable burden on both research staff and participants. In addition, if the protocol includes sleep restriction participants may accumulate a sleep debt which may influence findings.

In summary, constant routine protocols and protocols that implement ultra-short sleep-wake cycles can be used to measure the effect of circadian phase on variables of interest. However, FD protocols are often used to examine the effect of circadian phase on variables as they allow researchers to separate homeostatic and circadian influences and examine any interaction effects. The following section overviews shiftwork, which is the final predictor of eating behaviour examined in this thesis.

1.4 Shiftwork

Shiftwork refers to work with hours arranged so that individuals or teams of employees can cover more time at work than the typical 8h working day (Costa, 2003). Shiftwork is becoming increasingly prevalent worldwide. It is estimated that one third of employees in industrialised countries are involved in shiftwork (Åkerstedt, 2003). In America around 15% of the workforce is employed in shiftwork (United States Department of Labor, 2005). Similarly, The Fifth European Working Conditions Survey states that 17% of EU employees work shiftwork (Eurofound, 2012). In Japan, 51.2% of companies with over 1,000 employees report utilising shiftwork schedules (Ministry of Health, Labour and Welfare, 2005). Australia also follows the worldwide trend, with the Australian Bureau of Statistics (ABS) reporting approximately 1.4 million Australians (around 16% of the working population) are employed as shiftworkers. (Australian Bureau of Statistics, 2010).

Shiftwork can be advantageous for organisations as the schedules allow for increased production and flexibility (Costa, 2003). Additionally individuals may benefit, as some shift schedules may involve higher rates of pay or hours of work may be more suited to domestic responsibilities

(Barton, 1994). Conversely, shiftwork has been associated with adverse effects, such as sleep restriction and circadian disruption (Åkerstedt, 2003; Knauth et al., 1980; Rajaratnam, Howard & Grunstein, 2003). Numerous studies have examined the effect of these factors on the safety and performance of shiftworkers (Baulk, Fletcher, Kandelaars, Dawson, & Roach, 2009; Dorrian et al., 2008; Folkard & Tucker, 2003; Ftouni et al., 2003; Rajaratnam, Howard & Grunstein, 2003). Additionally, an increasing number of studies link shiftwork to health issues such as gastrointestinal disorders (Knutsson & Bøggild, 2010; Nojkov, Rubenstein, Chey, & Hoogerwerf, 2010), cardiovascular disorders (Åkerstedt, Knutsson, Alfredsson, & Theorell, 1984; Bøggild & Knutsson, 1999), metabolic syndrome (Esquirol et al., 2009; Karlsson, Knutsson, & Lindahl, 2001), and type 2 diabetes (Kawakami, Araki, Takatsuka, Shimizu, & Ishibashi, 1999). Many of these health disorders can develop as a result of changes in eating behaviour (although pathways and mechanisms are complicated), therefore Section 1.4.2 discusses them and their link with shiftwork.

1.4.1 *Shift schedules and shift type*

Shiftworkers may be employed to work on one of many shift schedules, making it difficult to compare shiftwork populations. Shiftwork may include permanent schedules, such as morning shift (e.g. 06:00–14:00), afternoon shift (e.g. 14:00–20:00) or night shift (20:00–06:00). Alternatively, some shiftworkers rotate between two or three of these shifts (Åkerstedt, 2003). Rotating rosters are typically continuous, semi-continuous, or discontinuous. Continuous rosters involve multiple teams of workers and are run over a 24h period, seven days per week. Semi-continuous rosters do not operate over the weekend; however, they run 24h per day over a five-day working week. Rotating discontinuous shift schedules typically consist of two teams of workers who are employed to work into the evening but not over the night period or weekend (Thierry & Meijman, 1994). Additionally, shifts can vary in rotation speed. Fast shift schedules result in shift changes every one to two days. Slow shift schedules involve individuals or teams remaining on the same shift for five or more days before changing to another shift type. Furthermore, shift schedules can change by direction of rotation—forward rotation: night, evening, morning, or backward rotation: morning, evening, night (Rajaratnam & Arendt, 2001; Thierry & Meijman, 1994). Shift schedules can be regular or irregular, and start and finish times may vary depending on the industry or organisation (Costa, 2003). The various shift schedules have a diverse impact on physiological and psychological factors such as sleep and mood, and these are discussed in later sections of this chapter.

1.4.2 *Heath disorders and shiftwork*

As mentioned above, shiftwork is associated with numerous health disorders. The mechanisms leading to the development of these health disorders in shiftworkers are complicated and still under investigation. These potentially life-threatening health disorders are not only concerning for the individual, but come with high economic and social costs that extend the burden to organisations and society. A brief summary of health disorders and their link to shiftwork is provided below.

1.4.2.1 Shiftwork and gastrointestinal disorders

Due to changes in the timing and frequency of meals and snacks (Waterhouse et al., 2003), it is not surprising that shiftwork has been linked to the development of gastrointestinal disorders. Studies have found gastrointestinal disorders ranging from mild disturbances, such as constipation and flatulence, to more serious conditions, such as gastroduodentitis and peptic ulcer, are more common in shiftworkers compared to day workers (Caruso, Lusk, & Gillespie, 2004; Koh, Kim, Da Yeon Oh, Lee, & Kim, 2014; Segawa et al., 1987). Indeed approximately 20–75% of shiftworkers report digestive troubles compared to only 10–25% of day workers (Costa, 2010). A review of gastrointestinal disorders among shiftworkers found that many of the studies included demonstrated an association between shiftwork and gastrointestinal diseases (Knutsson & Bøggild, 2010). Symptoms are thought to result from meals being consumed at sub-optimal circadian phases and disruption to the normal circadian rhythms in gastrointestinal functions (e.g. absorption of nutrients) (Costa, 2010; Knutsson & Bøggild, 2010). Shiftworkers also report consuming food of poorer quality (e.g. increased consumption of pre-packaged snacks and soft drinks (Lennernäs, Hambraeus, & Åkerstedt, 1995) which can lead to not only gastrointestinal complaints, but other health disorders (see Section 1.5.4 for a more detailed discussion of eating behaviour in shiftwork populations).

1.4.2.2 Shiftwork and cardio-metabolic disorders

Metabolic conditions include a number of health disorders that involve metabolic abnormalities, such as obesity, high blood pressure, glucose intolerance, increased triglycerides and elevated fasting glucose (Esquirol et al., 2009). There is a wide body of research associating these disorders with shiftwork (Esquirol et al., 2009; Karlsson et al., 2001; Lin, Hsiao, & Chen, 2009; Pietroiusti et al., 2010; Sookoian et al., 2007). The high incidence of metabolic disorders in shiftwork populations is concerning as they can lead to more serious health conditions, such as cardiovascular disease and type 2 diabetes (Eckel, Grundy, & Zimmet, 2005). The likelihood of

developing metabolic disorders may vary depending on the shift schedule. For example, forward rotating shift schedules have been linked to increased triglycerides and increased fasting glucose when compared to counter clockwise shift schedules (Costa, 2010). Additionally, high blood pressure was more frequently observed in rotating shiftworkers; however, the risk of hypertriglyceridaemia was associated with working permanent night shifts (Ruidavets, Cambou, Esquirol, Soulat, & Ferrieres, 1998). Some studies have suggested that most at risk of developing these disorders are night shiftworkers and rotating shiftworkers (Karlsson et al., 2001; Lin et al., 2009; Pietroiusti et al., 2010). For example, it has been postulated that the circadian disruption and sleep restriction associated with shiftwork is linked to increased likelihood of developing metabolic disorders (Hampton et al., 1996; Spiegel, Leproult, & Van Cauter, 1999). Sleep restriction and circadian disruption may vary depending on shift schedule and shift type. Therefore factors relating to each shift schedule need to be examined carefully in order to determine causal pathways in the development of each metabolic disorder.

In addition to the above evidence, epidemiological and laboratory studies have indicated that sleep restriction may be a factor in the development of obesity (Cappuccio et al., 2008; Dinges & Chugh, 1997; Patel & Hu, 2008; Schmid, Hallschmid, Jauch-Chara, Born, & Schultes, 2008; Spiegel, Leproult et al., 2004). Whilst there are various reasons why individuals may develop obesity as a result of sleep restriction, some research has indicated that one pathway may result from alterations in appetite hormones. Ghrelin has been found to increase, while leptin has been found to decrease, when individuals are sleep restricted (Knutson, Spiegel, Penev, & Van Cauter, 2007; Spiegel, Knutson, Leproult, Tasali, & Van Cauter, 2005). An alteration in these hormones may lead to increased hunger. Increased hunger has been demonstrated in healthy young males who have taken part in laboratory studies. Participants in these studies reported feeling hungrier following sleep restriction (Schmid et al., 2008; Spiegel, Tasali et al., 2004).

There is strong evidence to suggest that shiftwork can lead to the development of cardiovascular disorders. A review of 17 studies (Bøggild & Knutsson, 1999) concluded that there is a positive association between shiftwork and cardiovascular disease. For instance, shiftworkers have been found to have a 40% increased risk of developing ischemic heart disease when compared to day workers. Similar to other health conditions, shiftwork is thought to increase the risk of cardiovascular disease as a result of various factors. Circadian disruption, sleep restriction, the diet of shiftworkers and the stress associated with disruption to work and family life, are all

thought to play a role (Costa, 2010; Frost, Kolstad, & Bonde, 2009; Wang, Armstrong, Cairns, Key, & Travis, 2011).

A poor diet and one containing more saturated fats, as seen in some shiftwork populations (Esquirol et al., 2009), may result in increased risk of cardiovascular disease. For example, increased triglyceride (the major component of fat) may cause a build-up of fatty deposit in blood vessel walls and result in atherosclerosis, increasing the risk of cardiovascular disease (Malloy & Kane, 2000). Indeed, results from the Nurses' Health Study, which included over 80,000 women, showed a 17% increased risk of coronary artery disease with every 5% increase in energy intake from saturated fats (Hu et al., 1997). Additionally, shiftwork is associated with other risk factors for cardiovascular disease, such as smoking (Zhao & Turner, 2008) and a reduction in physical activity (Geliebter et al., 2000). Whilst pathways are complicated, it appears that alterations in eating behaviour could be one of various mechanisms in the development of cardio-metabolic diseases.

1.4.2.3 Shiftwork and cancer

Shiftwork may also lead to the development of some forms of cancer (Wang et al., 2015; Yong et al., 2014). In particular, the development of breast cancer has been linked to shiftwork (Wang et al., 2011); however, research is growing to suggest shiftwork may also be linked to other cancers, such as colon-rectal cancer and prostate cancer (Conlon, Lightfoot, & Kreiger, 2007; Kubo et al., 2006; Schwartzbaum, Ahlbom, & Feychting, 2007). The development of these cancers may develop as a result of eating behaviour. For example, colon cancer has been associated with a diet high in fat and low in fibre (Willett, 1989). Diet is also thought to play a role in the development of breast cancer (Willett, 1989); however, alterations and melatonin suppression due to light exposure at night is also linked to breast cancer in shiftworkers (Stevens, Davis, Thomas, Anderson, & Wilson, 1992; Stevens & Rea, 2001; Wang et al., 2015). Additionally, it has been postulated that light exposure may alter endogenous sex hormone concentrations, and in turn lead to the development of cancer (Key, Appleby, Barnes, & Reeves, 2002). Shiftwork has also been associated with various other risks of cancer, such as smoking and increased BMI (Schernhammer et al., 2001; Zhao & Turner, 2008).

It is important to note that research investigating mechanisms involved in the development of cancer are still currently being investigated. As mentioned above, pathways between shiftwork and health disorders are complicated. Various factors are likely to influence each other. Conclusions made in a review indicated that research investigating shiftwork and cancer in

particular should consider the many confounding factors that may also be important (Kolstad, 2008). More recent research has begun to investigate the role of factors associated with shiftwork, finding that sleep restriction increases the odds of developing breast cancer; however, daytime napping is associated with reduced risk (Wang et al., 2015). Furthermore, recent research also showed that when factors such as cumulative years of shiftwork and number of nights working rotating night shifts were controlled for, there was no association with rotating shiftwork and lung cancer (Kwon et al., 2015). These studies highlight the need for future research to examine and understand all confounding factors and variables involved in the development of health conditions.

In summary, shiftwork is becoming increasingly prevalent due to the 24h society. Shiftwork is hard to define due to the varying shift types and schedules shiftworkers may be employed to work. Therefore it is difficult to compare studies investigating shiftworkers. Nevertheless, a large body of research has been conducted that suggests shiftworkers are at increased risk of developing a variety of health disorders. Pathways are complicated and various factors are likely to play a role. It is important to investigate all possible mechanisms that may contribute to the development of serious health conditions. Of relevance to the current thesis, The World Health Organisation (WHO) (World Health Organisation, 2009) suggests that many of these health disorders occur as a result of lifestyle conditions such as obesity. Individuals are likely to develop obesity when they make alterations in their eating behaviour that result in a poor diet (Hill & Peters, 1998). Therefore, alterations in eating behaviour and factors related to shiftwork that influence eating behaviour should be examined as a possible pathway from shiftwork to the development of the health conditions as discussed. This investigation will help to understand one of many pathways leading to the development of obesity and other health conditions associated with alterations in eating behaviour.

The above section finalises the overviews of the major outcome variable (eating behaviour) and the predictor variables examined within this thesis (mood, sleep and shift-related factors). This chapter will now proceed with examination of the literature that provides evidence for these predictor variables.

1.5 Predictors of eating behaviour in shiftworkers

This section reviews the relevant literature to provide evidence of the proposed predictors of eating behaviour in shiftworkers examined within this thesis. The sub-sections are ordered to

work back through the predictor variables and investigate each predictor's influence on eating behaviour (as demonstrated in Figure 1.4). The ensuing sub-sections examine the effect of the variables on each other, again working backwards through the pathway demonstrated in Figure 1.4.

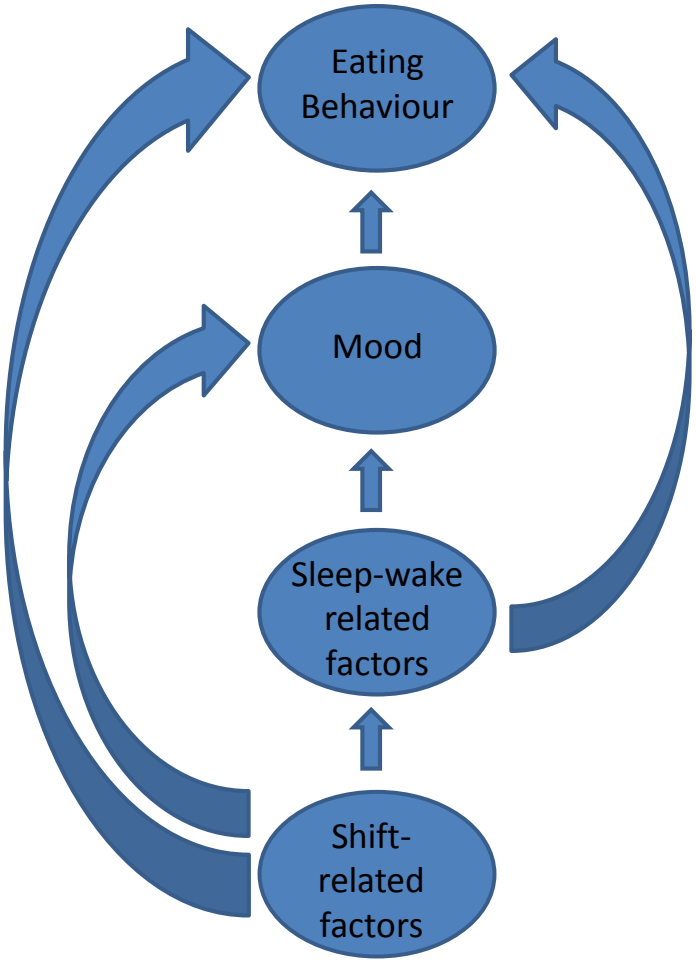


Figure 1.4 Proposed pathway leading to altered eating behaviour in shiftworkers

1.5.1 *Mood as a predictor of eating behaviour*

Research suggests mood influences eating behaviour in various ways, such as motivation to eat (Macht & Simons, 2000), food cravings (Willner et al., 1998), eating speed (Krebs, Macht, Weyers, Weijers, & Janke, 1996) and food intake (Greeno & Wing, 1994). Various mood domains (as discussed below) have different effects on eating behaviour. The following sections discuss research investigating the impact of mood on eating behaviour. Figure 1.5 highlights the factors in the pathway that are discussed in this section.

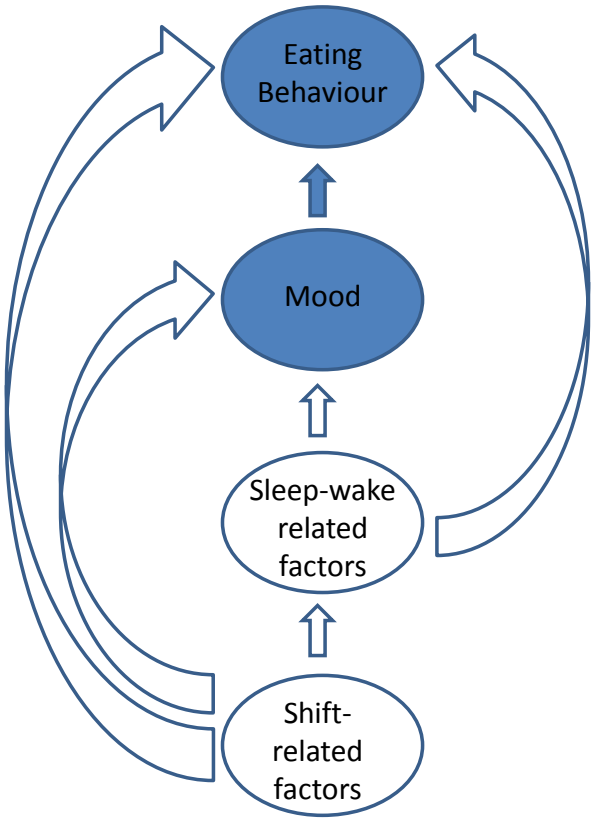


Figure 1.5 Mood as a predictor of eating behaviour

Note: Shaded areas represent the portion of the pathway discussed in this section

1.5.1.2 Depressive mood and eating behaviour

Whilst major depression may result in either an increased or decreased appetite, less severe depressive moods have been linked to poor diet. For example, individuals with depressive symptoms were found to be less likely to follow dietary recommendations in a community survey study (Sarlio-Lähteenkorva, Lahelma, & Roos, 2004). Additionally, lower consumption of fruit, vegetables and fish has been reported in individuals with depressive symptoms (Cohen, Kristal, Neumark-Sztainaer, Rock, & Neuhouser, 2002; Tanskanen et al., 2001). Depressive moods have also been linked to increased cravings and consumption of energy-dense sweet foods (Jeffery et al., 2009; Willner et al., 1998) and attentional bias to food cues (Hepworth, Mogg, Brignell, & Bradley, 2010). It has been hypothesised that individuals with depressive symptoms tend to consume carbohydrates to attain immediate relief from symptoms of depression (Christensen, 1997). In particular, a preference for sweet simple carbohydrates is often seen.

There are various theories relating to how carbohydrates may relieve individuals from depression, such as an increase in brain serotonin levels (Wurtman et al., 1981) and endogenous opiates

(Benton & Donohoe, 1999). Therefore it is thought that individuals with depressive symptoms 'self-medicate' with carbohydrates (Christensen, 1997). Taken together, this research suggests depressive mood may have a detrimental influence on eating behaviour and health.

Emotional eaters consume food in response to emotional states. One identified emotional eating style is restrained eating. Restrained eaters restrict their food intake to control their body weight, but moods such as depression and anxiety have been found to disinhibit self-control in restrained eaters (Polivy & Herman, 1976; Stunkard & Messick, 1985; Weissenburger, Rush, Giles, & Stunkard, 1986). It has been proposed that emotional eating styles such as restrained eating may be a mediator between depressive moods and eating behaviour (Macht, 2008). In some instances, however, eating behaviour has been found to alter due to mood regardless of eating style. A recent study found emotional eating style did not appear to play a role in increased consumption of energy-dense non-sweet foods when individuals were experiencing depressive symptoms (Konttinen, Männistö, Sarlio-Lähteenkorva, Silventoinen, & Haukkala, 2010). As the type of non-sweet energy dense foods chosen in this study were predominately fast foods, such as hamburgers and pizza, the authors suggest that convenience may have contributed to these food choices. Individuals may be less motivated when suffering from depressive symptoms (Konttinen et al., 2010) and therefore may be more likely to choose foods requiring little preparation. In summary, not only does depressive mood result in poorer food choices, such as simple carbohydrates, it may also result in higher consumption of convenience foods due to lack of motivation.

1.5.1.3 Stress/anxiety and eating behaviour

Not only is stress deleterious to mental and physical health due to automatic and endocrine responses, it is often associated with detrimental changes in health behaviours such as eating (Jones, 2003; O'Connor, O'Connor, White, & Bundred, 2000). Anxiety is related to stress and described as a psychological response of stress. In addition, it is often used as a measure in studies related to stress (Nishitani, Sakakibara, & Akiyama, 2009), therefore anxiety in this thesis, is discussed in conjunction with stress.

There is some evidence from animal studies that stress can lead to a decrease in food consumption (Levine & Morley, 1981). However, findings from both human and animal studies demonstrate that stress can contribute to overeating in some instances. In particular, stress can result in increased snack consumption with a particular preference for high-fat sweet foods (Conner, 1999; Greeno & Wing, 1994; Mikolajczyk, El Ansari, & Maxwell, 2009; Oliver, Wardle, &

Gibson, 2000; Wardle, Steptoe, Oliver, & Lipsey, 2000; Zellner et al., 2006). Furthermore, anxiety has been associated with eating behaviours related to obesity (Nishitani et al., 2009).

Although there are numerous studies suggesting that stress negatively influences eating behaviour, there is also evidence indicating that different types of stress may result in distinctive outcomes in eating behaviour. Ego-threatening stress involving potential negative evaluations, such as job interviews, have been linked to overeating (Heatherton, Herman, & Polivy, 1991; Oliver, Huon, Zadro, & Williams, 2001; Tanofsky-Kraff, Wilfley, & Spurrell, 2000). Similarly, work-related stress, such as deadlines, has been associated with increased energy intake from foods high in fat and sugar and an increase in snacking behaviour (O'Connor, Jones, Conner, McMillan, & Ferguson, 2008; Wardle et al., 2000). In contrast, physically stressful situations appear to result in decreased consumption of food (Heatherton et al., 1991; O'Connor et al., 2008).

In addition to the type of stress experienced, the severity of stress may also play a role in the relationship between stress and eating behaviour. In situations where an individual is experiencing particularly high levels of stress, food consumption may decrease (Stone & Brownell, 1994). However, if stress is prolonged, food consumption may increase. For example, when rats were subjected to prolonged stress (tail pinching) and exposed to kcal-dense foods they increased their food consumption. Unlike a previous experiment where rats decreased their food consumption when tail pinching ceased (Levine & Morley, 1981), the rats exposed to prolonged stress did not compensate by decreasing food consumption during the study (Rowland & Antelman, 1976). Similar findings have been demonstrated in humans. For example, women experiencing chronic stress were more likely to demonstrate emotional eating than women experiencing low levels of stress (Tomiyama, Dallman, & Epel, 2011).

1.5.1.4 Fatigue/tiredness and eating behaviour

Fatigue is a complex phenomenon and is therefore difficult to define. Fatigue involves both psychosocial and behavioural processes (Shen, Barbera, & Shapiro, 2006). Shen et al. (2006, p. 70) define fatigue as 'an overwhelming sense of tiredness, lack of energy and a feeling of exhaustion, associated with impaired physical and/or cognitive functioning'. Fatigue is commonly reported in shiftwork populations (Åkerstedt & Wright, 2009). This is concerning for the health of shiftworkers as certain types of fatigue, such as work fatigue, have been shown to be risk factors for weight gain (Lallukka, Laaksonen, Martikainen, Sarlio-Lähteenkorva, & Lahelma, 2005). In addition, fatigue has been related to eating rhythm abnormalities, and substitute eating and drinking (e.g. eating with the purpose of avoiding irritability) (Nishitani et al., 2009). Several

studies have suggested that carbohydrates may be chosen by certain individuals as they have been found to enhance feelings of vigour and alertness (de Castro, 1987; Wurtman & Wurtman, 1989). In particular, obese individuals and women with premenstrual syndrome have reported feelings of vigour following the consumption of carbohydrates (Lieberman, Wurtman, & Chew, 1986). Although carbohydrates can provide immediate relief from fatigue in some instances, this feeling is typically followed by a decline in energy over the long term (Thayer, 1987). Furthermore, Lieberman et al. (1986) suggests it may only be obese individuals who benefit from the increase in vigour as non-obese individuals generally report feelings of fatigue and sleepiness directly following a carbohydrate-rich lunch.

An important motivator for choosing simple carbohydrates when low in energy is the belief that it will raise energy levels. This expectation may arise from awareness that ingestion of simple carbohydrates with a high GI (such as lollies and soft drink) raises blood glucose, and in turn provides short-term energy (Thayer, 1987). A study investigating self-reported energy levels following a sweet snack found that participants reported subjective energy levels to be higher for approximately 20 minutes following the snack (Thayer, 1987). However, 1–2h following the sugary snack participants reported a drop in energy levels and felt tense. Individuals may experience a perception of feeling better in the short term as a result of the consumption of simple carbohydrates. Although blood glucose levels may rise quickly (sugar-high) when simple carbohydrates are consumed this is followed by rapid reduction in blood glucose level (sugar-crash) (Jenkins et al., 1982).

In summary, there is evidence that experiencing moods such as depression, stress, anxiety and fatigue may alter eating behaviour. Whilst the mood of shiftworkers has been investigated (see Section 1.6.3) there has been no research thus far to determine if mood is a predictor of eating behaviour in shiftworkers. Given the evidence that mood predicts food intake in many situations, this is a factor that requires investigation in shiftwork populations. In addition to mood, sleep is another factor influenced by shiftwork. There is evidence to suggest that sleep predicts eating behaviour. The literature examining sleep as a predictor of eating behaviour is reviewed in the following section.

1.5.2 *Sleep as a predictor of eating behaviour*

Sleep-related factors, such as duration, quality and efficiency, affect many physiological and psychological aspects. In particular, there have been a number of studies investigating the impact

of sleep restriction or total sleep deprivation on eating behaviour (see Table 1.1). This section discusses the impact of sleep restriction and total sleep deprivation on eating behaviour. Figure 1.6 illustrates the portion of the pathway examined within this section.

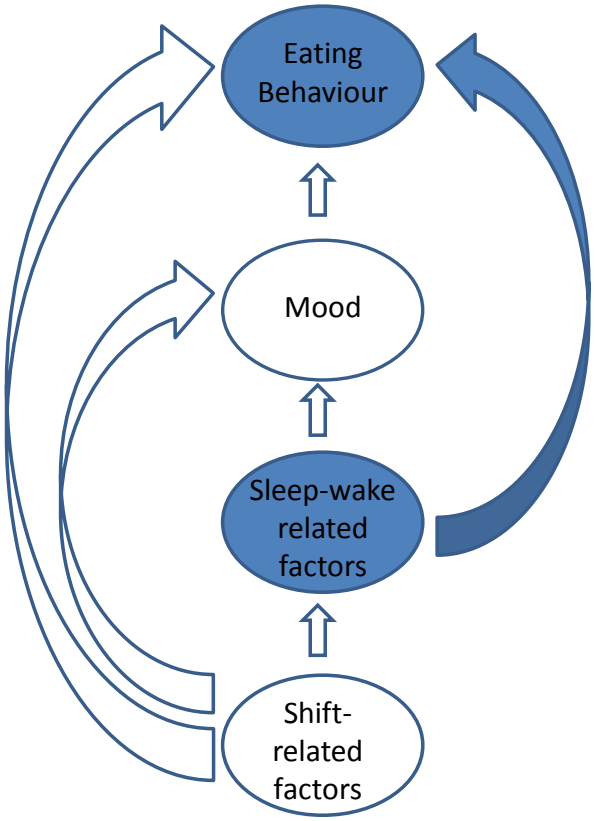


Figure 1.6 Sleep-wake related factors as a predictor of eating behaviour

Note: Shaded areas indicate the portion of the pathway discussed in this section

One of the possible mechanisms postulated for an increase in appetite and food consumption following sleep restriction is disruption to appetite hormones. Studies have demonstrated an increase in ghrelin and decrease in leptin (Schmid et al., 2008; Spiegel, Tasali et al., 2004) when sleep is restricted. Therefore, sleep-restricted individuals may experience elevated hunger levels resulting in increased food intake. Additionally, more recent studies have demonstrated increased activation in areas of the brain associated with reward in response to food images when sleep is restricted (Benedict et al., 2012). These findings may also be linked to alterations in appetite hormones. For example, intravenous infusions of ghrelin have been found to increase neural activation in areas of the brain involved in hedonic appetitive control in response to food (Malik,

McGlone, Bedrossian, & Dagher, 2008). Therefore, an increase in ghrelin when sleep is restricted could promote an increase in brain reward response to food resulting in increased food consumption, particularly a susceptibility towards kcal-dense foods (Hogenkamp et al., 2013).

Table 1.1 lists studies that have investigated eating behaviour (appetite, energy and macronutrient intake) in a laboratory setting. These studies will be reviewed in the following section.

Table 1.1 Summary of studies examining sleep deprivation or restriction and eating behaviour

First author, date	Sleep measure	Eating behaviour measurement	Participants	Findings
Spaeth, 2014	4h (5 nights) Control = 10 or 12h	- Energy intake - Macronutrients	*n* = 44 (52% males); m = 32.7y; BMI = 25.0 kg/m^2 (males), 24.6 kg/m^2 (females)	↑Men greater energy intake compared to women during sleep restriction =No race differences in energy intake during sleep restriction Race differences found in macronutrient intake
Hogenkamp, 2013	TSD (one night); Control = 8h	- Hunger (VA S) - Portion size (food images on a computer-based task)	*n* = 16 (males); m= 23y; BMI=23.6 kg/m^2	↑Hunger following TSD ↑Larger portion sizes were chosen following TSD
Markwald, 2013.	5h (5 nights); Control = 9h	- Energy intake - Macronutrients	*n* = 16 (8 males); m = 22.4y; BMI = 22.9 kg/m^2	↑Energy intake ↑Carbohydrate intake
Spaeth, 2013	4h (5 nights); Control = 10 or 12h	- Energy intake - Macronutrients	*n* = 31 sleep-restricted participants (48% male); m = 34y; BMI = 25.2 kg/m^2; 6 control participants (67% male); m = 34.0; BMI = 25.7 kg/m^2	↑Energy intake during sleep restriction ↑All macronutrients during sleep restriction
Benedict, 2012.	TSD (one night)	- Hunger (VAS) - Neural activation in response to food images	*n* = 12 (males); m = 23.3y; BMI= 22.5 kg/m^2	↑Hunger following TSD TSD associated with increased activation in right anterior cingulate cortex in response to food images
Reynolds, 2012	4h (5 nights); Control = 10h	-Hunger (VAS)	*n* = 14 (males); m = 27.4y, BMI = 23.5 kg/m^2	= Hunger
Benedict, 2011	TSD (one night)	- Hunger (VAS) - Energy intake - Macronutrients (buffet meal)	*n* = 14 males; m = 22.6y; BMI = 23.9 kg/m^2	↑Hunger following TSD =Energy intake =Macronutrient intake
St Onge, 2011	4h (4 nights); Control = 9h	- Energy intake - Macronutrients	*n* = 30 (15 males), m = 36.6y (males), 33.9y (females); BMI = 24.1 kg/m^2 (males), 23.0 (women) kg/m^2	=Hunger ↑Energy intake following sleep restriction ↑Fat and protein following sleep restriction

First author, date	Sleep measure	Eating behaviour measurement	Participants	Findings
Brondel, 2010	4h (one night)	- Hunger (VAS) - Energy intake (standard breakfast, buffet lunch and free-living conditions for dinner)	*n* = 12 males; m = 22y; BMI = 22.3 kg/m^2	=Hunger ↑Energy intake on day following sleep restriction ↑Fat in afternoon and night
Nedelcheva, 2009	5.5h (14 days); Control = 8.5h	- Energy intake - Macronutrients (Ad libitum access to palatable food)	*n* = 11 (6 males); m = 39y; BMI = 26.5 kg/m^2	=Energy intake from meals ↑ Energy from snacks =Macronutrients from meals ↑Carbohydrate from snacks
Schmid, 2009	4h (two nights)	- Energy intake - Macronutrients (Buffet breakfast, snack buffet and choice of main meals throughout the day after 11:00).	*n* = 15 (males); m = 27y; BMI = 22.9 kg/m^2	=Energy intake ↑Fat consumption following sleep restriction
Schmid, 2008	4.5h (one night), TSD (one night); Control = 7h	- Hunger (VAS)	*n* = 9 (males), m = 24.2y, BMI = 23.8 kg/m^2	↑Hunger following TSD
Spiegel, 2004	4h (2 nights); Control = 10h	- Hunger (VAS)	*n* = 12 (males), m = 22y; BMI = 23.6 kg/m^2	↑Hunger following sleep restriction

Notes: *TSD = total sleep deprivation; m = mean; BMI = body mass index; y = years; h = hours; VAS = visual analogue scale*
↑ an increase in the variable
=no change in the variable

1.5.2.2 Sleep restriction and hunger: Self-report measurement

To understand if appetite is increased when individuals have restricted sleep opportunities, studies have measured self-reported hunger levels during or following a period of sleep restriction or total sleep deprivation. Table 1.1 summarises studies that have investigated sleep restriction and eating behaviour. Seven of the studies investigated sleep restriction and hunger (Benedict et al., 2012; Benedict et al., 2011; Hogenkamp et al., 2013; Reynolds et al., 2012; Schmid et al., 2008; Spiegel, Leproult et al., 2004). Self-reported hunger has been widely measured by the use of visual analogue scales (VAS). These scales are described in more detail in Chapter 2 (Section 2.7.1). Of the seven studies examined in Table 1.1, five found an increase in hunger following total sleep deprivation or sleep restriction, while three found no differences in hunger. An increase in hunger is represented in Table 1.1 by an upwards arrow in the findings column (↑), whereas studies that found no differences in hunger is represented by an equal sign (=) in the findings column.

One of the pivotal studies investigating appetite following sleep restriction asked participants to report their hunger levels following two nights of 4h sleep restriction (Spiegel, Leproult et al., 2004). The 12 healthy males participating in the study reported they felt hungrier following sleep restriction compared to when they were in a control condition with a sleep opportunity of 10h sleep per night. Later studies concurred with these findings (Benedict et al., 2011; Hogenkamp et al., 2013; Schmid et al., 2008). Conversely, some studies have not demonstrated an increase in appetite following sleep restriction (Reynolds et al., 2012; Schmid et al., 2009; St-Onge et al., 2011).

Methodological differences in the study designs may explain the above contradictory findings. First, each study measured hunger at different times of the day. Results from a recent study demonstrated that hunger and appetite for specific food types follow a circadian rhythm (Scheer, Morris, & Shea, 2013), therefore suggesting hunger levels may differ depending on time of day. Hunger levels have been found to be highest in the evening (peaking around 20:00) and lowest in the morning (around 08:00) (Scheer et al., 2013). If hunger is measured at intervals across the period of sleep deprivation, and testing sessions go into the evening (when hunger levels are higher), sleep-deprived participant results may be impacted, even if scores are averaged across the day.

Another difference in methodology has been the amount of food consumed by participants during the study or prior to the experimental period. Two of the studies that found appetite increased following sleep restriction and total sleep deprivation did not provide participants with

food during the days hunger was measured (Schmid et al., 2008; Spiegel, Tasali et al., 2004). Participants were provided with nutrition intravenously in one of the studies (Spiegel, Tasali et al., 2004). The lack of experiencing the consumption of solid food (e.g. chewing and swallowing food) may have impacted on hunger levels. However, it is not only studies that have not provided food that have found hunger increased due to sleep restriction. Other studies have found increases in hunger following sleep restriction when participants were provided with regular standard meals during the experimental period (Benedict et al., 2011). Whilst the differences in food provided to participants may make it difficult to compare studies, most studies summarised in Table 1.1 included a control condition, and therefore any differences found suggest appetite levels alter due to sleep restriction.

1.5.2.3 Sleep restriction and food intake

Only a few studies have measured food intake. Food intake was measured in these studies by recording the energy intake of food consumed when individuals are sleep restricted. Similar to studies measuring self-reported hunger, findings from studies observing food intake have also been varied. One of the first studies to observe increased appetite following sleep deprivation (Dinges & Chugh, 1997), is not included in Table 1.1, as food intake was only reported anecdotally. However, an increase in participants' food intake was observed during three days of total sleep deprivation. More recently, a 14-day study where participants completed a sleep restriction (5.5h) and a control condition (8.5h) found that participants consumed more energy from snacks during sleep restriction; however, there was not an increase in total energy intake (Nedeltcheva et al., 2009). The majority of subsequent studies conducted in a laboratory environment have demonstrated increases in energy intake following or during a period of sleep restriction (Bosy-Westphal et al., 2008; Brondel, Romer, Nougues, Touyarou, & Davenne, 2010; Markwald et al., 2013; Spaeth, Dinges, & Goel, 2013; St-Onge et al., 2011). In contrast, some studies have not noted an increase in energy intake when participants have been subject to sleep restriction or total sleep deprivation (Benedict et al., 2011; Schmid et al., 2009).

Similar to the studies investigating subjective appetite, the choice of food available may explain some of the differences in findings. Some studies have provided buffet meals to participants and observed energy intake (Benedict et al., 2011; Brondel et al., 2010; Schmid et al., 2009). These studies have produced mixed results. In particular, Schmid et al. (2009) note that energy intakes were high in both the study's sleep restriction and control condition, suggesting a ceiling effect. This finding is not surprising, as research suggests than if large quantities of food are provided

then larger quantities of food may be consumed (Rolls, Morris, & Roe, 2002). Increases in energy intake following sleep restriction have typically been demonstrated when participants have had the opportunity to purchase foods themselves (St-Onge et al., 2011), when they had the opportunity to select foods ad libitum throughout the study period (Nedeltcheva et al., 2009; Spaeth et al., 2013), or in free living conditions (Bosy-Westphal et al., 2008). Similarly, participants were found to purchase more food following total sleep deprivation in a mock supermarket situation, although energy intakes were not examined in this study (Chapman et al., 2013). Overall, studies that found energy intake is higher when sleep is restricted generally provided participants with the opportunity to choose their own food. As these study designs are more likely to mimic the real world, it is likely that if individuals are in their own environment they may be at risk of higher energy intakes following sleep restriction.

In addition to the methodological considerations discussed above, demographic details of participants may influence results (e.g. weight status and gender). A study conducted by Nedeltcheva et al. (2009) included participants who were overweight on average (mean BMI = 26.5). Eating behaviour has been found to differ between overweight and individuals within the normal weight range. For example, eating in the absence of hunger has been observed in obese individuals (Hudson & Williams, 1981; Leon & Chamberlain, 1973). This has particularly been noted when obese individuals are experiencing emotions such as depression (Ganley, 1989). Mood was not measured in the above studies and therefore it is difficult to understand if the participants in the Nedeltcheva et al. (2009) study were experiencing negative mood states. It is possible that participants may have experienced some mood disturbance, as individuals who are deprived of sleep have reported higher levels of negative mood domains (Dinges et al., 1997). Participants may have been experiencing negative mood states and this may have resulted in increased snacking behaviour. The influence of negative mood states on eating behaviour when individuals are sleep restricted is an area that requires further research.

In addition to the above explanations for differences in findings, the weight of participants should be taken into consideration. Studies have suggested that eating behaviour may differ depending on the weight of the individual. For example, an increased intake of energy-dense foods has been seen in overweight and obese individuals (Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992; Lissner & Heitmann, 1995). Furthermore, individuals are overweight are more likely to consume food in response to negative emotions. On the other hand, individuals who are underweight are more likely to eat less than normal weight and overweight individuals when experiencing negative

emotions (Geliebter & Aversa, 2003). Many of the studies summarised in Table 1.1 investigated individuals within the normal weight range (refer to mean BMI reported in Table 1.1). A recent study included participants in various weight categories (Spaeth et al., 2013); however, due to the small sample size the authors were unable to investigate differences between the weight categories. This is an area that should be explored in the future; particularly as shiftworkers are often overweight (Biggi, Consonni, Galluzzo, Sogliani, & Costa, 2008; Esquirol et al., 2009; Lin et al., 2009).

In addition to weight status, gender differences may explain some of the mixed findings in this area of research. Gender has been found to influence eating behaviour and appetite (Ahima, Saper, Flier, & Elmquist, 2000; Van Der Lely, Tschop, Heiman, & Ghigo, 2004). In particular, sex hormones may explain differences observed in eating behaviour for males and females. For example, food intake differs for women depending on menstrual cycle phase (Asarian & Geary, 2013). Additionally, increased adiposity is linked to decreased testosterone concentrations in men (Asarian & Geary, 2013) as is sleep deprivation (Cote, McCormick, Geniole, Renn, & MacAulay, 2013; Leproult & Van Cauter, 2011).

The two studies that did not find an increase in energy intake only included male participants (Benedict et al., 2011; Schmid et al., 2009). Very few studies have included enough participants to investigate gender differences in energy intake following sleep restriction. However, a recent study has suggested that men may be likely to have a higher energy intake following sleep restriction (Spaeth, Dinges, & Goel, 2014). The menstrual phase of the female participants in this study was not determined. In addition to these differences, females have demonstrated reduced dietary restraint (which may result in increased food consumption) when sleep is restricted (Markwald et al., 2013), therefore future research involving female participants would be useful. In particular, it may be useful to understand alterations in eating behaviour depending on menstrual phase when individuals are restricted of sleep.

1.5.2.4 Sleep restriction and food choice

In addition to appetite and food intake it is important to determine differences in food choice when individuals are sleep restricted. As mentioned in Section 1.1.1 a diet high in fat, particularly a diet high in saturated fat, is likely to result in weight gain and development of health disorders. A common measurement of food choice in sleep restriction studies measures macronutrient intake (Benedict et al., 2011; Markwald et al., 2013; Spaeth et al., 2013, 2014); however, some

studies have measured food choice by measuring food cravings (Spiegel, Leproult et al., 2004) or asking participants to choose between food images (Hogenkamp et al., 2013).

Studies investigating food cravings when participants are sleep restricted have shown increased cravings for foods high in kJ, and rich in carbohydrates (Spiegel, Tasali et al., 2004). Studies investigating macronutrient intake following sleep restriction or total sleep deprivation have been mixed. In line with the study conducted by Spiegel et al. (2004) where participants reported increased cravings for carbohydrates, some studies have shown increased intake of carbohydrates following sleep restriction (Markwald et al., 2013) and an increased consumption of snacks high in carbohydrates (Nedeltcheva et al., 2009). Other studies have demonstrated increased consumption of fat following sleep restriction (Brondel et al., 2010; Schmid et al., 2009; Spaeth et al., 2014; St-Onge et al., 2011). While the findings have been varied, the studies have been conducted in various environments and possibly the differences have represented the availability of food options (Markwald et al., 2013). Nevertheless, studies overall suggest that food choice appears to alter when sleep is restricted.

Food images have also been shown to participants in sleep restriction studies to further understand food choice. Similar to the findings of Nedeltcheva et al. (2009) showing a high intake of snacks following sleep restriction, Hogenkamp et al. (2013) found that participants were more likely to choose images that displayed larger portion sizes in snacks (but not meals) following total sleep deprivation. Participants were sated (as measured by self-report) when these images were shown, suggesting that food may be chosen for reasons other than hunger (e.g. the rewarding effect of snack foods) when individuals are sleep restricted. Previous studies have demonstrated that sleep restriction and total sleep deprivation increase brain responses to food images (Benedict et al., 2012; St-Onge, Wolfe, Sy, Shechter, & Hirsch, 2014). In particular, brain responses were seen in areas involved in reward processing such as the anterior cingulate cortex, insula and dorsolateral cortex. The results of the study conducted by St-Onge et al. (2014) suggested that the insula (which is an area of the brain involved in energy homeostasis and regulation of pleasure seeking behaviours) was activated by images of unhealthy foods. These findings are also in line with studies that have found increases in ghrelin following sleep restriction (Spiegel, Tasali et al., 2004; Taheri, Lin, Austin, Young, & Mignot, 2004). Intravenous infusions of ghrelin have been found to increase activation of areas in in the brain involved in brain reward, such as the striatum (Malik et al., 2008).

In summary, there is an increasing body of research investigating sleep restriction and eating behaviour. The studies discussed above have produced mixed findings. The methodological differences and variations in participants taking part in the studies discussed above explain some of the mixed findings. Therefore, it is important to consider other factors that may predict eating behaviour such as gender, weight and mood state when sleep is restricted. Additionally, the above research suggests that individuals may be more likely to consume more food in their own environment when they have access to foods they have chosen themselves. Nevertheless, the above studies have provided evidence that eating behaviour is impacted by sleep restriction. In particular, non-homeostatic influences such as activation in brain areas involved in reward appear to play an important role. However, research in this area is limited. The following section of this chapter reviews the literature providing evidence for shift-related factors (circadian disruption, shift schedule and shift type) as predictors of eating behaviour.

1.5.3 *Shift-related factors as predictors of eating behaviour*

Shiftwork alters the daily routine, for example shiftworkers (particularly night shiftworkers) live on a schedule that directly opposes their endogenous circadian system (Roden, Koller, Pirich, Vierhapper, & Waldhauser, 1993; Sack, Blood, & Lewy, 1992). As a result shiftworkers experience circadian disruption (Åkerstedt, 2003). This section discusses circadian disruption and eating behaviour along with a review of studies that have examined shift schedule and shift type as predictors of eating behaviour. Figure 1.7 outlines the portion of the pathway discussed in this section.

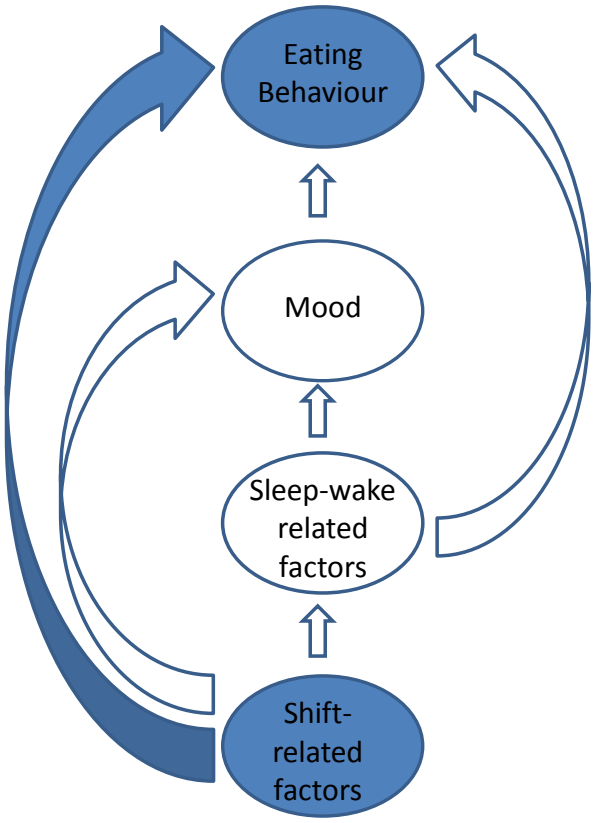


Figure 1.7 Shift-related factors as a predictor of eating behaviour

Note: Shaded areas indicate the portion of the pathway discussed in this section

1.5.3.2 Circadian disruption as a predictor of eating behaviour

Due to their unusual working hours, shiftworkers are likely to be consuming food at different times to day workers (e.g. during the night) (Geliebter et al., 2000; Waterhouse et al., 2003). Food consumption and food choice during the night is discussed in this section. Furthermore, there is evidence to suggest that the body is not designed to consume food during the night (Glenn Stanley et al., 1989; Rowland, Morien, & Li, 1996; Strubbe & van Dijk, 2002). This section includes a discussion on the physical response to food consumed during the night.

1.5.3.3 Circadian disruption and food consumption and choice

Studies demonstrate that individuals are likely to lose the desire to eat, and may feel less hungry at night (Waterhouse et al., 2003). Therefore, shiftworkers may not feel like eating meals. Indeed, studies have demonstrated shiftworkers may rely more on snacks during the night shift (Lennernäs et al., 1995; Reinberg et al., 1979; Tepas, 1990; Waterhouse et al., 2003). In addition, circadian disruption results in high levels of fatigue and some individuals may be too tired and

fatigued to prepare meals (Waterhouse et al., 2003). If individuals are tired or fatigued they may choose extra sleep over taking time to eat a meal (Lowden et al., 2010).

On the other hand, there is some evidence to suggest that individuals who have later sleep times (mid-point of sleep 05:30 or later) consume more energy at night and make poorer food choices overall when compared to participants in a study who report normal sleep times (mid-point of sleep between 01:00 and 05:29). In particular, one study showed later sleepers had fewer serves of fruit and vegetables, more fast foods and more soft drinks than participants who reported normal sleep times (Baron, Reid, Kern, & Zee, 2011). Given these findings it is not surprising that there is evidence to suggest that the timing of eating may play a role in weight gain (Arble, Bass, Laposky, Vitaterna, & Turek, 2009; Turek et al., 2005)**.** In particular, when individuals consume foods during the night they are more likely to gain weight (Gluck, Venti, Salbe, & Krakoff, 2008). Afternoon shiftworkers who sleep through the morning may also be at risk of weight gain. Weight gain was demonstrated in a study in which participants only had access to foods in the evening (Halberg, 1989). Furthermore, shifting meals to later in the day is associated with the inability to lose weight (Garaulet et al., 2013; Jakubowicz, Froy, Wainstein, & Boaz, 2012).

1.5.3.4 Physical response to food consumed at night

In addition to the impact of circadian disruption on food consumption and food choice, research indicates that if meals are eaten at unusual times metabolic responses may be affected (Atkinson, Fullick, Grindey, & Maclaren, 2008; Lowden et al., 2010; Pati et al., 2001; Romon, Edme, Boulenguez, Lescroart, & Frimat, 1993). The circadian system regulates many bodily functions, including appetite and lipid metabolism. Therefore, metabolism may differ depending on the time food is consumed (Atkinson et al., 2008; Lowden et al., 2010; Romon et al., 1993). Evidence for this has been found in animal studies. For example, when mice were fed at times that were different to their normal eating pattern they gained weight even though energy intake was only slightly higher than those fed at normal feeding times (Arble et al., 2009).

In addition to the animal studies mentioned above, metabolic responses of night eating have been investigated in humans. Various studies have found metabolic disturbances occur when the circadian system is disrupted (Holmbäck et al., 2002; Scheer, Kalsbeek, & Buijs, 2003; McHill et al., 2014; Nguyen & Wright, 2009;). For example, an increased triacylgycerol response was seen in participants when food was consumed during the night. Triacylgyceral is the major lipid component of dietary fat (Holmbäck et al., 2002; Morgan et al., 1998). Elevated concentration of plasma triglyceride found as a result of night eating may be due to a decrease in insulin sensitivity

(Morgan et al., 1998). Insulin resistance and lipid intolerance are associated with lack of adjustment to night shift (Lund, Arendt, Hampton, English, & Morgan, 2001). Insulin is involved in triglyceride clearance and if insulin sensitivity is reduced this may result in higher levels of triglycerides in the blood stream (Morgan et al., 1998). This metabolic response may cause artery walls to thicken and result in atherosclerosis, increasing the risk for cardiovascular disease (Corbin et al., 2001; Malloy & Kane, 2000).

Although studies are limited, there has been some research suggesting that the macronutrient content of food consumed may impact on metabolic responses in response to eating at night. Studies have demonstrated differences in metabolic responses to meals with different macronutrient breakdowns (high fat vs high carbohydrate meals) depending on time of day (Holmbäck et al., 2002; Holmbäck et al., 2003). For example, circadian patterns were seen in plasma glucose concentration in a seven-day cross-over design study investigating seven male participants. Glucose concentrations reached their peak in the early hours of the morning (00:00–04:00) following a high-fat diet. A circadian pattern was also observed for triglyceride following a high-fat meal. In particular the highest levels of triglyceride were seen 2h after a meal occurring at 04:00 (Holmbäck et al., 2002). These findings are similar to a previous study, which found increased triglyceride levels in men when meals were consumed at night (Sopowski, Hampton, Ribeiro, Morgan, & Arendt, 2001).

In summary, shiftworkers live on a schedule that works in opposition to their endogenous circadian system. Shiftwork schedules can result in alterations in the timing of food intake. As shiftworkers report not feeling as hungry during the night, they often rely on snacks. In addition, due to high levels of fatigue, shiftworkers may not feel like preparing meals. It is clear that metabolism is disturbed when food is consumed during the night. Further research investigating metabolic responses depending on the type of food consumed would be useful given the studies demonstrating variation in metabolic responses to food consumed during the night.

The following section examines the research to date that has examined the effect of shiftwork (shift schedules and shift type) on eating behaviour.

1.5.4 *Shift schedule and shift type as a predictors of eating behaviour*

In recent years, an increasing number of studies have investigated the eating behaviour of shiftworkers. This section focuses on the shaded factors in Figure 1.7, reviewing studies that have assessed eating behaviour in shiftwork populations. In particular, studies included have

investigated food consumption (energy intake and meal frequency) and food choice in shiftworkers. Studies have investigated the difference in eating behaviour between shiftworkers and day workers. Additionally differences in shift types (e.g. morning, afternoon and night shifts) have been investigated, and some studies have examined differences between shift schedules (e.g. rotating, permanent shiftworkers). Table 1.2 summarises the studies reviewed in this section that have investigated shiftwork and eating behaviour.

Table 1.2 Summary of studies investigating the effect of shiftwork on eating behaviour

First author, date	Work schedules	Eating behaviour measurement	Participants	Findings
Baliero, L., 2009	Night shiftworkers and day workers	Food frequency questionnaire	*n* = 150; m = 46.7 (day workers), 44.0 (night workers); BMI = 27.9 kg/m^2 (day workers), 28.9 kg/m^2 (night workers)	↓vegetables on night shift =Night and day workers for other food groups
Esqirol, Y., 2009	Rotating (M, A, N) and day workers	Diary	*n* = 198; 39–60y; BMI, 26.3 kg/m^2	=Total energy intakes on all shifts ↑Meal frequency on night shifts
Morikawa, Y., 2008	Shiftworkers with and without midnight shifts; day workers	Diet history questionnaire	*n* = 2,254 (males); 20–59y	=Total intakes in between shift types Nutrient intakes differed by age and type of shiftwork
Suwazono, Y., 2008	Rotating (M, A, N) and day workers	Interview	*n* = 7,254 (males) (2,926 shiftworkers; 4,328 day workers); m = 37.0y (shiftworkers), 36.6y (day workers); BMI = 23.3 kg/m^2 (shiftworkers), 23.5 kg/m^2 (day workers)	↑Shiftworkers consumed an extra meal regardless of shift type
Morikawa, Y., 2007	Shiftworkers (rotating two and three shifts) and day workers	Self-administered diet history	*n* = 1,529 (males); m = 35.5y; BMI = 22.5 kg/m^2	↑Shiftworkers who remained on a shiftwork schedule for the 10y study had the highest energy intake
Pasqua, I., 2004	Permanent (M, A, N)	Diary	*n* = 28 (males); m = 32.8; BMI = 26.3 kg/m^2 (winter), 26.2 kg/m^2 (summer)	=Energy intake and macronutrient consumption between shifts ↑Energy intake in winter compared to summer ↑Carbohydrate and fat in winter

First author, date	Work schedules	Eating behaviour measurement	Participants	Findings
Waterhouse, J., 2003	Permanent (N) and day workers	Questionnaire	*n* = 93 (males and females); m = 43y (shiftworkers), 50y (day workers)	↓Meal frequency on night shift ↓Appetite during night shift
de Assis, M., 2003	Permanent (M, A, N)	24h food recall	*n* = 66 (males); m = 30.2; BMI = 24.1 kg/m^2	=Energy intakes similar on all shifts Re-distribution of from day to night in night shiftworkers
Sudo, N., 2001	Early and late shiftworkers and day workers	Diary and photographic method	137 (females); m = 28y (day shift), m = 26y early shift), m = 2y (late shift); BMI = 20.2 kg/m^2 (day shift), 21.3 kg/m^2 (early shift), 22.1 kg/m^2 (late shift)	↓Energy and meal frequency on afternoon shifts
Gelibeter, A., 2000	Day shift and late shift	Questionnaire	*n* = (male and female); m = 45y (day shift), 41.6 (late shift); BMI = 27.8 kg/m^2 (day shift), 25.9 kg/m^2	↑Late shiftworkers reported consuming fewer meals ↑Food intake since working on later shifts
Lennernas, M., 1995	Rotating shiftworkers	Interview; 24h recall	*n* = 85 (males); m = 42y BMI – not reported	↓Less energy on night shift
Lennernas M., 1994	Rotating two and three shiftworkers	Dietary recall	*n* = 96 (males); 25–55y; BMI – not reported	↓Energy intake lower on night shift =Macronutrient intakes were similar regardless of shift type ↓Sucrose and caffeine on night shift
Lennernas, M., 1994	Rotating shiftworkers (M, A, N)	24h dietary recall	*n* = 22 (males), m = 35y; BMI = 24.5 kg/m^2	↓Energy and macronutrient intake was lower on night shift
Knuttson, A., 1990	Rotating shiftworkers (M, A, N) and day workers	Diary	*n* = 225 (males), 18–39y; BMI = 22.6 kg/m^2 (day workers), 24.5 kg/m^2 (shiftworkers)	↓Shiftworkers reduced their dietary fibre intake due to less potatoes and vegetables

First author, date	Work schedules	Eating behaviour measurement	Participants	Findings
Duchon, J., 1990	Rotating shiftworkers	Questionnaire	*n* = 36 (males), 18–39y BMI – not reported	Poorer health was related to altered meal frequency on night shift
Romon-Rousseaux, M., 1987	Rotating shiftworkers	Diary	*n* = 94 (males) 22–29y BMI – not reported	=Energy intake between shiftworkers and day workers
Attia, M., 1985	Rotating shiftworkers	Diary	*n* = 49 (males) 18–45y BMI – not reported	↓Hot meals and meals taken with the family were minimal for afternoon shiftworkers ↓Appetite was slightly lower on one of the rotating shift schedules
Reinburg, A., 1979	Rotating shiftworkers and day workers	Diary	*n* = 7 (males), m = 26y BMI – not reported	=Energy intakes between shifts ↑Carbohydrates intake on night shifts

Notes: M = morning shift; A = afternoon shift; N = night shift; m = mean; BMI = body mass index; y = years

↑Increase in variable; ↓Decrease in variable; =No differences in variable

1.5.4.1 Shiftwork and food consumption: Energy intake and meal frequency

As noted in Table 1.2, studies investigating shiftwork and energy intake and or meal frequency have provided mixed results. Some studies have found a higher intake of food consumption by shiftworkers (Morikawa et al., 2007; Suwazono et al., 2008), some have found no differences between the groups (de Assis et al., 2003; Reinberg et al., 1979), and others have found shiftworkers consume less food than day workers (Tepas, 1990). The definition of shiftwork varies from study to study. In addition, there are several shift types (e.g. morning, afternoon and night). Furthermore, shift schedules alter from study to study (e.g. permanent, rotating). The varying shift types and schedules are associated with factors that could result in alterations in eating behaviour. The following review of studies identifies some of the predictors of altered eating behaviour associated with the varying shift types and shift schedules.

As part of a larger study, a small number of male shiftworkers from a Japanese factory were interviewed about their eating habits (Suwazono et al., 2008). It found that these rotating shiftworkers ate an extra meal, regardless of the shift they were on, compared to day workers. No objective measure of energy intake was recorded during this study, therefore it is unclear if meals differed in size (e.g. smaller more frequent meals). Nevertheless, results concurred with previous studies suggesting individuals report increasing their food intake since beginning shiftwork (Geliebter et al., 2000; Morikawa et al., 2007). For example, a large longitudinal Japanese study compared male rotating shiftworkers with day workers (Morikawa et al., 2007). Participants in this study recorded their energy intake at the end point of a 10-year period on a self-administered dietary questionnaire. Interestingly, the study found that those who had higher energy intakes were individuals who were shiftworkers for the entire period of the 10-year study. Results suggest that long-term shiftworkers may experience alterations in eating behaviour. Energy intake was not recorded at the start point of this study and therefore it is difficult to determine if it increased over the course of the study.

A later study (Morikawa et al., 2008) included a further set of employees at the same factory along with the participants from their previous study (Morikawa et al., 2007). The participants in this study were stratified into age categories and work schedules: day shift, rotating shift (not working midnight shift), rotating shiftworkers (working midnight shift). Results showed that shiftworkers over the age of 30 who worked midnight shifts consumed the most energy compared with other groups, suggesting that age and shift schedule may also predict alterations in eating behaviour. Identifying predictors of eating behaviour helps to explain the differences between the

studies conducted thus far, and help with understanding which shift types and schedules may be more likely to result in alterations in eating behaviour.

In contrast to the above findings, a small study of Brazilian garbage collectors (*n* = 66) did not demonstrate any differences in energy intake when three different shifts were compared (morning, afternoon and night) (de Assis et al., 2003). To be eligible for this study, participants were required to have worked on these shifts for a minimum of six months. As mentioned above, it is possible that individuals need to be on shiftwork for longer periods for differences in energy intake to be observed. Some shiftworkers experiencing health problems due to alterations in diet may have reverted to day work. It is common for shiftworkers experiencing health problems to change to day work; this is known as the 'healthy worker effect' (Wen, Tsai, & Gibson, 1983). Shiftworkers in this study reported higher than average intakes of food. Individuals who have high food intakes are one of the many groups who are likely to under-report (Subar et al., 2003). Therefore it is possible that there were errors in the reporting of food intake in this study.

Some studies have found shiftworkers eat less than day workers (Lennernäs & Andersson, 1999; Ohtsuka, 2001; Tepas, 1990). Geliebter et al., (2000) found that evening and night shiftworkers reported eating fewer meals in a day. Nonetheless, shiftworkers still reported eating more food since beginning shiftwork. As shiftworkers and day workers did not differ in snack intake these results suggest shiftworkers consumed larger meal servings.

Although food diaries are often subject to misreporting (Subar et al., 2003), this method of measuring food intake may give a more accurate account of food consumption than questionnaires (refer to Section 1.1.3 for an overview of the measurement of dietary intake). It is also important to ensure type of shift is accurately defined, as this may play a role in findings. For example Sudo and Ohtsuka (2001) defined shiftworkers as those working outside of normal working hours; however, they did not include any individuals on night shift—those who are generally most affected by their work schedules (Åkerstedt, 2003). In addition, night and afternoon shiftworkers may have limited food availability. For example, some shiftworkers report relying on vending machines to obtain food during shiftwork (Lancaster, Pickles, & Dobson, 2001; Stewart & Wahlqvist, 1985). Environmental factors relating to the varying shift types may also predict alterations in eating behaviour.

In summary, studies investigating energy intake overall have provided contradictory results. Whilst many investigated the eating behaviour of shiftworkers, very few studies have examined

predictors of eating behaviour or confounding variables. It may be that shiftworkers on specific shift types and schedules are more at risk of altering their eating behaviour. This is an area that needs to be examined in further detail.

1.5.4.2 Shiftwork and food choice

In addition to overall food consumption it is important to understand the food choices shiftworkers make. Section 1.1.1 described the role of nutrients and how they are important to health. Poor food choices may result in the development of chronic health conditions. Shiftworkers are less likely to eat meals with their families, and the type of foods available may be limited (Stewart & Wahlqvist, 1985; Waterhouse et al., 2003). Therefore shiftworkers may make food choices which are unfavourable to health.

Various studies have suggested that food choices differ to those of day workers. A large Japanese study (*n* = 4,962) comparing rotating shiftworkers and day workers found that shiftworkers at significantly more fried foods (Harada et al., 2005). Likewise, a French population study found that night workers had poorer dietary habits than day workers (Lasfargues, Cacès, Le Clésíau, Lecomte, & Tichet, 1996). In particular, those on night shift consumed more sweet drinks than those on day shift, and male night workers in this study consumed more bread than day workers. Similarly a group of men who began working a rotating shiftwork roster increased their intake of soft drink and decreased their dietary fibre intake in the first six months of employment (Knutson, Andersson, & Berglund, 1990). In addition, a group of Italian rotating shiftworkers reported eating more saturated fats and foods with a higher GI (Di Lorenzo et al., 2003). Not surprisingly, these foods have been identified as contributing to increases in body fat (French et al., 1994). In addition, unhealthy eating may continue even after the completion of a shift. This behaviour was identified in a Swedish study of shiftworking nurses who reported a craving for sweet foods the day following night shift (Persson & Mårtensson, 2006).

Similarly, a longitudinal study investigated dietary habits of shiftworkers and day workers at a 21-year follow up (Puttonen et al., 2009). Results showed male shiftworkers were more likely to use butter, and male and female shiftworkers consumed vegetables less frequently than day workers. As discussed above, age may play a role in the type of food shiftworkers consume. Morikawa et al. (2007) found that younger shiftworkers (20–29 years) and older shiftworkers (50–59 years) reported eating fewer vegetables than day workers. Shiftworkers in the 40–49-year group had the lowest intakes of meat, fats and oil. It may be that the middle-aged shiftwork group (i.e. 40–49 years) in this study take leftover family meals to work, thus maintaining their vegetable intake.

Therefore, further investigation as to factors that result in different age groups making alternate food choices is required.

The above studies have predominately relied on questionnaires to investigate eating behaviour. Some studies have examined macronutrient intake. One of the first studies to investigate the eating behaviour of shiftworkers measured energy and macronutrient intake and found that night shiftworkers reported increase consumption of carbohydrate, which the authors attributed to increased snacking across the night (Reinberg et al., 1979).

As discussed previously, the environment of shiftworkers may result in food choices that are unfavourable to health. Shiftworkers, especially those on night shift often find that company canteens are closed during their meal breaks. Therefore these workers often resort to vending machines consisting of unhealthy food choices (Lancaster et al., 2001; Stewart & Wahlqvist, 1985). Various studies have suggested that shiftworkers consume snacks whilst they work a night shift (Reinberg et al., 1979; Waterhouse et al., 2003). On the other hand, Brazilian night workers exposed to a canteen that offered a hot meal high in nutrients reported that this meal made a significant contribution to their diet (de Assis et al., 2003). As suggested in Section 1.5.4 shiftworkers may also resort to snacking as a result of limited time availability (Persson & Mårtensson, 2006; Waterhouse et al., 2003). Shiftworkers may also be consuming snack food high in sugar, as they perceive it will help keep them awake at night (Persson & Mårtensson, 2006).

In summary, similar to studies comparing food intake of shiftworkers and day workers, studies investigating food choices of these two groups are limited. Although studies have generally relied on broad questions, it appears shiftworkers may make poorer food choices compared to day workers. Some studies that have investigated macronutrient intake have not found any differences in food choices between shiftworkers on different shifts (de Assis et al., 2003; Lennernäs, Abrahamsson, Hambraeus, & Åkerstedt, 1994; Lennernäs et al., 1995). As the food was not weighed or measured in many of the studies listed, misreporting may have occurred, and therefore results should be interpreted with caution. Although food diaries can be subject to inaccurate reporting (Subar et al., 2003), this method may be more reliable than questionnaires. Moreover, when these findings are considered with studies suggesting shiftworkers have more abdominal fat (Ishizaki et al., 2004; Karlsson, Knutsson, Lindahl, & Alfredsson, 2003; Nakamura et al., 1997), and are more likely to be overweight than day workers (Kivimäki et al., 2001; Niedhammer, Lert, & Marne, 1996; Suwazono et al., 2008) it appears further research is required to discover motivations behind food choice when individuals are employed in shiftwork.

This section has discussed the effect of factors examined within this thesis that predict eating behaviour. The next section discusses how these factors are related to each other, that is, sleep, circadian and shift-related factors as predictors of mood.

1.6 Predictors of mood

Studies have found links between mood and both sleep-wake related factors and shift-related factors. This section explores these factors.

1.6.1 *Sleep as a predictor of mood*

Various studies have investigated mood following total sleep deprivation or sleep restriction. In addition, studies employing FD, constant routine protocols and ultra-short sleep-wake cycles have examined the influence of circadian disruption on mood. This section provides an overview of studies examining the influence of sleep restriction or total sleep deprivation and circadian disruption on mood. Figure 1.8 demonstrates the factors overviewed in this section.

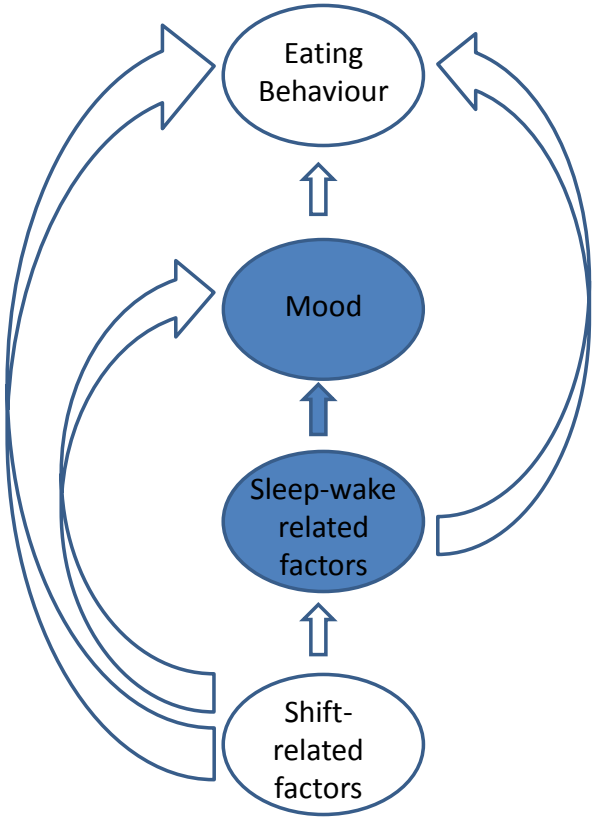


Figure 1.8 Sleep-wake related factors as a predictor of mood

Note: Shaded areas indicate the portion of the pathway discussed in this section

Overall, studies have provided evidence to suggest that loss of sleep predicts an increase in negative mood and a decrease in positive mood. Participants in total sleep deprivation studies depriving them of either one or two full nights of sleep reported a decrease in positive mood such as happiness, vigour and activation (Brendel et al., 1990; Paterson et al., 2011; Scott, McNaughton, & Polman, 2006). Decreases in negative mood have also been observed. For example, total sleep deprivation results in increases in fatigue (Brendel et al., 1990; Paterson et al., 2011), depression (Dinges et al., 1997) and confusion (Brendel et al., 1990). Not surprisingly, studies have also demonstrated an overall increase in overall mood disturbance (Blagrove & Akehurst, 2001; Brendel et al., 1990; Chuah, Venkatraman, Dinges, & Chee, 2006; Mastin, Peszka, Poling, Phillips, & Duke, 2005). Similar findings have been found in sleep restriction studies. For example, participants completing a sleep restriction protocol of seven nights of approximately 5h sleep reported increased fatigue, confusion and tension, and worse overall total mood disturbance (TMD) during the study (Dinges et al., 1997). Similar findings showing an increase in negative mood states, such as anger, tension, depression, fatigue and confusion have been demonstrated in other sleep restriction studies. In these studies participants were woken in the early hours of the morning, thus restricting sleep by advancing their wake time (Haack & Mullington, 2005; Selvi, Gulec, Agargun, & Besiroglu, 2007).

1.6.2 *Shift-related factors as a predictor of mood*

Various protocols have been designed to allow for the examination of the circadian influence and shiftwork (shiftwork schedule and shift type) on variables such as mood. This section overviews these factors, focussing on the portion of the pathway highlighted in Figure 1.9.

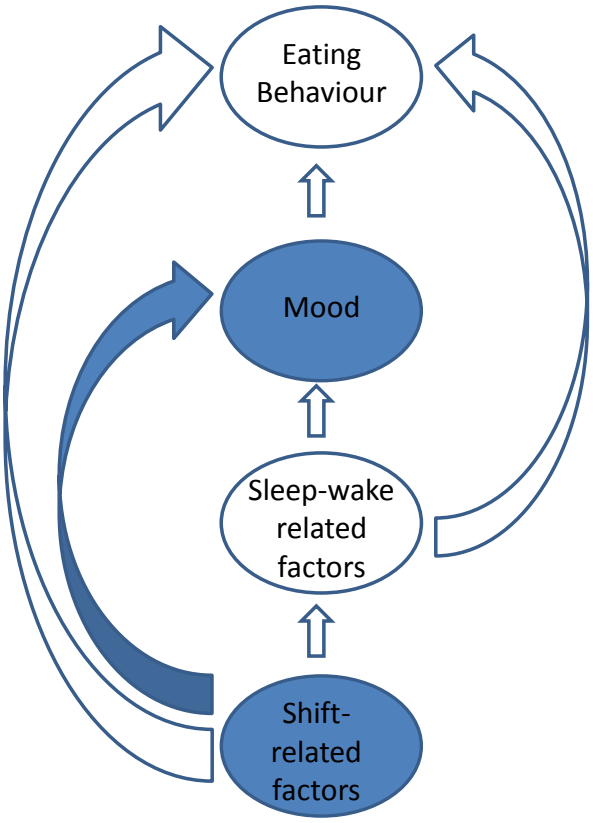


Figure 1.9 Shift-related factors as a predictor of mood

Note: Shaded areas indicate the portion of the pathway discussed in this section

Studies conducted under all protocol conditions have demonstrated a circadian influence on mood such that mood tends to be lower around the early hours of the morning (the circadian nadir) (Monk et al., 1997; Murray et al., 2002). For example, participants reported feeling least vigorous around 06:00 and most vigorous around 17:00. In addition, participants reported lower well-being around 02:00 and well-being was found to be highest around 16:00 (Monk et al., 1997). Similarly, a later study also employing a constant routine protocol (these protocols are discussed in Section 1.3.3) found that positive effect was lowest around 24:00 and highest around 15:00; however, no circadian variation in negative effect was found (Murray et al., 2002). Constant routine protocols allow the impact of circadian phase on mood to be examined as wake is extended to periods of >24h studies. However, employing these protocols may be confounded as participants are also awake for long periods of time, and therefore are likely to be experiencing high sleep pressure. As discussed in Section 1.3.3 it is difficult to examine circadian phase on variables in constant routine protocols results as results are often confounded by homeostatic processes (sleep pressure).

The influence of circadian phase on mood has been investigated using ultra-short sleep-wake cycle protocols. TMD and various mood domains such as vigour, depression, anger, tension, confusion and fatigue have been demonstrated to fluctuate with circadian phase (Kline et al., 2010). In addition, a previous study demonstrated that tension, physical comfort and subjective well-being, along with a composite score of mood, showed circadian variation (Birchler-Pedross et al., 2009). However, as discussed in Section 1.3.3, ultra-short sleep-wake cycles do not allow for the influence of prior wake on mood to be examined.

FD protocols (discussed in Section 1.3.3) allow for both the influence of prior wake and circadian phase to be examined. In these protocols, mood is measured at all possible combinations of circadian phase and prior wake. The influence of these two processes are separated by averaging mood data over consecutive or successive wake periods, eliminating any masking effects and allowing the independent influence of both prior wake and circadian phase to be analysed along with interaction effects (Hiddinga & van den Hoofdakker, 1997). The influence of circadian phase on mood has been demonstrated in studies employing FD protocols. For example, circadian variation in cheerfulness and happiness was demonstrated in a pivotal study conducted by Boivin et al. (1997). A later study found that elation followed a rhythm similar to core body temperature; however, depression did not demonstrate circadian variation (Koorengevel et al., 2003).

In summary, evidence suggests that sleep restriction and circadian phase can influence mood. Decreases in positive mood and increases in negative mood have been demonstrated when individuals are totally deprived or restricted of sleep. Additionally, a circadian variation has been noted in studies employing various protocol designs. However, constant routine protocols may be confounded by the influence of prior wake, and although ultra-short sleep-wake attempts to de-mask these effects they do not allow for examination of the influence of prior wake. FD protocols overcome these limitations by allowing for the separation of prior wake and circadian phase.

Taken together, the above studies demonstrate there is evidence to suggest mood is affected by total and partial sleep restriction, and circadian disruption. However, there is some variation in the mood domains impacted by these variables between the studies. Therefore it is important to ensure that results are not confounded by either prior wake or circadian phase. To ensure this does not occur, an FD protocol is beneficial.

1.6.3 *Shift schedule and shift type as a predictor of mood*

Shiftwork impacts several physiological and psychological factors. Table 1.3 summarises studies thus far that have investigated the effect of shiftwork on mood. Research investigating shiftwork and mood is limited; all studies reviewed demonstrate that shiftwork is associated with negative mood states or a decrease in positive mood (refer to Section 1.2 for an overview of mood to understand negative and positive mood domains). As demonstrated in Table 1.3, indicated by the upwards arrow in the findings column (↑), research over the past decade has found associations with shiftwork and negative mood states such as depression (Geiger-Brown, Muntaner, Lipscomb, & Trinkoff, 2004), stress (Srivastava, 2010) and fatigue (Paterson, Dorrian, Pincombe, Grech, & Dawson, 2010). In addition, studies summarised in Table 1.3 show decreases in positive mood states such as happiness, vigour and activation (Bohle & Tilley, 1993; Luna, French, & Mitcha, 1997; Paterson et al., 2010; Smith-Coggins, Rosekind, Hurd, & Buccino, 1994). Decreases in positive mood states are represented by the downwards arrow (↓) in the findings column in Table 1.3. The following section reviews studies investigating the relationship between shiftwork and mood and address shaded areas of the pathway demonstrated in Figure 1.9.

Table 1.3 Literature published investigating shiftwork and mood

First author, date	Shiftwork schedule	Mood measurement	Participants	Findings
Paterson, J., 2010	Rotating shiftworkers	Mood Scale II (Mood was measured on work days)	*n* = 20 (2 male); m = 44.5y	↑Fatigue increased on the night shift ↓Activation decreased on night shifts
Srivastava, U., 2010	Weekly rotating three shiftworkers and permanent day shiftworkers	Mood adjectives checklist Occupational stress index; presumptive stressful life events scale (Mood over the last week)	Day shift *n* = 100; m = 44.52y Night shift *n* = 100; m = 45.15y	↑Shiftworkers were more anxious, depressed, tense and angry ↑Shiftworkers had higher levels of job and life stress
Driesen, K., 2010	Day, three, five shift or irregular shiftwork schedules	Questionnaire (Mood experienced over the past two weeks)	Day shift*: n* = 6,404 (81.4% male); m = 42.45y Three-shift: *n* = 793 (91.8% male); m = 36.13y Five-shift: *n* = 985 (95.1% male); m = 38.06 y Irregular shift: *n* = 661 (67% male); m = 38.75	↑Depressed mood was higher in three-shiftworkers. Male shiftworkers were particularly at risk.
Nasrabadi, A., 2009	Night shiftworkers	Interview (Qualitative study asking participants to describe experiences)	*n* = 18 (5 males); 26–34y	↑Night shiftworkers reported chronic fatigue and stress
Geiger-brown, J., 2004	Permanent (day, evening and night shifts) and rotating shiftworkers	RCES-D depression scale (Mood over past two weeks)	*n* = 473 (females) m = 38y	↑Depressive symptoms were associated with working rotating shifts
Ruggiero, J., 2003	Day and night shift	Standard ShiftWork Index (Chronic Fatigue Scale) (general mood) Beck depression inventory (Mood over preceding two weeks) Beck anxiety inventory (Anxiety over last month)	Day shift: *n* = 67 (females) Night shift: *n* = 75 (females) m = 44.9y	↑Depressed mood was higher in night shiftworkers =Similar levels of fatigue and anxiety in both shifts

First author, date	Shiftwork schedule	Mood measurement	Participants	Findings
Bueno, J., 2003	Day and night shift	Present mood states list (Mood at beginning and end of each shift)	*n* = 10 (female); 23–36y	Participants were more tired and sleepy after night shift
Cavallo, A., 2002	Night float rotation and day time rotation	Questionnaire (Mood whilst on particular shift)	*n* = 52 (17 male); 25–40y	↑Participants were more tired and depressed on night float rotation
Luna, T., 1997	Rotating shiftworkers	Profile of Mood States (Mood whilst on particular shift)	*n* = 43 (male)	↑Fatigue and confusion increased on the night shift ↓Vigour decreased on the night shift
Florida-James, G., 1996	Night shift rotation	Profile of Mood States (Current mood)	*n* = 23 (one male); m = 20.4y	Circadian rhythms found in vigour-activity, fatigue-inertia, confusion bewilderment, friendliness and total mood disturbance
Smith-Coggins, R., 1994	Day shift and night shift	Mood Scales (Mood whilst on shift)	*n* = 6 (5 male); m = 34.0y	↓Happiness decreased on night shift
Bohle, P., 1993	Night shift	Profile of Mood States (Current mood)	*n* = 35 (female)	↑Fatigue increased on night shift ↓Vigour decreased on the night shift

Note: y = years; m = mean

Overall, various studies investigating shiftwork and mood demonstrate that shiftwork is associated with an increase in negative mood states such as depression, fatigue, stress and anxiety (Bohle & Tilley, 1993; Cavallo et al., 2002; Driesen, Jansen, Kant, Mohren, & van Amelsvoort, 2010a; Luna et al., 1997; Nasrabadi, Seif, Latifi, Rasoolzadeh, & Emami, 2009). Furthermore, whilst studies are limited, there is some evidence showing a decrease in positive mood when individuals work shiftwork (Luna et al., 1997; Smith-Coggins et al., 1994).

A recent study with a large sample size (*n* = 8,843) consisting of employees from a wide variety of sectors found that, although working a three-shift schedule showed higher rates of depression than other schedules included in the study, male shiftworkers were particularly at risk of depressive symptoms when compared to day workers (Driesen, Jansen, Kant, Mohren, & van Amelsvoort, 2010). However, the association between depressive symptoms and shiftwork was weaker when demographic characteristics such as long-term illness and psychosocial work characteristics (e.g. frequent overtime, social support and emotional, psychological and physical demands) were controlled for. These findings indicate psychosocial work characteristics particular to shiftwork should be considered. An understanding of predictors of mood in shiftworkers may help to determine how these may contribute to depression and other negative mood states. Shiftworkers in the abovementioned study had been involved in shiftwork for a number of years; therefore their depressive symptoms may have been underestimated. Long-term shiftworkers may have become accustomed to shiftwork and the lifestyle changes associated with shiftwork schedules. Longitudinal studies would be useful to determine if depressive symptoms are present when individuals begin shiftwork and if long-term shiftworkers are able to overcome these symptoms.

Similar to the above findings, depressive symptoms and fatigue were seen in a study investigating paediatric residents who were assigned to work day and night shift rotations (Cavallo et al., 2002). Whilst 85% of participants stated that they rarely felt depressed or moody during day rotations, 43% felt depressed or moody during night rotations. Over half of the residents participating in this study reported feeling more tired during night-shift rotations and of these participants 54% reported feeling depressed or moody. In contrast, a study investigating critical care nurses (Ruggiero, 2003) did not find differences in fatigue between day and night shiftworkers. The day and night shiftworkers also reported no differences in anxiety; however, night-shift nurses did report higher levels of depression. The majority of nurses who participated in this study worked 12h shifts and previous research has shown that shiftworkers working 12h shifts reported higher

levels of chronic fatigue than those working 8hr shifts (Iskra-Golec, Folkard, Marek, & Noworol, 1996). In addition, the authors noted that critical care shifts are demanding, and can result in high levels of fatigue regardless of shift schedule (Ruggiero, 2003). Although the timing of the shifts was not noted in this study, it is likely that many of the day working nurses had early morning starts due to the majority of shiftworkers in the current study working 12–13h shifts. There is evidence to suggest that early morning shifts are associated with reduced sleep because of early rises and the inability to compensate by going to sleep earlier due to domestic and social demands (Åkerstedt, 2003; Dorrian et al., 2008;) (see Section 1.7) this may also have led to higher levels of fatigue in the day shiftworkers. Indeed, both day and night shiftworkers in this study reported poor sleep quality. It is important for studies investigating shiftwork and mood to clearly state the timing of sleep episodes and sleep duration of participants, as these may be important confounding factors.

In addition to the above findings, a recent study investigating male participants working in Indian dairies concluded that shiftworkers working a rotating three-shift system had higher anxiety, stress, anger, tension and poorer overall general mental health when compared with day workers (Srivastava, 2010). In line with these findings, increased cortisol has been demonstrated in shiftworkers (Ulhôa, Marqueze, Kantermann, Skene, & Moreno, 2011). Cortisol is a hormone which increases with elevated levels of stress (Burke, Davis, Otte, & Mohr, 2005).

Various factors have been associated with increased levels of stress. Ulhôa et al. (2011) found that short sleep durations were associated with increases in cortisol. In addition, Srivastava (2010) reported that life stress was a key predictor for many of the negative mood states seen in shiftworkers. Although participants in Srivastava's (2010) study were similar in demographic variables (e.g. gender, age and number of years in the shift system), it would be useful to understand if female participants (particularly mothers) experience more life stress and negative mood states than men when employed in shiftwork. Indeed, there is evidence to suggest that mothers employed on evening shifts experience more work-family conflict than mothers employed on day shift (Barnett, Gareis, & Brennan, 2008) and this could lead to higher levels of stress and other negative mood states.

In addition to potential gender differences, shiftwork may have a greater impact on mood depending on cultural background. Female shiftworkers in family-orientated countries may experience more work-life conflict and therefore experience negative mood states such as depression and anxiety. Some cultures hold negative attitudes toward women working night shift

and spending time away from their family (Nikbakht Nasrabadi, Parsa Yekta, & Emami, 2004). Evidence for this was found in a qualitative study conducted in Iran. Female nurses in this study employed on night shifts stated that shiftwork resulted in a great deal of stress in daily living (Nasrabadi et al., 2009). Furthermore, the study concluded that night shift resulted in deleterious mental functioning for the participants. Nurses in this study were employed in night work involuntarily, and this may have had a greater impact on negative mood. On the other hand, if shiftworkers are working shifts by choice they may experience a greater level of positive mood. It may be useful to investigate the differences in mood for those who participate in shiftwork by choice and those who do not.

Taken together, the above findings suggest that shiftwork has been linked to some negative mood states. However, very few studies have examined if shiftworkers' mood varies depending on shift type. A recent study involving midwives employed in a hospital in South Australia (Paterson et al., 2010) working rotating shiftwork (morning, afternoon and night shifts) did not report experiencing variations in negative mood states such as depression depending on shift type. Contrary to previous studies suggesting that shiftwork can impact mood, participants in this study reported stable levels of positive mood across the various shift types. Nevertheless, the midwives in this study did report feeling more fatigued, and reported lower feelings of activation on night shifts. This study did not include any employees working day shifts, and only low levels of negative mood states were reported in the shiftworking midwives. Overall the study concluded negative mood (apart from fatigue) was not prevalent in this small sample of rotating shiftworkers. Although the majority of participants in this study were female, the number of dependents and marital status were not reported, therefore the impact of these factors cannot be determined. In addition, 13 of the 20 participants in this study were employed part time. Part-time employees who work shiftwork may not experience the same levels of life stress. Furthermore, these midwives reported only working approximately two night shifts in a row. Other studies showing decrements in mood have typically examined participants working night shifts for approximately one week (Driesen et al., 2010a) or permanent night shiftworkers (Ruggiero, 2003). Although self-reported sleep duration data were collected in this study, and sleep was included in the analyses, average sleep durations were not reported and therefore it is difficult to determine if participants were experiencing the sleep restriction often associated with night work (Knauth et al., 1980) and negative mood states (Dinges et al., 1997). However, the study did find a significant effect of sleep duration over the prior 24h on fatigue ratings, demonstrating that shorter sleep durations influenced this particular negative mood state.

Overall, there is evidence to suggest that shiftwork may result in negative mood states such as anxiety and depressive symptoms. Future research should investigate the specific components of shiftwork that lead to these negative mood states (i.e. sleep restriction, social support) as not all studies showed increased negative mood for shiftworkers. Future research employing longitudinal protocols would be useful in understanding causality. Additionally, determining gender and cultural differences that may impact mood when participating shiftwork would assist in the overall understanding of mood changes in shiftwork populations. Decreasing negative mood states will benefit the health of an individual, and increase the productivity at work and the work environment. On a larger scale, increasing positive mood in shiftwork populations could have broader economic and social benefits. Furthermore, given the relationship mood has with eating behaviour (see Section 1.5.1) a greater understanding on how to improve mood in shiftwork populations may benefit the health of shiftworkers.

The following section summarises shift schedule and shiftwork as predictors of sleep. This is the final relationship to be examined within this chapter.

1.7 Predictors of sleep

1.7.1 *The influence of shift schedule and shift type on sleep*

Shiftwork results in circadian disruption as shiftworkers are often required to work at times that directly oppose their body clock. In turn, shiftworkers often need to sleep at circadian phases when the body is designed to be awake. Shiftworkers also often experience high sleep pressure, particularly prior to the beginning of a night shift. Therefore it is not surprising that shiftworkers often experience disturbances to their sleep. Indeed, sleep restriction and decreased sleep quality is the most common complaint made by shiftworkers (Costa, 2010; Folkard, 2008). Sleep complaints have become such a significant issue for shiftworkers that Shiftwork Sleep Disorder has been included into the International Classification of Sleep Disorders. Shiftwork Sleep Disorder involves symptoms of excessive sleepiness or insomnia due to work schedules, and it is estimated that about 10% of night and rotating shiftworkers have this disorder (Costa, 2010). As discussed previously, shiftworkers work various shift types (e.g. morning, afternoon and night) and the effect on sleep may differ depending on the shift type. Additionally, shiftworkers work on various shift schedules and the speed and rotations of these systems has varying impacts on sleep. This section focusses on the factors indicated in the shaded areas of Figure 1.10.

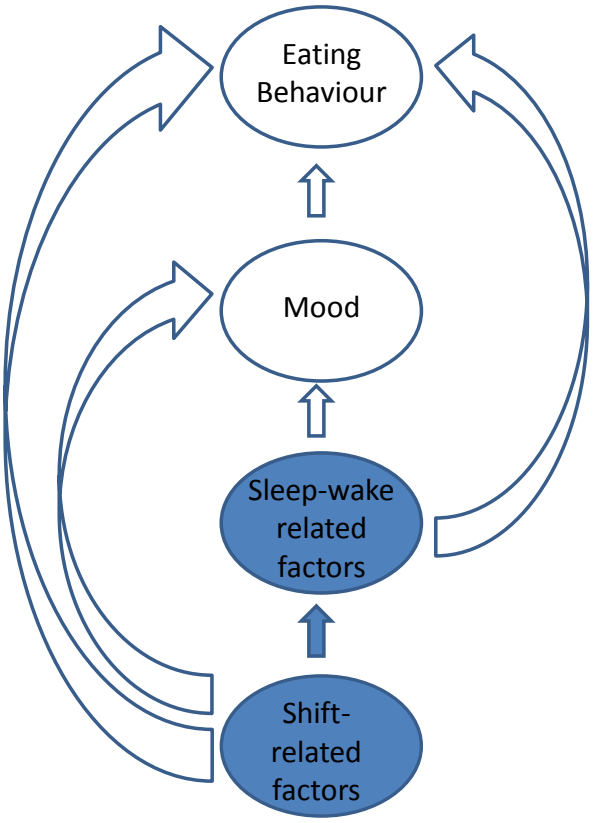


Figure 1.10 Shift-related factors as a predictor of sleep

Note: Shaded areas indicate the portion of the pathway discussed in this section

1.7.2 *The impact of night shift on sleep*

Night shiftworkers work in complete opposition to the internal body clock. Individuals on night shift typically begin their sleep episode an hour or two following the end of their shift (typically mid-morning). Therefore, the initiation of the night shiftworker's sleep episode coincides with the body's rising temperature phase, and as a result it is likely that increased awakenings will occur and the sleep episode will be shorter (Costa, 2010). Environmental factors such as noise and light are also likely to make initiating and maintaining sleep difficult for night shiftworkers (Sallinen & Kecklund, 2010). As a result night shiftworkers often report obtaining 2–4 h less sleep than day workers, Subjective sleep reports from night shiftworkers indicate poor sleep quality, with 50% reporting experiencing severe sleepiness (Härmä, Sallinen, Ranta, Mutanen, & Müller, 2002), most likely as a result of increased REM sleep and inferior NREM-2 sleep (Costa, 2010). As a consequence of decreased quality and quantity of sleep, and working through the circadian nadir, night shiftworkers report feeling sleepier at work when compared to day workers (Ohayon,

Smolensky, & Roth, 2010). In addition, night shiftworkers often report insomnia when trying to sleep at home (Tepas & Carvalhais, 1989; Torsvall, Åkerstedt, Gillander, & Knutsson, 1989).

As a result of difficulty initiating and maintaining sleep, sleep pressure (as discussed in Section 1.3.2) is frequently high for night shiftworkers. Additionally, many night shiftworkers state they do not sleep before their shift begins; resulting in a sleep debt before they begin a schedule of night shifts (Knauth et al., 1980). Indeed, some night shiftworkers may be awake for up to 20h before their shift even begins (Åkerstedt, 2003). Reports of sleepiness are even prevalent on days off for night shiftworkers and normal levels of sleepiness are often not returned until two nights of sleep have occurred following the final night shift (Åkerstedt, 2003).

1.7.3 *The impact of morning shift on sleep*

Similar to night shifts, morning shifts are also associated with a reduction in sleep of 2–4h (Åkerstedt, 2003; Fischer, Bruni, Berwerth, de Castro Moreno, Fernandez, & Riviello, 1997; Knauth & Rutenfranz, 1981; Tilley, Wilkinson, & Drud, 1981; Yeung, Sletten & Rajaratnam, 2011). Morning shiftworkers need to rise very early (e.g. between 04:00 and 05:00); however, it is difficult to initiate sleep earlier in the evening to compensate for these early wake times. If morning shiftworkers attempt to advance their sleep episodes this will coincide with the forbidden sleep zone; a time when the circadian system is promoting wake (Shekleton et al., 2013) (see Section 1.3.2). Family and social commitments in the evening also make it difficult for morning shiftworkers to go to bed earlier (Costa, 2010). Wake times for morning shiftworkers are close to the circadian nadir when the body clock is promoting sleep, making it difficult to terminate sleep. Consequently, morning shiftworkers subjectively report difficulty awakening and not feeling refreshed upon waking (Åkerstedt, 2003). Furthermore, morning shiftworkers report high levels of sleepiness and fatigue for the rest of the day (Costa, 2010). Similar to night shiftworkers, morning shiftworkers attempt to compensate for their loss of sleep with a nap in the afternoon (Dorrian et al., 2008).

1.7.4 *The impact of afternoon shift on sleep*

In contrast to morning and night shifts that have been associated with reduced sleep, afternoon shift does not appear to disturb sleep. Studies demonstrate that shiftworkers on afternoon shift have longer sleep durations than morning or night shifts (e.g. Dorrian et al., 2008). However, if the shift ends late (e.g. 11:00 or 12:00) and a long commute home follows the shift, the sleep episode will be delayed and sleep may be more difficult to initiate (Costa, 2010).

1.7.5 *The impact of shift schedule on sleep*

There are various shift schedules shiftworkers may be employed to work (to further understand shift schedules refer to Section 1.4.1). In addition to shift type, factors relating to the shift schedule also influence sleep. For example, the speed of rotation, recovery sleep opportunities in between shifts, shift duration and number of consecutive shifts worked in a row are all factors that may play an important role in the sleep of shiftworkers (Barton & Folkard, 1993; Fischer, deCastro Moreno, da Silva Borges & Louzada, 2000;Knauth & Hornberger, 2003; Sallinen & Kecklund, 2010).

Shiftworkers on rotating shifts have more disruption to their sleep-wake cycle and therefore obtain less sleep and have poorer sleep quality than those on permanent shifts (Gold et al., 1992). Furthermore, it has been reported that shift schedules that change between shifts frequently (fast rotating or irregular shift schedules) are most likely to affect sleep (Moreno, Matuzaki, Carvalho, Alves, Pasqua & Lorenzi-Filho, 2003; Wilkinson, 1992). For example; shiftworkers on fast rotating shift schedules reported obtaining approximately 5.8h sleep compared to weekly rotating shiftworkers who obtained 6.3h sleep and permanent night shiftworker who reported 6.7h sleep (Wilkinson, 1992). Concurring with these findings Moreno et al. (2003) found that truck drivers on an irregular schedule (working at any time according to the tasks demands) had shorter sleep durations when compared to workers on permanent day shift schedules.

The direction of rotation is also likely to impact on sleep. If a shiftworker is on a backward rotating shift schedule there may be more opportunity to sleep due to extended rest periods in between shifts. On the other hand, if a shiftworker works a fast backward shift rotation there is limited time for sleep. For example, a fast backward rotating roster may require a shiftworker to work an afternoon shift followed by a morning shift, and as a result the rest interval will only be 8h (Costa, 2010). However, differing shift start length and start times on shifts may impact the available time for sleep. Forward rotating shift schedules (morning shift followed by afternoon then night shift) are not only thought to be more beneficial due to extra sleep time, they are also thought to be more compatible with circadian rhythms as they result in a circadian phase delay. Circadian phase delays result in the minimum core body temperature occurring earlier (Czeisler & Dijk, 1995). Studies suggest that humans tend to adapt to delays in circadian phase more easily than they advance (Mitchell et al., 1997; Eastman & Martin, 1999).

In summary, night shiftworkers work in complete opposition to the circadian system, and therefore sleep episodes fall at times when the body is designed to be awake. Environmental factors such as noise and light also make it difficult for night shiftworkers to remain asleep. Morning shiftworkers may find it difficult to initiate sleep due to attempting to begin sleep episodes in the forbidden sleep zone and due to family and social obligations. Afternoon shiftworkers do not often experience sleep disturbances but they may have difficulties if they have a long commute home. Disruption to the circadian system, lack of sleep before night shift begins and environmental factors can result in disturbances in the quantity and quality of shiftworkers' sleep.

This section has discussed the effect of predictors of eating behaviour that this thesis investigates. In addition, the relationships the predictor variables have with each other were discussed. This discussion provides evidence for a pathway (see Figure 1.11) for examination by this thesis. The following section outlines the research aims, which relate to the examination of this pathway, as illustrated in Figure 1.11 (a copy of Figure 1.4).

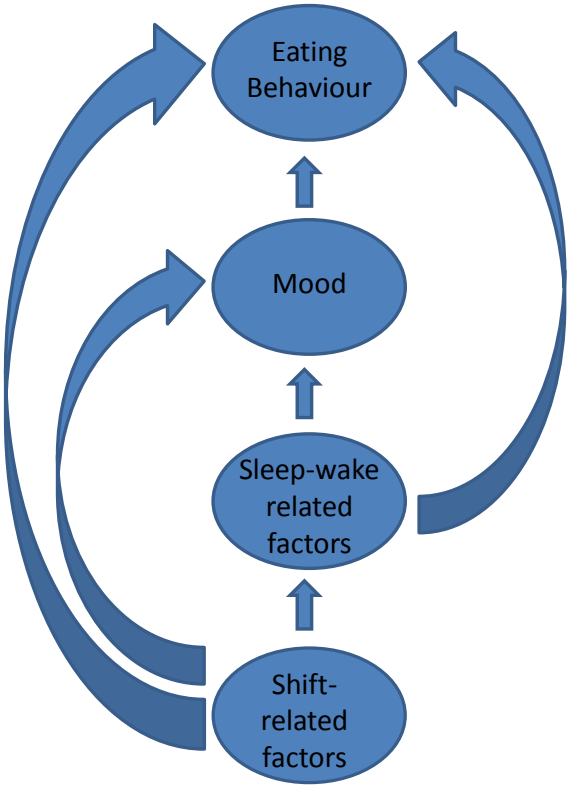


Figure 1.11 Pathway of factors examined in this thesis

1.8 Research aims

The first aim of this thesis is to *determine predictors of eating behaviour in shiftworkers*. Specifically, this thesis attempts to understand if the factors identified throughout this chapter: mood, sleep, circadian disruption and shiftwork, predict eating behaviour in shiftworkers. The proposed pathway is outlined in Figure 1.11. The second aim of this thesis is to *examine the relationships these variables have with each other*.

As discussed in Section 1.6.3 negative mood states such as depression, stress and fatigue are often reported by shiftworkers (Nasrabadi et al., 2009; Paterson et al., 2010). Negative mood states have been found to predict alterations in eating behaviour. For example depressive mood has been linked to increased cravings and consumption of energy-dense sweet foods (Jeffery et al., 2009; Willner et al., 1998). Stress has been linked to overeating and consumption of high-fat sweet foods (Heatherton et al., 1991; Wardle et al., 2000). Carbohydrates have also been found to be consumed to decrease feelings of fatigue (de Castro, 1987; Wurtman & Wurtman, 1989).

In addition to the above, and based on literature overviewed in Section 1.7, shiftworkers report obtaining less sleep and poorer sleep quality when compared to day workers (Åkerstedt, 2003). Studies have found that individuals subject to total sleep deprivation or sleep restriction reported increases in hunger (Hogenkamp et al., 2013; Spiegel, Tasali et al., 2004) and increased their energy intake (Markwald et al., 2013; Spaeth et al., 2013). In addition, sleep deprivation and restriction alter food choice such that alterations in macronutrient content of food has been demonstrated following total sleep deprivation and sleep restriction (Brondel et al., 2010; St-Onge et al., 2011) (see Section 1.5.3.)

Furthermore, shiftworkers work in direct opposition to their endogenous circadian system (Roden et al., 1993; Sack et al., 1992). Therefore they may be consuming foods when the body is designed to be sleeping. This results in food consumption at sub-optimal circadian phases. Research in this area is minimal; however, there is some evidence to suggest individuals consume more energy at night and make poorer food choices (Baron et al., 2011) (see Section 1.5.4).

As discussed in Section 1.4.1, shiftworkers can work on various shift schedules and shift types (Åkerstedt, 2003). Various studies (reviewed in Section 1.5.4) suggest that these varying shift schedules and shift types predict alterations in eating behaviour. For example, shiftworkers have been found to consume fewer vegetables on night shift (Balieiro et al., 2014) and appetite has

been found to decrease on rotating shift schedules (Attia, Mustafa, Khogali, Mahmoud, & Arar, 1985).

As a result of the examination of the literature in this chapter, this thesis proposes three hypotheses. The hypotheses and the studies examining them are listed below.

1.8.1 *Hypothesis 1*

Hypothesis 1 consists of four sub-hypotheses.

- Hypothesis 1a (Chapters 6 and 7): Mood will predict the eating behaviour in shiftworkers.
- Hypothesis 1b (Chapters 3, 4, 6 and 7): Sleep-wake related factors (e.g. sleep duration, sleep quality, sleep efficiency, prior wake) will predict eating behaviour.
- Hypothesis 1c (Chapter 4): Circadian phase will predict eating behaviour.
- Hypothesis 1d (Chapters 6 and 7): Shiftwork (shift schedule, shift type) will predict eating behaviour.

1.8.2 *Hypothesis 2*

Hypothesis 2 consists of three sub-hypotheses based on factors related to shiftwork predicting mood.

- Hypothesis 2a (Chapter 5): Sleep-wake-related factors will predict mood.
- Hypothesis 2b (Chapter 5): Circadian phase will predict mood.
- Hypothesis 2c (Chapter 7): Shiftwork (shift schedule, shift type) will predict mood.

1.8.3 *Hypothesis 3*

Hypothesis 3: (Chapter 7): Shiftwork will predict sleep (sleep duration, sleep quality, sleep efficiency).

Chapter 2
General methodology

2.1 Study protocols

Four study protocols were employed to collect data for this thesis. Data for Studies 1 and 2 were collected in a laboratory environment using healthy young male participants. Data for Studies 3 and 4 were conducted in a field environment using shiftwork participants. Table 2.1 provides a summary of each study protocol. This chapter details ethical considerations, participant recruitment, study conditions, procedures and measures.

Table 2.1 Overview of study protocols

Study	Participants	Setting	Mood measure	Sleep-wake measure	Circadian phase measure	Eating behaviour measure
Study 1	Healthy young males *n* = 12	Laboratory	n/a	Sleep duration (hours) (PSG)	n/a	Hunger (VAS) Energy and macronutrient intake (food analysis)
Study 2	Healthy young males *n* = 22	Laboratory	POMS	Sleep duration (hours) (PSG) Prior wake (hours)	Core body temperature (rectal thermistor)	Snack consumption (observation) Snack choice (observation)
Study 3	Shiftworkers (various industries) *n* = 118	Field	Chronic Fatigue Scale	Sleep duration (hours: self-report) Sleep quality (scale)	n/a	Energy and macronutrient intake (dietary questionnaire)
Study 4	Shiftworking nurses *n* = 42	Field	Anxiety, stress, depression, tiredness, happiness (VAS)	Sleep duration (actigraphy) Sleep efficiency (percentage of time in bed spent asleep: actigraphy)	n/a	Energy and macronutrient intake (food diary)

Note: TIB = time in bed; POMS = Profile of Mood States; VAS = visual analogue scales; PSG = polysomnography

2.2 Ethical considerations

All studies included in this thesis were granted ethics approval by the University of South Australia's Human Research Ethics Committee. Studies 3 and 4 were also granted ethics approval by SA Health and the relevant ethics committees of the hospitals involved (Royal Adelaide Hospital, The Queen Elizabeth Hospital, Lyell McEwin Hospital and Modbury Hospital Human Research Ethics Committees) in accordance with guidelines established by the National Health and Medical Research Council of Australia.

Prior to participation in all studies, volunteers were provided with an information sheet (Appendices D, E, F, G). Participants in Studies 1 and 2 had one-on-one interviews with a member

of the research team, at which time the equipment involved in the study and the laboratory conditions were explained. Participants were shown the laboratory and given the opportunity to ask questions about the study. Participants in all studies, apart from Study 3, were required to complete a participant consent form (Appendices H, I, J) prior to participation to state that they understood the procedures of the study, that their participation was voluntary and that they were free to withdraw from the study at any time. As advised by the University of South Australia Human Research Ethics Committee, the consent form was not a requirement for participants in Study 3, as participation was anonymous and questionnaire-based only.

Participants in Study 3 were recruited following attendance at a general information session held by a member of the research team at the shiftworker's workplace, or were informed about the study via their manager at their place of employment, as deemed appropriate by the participating organisation. In the instance of a manager explaining the study to staff, a meeting was held between the manager and a member of the research team to ensure the manager understood the details of the study. Participants in Study 4 attended a general information session in the wards of each of the hospitals. Interested volunteers attended a further one-on-one interview with a member of the research team. During the interview the study was explained in detail and participants were given the opportunity to ask questions about the study.

2.3 Safety considerations

2.3.1 *Laboratory studies: Studies 1 and 2*

Depending on the condition participants were assigned to, participants in Studies 1 and 2 may have been exposed to sleep restriction. Therefore, all participants in Studies 1 and 2 were provided with taxi vouchers for their journey to and home from the laboratory. Prior to commencement, all members of the research team were trained in safety procedures (e.g. evacuations, blood handling). Induction sessions were held at the beginning of each protocol for participants. Participants were briefed in relation to evacuation procedures, and a fire drill was performed to ensure the participants were familiar with what would happen in the event of an emergency. Infra-red cameras were installed in bedrooms and living areas in the laboratory, and a member of the research team monitored participants at all times. At the end of each study a de-briefing session was held with participants explaining the potential effects of sleep restriction (e.g. sleepiness, mood fluctuations). Additionally, participants were provided with information about how to return to a normal sleep routine. Participants were told they could telephone or visit a

member of the research team at any time following the study if they had any questions or concerns regarding possible effects of participating in the study. Participation in Study 2 involved the use of capsules to record body temperature. The data for this is not published in this thesis; however, has been published elsewhere (Darwent, Zhou, Heuvel, Sargent, & Roach, 2011). All participants were checked to ensure capsules were no longer in their system prior to leaving the laboratory. If the research team could not confirm the absence of a capsule, participants were provided with a wrist-band stating they would be unable to have an x-ray and asked to return to the laboratory on a specified date to allow the research team to check that the capsule was no longer in their system.

2.3.2 *Field studies: Studies 3 and 4*

Data collection for Studies 3 and 4 were arranged in consultation with the organisations involved in each study to ensure minimum disruption to both participants and the organisation. For both field studies, the data collection protocol was approved by either the nursing director at each hospital or by the manager of the field location. Study 3 involved an anonymous questionnaire, which was completed in the participant's own time and returned via reply paid envelope, therefore no specific safety considerations were required. Study 4 involved wearing a wrist activity monitor (Actiwatch 2, Respironics Inc., USA, 2009) (see Figure 2.1) and completing a sleep, mood and food consumption diary as part of a daily log book (Appendix K). Approximately three of the hospital wards did not allow watches to be worn on the wrist due to occupational health and safety procedures, therefore the wrist activity monitor could not be worn on the wrist during work times at these locations (this equated to approximately 15 participants in total). When these procedures applied, participants wore the activity monitor on an alternative area during work hours (e.g. on their belt strap or pinned to their shirt). As participants indicated the times they were at work (as part of their log book) it was determined they were awake during the time they wore their activity monitor in the alternative location and thus results were not affected.



Figure 2.1 Actiwatch 2 (Respironics, USA, 2009)

Note: Participants were provided with an actiwatch to wear around their non-dominant wrist to measure sleep-wake activity prior to Studies 1 and 2 and during Studies 1, 2 and 4

2.4 Participant recruitment

2.4.1 *Studies 1 and 2*

Potential participants for Studies 1 and 2 were recruited by the placement of flyers advertising the studies at universities and backpacker hostels. Interested volunteers initially contacted the research team via phone or email. The research team then emailed interested volunteers a study information sheet (Appendices D and E), general health questionnaire (GHQ; Appendix L and M), and a consent form (Appendices H and I). As it was important to ensure participants were able to consume all food provided in Study 1, volunteers interested in this study were also sent a dietary questionnaire containing a list of all foods provided in the buffet (Appendix N) and all foods used in meals within the study (Appendix O), which enabled them to indicate any food they would prefer not to consume during the study. When GHQs were returned to the research team they were screened to determine suitability for the study. If inclusion and exclusion criteria were met, the volunteers were invited to the laboratory for a meeting with the research team for a screening interview. Additionally, participants were able to learn further details about the study and invited to view the laboratory environment. If volunteers were suitable and still interested in participating in the study, they were contacted to complete a sleep diary (Appendix P) and wear a wrist activity monitor (Actiwatch 2, Respironics Inc., USA, 2009) to measure sleep and wake patterns for one week prior to the study.

2.4.2 *Study 3*

Potential participants for Study 3 were recruited in two different ways depending on the organisation. Three of the six organisations allowed the research team to conduct information sessions at the workplace. The remaining three organisations preferred the research team to discuss the study with a manager who would then explain the study to employees. Following the information sessions, interested volunteers were provided with an information pack containing a study information sheet (Appendix F), a modified version of the Standard ShiftWork Index (SSI) (Barton, Folkard, Smith, Spelten, & Totterdell, 1993) (Appendix Q), Cancer Council Dietary Questionnaire for Epidemiological Studies (CCDQ) (Appendix R) (Giles & Ireland, 1996) and a reply paid envelope.

2.4.3 *Study 4*

Participants were recruited for Study 4 via information sessions held within wards at the hospitals involved in the study. During this information session the background and importance of the study were explained to participants along with a brief explanation of the protocol. Participants were shown equipment to be used in the study (wrist activity monitor and log book) and given the opportunity to ask questions. Following the information sessions participants were given the option of having a one-on-one meeting with the research team on the day of the information session. Alternatively, they could contact the research team at a later date to arrange a one-on one meeting. During the one-on-one meeting participants were provided with a study pack, which contained a participant information sheet (Appendix G), consent form (Appendix J), log book (Appendix K) and wrist activity monitor (Actiwatch 2, Respironics Inc., USA, 2009). The details of the study and use of these materials were explained thoroughly at the one-on-one meeting.

2.5 Inclusion/exclusion criteria

2.5.1 *Studies 1 and 2*

Young healthy males aged between 18 and 35 years were recruited as participants in Studies 1 and 2. Females were excluded from these studies to avoid any influences of the menstrual cycle confounding with variables of interest (e.g. eating behaviour and/or mood) (Buffenstein, Poppitt, McDevitt, & Prentice, 1995; Dye & Blundell, 1997; Gallant, Hamilton, Popiel, Morokoff, & Chakraborty, 1991; Ross, Coleman, & Stojanovska, 2003). Participants in both studies were required to be physically healthy, and therefore included those within the healthy weight range (BMI between 19 and 24 kg/m^2) (World Health Organisation, 2015). Participants were excluded if

they reported any medical conditions, or were currently taking any medications or non-prescription drugs. Additionally, participants were required to be psychologically healthy. Consequently, participants were excluded if they reported any mood disorders (e.g. anxiety or depression).

To be included in the laboratory studies participants were required to have normal sleeping patterns. Sleeping patterns were considered normal if the participants demonstrated (via actigraphy) regular sleep times and obtaining between 7 and 9h sleep per night (National Sleep Foundation, 2015). As part of the GHQ, participants completed the Pittsburgh Sleep Quality Index to assess their sleep quality. The Pittsburgh Sleep Quality Index consists of seven subscales measuring various sleep domains (e.g. sleep disturbance, sleep latency). Each of these subscales are then used to calculate a global score. Global scores above five indicate that the individual is a 'good sleeper' as opposed to a 'poor sleeper' (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Poor sleepers were excluded from the study. In addition, the Epworth Sleepiness Scale was completed by participants to measure levels of daytime sleepiness. Participants were excluded from the study if they had a score higher than 10 on the Epworth Sleepiness Scale, as this indicates increased daytime sleepiness (Johns, 1991).

In order that the protocol not impose too large a change on participants, they were not frequent consumers of alcohol (e.g. >2 standard drinks per day) (National Health & Medical Research Council, 2014). Participants were also excluded if they participated in more than 1h of moderate exercise per day (as they would not be able to exercise during the study). Additionally, the protocol required abstinence from caffeine, and therefore participants included in this study did not report habitually consuming more than 300 mg of caffeine per day. To ensure participants were not experiencing circadian disruption, individuals were excluded from the study if they had worked shiftwork or had participated in transmeridian travel during the three months prior to the beginning of the study. Similar exclusion/inclusion criteria has been used in previous laboratory studies (Lamond et al., 2007; Reynolds et al., 2012).

2.5.2 *Study 3*

Participants for Study 3 were shiftworkers employed at the various organisations involved in this study. Participants were excluded from the study if they were under the age of 18 years.

2.5.3 *Study 4*

Participants for Study 4 were employed as nurses at the hospitals in which the study was conducted. Participants were excluded from the study if they were under the age of 18 years, pregnant or had a medical condition which may interfere with sleeping patterns or diet (e.g. Crohn's Disease).

2.6 Experimental conditions

2.6.1 *Study 1*

Data for Study 1 were collected over an eight-month period at the Centre for Sleep Research, Adelaide, South Australia. The Centre for Sleep Research is located at the University of South Australia (City East Campus). The study consisted of a control condition (8h sleep opportunity) and a sleep restriction condition (4h sleep opportunity). An overview of the protocol is provided in Figure 2.2. The X axis of the diagram indicates the time of day over a 24h period, and the Y axis indicates the experimental day. The black bars represent sleep opportunities and the shaded area represents the extra time in bed the control condition participants were provided with. Unfilled areas represent wake periods.

This thesis focuses only on the buffet meal testing sessions (represented by the letter 'B') in Figure 2.2. The buffet meal-testing sessions occurred on both the second training/adaptation day and on the recovery day at 12:00. Participants also completed a series of five test batteries per day during the experimental period of the study as part of a larger study. Results of the larger study form part of other publications (Kosmadopoulos, Roach, Heath, & Sargent, 2011). Testing did not occur during the mornings of the study, as the participants were required to take part in glucose tolerance testing and blood draws (as part of the larger study). When participants were not involved in testing sessions they were permitted to undertake quiet activities such as watching DVDs, reading, drawing or writing in their own private living rooms. As caffeine and exercise have stimulating effects, participants were not permitted to exercise or consume caffeine at any time during the protocol. In addition, participants were not permitted alcohol during the study, as alcohol may have impaired performance in the cognitive tasks (performed as part of the larger study). To ensure compliance to the protocol, participants were monitored by a closed circuit television system.

Participants in both conditions were served an identical buffet meal on two occasions during the study. The first buffet meal was served at 13:00 after the first sleep opportunity in the laboratory

and following a 17h fast. During the remainder of the study, participants were provided with a kJ-controlled diet following dietary guidelines to suit sedentary males between the ages of 18 and 35 within a healthy BMI range (Australian National Health and Medical Research Council and the New Zealand Ministry of Health, 2006).

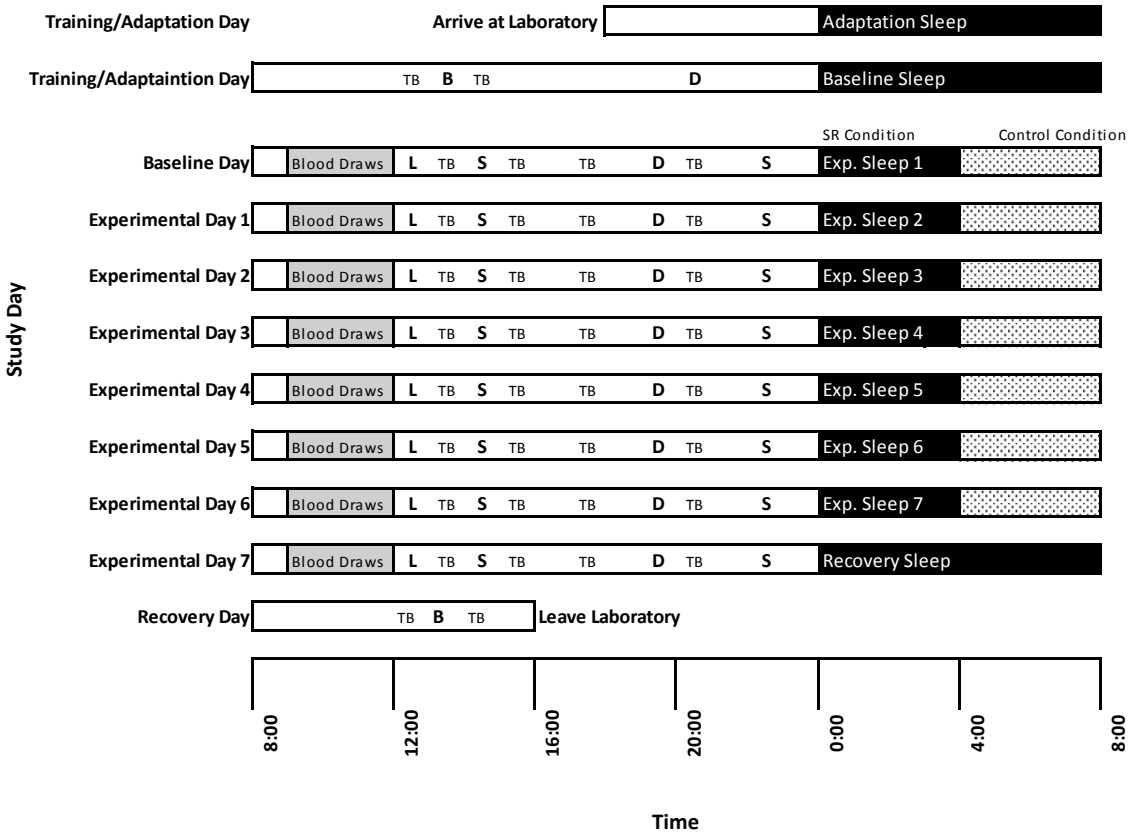


Figure 2.2 Protocol diagram for Study 1

Notes: Unfilled areas represent wake periods; black filled areas represent sleep episode for both conditions; shaded areas represent extra time in bed for control condition
SR = sleep restriction; TB = test battery; B = buffet meal; L = lunch S = snack; D = dinner; Exp. = experimental

Approximately 1h prior to bedtime (23:00 during the control condition and (03:00 in the sleep-restriction condition) participants were prepared for their sleep episodes, during which their sleep was recorded using PSG (described in detail in Section 2.7.4) Participants slept in their own private bedrooms, and were required to remain in their rooms until lights were turned on and a researcher entered the room to wake them. Infra-red cameras were used during all sleep episodes to monitor the participants. In addition, an intercom system connected to the control room could be used if a participant needed to contact a member of the research team during the night (e.g. to use the bathroom).

2.6.2 *Study 2*

Data for Study 2 were collected over a two-year period at the Centre for Sleep Research. Participants were randomly allocated into one of two conditions. The study employed an FD protocol (for further information on this protocol design refer to Section 1.3.3). Participants were provided with either the equivalent of a 6h sleep opportunity per 24h day which is referred to as the 'moderate sleep restriction'; alternatively participants were provided with the equivalent of a 4h sleep opportunity per 24h day, which is referred to as the 'severe sleep restriction' condition. The protocol for Study 2 is illustrated in Figure 2.3. The X axis represents the time of day over a 24h period, and the Y axis represents the study day. The black bars represent sleep opportunities and the shaded areas represent the extra time in bed the moderate sleep restriction condition was provided with. Unfilled bars represent wake periods.

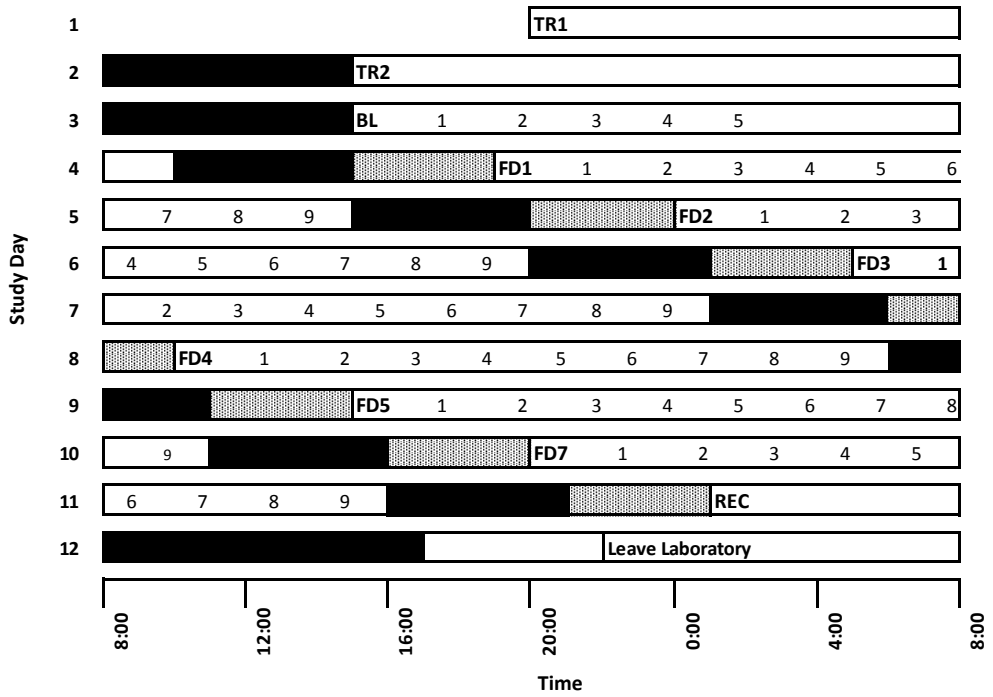


Figure 2.3 Protocol diagram for Study 2

Notes: Unfilled areas represent wake periods; black filled areas represent sleep episode for both conditions; shaded areas represent extra time in bed for moderate sleep restriction condition
Numbers represent test batteries
TR = training day; BL = baseline; FD = forced desynchrony study day; REC = recovery

During each wake episode the participants completed a series of test batteries every 1.5h after waking and every 2.5h thereafter. These test batteries are indicated in Figure 2.3 by the numbers 1–9. The test batteries included the mood task along with other neurobehavioural tests (as part of

a larger study). Results from other neurobehavioural tests have been published elsewhere (Paech et al., 2012; Sargent et al., 2010; Zhou et al., 2011). In the moderate sleep restriction condition, participants completed eight test batteries per wake episode. However, due to the extended time awake, participants in the severe sleep restriction condition completed nine test batteries per wake episode. Similar to Study 1, participants were able to undertake low intensity activities when they were not completing test batteries. Participants in Study 2 were also monitored by a closed circuit television system to ensure compliance to the protocol (e.g. to ensure participants did not nap during wake episodes).

Throughout the study, participants were restricted from eating *ad libitum*. Food consumption in Study 2 was not kJ controlled; however, in both conditions participants were served three standardised meals (i.e. breakfast, lunch, dinner) at the same elapsed time into each wake period (i.e. 0.5h, 7.5h, 15h). Breakfast consisted of a choice of toast, fruit yoghurt and cereal; lunch consisted of a choice of salad and cold meats for sandwiches, soup and noodles; and dinner consisted of a hot meal of rice or pasta served with meat and vegetables. In addition to meals, snack opportunities were provided at the same elapsed time into each wake period (i.e. 2.5h, 5h, 10h, 12.5h, 17.5h) in both conditions. Participants in the severe sleep restriction condition were provided with an extra snack opportunity at 20:00. Participants were required to choose and consume their snack individually to ensure their decision was not influenced by others.

Approximately 1h prior to bedtime in both conditions, electrodes were applied to participants for recording of sleep via PSG. In line with Study 1, participants slept in their own private bedrooms, and were required to remain in their rooms until lights were turned on and a researcher entered the room to wake them. Infra-red cameras were used during all sleep episodes to monitor the participants, and the intercom system was located next to the participants' beds.

2.6.3 *Study 3*

Data collection for Study 3 was conducted over a two-year period. The study included six organisations. Figure 2.4 outlines the protocol for Study 3. First, participants attended an information session at their workplace. Interested participants were then provided with an information pack, which included a reply paid envelope. Participants completed an anonymous questionnaire in their own time, which took them approximately 40 minutes to complete. Participants were asked return the questionnaire to the research team in the supplied reply paid envelope.

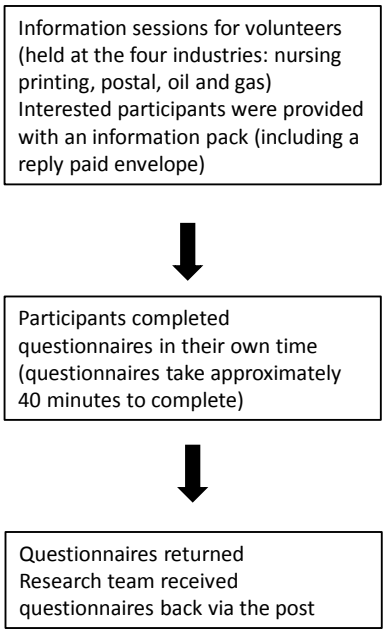


Figure 2.4 Protocol diagram for Study 3

Note: This study was a questionnaire-based study that required participants to complete a 40-minute anonymous questionnaire in their own time. Questionnaires were then returned via post to the research team

2.6.4 *Study 4*

Study 4 was conducted over a nine-month period in three metropolitan hospitals located in Adelaide, South Australia. The duration of the study was 14 days, and during this time participants were asked to monitor sleep, mood and diet during different shift types. Following the recruitment procedure participants could complete the protocol at a time which best suited them. Participants were issued a wrist activity monitor (Actiwatch 2, Respironics Inc., USA, 2009) and log book (Appendix K) at the commencement of the study. Those participating in this study were required to wear the activity monitor for the entire 14 days of the study (except when it might get wet, e.g. showering, swimming). The log book contained the work and sleep diaries that participants were asked to complete daily. Mood diaries were only completed on working days. The mood diaries consisted of a series of VAS to measure the five mood domains of interest. The food diary section of the log book was required to be completed for a maximum of three days per shift type (i.e. morning, afternoon and night shifts) and on one day off during the two-week study period. Participants were asked to record their dietary intake for three days, as it has been suggested that at least two days of recording is required to estimate the typical dietary intake of a population (Erdman Jr et al., 2012). Therefore, 10 days was the maximum number of days the food diary was completed and the minimum was four days (see Figures 2.5 and 2.6). Figures 2.5

and 2.6 demonstrate the protocol for two example participants. Figure 2.5 represents the maximum amount of times a participant may have completed the various measurements. Figure 2.6 represents the minimum amount of days a participant may have completed the various measurements. Measurements used within the study are listed on the top of the figure and the 'X' indicates the day (study day is indicated on the Y axis) a participant completed the measure.

Study Day	Shift Type	Activity Monitor	Sleep Diary	Mood Diary	Food Diary
1	Afternoon	X	X	X	X
2	Afternoon	X	X	X	X
3	Morning	X	X	X	X
4	Morning	X	X	X	X
5	Day Off	X	X		X
6	Day Off	X	X		
7	Afternoon	X	X	X	X
8	Morning	X	X	X	X
9	Day Off	X	X		
10	Day Off	X	X		
11	Day Off	X	X		
12	Night	X	X	X	X
13	Night	X	X	X	X
14	Night	X	X	X	X

Measurement

Figure 2.5 Protocol for Study 4: Maximum

Note: Example of a participant who worked shifts during the protocol requiring completion of the food diary the maximum amount of times possible

Study Day	Shift Type	Activity Monitor	Sleep Diary	Mood Diary	Food Diary
1	Morning	X	X	X	X
2	Morning	X	X	X	X
3	Day Off	X	X		X
4	Morning	X	X	X	X
5	Morning	X	X	X	
6	Morning	X	X	X	
7	Morning	X	X	X	
8	Day Off	X	X		
9	Day Off	X	X		
10	Morning	X	X	X	
11	Morning	X	X	X	
12	Morning	X	X	X	
13	Day Off	X	X		
14	Day Off	X	X		

Measurement

Figure 2.6 Protocol for Study 4: Minimum

Note: Example of a participant who worked shifts during the protocol requiring completion of the food diary the minimum amount of times possible

2.6.5 *The laboratory environment: Studies 1 and 2*

In both Study 1 and Study 2 participants were required to remain in the sleep laboratory at the Centre for Sleep Research (University of South Australia, City East Campus) for the entire duration of the protocol (see Figure 2.7 for a floor plan of the protocol). As indicated in Figure 2.7, the laboratory consists of six bedrooms. However, in Studies 1 and 2, three of the bedrooms were converted to living rooms, because the participants completed the protocol in groups of three. This design allowed the participants to have their own private space for sleeping, relaxing and completing their test batteries throughout the experiment. As participants lived in the laboratory for 14 days, they were allocated their own toilet and shower for personal comfort (either in the ensuite or in the bathroom). Meals were consumed communally at a dining table within the kitchen area of the laboratory. However, as mentioned previously, snacks were consumed individually in the participant's living rooms to ensure they were not influenced by the snack choice of others. The test batteries were completed in the participants' bedrooms, which included a computer (for computer-based tasks) and a desk for written tasks. Each living room contained a comfortable chair and a table. In addition, a television and DVD player were provided in each of the living rooms.

The laboratory was sound attenuated, and remained temperature controlled (22 ± 1°C) at all times. In addition, the laboratory was light controlled in both studies such that light intensity was maintained at 10–15 lux at angle of gaze in wake periods and <0.03 lux during sleep episodes. Comparable temperature and light levels have been used in previous studies (Boivin & Czeisler, 1998; Boivin, Duffy, Kronauer, & Czeisler, 1996). For similar reasons, participants did not have access to time cues throughout the study (e.g. no clocks, telephones, sunlight). Furthermore, members of the research team were instructed and trained not to provide participants with any time-of-day information.

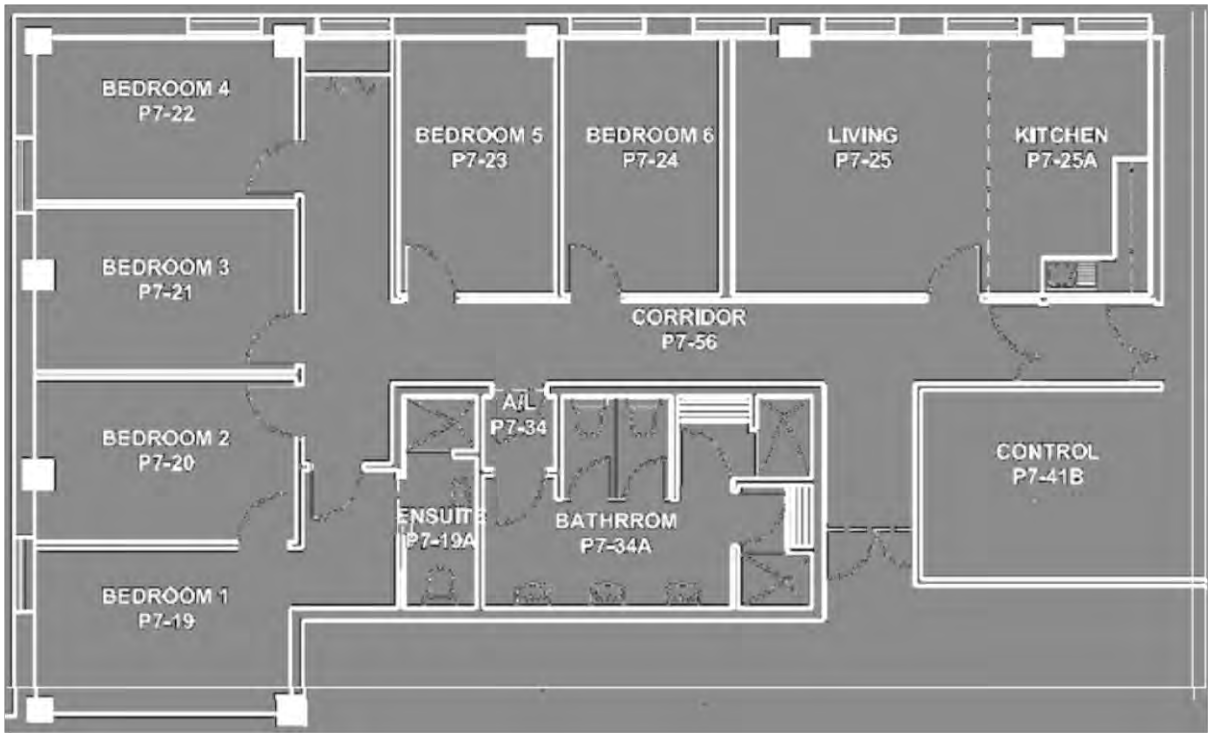


Figure 2.7 Floor plan of the laboratory environment

Notes: Bedrooms 1, 5 and 6 were converted to living areas. Sleep was monitored in the control area, the control area is located outside of the sleep laboratory. Participants were provided with their own shower and toilet in either the bathroom or ensuite. Meals were consumed in the kitchen. Snacks were consumed individually in the participant's living room. The living room area was used for some of the testing sessions that formed part of the larger study

2.7 Measures

2.7.1 *Screening measures*

The laboratory studies (Studies 1 and 2) required participants to be screened prior to participating in the study (see inclusion/exclusion criteria above). Participants in the laboratory studies were

required to complete adapted versions of the GHQ (Appendices L and M) (Goldberg & Williams, 2000). The GHQ includes questions relating to general health and lifestyle factors that could affect the results of these studies. For example, participants are asked questions relating to stress and workload such as, 'Are you currently experiencing a greater than your normal amount of stress? (e.g. sick relative, relationship break-up, getting married, moving house)' and are required to tick a box indicating either yes or no.

A Chronbach's alpha score of between 0.82 and 0.86 has been reported for the GHQ, demonstrating good internal reliability. In addition, concurrent validity has been demonstrated. Studies have found the GHQ correlates with appropriate comparable criterion. For example the GHQ has shown a negative correlation with the global quality-of-life scale (Goldberg & Williams, 2000; Quek, Low, Razack, & Loh, 2001).

Following analyses of the GHQ by members of the research team, each volunteer was required to attend a one-on-one interview with a member of the research team where the GHQ was discussed in further detail. If volunteers were considered suitable following the interview, participants were required to maintain their habitual sleep-wake pattern with ≥8h sleep opportunity each night for at least one week to ensure that they did not enter the laboratory with a sleep dept. Sleep-wake patterns during this period were verified by activity monitors (Actiwatch 2, Respironics Inc., USA, 2009) and sleep diaries, which are described in detail in Section 2.7.4.

2.7.2 *Assessment of eating behaviour*

2.7.2.1 Food analysis of a buffet meal (Study 1)

An identical buffet meal served on two occasions was used to measure food consumption choice (energy and macronutrient content of the food). The buffet meal consisted of 33,360 kJ, almost three times the recommended daily intake for males of average height and weight between 18 and 30-years (Australian National Health and Medical Research Council and the New Zealand Ministry of Health, 2006). Participants could choose from a variety of different foods varying in taste (sweet, e.g. cake, fruit, and savoury, e.g. a packet of chips, cold meats) and fat (high fat, e.g. meat pies, ice cream sundae, and low fat, e.g. salad, fruit-flavoured jams). The food items varied in levels of macronutrients (i.e. fat, protein and carbohydrate). Food from the buffet was weighed and measured to the nearest 1 g before and after consumption. Buffet meals are commonly used to measure eating behaviour (Allirot et al., 2014; Brondel et al., 2010; Wren et al., 2001).

2.7.2.2 Observation of snack consumption and snack choice (Study 2)

The measurement of eating behaviour used in Study 2 was snack choice. Snacks were assigned to one of three categories based on the type of snack: sweet (e.g. sweet biscuits); savoury (e.g. packet of potato chips); healthy (e.g. piece of fresh fruit). Participants could choose one snack only from one of the three categories per snack opportunity; alternatively they could choose not to snack. It has been suggested that some foods (e.g. carbohydrates) may increase alertness (Holt, 1999). Therefore participants were asked to consume their snacks within 30 minutes to ensure they were not consuming food in a time frame too close to test batteries and thus impacting on their performance. If the snack was not consumed within this time, it was removed by a member of the research team.

2.7.2.3 Dietary questionnaire (Study 3)

The Cancer Council Dietary Questionnaire (Giles & Ireland, 1996) (Appendix R) was used to measure eating behaviour in Study 3. The CCDQ is an FFQ developed by the Anti-Cancer Council of Victoria (ACCV). Refer to Section 1.1.3 for a more detailed discussion of the FFQ as a measurement of eating behaviour. The CCDQ is a semi-quantitative self-administered questionnaire designed to measure typical eating behaviour over a 12-month period. The first 10 questions ask participants to report on the foods they may consume on a daily or weekly basis, such as the amount of fruit, milk bread and sugar consumed per day; the types of vegetables consumed per day; the type of milk, cheese, bread and spreads typically consumed; and the quantity of eggs consumed per week. Additionally, four sets of photographs of scaled portions are included (these are used to calculate a portion size calibrator). Each photograph shows three different serving sizes for potatoes, vegetables, steak and casserole (see Figure 2.8 for an example). Participants can select a nil intake (e.g. 'I never eat casserole') or one of seven serving size portions. Following the photographs is a list of 74 food items with 10 frequency-response questions with options ranging from 'never' to '3 or more times per day'. The list of food items is classified into four categories (sweets, cereals and snacks, dairy products, meat and fish, and fruit and vegetables). The final section asks participants questions about alcohol consumption (how much, how often and the maximum amount of alcohol consumed at a time). The CCDQ is quick and easy to use, and has been validated relative to seven-day weighed food records (Hodge, Patterson, Brown, Ireland, & Giles, 2000). The CCDQ is scanned by the ACCV, and provides users with analysis of total energy, macro and micro nutrient intakes and distribution of energy by

macronutrients.

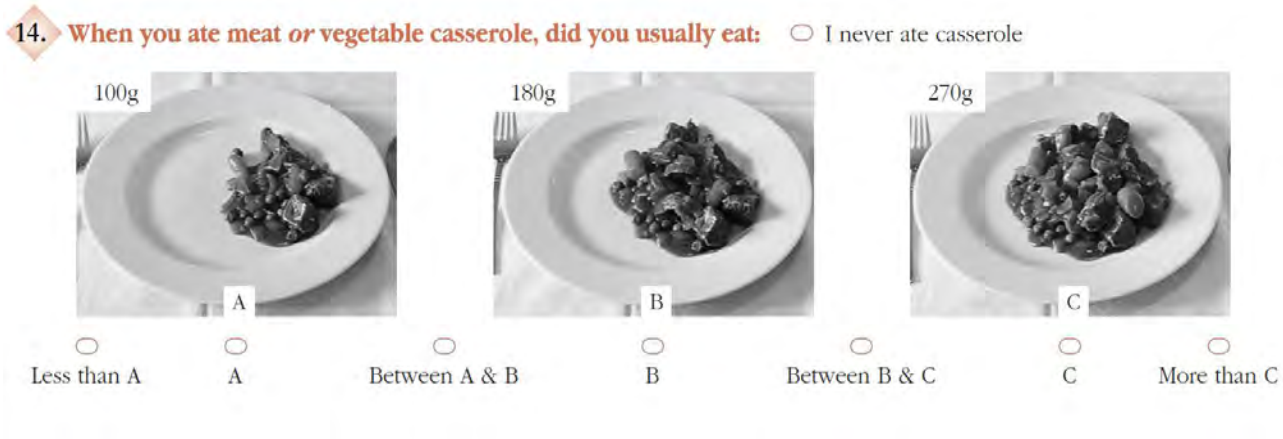


Figure 2.8 Photograph of scaled food portions

Source: The Cancer Council Dietary Questionnaire (Giles & Ireland, 1996)
Note: Participants can choose to report they do not eat the food shown in the photograph, or they can report one of the seven serving size portions

2.7.2.4 Food diaries (Study 4)

Eating behaviour in Study 4 was measured using food diaries located within the log book (Appendix K). See Chapter 1 (Section 1.1.3) for a more detailed discussion of food diaries (also known as dietary records) as a measurement of eating behaviour). Food diaries are considered the gold standard for measuring food intake in field studies (Thomson & Subar, 2001). Food diaries have demonstrated concurrent validity when compared to observed food intake. For example, product-moment correlation coefficients have ranged from 0.68 to 0.97 for food intake and from 0.75 to 0.92 for nutrient intake (Karvetti & Knuts, 1992). In Study 4 participants were asked to keep a record of all food and drink consumed on three days per shift type and on one day off. Participants were asked to record the method of cooking (e.g. boiled pasta), the type of food consumed (e.g. wholemeal bread) and the quantity of food (e.g. two teaspoons of white sugar or the weight in grams). In addition, participants were asked to provide the brand names of foods and recipes where possible.

2.7.3 *Assessment of mood*

Mood was not measured in Study 1. The mood measures used within the other three studies are described below.

2.7.3.1 Profile of Mood States (Study 2)

Mood was assessed using the Profile of Mood States (POMS) (McNair, Lorr, & Droppleman, 1971) (Appendix S) in Study 2. Transient mood states are assessed in POMS by asking participants to respond to 65 adjectives. For each adjective included in the POMS, participants complete a 5-point Likert-type scale ranging from 'not at all' to 'extremely'. POMS measures five negative mood domains: Tension-anxiety (T-A), depression-dejection (D-D), anger-hostility (A-H), fatigue-inertia (F-I) and confusion-bewilderment (C-B), and one positive mood domain, vigour-activity (V-A). A TMD score is computed by summing the negative domain scores and subtracting the positive domain score. Higher scores indicate greater mood disturbance. The POMS has been demonstrated as a valid and reliable measure (Pelled & Xin, 1999) and has been frequently used in previous sleep studies (Brendel et al., 1990; Dinges et al., 1997; Kline et al., 2010).

2.7.3.2 Chronic Fatigue Scale (Study 3)

The Chronic Fatigue Scale in Section 2 of the SSI (Barton et al., 2003) was used to measure mood in Study 3. The scale was developed using existing fatigue scales, previous literature and through consultation with colleagues with experience in the area. Barton et al. (2003, p. 11) describe chronic fatigue as 'general tiredness and lack of energy irrespective of whether an individual has not had enough sleep or has been working hard, which persists even on rest days and holidays'. The Chronic Fatigue Scale consists of 10 items on a 1–5 point Likert type scale. The scale has anchor points of 'not at all', 'somewhat' and 'very much so'. Five of the 10 items are reverse scored, as they are associated with feelings of vigour and energy. The other five items are associated with feelings of tiredness and lack of energy. The scale provides one overall score of chronic fatigue with the highest score possible score being 50 and the minimum score being 10. Higher scores indicate higher levels of chronic fatigue. The Chronic Fatigue Scale has been found to have a reliability coefficient of 0.91 for internal consistency (Smith et al., 2001).

2.7.3.3 Visual Analogue Scales (Study 4)

VAS were used in Study 4 to measure moods identified as affecting eating behaviour (e.g. happiness, anxiety, depressive mood, stress and tiredness). A separate scale was used to assess each mood. As mentioned previously, each VAS measured 100 mm and was anchored with 'not at all' on the far left hand side of the scale and 'extremely' on the other side of the scale (see Figure 2.9 for VAS relating to mood). Participants were instructed to complete these scales by placing a vertical line on the scale representing how they were feeling at that point of time. The scales were included in participants' logbooks and participants were asked to complete the VAS twice each

working day (before the start of their shift and at the end of their shift). Validity and reliability of VAS have been examined in numerous studies, and has been found to be a reliable and valid measurement for studying mood (McCormack, Horne, Sheather, 1988). For example, test-retest reliability has been measured in clinical patients in a large study of two groups of patients (Folstein & Luria et al., 1973). Within-group reliability coefficients of 0.61 were found for one sample and 0.73 for another sample. The same study demonstrated that VAS were highly correlated with the Self Depression Scale and Clyde Mood Scales. Internal reliability has also been measured in women with premenstrual mood symptoms (Steiner, Streiner, Steinberg, Stewart, Carter, Berger et al., 1999). A Cronbach's alpha of 0.89 was demonstrated between the VAS and Premenstrual Tension Syndrome Observer and The Self Rating Scales (Steiner, Haskett & Carroll, 1980). Concurrent validity was demonstrated by comparing VAS to both the Beck Depression Inventory and the Depression Scale of Symptom Check List-90 (Little & McPhail 1973; Davies, Burrows & Pynton, 1975). Furthermore, discriminate validly of VAS was demonstrated when pain ratings between patients were compared. The study included participants expecting pain and patients who received analgesics (Joyce, Zutshi, Hrubes, & Mason, 1975).

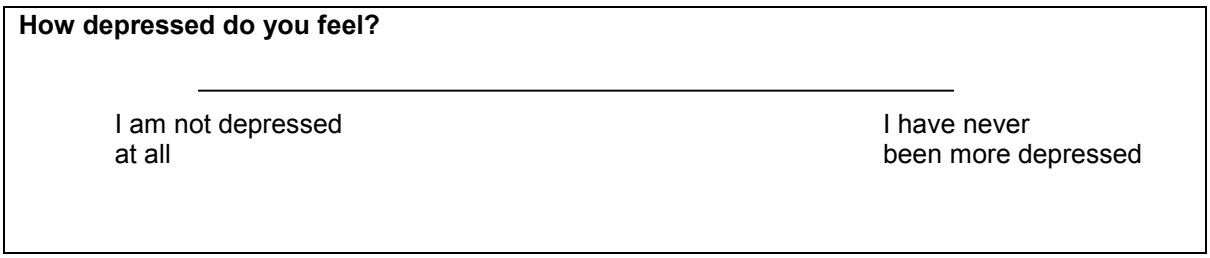


Figure 2.9 Example of a Visual Analogue Scale

Note: These scales were used in Study 4 to measure mood. Participants are asked to place a vertical line on the 100 mm scale representing how they feel at the time of completion

2.7.4 *Assessment of sleep*

2.7.4.1 Polysomnography (Studies 1 and 2)

PSG was used in Studies 1 and 2 to measure sleep. The system used to record sleep in both studies was the Compumedics E-Series PSG/EEG system (Melbourne, Australia). In both studies Grass™ gold-plated cup electrodes (Astro-Med. Inc., Rhode Island, USA) were applied to the face and scalp of participants in adherence to the international guidelines of electrode placement (Rechtschaffen & Kales, 1968). Two EEG electrodes were attached to the scalp relative to each hemisphere of the brain. A reference pair of electrodes was positioned behind each opposite ear (C3/A2 and C4/A1). Two EOG electrodes were attached below the left (LOC) and right outer canthi

(ROC) and EMG electrodes were attached to each participant's chin (approximately four cm apart). Experienced technicians monitored signals during sleep episodes to minimise the loss of data due to poor signal quality or loss of signals.

The PSG data were scored in 30-second epochs in both studies according to standard scoring criteria (Rechtschaffen & Kales, 1968). Sleep was scored by an experienced scorer. In addition, a random sample of 30% of sleep recordings was scored by a second scorer. The second scorer was blind to the condition, protocol day and participant. The concordance level between the two scorers averaged between 85 and 90%. When significant discrepancies occurred between scorers the sleep was reviewed again by both scorers, and a mutual agreement was made.

Two sleep variables (sleep duration and sleep efficiency) are reported in this thesis. Sleep duration was calculated as the amount of time in bed within a scheduled sleep episode or within a particular elapsed time and/or circadian phase bin. Sleep efficiency was calculated as a percentage, which was calculated as total sleep time divided by recording time (the total amount of time sleep was recorded for the sleep episode or within the particular elapsed time and/or circadian phase bin) times 100 (TST/RC*100).

2.7.4.2 Sleep diaries (Studies 1, 2 and 4)

Sleep diaries were used in Studies 1 and 2 to assess sleep habits prior to entering the laboratory. Sleep diaries were also used in Study 4 to determine sleep duration in conjunction with wrist activity monitors (Actiwatch 2, Respironics Inc., USA, 2009) to measure subjective sleep quality.

In Study 4, participants were asked to complete a sleep diary as part of their log book for the entire 14-day period of the study (Appendix K). Participants reported their sleep onset time and wake time (to the nearest minute), and the number and length of awakenings. In addition, participants were asked to provide a subjective rating of the sleep using a scale of 1–5 (higher scores indicated poorer quality of sleep). The sleep diaries used in Studies 1 and 2 were similar to those used in Study 4 (Appendix P), but they also included a sleepiness scale that ranged from 1 (feeling active and vital, alert and wide awake) to 7 (sleep onset will be soon, lost struggle to remain awake). Participants were asked to complete the scale before they went to sleep and when they woke up.

2.7.4.3 Standard ShiftWork Index (Study 3)

Sleep duration was measured in Study 3 by questions included in Section 1 (general information) of the SSI (see Appendix Q). Participants were asked to report the amount of sleep they typically obtain (in hours) between each working day for every type of shift they work (i.e. morning, night and afternoon shifts). This questionnaire requires participants to report their average sleep durations for each different shift type (morning, afternoon and night). As rotating shiftworkers work multiple shift types, average sleep duration between working days for all shift types was calculated for rotating shiftworkers in this study. The SSI has been used to obtain general information about shiftworkers in many shiftwork studies worldwide (Barton, Spelten, Totterdell, Smith, Folkard et al., 1995).

2.7.4.4 Wrist activity monitors (Studies 1, 2 and 4)

Sleep and wake activity were measured objectively in Study 4 using wrist activity monitors (Actiwatch 2, Respironics Inc., USA, 2009). In addition, wrist activity monitors were used to assess sleep habits prior to entering the laboratory in Studies 1 and 2.

In Study 4 participants were asked to wear the monitor for 14 consecutive days and nights on their non-dominant wrist. Participants removed the watch if they were likely to get it wet (e.g. swimming, showering). In addition, occupational health and safety procedures in some wards did not allow nurses wear watches around their wrist. If this was a requirement, nurses either pinned the activity monitor to their shirt or attached it to themselves using a similar method (e.g. worn around the belt loop of their pants) whilst at work, and then placed it back on their wrist after work.

In Studies 1 and 2 participants were asked to wear the wrist activity monitors on their non-dominant wrist for two weeks prior to entering the laboratory (except when the monitor was likely to get wet).

Wrist activity monitors use a motion-sensitive device to record sleep and wake activity. A piezo-electric accelerometer with a sensitivity of 0.1 g is contained in each monitor. Movement was sampled in one-minute intervals every 125 minutes. Sleep periods were determined by activity counts of <40. Data from the activity monitors were derived from software developed for these devices (Actiware- sleep software, Respironics Inc., USA, 2009). Data were compared with sleep diaries to validate recordings and give an overall picture of sleep and wake during the 14-day period of the study. Activity monitors and the associated algorithms have been validated in

previous field and laboratory studies (Signal, Gale, & Gander, 2005; Stanley, Dorling, Dawson, & Hindmarch, 2000).

A measure of sleep duration was determined using the period between sleep onset time and wake time (less awakenings). Objective sleep quality was ascertained from the Actiware program using the sleep efficiency percentage (percentage of time in bed spent asleep). Subjective sleep quality was determined using a self-report sleep quality scale included in the sleep diaries. This scale asks participants to report their sleep quality on a scale of 1 (very good) to 6 (very poor); only whole numbers were reported on this scale.

2.7.4.5 Assessment of circadian phase: Study 2

Circadian phase was assessed in Study 2. Core body temperature was used to measure circadian phase and was recorded continuously in one-minute epochs with indwelling rectal thermistors (Steriprobe 491B; Cincinatti Sub-Zero Products, Cincinnati, Ohio). The thermistors were connected to a Mini-Mitter datalogger (Bend, Oregon, USA).

The core body temperature data were used to estimate circadian phase for participants in Study 2. This involved a five-step process as follows:

1 Raw core body temperature data was cleaned for invalid or missing values (e.g. due to downloading or technical malfunctions).

2 The data was de-masked for physical activity using a purification of intercepts approach (Jim Waterhouse et al., 2000).

3 The data was de-masked for sleep-wake differences using a sleep-state correction factor.

4 A cosine equation was fitted with a fundamental period and a single harmonic to the de-masked core body temperature data using the least squares method.

5 The data were assigned a circadian phase estimate (0–360, 0 represents the minimum of the fitted core body temperature curve) to each minute of the FD portion of the protocol using the resultant cosine equation. For further details relating to this process refer to Darwent et al. (2010).

This concludes the general methodology chapter. Chapters 3, 4, 5, 6 and 7 present the results.

Chapter 3
Food consumption and food choice following one week of sleep restriction (Study 1)

Heath, G., Dorrian, J., Kosmadopoulos, A., Sargent, C. (2011). Food consumption and food choice following one week of sleep restriction: A pilot study. In: Kennedy, G. A., Sargent, C. (Eds). *Little clock, big clock: Molecular to physiological clocks.* Australasian Chronobiology Society, Melbourne, Australia, pp. 17–21. (Appendix A)

Note: This chapter reports energy intake in kcals as it was published in an international publication. One kcal is equivalent to 4.2 kJ (Whitney & Rolfes, 2013).

3.1 Abstract

There is evidence to suggest that restricting sleep may result in overconsumption of food and poor food choices. This has been attributed to disruption in appetite hormones following sleep restriction. The aim of this study was to investigate food consumption and food choices before and after either one week of sleep restriction or a control condition consisting of one week of 8h time in bed.

Twelve healthy males (age: 24.6 ± 3.1 years; BMI: 22.9 ± 1.3 kg/m2, mean ± standard deviation [SD]) completed either a sleep restriction (*n* = 6) or a control condition (*n* = 6). The protocol began with an adaptation and two baseline days (8h time in bed), seven sleep restriction days (4h time in bed) or seven control days (8h time in bed) and one recovery day (8h time in bed). On the first baseline and recovery days, participants were served an identical buffet meal (33,360 kJ in total). All food was weighed and measured before, and immediately after, the buffet meal. The kcal and macronutrient content of food was calculated using a nutritional database (CalorieKing). Prior to each buffet participants reported their subjective hunger.

Mann-Whitney tests were conducted to examine the difference between conditions in total kcals consumed, macronutrient content and self-reported hunger. There were no significant differences in kcals or macronutrients consumed (p >0.05). However, there was a significant difference in self-reported hunger (p = 0.02) such that participants who were sleep restricted reported feeling hungrier than control participants.

Although self-reported hunger was higher on the recovery day when the sleep restriction condition was compared to the control condition, there was no difference in food consumption or food choices between conditions. A ceiling effect may have prevented participants from consuming more food despite increased hunger. Examining food consumption over an entire day following sleep restriction may provide a clearer understanding of how sleep restriction affects food consumption and food choice.

3.2 Introduction

Obesity rates have more than doubled in Australia over the past two decades (Cameron et al., 2003). Over the same period of time, sleep duration has decreased (Bartlett, Marshall, Williams, & Grunstein, 2008). Epidemiological studies that have demonstrated a relationship between sleep restriction and obesity (Patel & Hu, 2008) do not appear to be coincidental.

Laboratory studies suggest that hunger increases following sleep restriction due to altered levels of endocrine hormones that regulate appetite (Schmid et al., 2008). In addition, there is some evidence to suggest poor food choice may occur when sleep is restricted. For example, heightened cravings for kcal-rich foods were reported following two nights of sleep restriction (4h time in bed) compared to two nights of sleep extension (10h time in bed) (Spiegel, Tasali et al., 2004).

Although the above findings suggest sleep restriction may influence food consumption and food choice, very few studies have examined objective measures of food intake following or during a period of sleep restriction. Results from a recent experimental study demonstrated increased food consumption and a higher percentage of fat consumption following a single night of sleep restriction (4h time in bed) (Brondel et al., 2010). Two previous studies examining the influence of sleep restriction on food intake did not find differences in total food consumption (Nedeltcheva et al., 2009; Schmid et al., 2008); however, one of these studies did show an increase in kcals from snacks during sleep restriction (Nedeltcheva et al., 2009). The disparity in results from previous studies may have occurred due to participants' kcal intake surpassing energy demands prior to testing in both the sleep restriction and control condition. To ensure energy balance remained constant, participants in the current study followed a kcal-controlled diet.

The aim of the current study was to examine participants' self-reported hunger, food consumption and food choice in a buffet meal before and after one week of sleep restriction (4h time in bed) and a control condition (8h time in bed) for the same time period. It was hypothesised that hunger and food consumption would be higher in the sleep restriction compared to the control condition following the experimental period. In addition, it was hypothesised that the sleep restriction condition would show a preference for high fat and high carbohydrate foods following the experimental period when compared to the control condition.

3.3 Methods

3.3.1 *Participants*

Twelve healthy males (24.6 ± 3.1 years, mean ± SD) completed the current study. Participants had normal sleep patterns, were not dieting, had no food allergies and were of a healthy weight range (BMI: 22.9 ± 1.3 kg/m2). Participants were excluded from the study if they were taking medication known to affect sleep or had a medical condition, if they consumed high levels of alcohol or caffeine, or if they had undertaken transmeridian travel or shiftwork in the three months prior to the start of the study. Ethics approval for this study was obtained from the University of South Australia Human Research Ethics Committee. Written informed consent was obtained from all participants and the research methods conformed to the guidelines established by the National Health and Medical Research Council of Australia.

3.3.2 *Protocol*

Participants were randomly assigned to either a sleep restriction condition (*n* = 6) or a control condition (*n* = 6) for 12 consecutive days in a sleep laboratory at the Centre for Sleep Research. In both conditions, the first three days (one adaptation and two baseline days) consisted of 8h time in bed (00:00–08:00). During the next seven days the sleep restriction condition were provided with 4h time in bed (04:00–08:00) and the control condition were provided with 8h time in bed (00:00–08:00). On the final night in the laboratory, participants in both conditions were provided with an 8h recovery sleep opportunity (00:00–08:00).

Participants in both conditions were served an identical buffet meal on two occasions during the study. The first buffet meal was served at 13:00 after the first 8h sleep opportunity in the laboratory (baseline day) and following a 17h fast. The buffet was served again on the final day of the study (recovery day) at 13:00, again after a 17h fast. The buffet meal was more than double the recommended daily intake (7,943 kcal in total). Participants could choose from a variety of different foods with varying levels of macronutrients (i.e. fat, protein, carbohydrate). Participants consumed the buffet individually in their own private living area and were given 1h to consume food *ad libitum*. During the hour in which the buffet was served, participants were instructed to remain quietly in their living areas with their televisions off. At 14:00 all food was removed from the participants' living areas. Food from the buffet was weighed and measured to the nearest gram before and after consumption. Self-reported hunger was measured 45 minutes prior to each buffet meal.

During the remainder of the study, participants consumed a kcal-controlled diet following the nutrient reference values of Australia and New Zealand and to suit sedentary males with normal BMI (Australian National Health and Medical Research Council and the New Zealand Ministry of Health, 2006). Throughout the experimental period of the study, participants completed glucose tolerance tests, blood draws and neurobehavioural test batteries as part of a larger study. When not completing these tasks, participants were given free time to complete quiet activities such as reading or watching DVDs. Participants were monitored by a closed circuit television system to ensure compliance to the protocol.

3.3.3 *Measures*

Food consumption was measured by calculating the total number of kcals consumed during the buffet meal. Food choice was measured by determining the macronutrient content (fat, protein and carbohydrate) of the food consumed during the buffet. Kcal and macronutrient content of food was ascertained by a nutritional database (CalorieKing).

Self-reported hunger was measured using a VAS. Participants were asked, 'How hungry do you feel right now?' and asked to rate their hunger by drawing a line through the scale. The scale ranged from 0 mm ('I am not at all hungry') to 100 mm ('I have never been more hungry').

3.3.4 *Data analysis*

Data screening revealed non-normal distributions for all variables except for fat. Therefore, the difference between recovery and baseline data for each participant was computed to obtain a new variable (difference: recovery – baseline). A series of Mann-Whitney U tests were then performed to analyse differences in ranked position of scores between the two conditions (Field, 2009).

3.4 Results

The difference (recovery – baseline) in kcal intake for the sleep-restricted participants (median = –89.85 kcal) did not significantly differ from control participants (median = 36.82 kcal), Mann-Whitney U = 17.0, z = –0.16, p >0.05 (See Table 3.1; Figure 3.1). The difference (recovery – baseline) in self-reported hunger for sleep-restricted participants (median = 10) was significantly different when compared to the control condition (median = 4.5) Mann-Whitney U = 4.5, z = –2.17, *p* = 0.03. The participants in the sleep restriction condition reported feeling hungrier than

the control condition before the buffet on recovery day compared to before the buffet on baseline day (see Table 3.1; Figure 3.1).

Similarly, the difference (recovery – baseline) in macronutrient intake for the sleep-restricted participants; fat: median = –0.15, protein: 1.15, carbohydrate: 5.89 did not significantly differ from control participants; fat: median = 5.47, –7.96, 9.81. Fat: U = 17.0, z = –0.16, p >0.05; protein: Mann-Whitney U= 16.0, z = –0.32, p >0.05; carbohydrate: U = 17.0, z = –0.16, p >0.05 (see Table 3.1; Figure 3.1).

Table 3.1 Increases, decreases or no change in dependent variables

DV	SR condition		Control condition		
	n increase	*n* decrease	*n* increase	*n* decrease	*n* no change
Energy (kcal)	3 ↑	3 ↓	3 ↑	3 ↓	0
Fat (g)	3 ↑	3 ↓	3 ↑	3 ↓	0
Protein (g)	3 ↑	3 ↓	3 ↑	3 ↓	0
CHO (g)	3 ↑	3 ↓	4 ↑	2 ↓	0
Hunger (VAS)	5 ↑	1 ↓	1 ↑	3 ↓	2

Notes: ↑ = number of subjects (n) showing an increase from baseline to recovery; ↓ = number of subjects (n) showing a decrease in variable from baseline to recovery
DV = dependent variable; SR = sleep restriction; kcal = kilocalories; g = grams; CHO = carbohydrate; VAS = visual analogue scale; g = grams

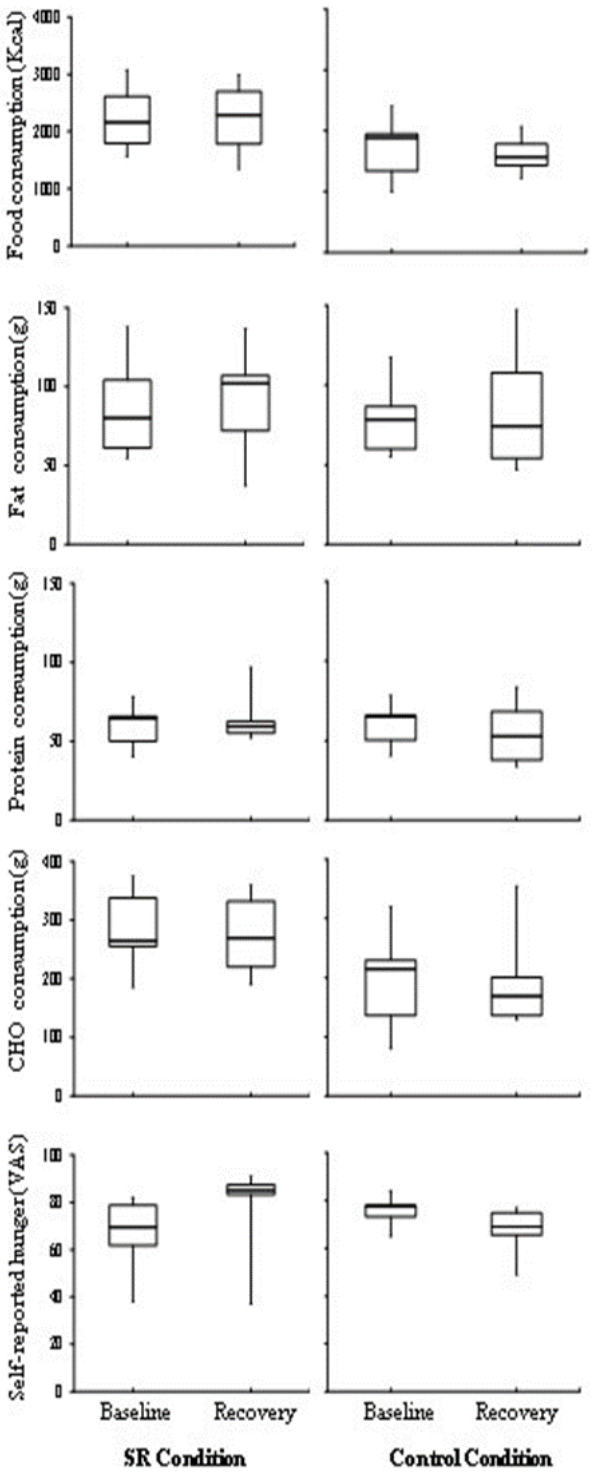


Figure 3.1 Comparison of dependent variables by condition

Notes: The bottom and top of the boxes represent the 25th and 75th percentiles respectively. The median is shown by the line inside the box. The whiskers represent the distance between the lowest and highest values

3.5 Discussion

Contrary to expectation, the results of the present pilot study showed that participants in the sleep restriction condition did not increase their food consumption or make poorer food choices following sleep restriction.

Furthermore, food consumption and food choice was not different when the sleep restriction was compared to a control condition. However, similar to previous studies (Schmid et al., 2009; Spiegel, Tasali et al., 2004), participants who were sleep restricted reported feeling hungrier following sleep restriction when compared to control participants who had been provided with 8h time in bed for one week.

Although sleep-restricted participants reported feeling hungrier, contrary to expectation there was no increase in food consumption or alteration in food choice following sleep restriction. It is possible that a ceiling effect may have prevented the sleep-restricted participants from consuming more food following sleep restriction. In addition, it is possible the novelty of the first buffet meal in the laboratory may have resulted in higher than usual food consumption. Furthermore, the participants were aware they would not have access to unhealthy foods during the study, so this may have resulted in food choices they would not normally make on a day-to-day basis during the baseline buffet meal.

This was a pilot study, and the small number of participants is a limitation. Consequently results must be interpreted with caution. In addition, if this study was to be replicated, the protocol could be improved by holding the second buffet prior to the recovery sleep opportunity to ensure the effect of sleep restriction is still evident. If appetite hormones do become disrupted as a result of sleep restriction, we do not know the duration it takes for the body to readjust hormone levels. In addition, any psychological variables that may result from increased food consumption and choice, such as mood or feelings of fatigue, may have returned to normal levels following the recovery sleep. However, a study examining eating habits of nurses reported participants craved and consumed sweet foods even after a recovery sleep following night shiftwork (Persson & Mårtensson, 2006). Night shiftwork is commonly associated with sleep restriction and feelings of fatigue (Åkerstedt, 2003).

As there is evidence from previous studies to suggest factors associated with sleep restriction may influence food consumption and food choice (e.g. altered appetite hormones, psychological factors) (Schmid et al., 2008; Spiegel, Tasali et al., 2004), future studies in this area should be

conducted. Due to the large individual differences seen in participants from this study, other factors (e.g. health, locus of control, eating style) that may moderate food consumption and food choice when sleep is restricted should also be investigated. Obesity is now considered a global epidemic; therefore, it is important to explore all mechanisms which may lead to the development of this chronic health condition.

Chapter 4

The effect of sleep restriction on snacking behaviour during simulated shiftwork (Study 2)

Heath, G., Roach, G., Dorrian, J., Ferguson, S., Darwent, D., Sargent, C. (2011). The effect of sleep restriction on snacking behaviour during a week of simulated shiftwork. *Accident Analysis & Prevention, 45*, 62-67. (Appendix B)

4.1 Abstract

Due to irregular working hours, shiftworkers experience circadian disruption and sleep restriction. There is some evidence to indicate that these factors adversely affect health through changes in snacking behaviour. The aim of this study was to investigate the impact of sleep restriction, prior wake and circadian phase on snacking behaviour during a week of simulated shiftwork. Twenty-four healthy males (age: 22.0 ± 3.6 years, mean ± SD) lived in a sleep laboratory for 12 consecutive days. Participants were assigned to one of two schedules: a moderate sleep restriction condition (n = 10) equivalent to a 6h sleep opportunity per 24h or a severe sleep restriction condition (n = 14) equivalent to a 4h sleep opportunity per 24h. In both conditions, sleep-wake episodes occurred 4h later each day to simulate a rotating shiftwork pattern. While living in the laboratory, participants were served three meals, and were provided with either five (moderate sleep restriction condition) or six (severe sleep restriction condition) snack opportunities daily. Snack choice was recorded at each opportunity and assigned to a category (sweet, savoury or healthy) based on the content of the snack. Data were analysed using a Generalised Estimating Equations (GEE) approach. Analyses show a significant effect of sleep restriction condition on overall and sweet snack consumption. The odds of consuming a snack were significantly greater in the severe sleep restriction condition (p <0.05) compared to the moderate sleep restriction condition. In particular, the odds of choosing a sweet snack were significantly increased in the severe sleep restriction condition (p <0.05). Shiftworkers who are severely sleep restricted may be at risk of obesity and related health disorders due to elevated snack consumption and unhealthy snack choice. To further understand the impact of sleep restriction on snacking behaviour, future studies should examine physiological, psychological and environmental motivators.

4.2 Introduction

Traditionally, there has been considerable focus on obesity as a major public health concern. Recently, there has been increasing interest as to how obesity affects performance in the workplace. Obesity has been associated with reduced productivity and higher rates of absenteeism (Narbro et al., 1996), and in America the annual cost of obesity on full time employment is estimated to be $73.1 billion US (Finkelstein, daCosta DiBonaventura, Burgess, & Hale, 2010). This is of significant concern to industry and organisations, as obesity rates have risen dramatically throughout the world over the past 15 years (World Health Organisation, 2009).

According to the WHO,the rising rates of obesity can be attributed to behavioural and lifestyle changes. Over the past two decades, there has been a shift to a 24h society. In turn, the demand for industry, organisations and services to operate round-the-clock has led to an increase in shiftwork in recent years (Australian Bureau of Statistics, 2010; United States Department of Labor, 2005). Shiftwork is associated with lifestyle and behavioural factors that may predispose shiftworkers to obesity. Therefore, it is not surprising that when compared to day workers, shiftworkers are more overweight and obese (Atkinson et al., 2008) and suffer from numerous chronic health conditions related to obesity, such as cardiovascular disease (Bøggild & Knutsson, 1999) and type 2 diabetes (Kawachi et al., 1995).

Shiftworkers experience circadian disruption and sleep restriction, and there is emerging evidence to suggest these two factors may contribute to the increased incidence of obesity seen in shiftwork populations. Due to irregular working hours, shiftworkers sleep and eat at sub-optimal circadian phases, consequently affecting the quality, quantity and distribution of food intake.

One of the first studies to examine eating behaviour (Reinberg et al., 1979) found night shiftworkers consume snacks throughout their shift, and more recent studies concur with these findings (Waterhouse et al., 2003). Furthermore, studies suggest shiftworkers have poor dietary habits (Di Lorenzo et al., 2003; Harada et al., 2005). A number of factors may contribute to the snacking behaviour seen in shiftwork populations. Appetite hormones display a circadian rhythm (Cummings et al., 2001; Simon, Gronfier, Schlienger, & Brandenberger, 1998), and altered metabolic responses to eating at night suggest the body is not designed to consume and process food during this time (Atkinson et al., 2008). Therefore, shiftworkers may not be as hungry at night and thus prefer to snack rather than consume heavy meals (Lowden, Holmbäck, Åkerstedt, Forsulnd, Forslund, & Lennernäs, 2001; Waterhouse et al., 2003). Additionally, the workplace

environment may contribute to snack choice during night shift. Shiftworkers have limited access to canteen facilities when working night shift, and often rely on vending machines to obtain food (Stewart & Wahlqvist, 1985). Although it is clear that shiftworkers consume snacks at inappropriate circadian phases, there are limited controlled studies investigating the influence of circadian processes on snacking behaviour.

Along with circadian disruption, sleep restriction may also contribute to the high incidence of obesity seen in shiftworkers. Shiftworkers report poor quality and quantity of sleep when compared to day workers (Åkerstedt, 2003). This is of concern, as a relationship between shorter sleep durations (<8h) and obesity has been found in shiftwork populations (Moreno, Louzada, Teixeira, Borges, & Lorenzi-Filho, 2006). Laboratory studies have begun to investigate causal pathways to help understand the link between sleep restriction, obesity and related diseases. Participants in these studies have reported an increase in appetite and cravings for kcal-rich foods following sleep restriction (Spiegel et al., 2005). Additionally, there is evidence to suggest hormones involved in appetite regulation are disturbed as a result of sleep restriction. Studies have shown that levels of ghrelin increase, while levels of leptin decrease, when individuals are deprived of sleep (Knutson et al., 2007; Spiegel et al., 2005), indicating sleep restriction may result in increased hunger. However, a laboratory study investigating energy intake following sleep restriction found that sleep restriction resulted in increased energy from snacks but not meals. In addition, there was no difference in leptin and ghrelin levels when the two conditions were compared (Nedeltcheva et al., 2009). This finding suggests snacking may be a result of processes other than hunger (i.e. non-homeostatic) and snacking should be investigated separately to other eating episodes, such as meals.

Overall, snacking behaviour may be influenced by both circadian and homeostatic (i.e. prior wake-sleep) components. Additionally, there is evidence to suggest sleep restriction impacts on snacking behaviour. Therefore, a protocol that allows for examination of all three factors is required. An FD protocol extends or shortens the waking day outside the range of entrainment of the circadian pacemaker. This protocol desynchronises homeostatic and circadian processes, and allows for the examination of variables at all possible levels of prior wakefulness and circadian phase (see Kleitman, 1939 for further detail). Thus far, only one study (Waterhouse et al., 2003) has investigated the separate influences of circadian and homeostatic processes on eating behaviour, concluding food intake was governed more by the wake period, rather than circadian processes. However, participants lived on a normal sleep-wake ratio of 1:2 (the equivalent of an

8h sleep opportunity per 24h day). This study expanded on previous research by employing an FD protocol, which simulated a rotating shiftwork schedule with two levels of sleep restriction (moderate and severe). As it is unclear if the level of sleep restriction affects snack consumption and snack choice, the study aimed to investigate the effect of both moderate and severe sleep restriction on snacking behaviour. Furthermore, the study examined the separate effects of prior wake and circadian phase on snack consumption and choice.

4.3 Materials and methods

This section provides details about the participants and protocols, and the processes regarding snacking, sleep, phase estimates, and statistical analyses for Study 2.

4.3.1 *Participants*

Twenty-four healthy males participated in this study. Fourteen participants (age 21.8 ± 3.8 years, mean ± SD) were randomly allocated to a severe sleep restriction, and 10 participants (age 22.3 ± 3.5 years) were allocated to a moderate sleep restriction condition. Participants were of a healthy weight range (BMI 22.2 ± 1.9kg/m^2), did not smoke, and had normal sleeping patterns. Participants were excluded from the study if they were suffering from a medical condition or using medication known to affect sleep, if they had undertaken shiftwork or transmeridian travel in the three months prior to the start of the study, and if they consumed high levels of caffeine or alcohol. Ethics approval for this study was obtained from the University of South Australia Human Research Ethics Committee. Written informed consent was obtained from all participants, and the research methods conformed to the guidelines established by the National Health and Medical Research Council of Australia.

4.3.2 *Protocol*

Participants spent 12 consecutive days in a purpose-built, time-isolation laboratory at the Centre for Sleep Research in Adelaide, Australia. In both conditions, the first three days were 24h in length (16h of wake and an 8h sleep opportunity at night). These days allowed participants to familiarise themselves with the laboratory environment and train on the performance tasks they were required to complete as part of a larger study. After the third night, participants in both conditions began the rotating shiftwork schedule, which consisted of seven 28h 'days'. The severe sleep restriction condition consisted of a 23.3h wake episode and 4.7h sleep opportunity (this is equivalent to a 4h sleep opportunity per 24h day). The moderate sleep restriction condition

consisted of a 21h wake episode and 7h sleep opportunity (this is equivalent to a 6h sleep opportunity per 24h day).

Throughout the study, participants were restricted from eating *ad libitum*. Participants were served standardised meals (i.e. breakfast, lunch, dinner) at the same elapsed time into each wake period (i.e. 0.5h, 7.5h, 15h). Breakfast consisted of a choice of toast, fruit, yoghurt and cereal; lunch consisted of a choice of salad and cold meats for sandwiches, soup and noodles; and dinner consisted of a hot meal of rice or pasta served with meat and/or vegetables. Snack opportunities were also provided at the same elapsed time into each wake period (i.e. 2.5h, 5h, 10h, 12.5h, 17.5h) in each condition. Participants in the severe sleep restriction condition were provided with an extra snack opportunity at 20h. Water was made available at all times. Participants chose and consumed their snack separately to ensure their decision was not influenced by others.

As part of a larger study, participants completed neurobehavioral test batteries 1.5h after waking and every 2.5h thereafter during wake periods. The results of these test batteries have been reported elsewhere (Darwent et al., 2010; Sargent, Ferguson, Darwent, Kennaway, & Roach, 2010; Zhou et al., 2010, 2011, 2012). When not completing test batteries, participants were able to undertake low intensity activities such as reading or watching DVDs. To ensure compliance to the protocol, participants were monitored by a closed circuit television system.

4.3.3 *Snacking*

Snacks were assigned to one of three categories according to the content of the snack:

1 Sweet (1 × 31.3 g muesli bar, 2 × 18 g sweet biscuits)

2 Savoury (1 × 19 g packet of potato chips, or 1 × 25 g packet of savoury crackers)

3 Healthy (1 × piece of seasonal fresh fruit, 1 × 40 g packet of dried fruit and nuts).

Participants could choose one snack only from one of the three snack categories per snack opportunity; alternatively, they could choose not to snack. If participants chose to snack, they were given 30 minutes to consume it. If the snack was not consumed within this time, it was removed by a member of the research team.

4.3.4 *Sleep*

Sleep was monitored using a standard PSG montage, which involved electrodes being attached to the scalp and face prior to each sleep opportunity. Sleep was scored in 30-second epochs in

accordance with accepted criteria (Iber et al., 2007). Sleep efficiency was calculated as a percentage of time in bed spent asleep. Average sleep efficiency during the FD phase of the protocol for the moderate sleep restriction condition was 94.4 ± 2.4%, and average sleep efficiency for severe sleep restriction condition was 95.9 ± 1.9%.

4.3.5 *Core body temperature*

Core body temperature was recorded continuously in one-minute epochs with indwelling rectal thermistors (Steriprobe 491B; Cincinatti Sub-Zero Products, Cincinnati, Ohio). The thermistors were connected to a Mini-Mitter datalogger (Bend, Oregon, USA).

4.3.6 *Phase estimates*

Core body temperature data from six of the experimental days (2–7) were used to generate circadian phase estimates for each participant. Following the cleaning of the raw core body temperature data, the data were de-masked for sleep-wake differences and physical activity. A cosine equation was then fitted to the de-masked core body temperature data. The data were assigned a circadian phase estimate (i.e. 0–360 degrees) to each minute of the experimental period of the study using a resultant cosine equation (for more details regarding this process, see Darwent et al., 2010).

4.3.7 *Statistical analyses*

Each snack opportunity was assigned a circadian phase (six bins with a width of 60 degrees, ~4h) and a level of prior wakefulness (five levels: 2.5h, 5h, 10h, 12.5h, 17.5h of prior wakefulness). The snack opportunity at 20h of prior wakefulness (provided to the 4h condition only) was excluded from the analysis to allow for equal comparisons between the conditions.

Logistic regression for a snack (yes/no) was conducted using a GEE approach with exchangeable correlation structure and robust standard errors accounting for clustering over subjects. Initial models included main and two-way interaction terms. Where effects were significant within condition, planned repeated contrasts (Wald statistics) were conducted for prior wake, and core body temperature bins were compared to zero degrees (circadian nadir) (see Figure 4. 1). Since interactions were not significant, final models included main effects only. In order to further investigate main effects of prior wake and phase, separate models were run for each condition.

4.4 Results

This section presents the results, which are summarised in Table 4.1.

Table 4.1 Main effects of condition, prior wake and circadian phase for overall, sweet, savoury and healthy snack consumption

Dependent variable	Independent variable	OR	St error of OR	Z	*p*	95% CI lower	95% CI upper
Snacking (overall)	Condition	0.58	0.12	−2.17	0.03	0.36	0.95
	Prior wake	0.82	0.07	–2.29	0.02	0.69	0.97
	Circadian phase	1.25	0.11	2.59	0.01	1.06	1.48
Sweet Snack	Condition	0.54	0.12	–2.81	0.01	0.35	0.83
	Prior wake	1.13	0.07	1.86	0.06	0.99	1.28
	Circadian phase	1.07	0.06	0.18	0.18	0.97	1.19
Savoury Snack	Condition	0.87	0.15	−0.78	0.44	0.62	1.22
	Prior wake	0.86	0.06	−2.37	0.02	0.75	0.97
	Circadian phase	0.99	0.03	−0.05	0.96	0.93	1.07
Healthy Snack	Condition	1.16	0.26	0.65	0.52	0.75	1.79
	Prior wake	0.94	0.05	–1.16	0.25	0.84	1.05
	Circadian phase	1.03	0.03	1.10	0.27	0.97	1.10

Note: St error = standard error; CI = confidence interval; OR = odds ratio

4.4.1.2 Overall snack consumption

Significant main effects were found for overall snack consumption. There was a significant effect of condition, prior wake and circadian phase (p <0 .05). There was a 40% reduction in the odds of choosing a snack in the moderate sleep restriction condition compared to the severe sleep restriction condition (95% confidence interval [CI] = 0.36–0.95) (Table 4. 1). Fewer snacks were consumed following a meal in both conditions (Figure 4. 1). All circadian phases were significantly different to the circadian nadir in the severe sleep restriction condition, such that there were higher frequencies of snack consumption during the biological day compared to the biological night (Figure 4. 1). There were no significant differences between the phases in the moderate sleep restriction condition.

4.4.2 *Sweet snack consumption*

Significant main effects were found for the consumption of sweet snacks. A significant main effect was found for condition (p <0.05), and prior wake was approaching significance (p = 0.06) (Table 4.1). Separate models were then run for each condition. Where effects were significant within condition, Wald comparisons were conducted to test the effect of prior wake (planned contrasts) and circadian phase (compared to bin zero) on sweet snack consumption for each condition. The odds of choosing a sweet snack were reduced during the snack opportunity following lunch and dinner. Overall, the odds of choosing a sweet snack increased across the day in the severe sleep restriction condition. No significant effects were found for circadian phase on sweet snack consumption.

4.4.3 *Savoury snack consumption*

A significant effect was found for prior wake on savoury snack consumption ($p < 0.05$) (Table 4. 1). Wald comparison showed that there were reduced odds of consuming a savoury snack at 17.5h of prior wakefulness compared to 12h of prior wakefulness. No significant effects were found for condition or circadian phase on savoury snack consumption.

4.4.4 *Healthy snack consumption*

No significant effects were found for condition, prior wake or circadian phase on healthy snack consumption (Table 4. 1).

4.5 Discussion

This study investigated the influence of sleep restriction (severe and moderate) on snacking behaviour. Furthermore, the design of the study allowed for separate examination of homeostatic (prior sleep-wake) and circadian processes on snacking behaviour. Results suggest that individuals who are severely sleep restricted to the equivalent of 4h sleep opportunity per 24h had greater odds of consuming a snack when compared to individuals restricted to the equivalent of 6h of sleep per 24h. Moreover, when snack choice was examined, odds of choosing a sweet snack were increased when sleep was severely restricted. No significant differences were found between the two conditions for the consumption of savoury or healthy snacks. The lowest frequencies of snack consumption were around the circadian nadir.

The above findings concur with results from a previous laboratory study in which participants who were restricted to 5.5h of sleep per night consumed more energy from snacks than when they were provided with an 8.5h sleep opportunity per night (Nedeltcheva et al., 2009). The study concluded that the increased consumption of snacks was not due to increased energy needs. In contrast to the present study, Nedeltcheva et al. (2009) found that the increase in snacking was more likely to occur at night rather than during the day. An advantage of the current study was that the FD protocol allowed for examination of homeostatic and circadian processes separately. When these processes were separated, we found that snacks were consumed more frequently during the biological day compared to the biological night. These contrasting findings demonstrate the need to separate homoeostatic and circadian processes to ensure results are not confounded.

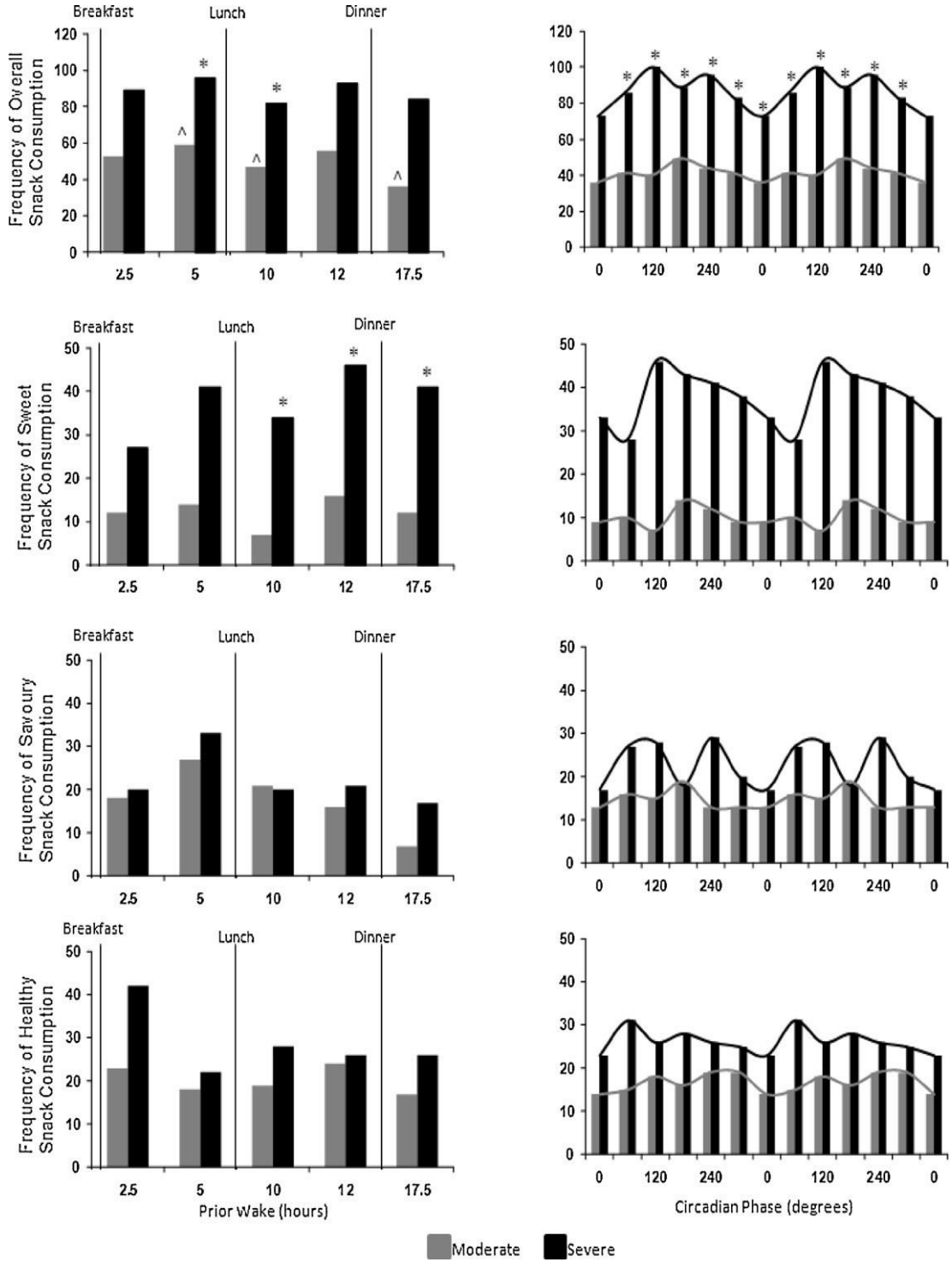


Figure 4.1 Frequency of overall sweet, savoury and healthy snacks by condition

Notes: Prior wake data were analysed using planned repeated contrasts. Circadian phase data (double plotted) were compared to zero degrees (circadian nadir)
**Represents significant difference (p <0.05) for severe sleep restriction condition*
ˆRepresents significant difference
(p < 0.05) for moderate sleep restriction condition

Interestingly, shiftworkers consume more snacks at work when compared to day workers (Waterhouse et al., 2003). This behaviour may be due to the severe sleep restriction often reported by night shiftworkers. Indeed, nurses working night shift have reported they consume sweet snacks as they perceive it will help keep them awake (Persson & Mårtensson, 2006). Furthermore environmental factors may influence the snacking behaviour of shiftworkers. There are limited food options available at night and shiftworkers may not have the time to prepare healthy meals before their shift. Furthermore the investigation of reasons behind snack consumption and choice in shiftwork populations will demonstrate the role environmental factors may play.

In the current study, only limited snack choices were offered to participants; however, even with the narrow range of choice there were significantly increased odds of choosing snacks from the sweet category when sleep was severely restricted. Furthermore, these findings concur with previous research suggesting the energy from snack consumption in sleep-restricted individuals was more likely to come from carbohydrates (Nedeltcheva et al., 2009). Although macronutrient content was not analysed in the current study, the snack choices in the sweet category had a high percentage of carbohydrate. Interestingly, carbohydrate cravings are associated with depressed mood (Lieberman et al., 1986) and both shiftworkers and severely sleep deprived individuals are reported to experience mood disturbances (Dinges et al., 1997; Gordon, Cleary, Parker, & Czeisler, 1986). This further demonstrates the need for future research to investigate psychological motivations behind snack choice as mood may mediate the relationship between sleep restriction and snack choice.

The FD protocol, which allowed for separate analysis of homeostatic and sleep-related processes on snacking behaviour, has built on previous sleep restriction studies. However, it is important to note there were some limitations of the current study that may reduce external validity and generalisation to shiftworkers. For example, to ensure a homogenous sample, the current study only included healthy young males; future studies should investigate snacking behaviour in females and older age groups during sleep restriction. Although the current protocol allowed for examination of snacking behaviour at all possible levels of prior wake and at all circadian phases, the rotating schedule applied in this study does not correspond with a typical rotating shift schedule. Furthermore, as the protocol was relatively short, the long-term effects of sleep restriction on snacking behaviour cannot be determined. Nonetheless, our findings suggest that when individuals are severely sleep restricted they are more likely to snack on sweet foods. As a

result, individuals who are severely sleep restricted may be at risk of weight gain due to poor food choices. This finding has implications for shiftwork populations as they often report severe sleep restriction (Åkerstedt, 2003) and compared to day workers, shiftworkers are more overweight and obese (Atkinson et al., 2008). Future research should focus on understanding the mechanisms involved in unhealthy snack choice and consumption when sleep is severely restricted, including psychological (i.e. mood, perception of alertness), physiological (i.e. appetite as a result of hormonal disruption), and environmental factors (i.e. time constraints, facilities available). A greater understanding of shiftworkers' snack consumption and choice will allow for the preparation of health promotion strategies, which will in turn be beneficial for both individuals and organisations.

Chapter 5
The impact of circadian disruption on sleep, work and health (Study 2)

Heath, G., Sargent, C., Darwent, D., Ferguson, S. A., Kennaway, D. J., Hampton, L. K., Matthews, R. W., Roach, G. D. (2010). Subjective mood is influenced by sleep-related and circadian processes in a forced desynchrony protocol with severe sleep restriction. In: Sargent, C., Darwent, D., Roach, G. D. (Eds). *Living in a 24/7 world: The impact of circadian disruption on sleep, work and health.* Australasian Chronobiology Society, Adelaide, Australia, 7–11. (Appendix C)

5.1 Abstract

Studies show subjective mood declines when sleep is severely restricted to 4–5h per night. In addition, mood follows a circadian rhythm such that subjective mood is lowest around the circadian nadir. These findings are important for shiftworkers who often report severe sleep restriction and are subject to circadian disruption. The current study aims to examine the effect of prior wake and circadian phase on subjective mood when sleep is severely restricted to the equivalent of 4h of sleep opportunity per 24h day.

Fourteen healthy males (21.8 ± 3.8y) lived in a time isolation laboratory for 12 consecutive days. Participants were scheduled to 3 x 24h adaptation days (16h wake, 8h sleep opportunity), followed by 7 x 28h FD days (23.3h wake, 4.7h sleep opportunity). TMD was assessed every 2.5h during wake using the POMS scale. Core body temperature was continuously recorded with rectal thermistors, and used to determine circadian phase.

A significant effect of prior wake was found for TMD (p = <0.001). Scores for TMD increased with duration of wakefulness. A significant effect of circadian phase was found for TMD (p = <0.001). TMD scores were highest around the circadian nadir and lowest around the circadian acrophase. No interaction effects were found.

These findings suggest mood is influenced by sleep-related and circadian processes separately in a controlled laboratory environment when sleep is severely restricted. Field-based research investigating sleeping patterns and mood in shiftworkers would provide further understanding of how other factors such as work and family mediate between sleep restriction/circadian disruption and mood in an external environment.

5.2 Introduction

It is generally accepted that sleep plays a restorative role in general well-being and daily functioning (Vandekerckhove & Cluydts, 2010). FD studies have shown that the duration of prior wake and circadian phase affect mood (Boivin et al., 1997; Koorengevel et al., 2003). Mood tends to decline with increasing duration of prior wake and reaches its lowest point around the circadian nadir. In these studies the ratio of sleep and wake was kept within a normal range (i.e. the equivalent of 8h sleep per 24h day); however, there is evidence to suggest that sleep dose also alters mood. For example, participants who are subject to severe sleep restriction (i.e. 4–5h sleep opportunity per night) for one week report higher levels of anxiety, depression, fatigue and confusion than controls provided with a normal sleep opportunity of 8h per night for one week (Dinges et al., 1997). To date, there have been no studies employing an FD protocol to assess mood when sleep is severely restricted. Therefore, the current study examined the influence of prior wake and circadian phase in an FD protocol with severe sleep restriction (i.e. 4h per 24h day).

5.3 Methods

5.3.1 *Participants*

Fourteen healthy males (age: 21.8 ± 2.5 years, mean ± SD) participated in this study. All participants were in the healthy weight range (BMI 22.4 ± 2.3 kg/m^2), were non-smokers, with normal sleeping patterns. Participants did not have any medical conditions and were not taking any medications. Participants were excluded from the study if they were shiftworkers, had recently travelled through time zones or reported a high caffeine or alcohol intake. Ethics approval for this study was obtained from the University of South Australia Human Ethics Committee. Written informed consent was obtained from all participants, and the research methods conform to the guidelines established by the National Health and Medical Research Council of Australia

5.3.2 *Measures*

Mood was assessed using the POMS (McNair, Lorr, & Droppleman, 1971). POMS assesses transient mood states by asking participants to respond to 65 adjectives. Participants completed a 5-point Likert type scale ranging from ‘not at all’ to ‘extremely’. POMS measures five negative mood domains: T-A, D-D, A-H, F-I and C-B, and one positive mood domain, V-A. A TMD score is

computed by summing the negative domain scores and subtracting the positive domain score. Higher scores indicate greater mood disturbance.

Core body temperature was recorded continuously in one-minute epochs with indwelling rectal thermistors (Steriprobe 491B; Cincinatti Sub-Zero Products, Cincinnati, Ohio, USA). The thermistors were connected to a MiniMitter datalogger (Bend, Oregon, USA).

Sleep was monitored using PSG. Prior to each sleep opportunity, electrodes were attached to the face and scalp using a standard montage. Sleep was scored in 30-second epochs in accordance with accepted criteria (Rechtschaffen & Kales, 1968). Sleep efficiency was calculated as the percentage of time in bed spent asleep.

5.3.3 *Protocol*

The participants were required to live in a time isolation laboratory for 12 consecutive days. The first three days were 24h in length and consisted of a 16h wake episode during the day followed by an 8h sleep opportunity at night. These days were used to train participants on the POMS and to allow participants to familiarise themselves with the laboratory environment. The FD protocol began upon waking after the third night and consisted of seven 28h 'days', each with a 23.3h wake episode and 4.7h sleep opportunity (this is equivalent to a 4h sleep opportunity per 24h day). During the wake episodes the POMS was administered every 2.5h as part of a 1h test battery (i.e. nine test batteries in total). The first test battery began 1.5h after scheduled wake-up time.

5.3.4 *Data reduction and statistical analysis*

Core body temperature data from six FD days (2–7) were used to generate circadian phase estimates for each participant. The generation of phase estimates from core body temperature data was a 4-step process:

1 clean the raw core body temperature data
2 de-mask for physical activity and sleep-wake
3 fit a cosine equation to the de-masked core body temperature data
4 assign a circadian phase estimate (i.e. 0–360 degrees) to each minute of the FD portion of the protocol using a resultant cosine equation (Darwent et al., 2010.

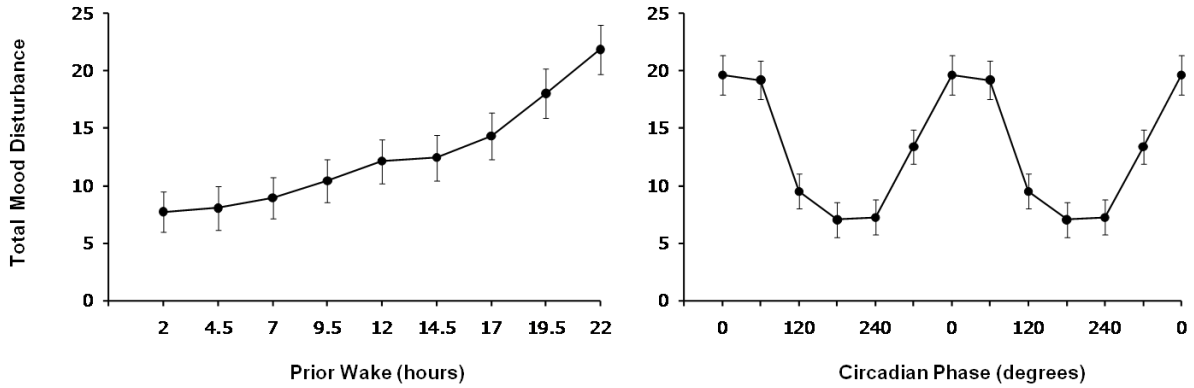


Figure 5.1 Main effects of prior wake and circadian phase on total mood disturbance

Note: Circadian phase data are double plotted. Values are mean ± SEM

Individual data points were grouped according to circadian phase and level of prior wakefulness. For analysis of the circadian component, a bin width of 60 degrees (~4h) was selected. For analysis of the prior wake component, nine levels of prior wake were identified that corresponded to the midpoint of each test battery. The main and interaction effects of prior wake and circadian phase on TMD and the six mood domains were analysed using linear mixed model analysis. To control for any differences in sleep duration across the study days, sleep efficiency was included as a covariate in all analyses.

5.4 Results

5.4.1 *Total mood disturbance*

There was a significant main effect of prior wake for TMD, $F_{(8, 118)} = 18.6$, $p = <0.001$ (Figure 5.1). TMD scores rose progressively with increasing duration of prior wake. There was a significant main effect of circadian phase for TMD, $F_{(5,171)} = 37.7$, $p = <0.001$ (Figure 5.1). TMD was greatest at the circadian nadir and lowest at the acrophase.

5.4.2 *Negative mood domains*

There was a significant main effect of prior wake for all negative mood domains except A-H (Table 5.1). Scores on the negative mood scales were lowest at the first testing session and increased over the wake period. A significant main effect of circadian phase was found for all of the negative mood domains (Table 5.1). Scores on the negative mood scales were highest at, or just after, the circadian nadir and lowest at, or just after, the acrophase.

Table 5.1 Main effects of prior wake and circadian phase on mood domains

Mood Domain	Prior Wake			Circadian Phase		
	F	df	*p*	F	df	*p*
Tension-Anxiety (T-A)	4.1	8,91	<0.001	10.6	5,146	<0.001
Depression-Dejection (D-D)	3.1	8,90	<0.01	6.3	5,149	<0.001
Anger-Hostility (A-H)	2.5	8,68	0.053	3.8	5,104	<0.01
Fatigue-Inertia (F-I)	20.3	8,97	<0.001	42.5	5,183	<0.001
Confusion-Bewilderment (C-B)	14.0	8,123	<0.001	30.2	5,171	<0.001
Vigour-Activity (V-A)	12.3	8,112	<0.001	38.3	5,190	<0.001

Note: Denominator degrees of freedom are displayed as adjusted by SPSS using a Satterthwaite correction

5.4.3 *Positive mood domains*

There was a significant main effect of prior wake for the positive mood domain of V-A (Table 5.1). Scores for V-A were highest at the first testing session and reduced over the wake period. There was a significant effect of circadian phase for V-A, such that scores were highest around the circadian acrophase and lowest around the circadian nadir.

5.5 Discussion

The current study revealed mood is affected by sleep-related and circadian processes independently when sleep is severely restricted. Participants became increasingly anxious, depressed, confused, more fatigued, and felt less active with increasing duration of prior wake and around the circadian nadir; however, the level of mood disturbance found did not reach clinical significance (McNair, Lorr, & Droppleman, 1971). No interactions of prior wake and circadian phase on mood were found.

In contrast to previous FD studies, the current study included severe sleep restriction in the protocol. Participants in this study remained awake for 23.3h and were given a sleep opportunity of 4.7h, which is equivalent to 4h of sleep per 24h day. A previous FD study found that mood (cheerfulness and happiness) was not significantly affected by prior wake; however, there was a trend for mood to decline over the wake period (Boivin et al., 1997). A subsequent FD study found depression was not significantly affected by duration of prior wake (Koorengevel et al., 2003); in both of these studies participants' sleep-wake was kept in line with a normal sleep ratio of 1:2 (i.e. the equivalent of 8h sleep per 24h day). The severe sleep restriction and lengthy duration of prior wake in the current study may explain why we found a significant deterioration in mood and the

previous studies did not. In addition, the previous FD studies used measures other than POMS to assess mood. Future studies should assess mood with POMS in an FD protocol with a normal sleep-wake ratio as this would allow for a direct comparison between the sleep doses.

In line with previous research (Boivin et al., 1997; Koorengevel et al., 2003), the current study found mood displayed a circadian rhythm. Participants reported feeling more depressed, anxious, confused, angry and fatigued around the circadian nadir than they felt around the acrophase. Feelings of activity were lowest around the circadian nadir. Therefore, individuals who are required to remain awake throughout the biological night, such as shiftworkers, are likely to find their mood deteriorates during the early hours of the morning. The deterioration in mood may be compounded for shiftworkers due to the severe sleep restriction they often experience (Åkerstedt, 2003). Indeed, shiftworkers often report mood disturbances such as anxiety and depression (Gordon et al., 1986).

The results of this study suggest severe sleep restriction, duration of prior wake and circadian phase impact on mood. Therefore, the current study has practical significance not only for shiftworkers who report severe sleep deprivation and circadian disruption (Åkerstedt, 2003), but also for any individuals who are deprived of sleep and have long durations of wakefulness. Mood states have been associated with various outcomes. Negative mood states have been found to influence job attitudes and behaviours (Brief & Weiss, 2002) and psychological wellbeing (Vandekerckhove & Cluydts, 2010). In contrast, positive mood such as happiness and thinking optimistically may play a role in the prevention of cardiovascular disease (Kubzansky, Sparrow, Vokonas, & Kawachi, 2001). A limitation of laboratory studies is that participants are not in their natural environment. Laboratory studies are unable to ascertain if other factors such as social, family and work pressures mediate the relationship between sleep restriction, circadian disruption and mood disturbances. Field studies investigating the mood of shiftworkers may enhance our understanding of how sleeping patterns and circadian disruption affect mood in this population.

Chapter 6
Predictors of eating behaviour in shiftworkers (Study 3)

6.1 Introduction

The prevalence of shiftwork has increased over the past few decades (Australian Bureau of Statistics, 2010; Harrington, 2001; United States Department of Labor, 2005). Shiftwork has a broad definition (working hours outside of 9am–5pm Monday to Friday), and shiftworkers may be required to work on one of various shift schedules (e.g. rotating or permanent shifts) or shift types (e.g. morning, afternoon, night (Åkerstedt, 2003; Costa, 2010). Shiftwork has many advantages. At an organisational level, shiftwork is designed to increase productivity and optimise production in the workplace. At an individual level, shiftwork schedules may promote work-life balance and assist with family demands such as child care (Presser, 1995). Conversely, shiftwork has been associated with a number of negative consequences including circadian disruption, sleep restriction (Åkerstedt, 2003; Costa, 2003) and high levels of fatigue (Paley & Tepas, 1994). A large body of research provides evidence to suggest that these factors lead to detrimental effects for the safety and performance of shiftworkers (Åkerstedt & Wright, 2009; Arendt, 2010; Dorrian et al., 2008; Rajaratnam & Arendt, 2001). More recently, attention has focussed on the impact of shiftwork on long-term health. Numerous studies have linked shiftwork with several serious health disorders. For example, shiftwork has been associated with cardiovascular disease, metabolic syndrome, gastrointestinal disease, type 2 diabetes and some forms of cancer (Costa, Haus & Stevens, 2010; Karlsson et al., 2001; Knutsson & Bøggild, 2010; Puttonen et al., 2010).

Many of the abovementioned health disorders can develop as a result of lifestyle-related conditions such as obesity (McGinnis & Foege, 1998; Orzano & Scott, 2004). Numerous studies have suggested that when compared to day workers, shiftworkers are more likely to be overweight or obese (Biggi et al., 2008; Esquirol et al., 2009; Lin et al., 2009; Suwazono et al., 2008). There are various pathways that lead to the development of obesity; however, unhealthy eating behaviour such as increased consumption of energy dense foods which are high in fat is a major contributing factor to the occurrence of this disease (World Health Organisation, 2015).

The eating behaviour of shiftworkers is currently being investigated to determine if it differs from day workers; however, findings from studies conducted thus far have varied. Some studies suggest there is no difference in energy intake or dietary composition in shiftworkers when compared to day workers (Åkerstedt, 2003; de Assis et al., 2003; Esquirol et al., 2009; Lennernäs et al., 1995). In contrast, other studies have found that shiftworkers have a lower energy intake when compared to day workers (Lennernäs & Andersson, 1999; Sudo & Ohtsuka, 2001; Tepas, 1990). Still others have provided evidence to suggest participating in shiftwork alters eating

behaviour such that energy intake is increased (Morikawa et al., 2007; Suwazono et al., 2008) and the composition of their diet is poorer than day workers (Di Lorenzo et al., 2003; Harada et al., 2005; Knutson et al., 1990; Puttonen et al., 2009).

As mentioned above, shiftworkers can be employed to work one of several shift schedules (permanent, rotating etc.) and on these shift schedules they may work one or more shift types (morning, afternoon, night) (Åkerstedt, 2003; Costa, 2010). Each of these shift types and shift schedules are associated with varying levels of disruption to physiological and psychological factors. Shift type can influence the amount of sleep a shiftworker obtains. For instance, morning and night shiftworkers are at increased risk of sleep restriction when compared to afternoon shiftworkers (Åkerstedt, 2003; Knauth et al., 1980). Furthermore, the shift schedule an individual works may have an impact on the amount of sleep restriction experienced. For example, it has been reported that shift schedules that change between shifts frequently (fast rotating) are most likely to affect sleep (Wilkinson, 1992). In addition to sleep restriction, increased levels of fatigue have been associated with shiftwork (Bohle & Tilley, 1993; Cavallo et al., 2002; Metzner & Fischer, 2010; Paterson et al., 2010). In particular high levels of fatigue have been associated with working a night shift (Bohle & Tilley, 1993; Luna et al., 1997; Nasrabadi et al., 2009). Taken together, these findings suggest that the disruption to sleep and fatigue levels may alter depending on shift type and shift schedule.

The varying levels of sleep restriction and fatigue a shiftworker may experience as a result of working different shift schedules or shift types may be associated with alterations in eating behaviour. Studies have demonstrated that both sleep restriction and fatigue can impact on eating behaviour (Bosy-Westphal et al., 2008; Brondel et al., 2010; St-Onge et al., 2011). Additionally, other work-related factors such as the number of years an individual has been employed in shiftwork have also been found to impact on eating behaviour. The impact sleep restriction, fatigue and work-related factors have on eating behaviour are explored separately below.

6.1.1 *Sleep restriction*

As a consequence of circadian disruption and social and family obligations, sleep duration may differ depending on shift type. Studies have demonstrated that shiftworkers obtain less sleep when compared to day workers (Pilcher, Lambert, & Huffcutt, 2000). In particular, night shiftworkers are at considerable risk of short sleep durations as they are required to sleep in

opposition to their body clock (Ursin, Bjorvatn, & Holsten, 2005). It is difficult to fall asleep and maintain sleep during the early hours of the morning, when night shiftworkers are attempting sleep following their shift (Åkerstedt, 2003). Additionally, shiftworkers employed on morning shifts often restrict their sleep due to early wake times (Ingre, Kecklund, Åkerstedt, Söderström, & Kecklund, 2008).

There is evidence to suggest that appetite may increase as a consequence of sleep deprivation due to endocrine changes associated with appetite regulation. Whilst findings are mixed, some studies suggest that the hormone ghrelin increases; and levels of the hormone leptin decreases when sleep duration is shortened (Spiegel, Leproult et al., 2004; Spiegel, Tasali et al., 2004). These findings indicate that sleep deprived individuals may experience increased appetite following sleep restriction. Indeed, research thus far has provided evidence demonstrating that short sleep durations result in increased energy intake (Bosy-Westphal et al., 2008; Brondel et al., 2010; St-Onge et al., 2011). Restricting sleep has also been associated with alterations in food choice. For example, cravings for kcal-dense foods (Spiegel, Tasali et al., 2004) and increased snacking behaviour (Nedeltcheva et al., 2009) have been reported in sleep-restricted individuals. These findings from laboratory studies are in line with studies that have found shiftworkers alter their eating behaviour (Balieiro et al., 2014; Morikawa et al., 2008; Suwazono et al., 2008). Not all studies have found eating behaviour is altered in shiftworkers (de Assis et al., 2003); however, these studies did not investigate the sleep durations of shiftworkers who participated, therefore it is not yet known if sleep restriction predicts eating behaviour in shiftworkers. Given the evidence from laboratory studies suggesting sleep restriction alters eating behaviour, combined with the studies showing sleep durations are shorter in shiftwork populations, Study 3 examined if sleep duration predicts eating behaviour in shiftworkers.

6.1.2 *Fatigue*

In addition to sleep restriction, shiftworkers commonly report experiencing high levels of fatigue (Åkerstedt & Wright, 2009). Fatigue can be difficult to define, and while the term fatigue is often used interchangeably with sleepiness, research suggests that these two factors should be measured as separate constructs. Feelings of sleepiness can result from alterations or an imbalance in sleep-wake mechanisms. Alterations in sleep and wake can also lead to feelings of fatigue; however, fatigue occurs due to a number of psychological and physiological factors (Åkerstedt & Wright, 2009; Shen et al., 2006). For example, fatigue can result from difficult work, extended duty, and family or personal circumstances (Boivin, Tremblay, & James, 2007). In

shiftwork populations fatigue is often associated with the circadian disruption this population experiences (Boivin et al., 2007; Costa, 2010). Fatigue that is shorter in duration and can be alleviated by resting, exercise and stress management, is referred to as acute fatigue. In contrast, chronic fatigue is ongoing and persists over time (Shen et al., 2006). Studies have found that shiftworkers may be at risk of developing chronic fatigue (Nasrabadi et al., 2009).

Although studies are limited, fatigue has been associated with alterations in eating behaviour. In particular, night shiftworkers have reported increased sugar intake and consumption of sweet snacks as they felt it helped them maintain alertness and keep awake whilst on night shift (Krauchi, Nussbaum, Wirz-Justice, & Horne, 1990; Persson & Mårtensson, 2006). Furthermore, when individuals are fatigued or exhausted they may choose unhealthy processed food as these foods are perceived as being quick and easy to prepare (Stewart & Wahlqvist, 1985; Wong, Wong, Wong, & Lee, 2010). Indeed, studies involving shiftworkers have found that they often rely on quick and easy options to provide food whilst at work such as vending machines (Lancaster et al., 2001). Additionally, nurses have reported that they do not have the energy to cook meals in between night shifts, and resort to consuming meals that do not require much preparation during these times (Persson & Mårtensson, 2006). These studies indicate that the fatigue associated with shiftwork may be a possible pathway to altered eating behaviour due to the perceived alertness sugary foods create, and the lack of energy for preparation of foods whilst fatigued. Therefore, along with sleep duration, fatigue should be examined as a predictor of eating behaviour in shiftworkers.

6.1.3 *Work-related factors*

A limited number of studies have examined work-related factors associated with shiftwork to determine if these factors predict eating behaviour. In particular, a large (*n* = 1,529), longitudinal study conducted at a Japanese factory found that shiftwork history (years the individual has been employed in shiftwork) predicted energy intake (Morikawa et al., 2007). The male participants in this study recorded their energy and macronutrient intake on a self-administered diet history questionnaire at the end point of a 10-year study. Participants were split into four groups: day workers who remained on day shift for the duration of the study, day workers who changed to shiftwork during the study, shiftworkers who reverted back to day shifts, and shiftworkers who remained employed in shiftwork for the entire duration of the study. Interestingly, results showed that individuals with the highest energy intake of these four groups were those who had been employed in shiftwork for the entire period of the 10-year study. These findings suggest that long-

term shiftworkers may be more at risk of obesity due to increased energy intake than day workers or those who participate in shiftwork for only a short period of time. These findings concur with a recent study that concluded that shiftwork history was associated with weight gain (Marqueze, Lemos, Soares, Lorenzi-Filho & Moreno, 2012). Some studies investigating shiftworkers and eating behaviour have only used an inclusion criteria of a minimum of six months employed in shiftwork (de Assis et al., 2003) or one year employed in shiftwork (Lennernäs et al., 1995). Energy intake was not examined at the beginning of Morikawa et al.'s (2007) study, making it difficult to determine if energy intake increased over the duration of shiftwork. Nevertheless, similar findings have been demonstrated in a previous longitudinal study. Knutson et al. (1990) investigated individuals beginning a shiftwork schedule. Participants who began working on afternoon or night shifts reported an increase in energy intake since beginning employment in shiftwork. These findings suggest eating behaviour may alter over the period of shiftwork employment. Therefore, in addition to sleep restriction and fatigue, studies should also consider work-related factors such as shiftwork history as a predictors of eating behaviour.

In summary, the above findings demonstrate that a number of factors may alter the eating behaviour of shiftworkers. Although there has been an increasing number of studies examining the dietary intake of shiftworkers, very few have investigated predictors of eating behaviour. Examining not only the differences in dietary intake and composition in shiftworkers employed on various shift types and shift schedules, but also the factors that could predict alterations in the diet, will help gain a deeper understanding of the mechanisms that may contribute to obesity in shiftwork populations. Based on the literature discussed above it was hypothesised that:

Sleep duration, fatigue and work-related factors will predict alterations in eating behaviour.

6.2 Methods

6.2.1 *Participants*

The study recruited 131 participants from six organisations. Participants came from four industries: printing, postal, nursing, and oil and gas. Eight participants were excluded due to incomplete dietary questionnaires. One participant was excluded, as the industry reported on their questionnaire did not match any of the other industry categories. A further four participants were excluded as the work hours they reported (e.g. working between 9am and 5pm) classified them as day workers rather than shiftworkers. Therefore, the final sample consisted of 118

participants. This study attempted to recruit as many participants as possible within the constraints of the field study.

6.2.2 *Ethics*

In accordance with the guidelines of the National Health and Medical Research Council of Australia, ethics approval for this study was obtained from the University of South Australia Human Research Ethics Committee. In addition, where required, ethics approval were obtained from the human research ethics committees relevant to the specific organisations (see Chapter 2, Section 2.2 for further detail).

6.2.3 *Study design*

The current study was a cross-sectional design-survey study.

6.2.4 *Procedure*

Recruitment methods varied slightly depending on the procedure preferred by each organisation. The research team either held information sessions at the location of the organisation, or the details of the study were explained to a senior staff member who then described the study to their employees. Directly following the information session, interested volunteers were provided with a study pack containing an information sheet, questionnaire and a reply paid envelope. Participants were required to complete the questionnaire in their own time. The questionnaire took approximately 30 to 45 minutes to complete. Upon completion, the questionnaire was returned to the research team in the provided reply paid envelope. Remuneration was not provided for this study; however, participants were given the opportunity to receive a dietary analysis based on the food consumption they reported in their questionnaire. As questionnaires were anonymous, if participants wished to receive the dietary analysis they were required to contact the research team advising the numerical code on the questionnaire and their address. Upon receipt of this request a copy of the dietary analysis was posted to the participant.

6.2.5 *Measures*

6.2.5.1 Eating behaviour

Eating behaviour was defined in this study as average daily energy intake in kJ and average daily macronutrient intake (fat, protein and carbohydrate) as a percentage of daily energy intake. Analysis of nutrients is a common method for measuring eating behaviour (Penfield & Axelson, 1984). In addition, measuring macronutrient intake as a percentage of daily energy intake allowed the diet of the shiftworkers in this study to be compared to the acceptable macronutrient

distribution range for Australian adults outlined in *The Nutrient Reference Values for Australians* (National Health & Medical Research Council, 2006).

Eating behaviour was assessed using the Cancer Council Dietary Questionnaire (CCDQ) (Giles & Ireland, 1996) (see Appendix R). CCQD is a semi-quantitative self-administered food frequency questionnaire (FFQ) designed to measure typical eating behaviour over a 12-month period. It is comprised of four sections. Section 1 asks participants to respond to a list of food items typically consumed on a daily basis (e.g. milk and bread). Section 2 asks participants to respond to a set of photographs containing pictures of serving sizes to indicate which plate best represents their typical serving size for each meal. Responses are used to calibrate typical portion sizes. For example, the CCDQ displays photographs of three different serving sizes of foods (e.g. casserole) and asks participants to report if their usual serving size is either less than, equal to or greater than each of the three serving sizes shown in the photographs. Participants also have the opportunity to state they do not eat foods shown in the photograph. Section 3 requires participants to respond to a list of food items from four categories (cereals, sweets and snacks; dairy products, meat and fish; fruit and vegetables). Participants are asked to report how much and how often they consume these foods from 10 frequency response options ranging from 'never' to '3 or more times per day'. The final section of the questionnaire asks participants to respond to questions relating to alcohol consumption. The CCDQ is quick and easy to use and has been validated relative to seven-day weighed food record (Hodge et al., 2000) Weighed food records are considered gold standard in dietary measurement (Thomson & Subar, 2001). Results from the study by Hodge et al. (2000) showed the highest correlation coefficient between the CCDQ and the weighed food records was for carbohydrate (r = 0.78). The lowest correlation coefficient was for vitamin A (r = 0.28). Correlations in the validation study were energy-adjusted and de-attenuated. The CCDQ has also been validated against a three-day weighed food record (Xinying, Noakes, & Keogh, 2004).

Completed questionnaires are sent to the ACCV for analysis, which analyses questionnaires based on responses provided and returns a spreadsheet containing average daily energy, nutrient and alcohol intake for each participant. Each of the daily macronutrient and alcohol intakes was then calculated as a percentage of daily energy intake in kilojoules for each participant using the following values for each macronutrient: 17kJ/g for carbohydrate and protein, 29 kJ/g for alcohol and 37 kJ/g for fat. Eating behaviour was operationalised as daily energy intake and daily

macronutrient intake (as a percentage of daily energy intake). For further information regarding the CCDQ refer to the user guide (Appendix T).

6.2.5.2 Sleep

6.2.5.2.1 *Sleep duration*

Section 2 of the SSI (Appendix Q) (Barton et al., 1993) asks participants to report their sleep duration (in hours). The SSI is described in more detail in Chapter 2 (Section 2.7). Sleep duration relates to the amount of sleep that the participant would typically attain between each working day for every type of shift they work (e.g. morning, night and afternoon). Rotating shiftworkers reported the amount of sleep they typically obtained between each shift type. As rotating shiftworkers in Study 3 worked a variety of shifts, an average sleep duration between working days was calculated. Therefore, sleep duration was operationalised as the average sleep duration (in hours) a participant reported obtaining between working days.

6.2.5.2.2 *Chronic fatigue*

Chronic fatigue was measured using the scale provided in Section 2 of the SSI (see Appendix Q). The SSI defines chronic fatigue as general tiredness and lack of energy on work and rest days regardless of sleep obtained or work hours (Barton et al., 1993). The Chronic Fatigue Scale is a 5-point Likert type scale with 10 items. Responses can range from 'not at all' to 'very much so'. Five items in the scale are related to general feelings of tiredness or lack of energy. The remaining five items relate to feelings of vigour and energy, and are reversed scored. The Chronic Fatigue Scale has been found to have a reliability coefficient of 0.91 for internal consistency (Smith et al., 2001). Scores on the Chronic Fatigue Scale can range from 10 to 50 with higher scores representing a greater level of chronic fatigue. Chronic fatigue was operationalised as the participant's score on the Chronic Fatigue Scale as a continuous variable.

6.2.5.3 Work-related variables

Shift schedule, shiftwork history, total hours worked and industry were assessed using Section 1 of the SSI (Barton, Spelten, Totterdell, Smith, Folkard, & Costa, 1995). The SSI has been used in numerous studies worldwide (Barton et al., 1995; Nag & Nag, 2004; Ruggiero, 2005; Spelten, Barton, & Folkard, 1993). Questions are open ended and ask participants to report their shift schedule, the number of years they have been employed in shiftwork, typical weekly working hours (including overtime) and the industry they are currently employed in. This study identified that shiftworkers were employed in one of four different shift schedules: permanent morning

(e.g. 07:00–15:30), permanent night (e.g. 21:00–07:30), 8h rotating (e.g. rotating between morning afternoon and night shift) and 12h rotating (rotating between morning and night shifts). Participants were employed in four industry types (printing, postal services, nursing, or oil and gas). The responses from completed questionnaires allowed variables to be operationalised as follows:

- shift schedule – schedule participant's current shift schedule (permanent morning, permanent night, 8h rotating or 12h rotating)
- shiftwork history – number of years reported employed in shiftwork
- total hours worked – number of hours reported working per week
- industry – participant's current industry (printing, postal services, nursing, or oil and gas).

6.2.5.4 Demographic variables

Age, BMI, dependents and marital status were included in this study, as previous research has suggested that these variables can affect eating behaviour (Axelson, 1986; Devine & Olsen, 1992; Devine, Wolfe, Frongillo & Bisogni, 1999; Lissner & Heitmann, 1995; Rolls, Fedoroff & Guthrie, 1991). Table 6.1 outlines the effect each of these variables has on eating behaviour. The demographic variables used to predict eating behaviour in Study 3 were reported by the participant in Section 1 of the SSI (Barton et al., 1995).

Table 6.1 Demographic variables and their effect on eating behaviour

Variable	Effect on eating behaviour
Age (years)	An individual's age can impact on eating behaviour. For example, life experiences occurring across the lifespan may alter food choices. Research suggests that food and cooking skills are more common amongst older individuals (Devine, Wolfe, Frongillo Jr, & Bisogni, 1999)
Gender (male or female)	Research suggests there are gender differences in eating behaviour. In particular, men have a higher energy intake compared to women (Rolls, Fedoroff, & Guthrie, 1991)
BMI (kg/m^2)	Individuals with higher BMI are more likely to consume energy-dense foods and have a high intake of dietary fats (Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992; Lissner & Heitmann, 1995)
Dependents (number of children living at home)	Having dependents at home has been identified as a factor that may impact on eating behaviour. For example, mothers have been found to place children's wellbeing above their own nutritional needs. In contrast, parents may make positive nutritional changes in order to set a good example (Devine & Olson, 1992)
Marital status (married/not married)	Individuals living with a partner whom they share food preparation and meal times with may alter their eating behaviour. For example, if a partner alters their diet for health reasons, both partners may decide to make those changes to co-operate or ease the burden of food preparation (Devine & Olson, 1992)
Education (SES) (post graduate, graduate, vocational, secondary)	Educational level was used in Study 3 as a measure of SES. Various studies demonstrate differences in eating behaviour according to educational level. Individuals with a higher level of education consume a healthier diet (Axelson, 1986; Hulshof et al., 1991; Murphy, Rose, Hudes, & Viteri, 1992). In particular, those with a low SES have been found to have a diet high in fat (Murphy et al., 1992)
Industry (printing, postal, nursing, or oil and gas)	The place of work can affect eating behaviour, particularly food choices. Norms for eating may alter from site to site. Some workers have discussed subtle pressure to consume healthier options whilst at work (Devine & Olson, 1992)

Notes: BMI = body mass index; SES = socio economic status

6.2.5.5 Statistical analysis

There were no clear patterns in missing data between participants or variables. Less than 5% of data were missing for all variables except for shiftwork history (11% missing) and BMI (7% missing). The literature suggests that statistical data is not likely to be biased when less than 10% of data are missing (Bennett, 2001; Schafer, 1999). All data were screened for normality. Boxplots were used to identify extreme scores (Field, 2013). On inspection of the boxplot, one participant was identified as reporting an extreme score for energy intake. The extreme score was removed from the data set. Marital status was categorised into 'married' and 'not married' (divorced,

widowed or single) in order to have cell sizes that were sufficient for the analysis. Dependents were categorised into 'yes' (dependent <18 years?) or 'no'. Education was categorised into four categories: post-graduate, undergraduate, vocational, and secondary.

SPSS version 21 (SPSS, Chicago, Illinois, USA) was used for statistical analysis. A series of statistical tests were performed to investigate the data. One-way analysis of variance (ANOVA) tests were conducted to determine differences in predictor variables and dietary intake by shift type. In addition, Pearson correlation analyses were conducted for all continuous variables to examine associations between dietary intakes, fatigue, sleep, and work-related variables and demographic variables. Magnitudes of correlations were interpreted as trivial, 0.1; small, 0.3; moderate, 0.3–0.5 and large, >0.5 (Cohen, 1988). Regression analyses were conducted to determine predictors of eating behaviour. A significance level of 0.05 was used to determine statistical significance. Data are presented as mean ± SD.

6.3 Results

6.3.1 *Demographics*

Study 3 included 118 shiftworkers aged between 18 and 62 years (43.4 ± 9.9 years). Of all participants, 68% were male. A large proportion of participants were married (83%). Just under half had not completed any vocational or tertiary education (42%). On average, shiftworkers in this study were classified as overweight (BMI 27.0 ± 4.5 kg/m^2). Just over half did not have any dependents under the age of 18 years living with them (66%) (see Table 6.2). A power analysis demonstrated that based on the sample of 118 participants and 10 predictor variables, with power set at 0.8 and alpha level set at 0.05 the study had power to detect $R^2 = 0.13$. For this reason the study is underpowered to detect small effects.

6.3.2 *Sleep*

The average sleep duration between shifts in this sample was 7h. Shiftworkers on a 12h rotating shift schedule obtained significantly less sleep than those employed on any of the other shift schedules (see Table 6.2). Figure 6.1 separates the shiftworkers in Study 3 into various classifications of sleep duration.

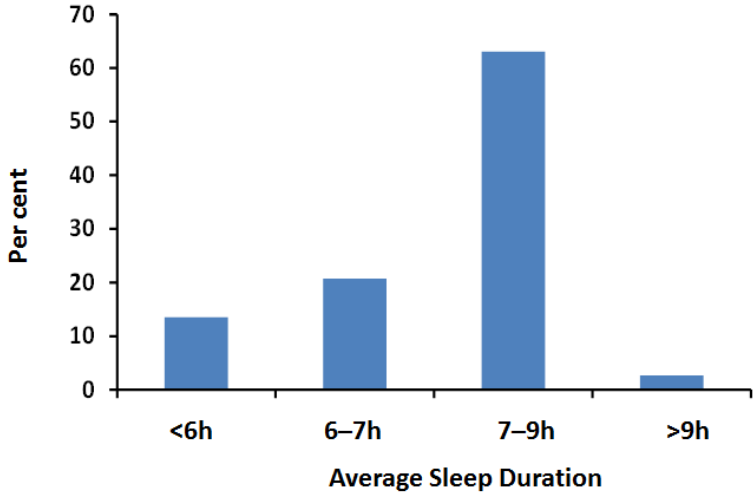


Figure 6.1 Average sleep duration between shifts for all participants (percentage)

Note: The majority of shiftworkers were obtaining the recommended amount of sleep (7–9 hours per night) (National Sleep Foundation, 2015). However, 34.2% were obtaining less than the recommended amount of sleep

6.3.3 *Chronic fatigue*

Although those on 8h rotating shift and permanent night shift reported slightly higher levels of fatigue than morning and 12h rotating shiftworkers, there was no significant difference in fatigue found between the shifts (see Table 6.2).

6.3.4 *Work-related variables*

The average working hours per week for participants was 39.8 ± 11.6 hours. On average shiftworkers in the present study had been employed in shiftwork for 14.7 ± 10.0 years (see Table 6.2).

Table 6.2 Demographic, sleep/fatigue and work-related characteristics of study participants

	Morning (*n* = 33)	**Night (*n* = 27)**	**8h Rotating (*n* = 29)**	**12h Rotating (*n* = 29)**	**F**	**df**
Demographic factors						
Age (years)	44.8 (9.9)	42.7 (9.9)	41.2 (11.7)	44.17 (7.9)	0.58	3,113
Gender %						
Male	78.8	63	34.5	96.4		
Female	21.2	37	65.5	3.6		
Marital status %						
Married	81.8	74.1	85.7	93.1		
Not married	18.2	25.9	14.3	6.9		
Education %						
Postgraduate	12.5	7.4	32.1	17.2		
Undergraduate	21.9	14.8	32.1	3.4		
Vocational	21.9	7.4	14.3	44.8		
Secondary	43.8	70.4	21.4	34.5		
Industry %						
Printing	18.2	14.8	20.7	0		
Postal	63.6	77.8	0	0		
Nursing	15.2	7.4	75.9	0		
Oil & Gas	3	0	3.4	100		
BMI (kg/m^2)	25.8 (2.8)	26.8 (5.1)	27.5 (5.5)	28.3 (4.0)	1.68	3,113
Sleep/fatigue related factors						
Sleep duration (hours)	7.5 (1.0)	7.0 (1.1)	7.4 (0.9)	6.3 (1.0)	8.42*	3,113
Chronic fatigue (score: 10–50)	25.9 (5.9)	28.1(8.4)	28.0 (7.8)	25.1 (7.7)	1.42	3,113
Work-related factors						
Total hours worked (hours)	40.4 (16.1)	35.9 (9.6)	38.9 (10.0)	44.0 (7.2)	2.44	3,113
Shiftwork history (years)	18.7 (11.5)	9.0 (5.9)	13.5 (10.5)	18.5 (8.8)	6.37*	3,113

Notes: Mean (standard deviation) unless indicated otherwise
** significant at p<.05*
BMI = body mass index

6.3.5 *Dietary intake*

On average, male shiftworkers reported consuming 9,075.4 ± 3,204.6 kJ per day and female shiftworkers consumed on average 7,719.6 ± 2,918.8 kJ per day. Shiftworkers in Study 3 reported that 34.3% ± 5.2% of their diet was from fat, and 14.0 %, ± 2.9% consisted of saturated fat (on average). Dietary intake was compared by shift type (Table 6.3). Results showed 12h rotating shiftworkers had the highest energy consumption, while night shiftworkers consumed the highest percentage of energy from fat. However, results from a one-way ANOVA showed that there were

no significant differences between shifts for energy or fat intake (as a percentage of daily energy intake). Results from the one-way ANOVA showed that night shiftworkers had a significantly higher percentage of saturated fat in their diet compared to 8h rotating shiftworkers and morning shiftworkers. Morning shiftworkers reported the highest levels of carbohydrate consumption on average, whereas 8h rotating shiftworkers had the highest percentage of protein in their diet. Results from the one-way ANOVA did not demonstrate any significant differences between the shift types for carbohydrate or protein intake (as a percentage of daily energy intake). The 12h rotating shiftworkers had the highest percentage of alcohol in their diet; however, these findings were not significant.

Table 6.3 Dietary intake by shift type

	Morning (*n* = 33)	**Night (*n* = 27)**	**8h Rotating (*n* = 29)**	**12h Rotating (*n* = 29)**	**F**	**df**
Energy	7,954	8,816	8,530	9,318	1.0	3,113
(kJ)	(2,979)	(3,616)	(3,080)	(2,852)		
Fat %	33.0 (6.0)	35.9 (5.0)	34.3 (5.3)	34.5 (4.0)	1.4	3,113
Fat g	71.0 (28.8)	85.8 (38.9)	79.9 (34.1)	87.2 (30.5)		
SFA %	12.9 (2.7)	15.5 (3.1)	13.8 (2.8)	14.1 (2.4)	4.2*	3,113
SFA g	30.0 (13.2)	37.3 (16.9)	32.0 (15.1)	33.2 (12.9)		
CHO%	40.7 (6.8)	41.8 (6.1)	41.3 (6.8)	38.7 (6.9)	1.1	3,113
CHO g	196.5 (81.2)	211.2 (86.5)	208.5 (87.3)	213.3 (78.8)		
Protein%	19.0 (2.6)	19.2 (3.7)	20.7 (3.2)	19.6 (3.6)	1.3	3,113
Protein g	89.4 (34.3)	99.9 (43.4)	101.9 (37.6)	105.5 (33.0)		
Alcohol%	8.8 (9.24)	5.5 (6.79)	6.5 (5.52)	10.1 (8.88)	2.0	3,113
Alcohol g	17.7 (17.28)	14.1 (21.18)	12.3 (10.53)	24.8 (23.04)		

Notes: Mean (standard deviation)
** significant* p *<.05*
kJ = kilojoules; g = grams; %, per cent of total daily energy intake; SFA = saturated fat; CHO = carbohydrate
It is recommended that the daily energy intake of adults contain between 45 and 65% carbohydrates, 15 and 25% protein, 20 and 35% fat in order to maintain health. Source:
Council and New Zealand Ministry of Health, Nutrient Reference Values for Australia and New Zealand, 2006 <https://www.nrv.gov.au/chronic-disease/macronutrient-balance>

Table 6.4 shows associations between dietary intakes, fatigue, sleep, and work-related and demographic variables. Findings from the correlation analyses showed energy intake was not significantly correlated with any other continuous variable. Percentage of fat consumed in the

diet had a small positive correlation with chronic fatigue levels and BMI. Sleep duration had a small negative correlation with BMI and the total hours worked per week. Age had a small positive correlation with BMI and a large correlation with years worked in shiftwork. Sleep duration and chronic fatigue were not correlated.

Table 6.4 Associations between dietary intake, fatigue, sleep, work and shift-related variables

	Energy (kJ)	Fat	SFA	CHO	Protein	Alcohol	BMI	Age	Shiftwork length	Total hours worked	Chronic fatigue	Sleep duration
Energy (kJ)	1	.085	.099	.027	–.157	–.011	.093	–.157	–.091	–.153	.020	–.037
Fat	.085	1	.780	–.526	.070	–.318	.276	.005	–.040	.051	.266	.053
SFA	.099	.780	1	–.312	–.118	–.253	.213	–.066	–.155	.076	.183	.033
CHO	.027	–.526	–.312	1	–.315	–.499	–.163	.075	–.015	.125	–.210	–.126
Protein	–.157	.070	–.118	–.315	1	–.267	.036	–.054	.001	–.176	.075	.080
Alcohol	–.011	–.318	–.253	–.499	–.267	1	–.072	–.063	.049	–.089	–.031	.052
BMI	.093	.276	.213	–.163	.036	–.072	1	.223	.159	.113	.128	–.211
Age	–.157	.005	–.066	.075	–.054	–.063	.223	1	.580	.054	.154	–.146
Shiftwork length	–.091	–.040	–.155	–.015	.001	.049	.159	.580	1	.022	.048	–.095
Total hours	–.153	.051	.076	.125	–.176	–.089	.113	.054	.022	1	–.015	–.226
Chronic fatigue	.020	.266	.183	–.210	.075	–.031	.128	.154	.048	–.015	1	–.060
Sleep duration	–.037	.053	.033	–.126	.080	.052	–.211	–.146	–.095	–.226	–.060	1

Note: kJ = kilojoules; SFA = saturated fat; CHO = carbohydrate; BMI = body mass index; shaded numbers are significant correlations (p <.05)

6.3.5.2 Daily energy intake

The regression analysis indicated that energy intake was significantly predicted by gender, age and total hours worked when sleep duration was controlled for (Table 6.5). Specifically, females and younger participants consumed less energy (kJ) than males and older participants. Participants who worked fewer hours had a higher energy intake. Results showed that gender explained 4% of the variance in daily energy intake, age explained an additional 3% of the variance, total hours worked explained an additional 4% of the variance.

Table 6.5 Regression analysis for daily energy intake (kilojoules)

Independent variable	Parameter Estimate	SE	*p* value	95% CI Low	95% CI High	R^2 (Cum)
Gender						
Female	–2164.12	611.96	<0.01	–3377.54	–756.12	
Male	Reference					0.04
Age (years)	–69.94	28.04	0.01	–125.55	–14.33	0.07
Hours worked (hours)	–60.03	23.78	0.01	–107.19	–12.86	0.11
Sleep duration (hours)	–185.80	256.26	0.47	–693.93	322.32	0.16

Notes: Cum = cumulative; CI = confidence interval; SE = standard error

6.3.5.3 Fat as a percentage of daily energy intake

The final model showed that fat was predicted by chronic fatigue, sleep, BMI and age when shift schedule and gender were controlled for (Table 6.6). Figure 6.2 demonstrates that as sleep duration and chronic fatigue increased participants consumed a higher percentage of fat in the diet. Participants who obtained greater than 7.2h of sleep were consuming slightly higher than recommended levels of fat (red dotted lines indicate upper and lower levels of the acceptable macronutrient distribution range). Sleep duration explained 7% of the variance in fat intake. Furthermore, participants who scored higher than 31 on the Chronic Fatigue Scale (scores ranged from 10 to 50) consumed slightly higher than recommended levels of fat. Chronic fatigue explained 7% of the variance in fat intake. BMI also significantly predicted fat intake, and an additional 7% of the variance in fat intake was explained by BMI.

Table 6.6 Regression analysis for fat as a percentage of energy intake

Independent variable	Parameter estimate	SE	*p* value	95% CI Low	95% CI High	R^2 (Cum)
BMI (kg/m^2)	0.28	0.10	0.01	0.07	0.49	0.07
Chronic fatigue (score 10–50)	0.15	0.06	0.01	0.03	0.28	0.14
Sleep Duration (hours)	1.04	0.47	0.03	0.10	1.99	0.14
Gender						
Female	1.94	1.16	0.10	–0.37	4.26	
Male	Reference					0.15
Shift type						
12h rotating	1.86	1.39	0.18	–0.91	4.64	
8h rotating	–0.90	1.38	0.51	–3.65	1.85	
Night	1.48	1.41	0.29	–1.32	4.29	
Morning	Reference					0.19

Notes: Cum = cumulative; CI = confidence interval; SE = standard error; h = hour

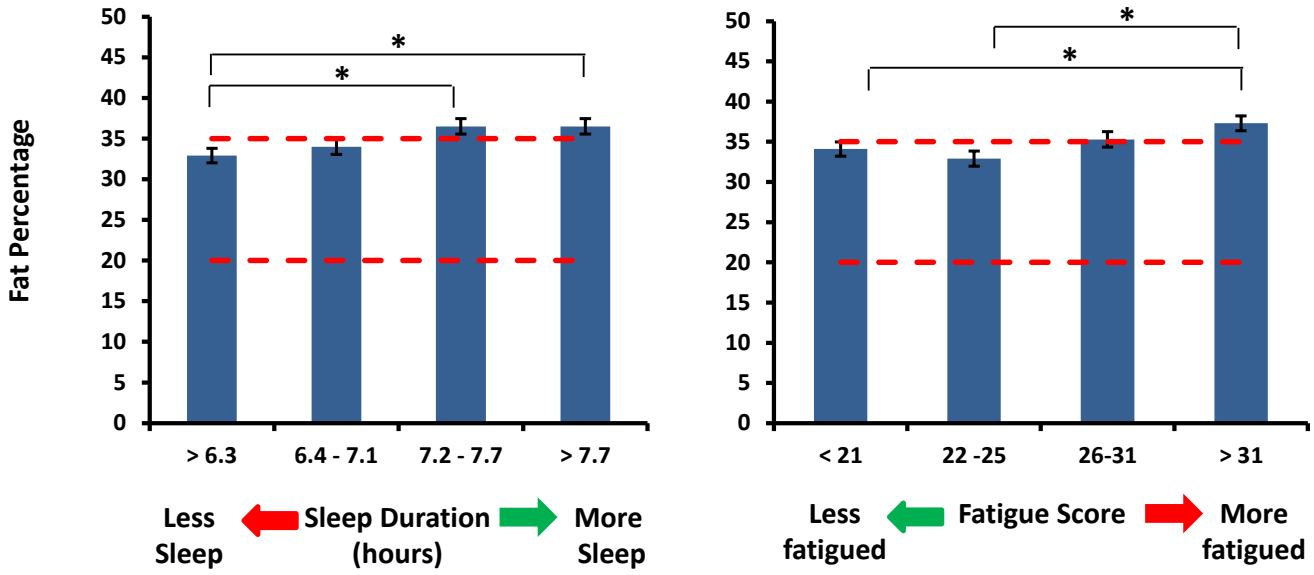


Figure 6.2 Sleep duration and fatigue significantly predicted fat intake as a percentage of daily energy intake

Notes: Bars represent estimated marginal mean score ± standard error
dotted lines represent upper and lower acceptable macronutrient range
** Indicates significant p <0.05*
Sleep duration is reported in hours
The fatigue score represents participant's scores on the Chronic Fatigue Scale (scores range from 10 to 50)

6.3.5.4 Saturated fat as a percentage of daily energy intake

The final regression analysis showed that saturated fat intake was predicted by BMI and shift schedule (when controlling for age, industry, marital status, chronic fatigue and total hours worked) (Table 6.7). As BMI increased, the percentage of saturated fat in the diet increased, explaining 4% of the variance in saturated fat intake. Furthermore, as demonstrated in Figure 6.3, working night shift compared to morning shift predicted an increase in saturated fat in the diet, explaining an additional 8% of the variance. The figure shows that all shiftworkers consumed higher than recommended levels of saturated fat (the dotted line represents 10%, which is the recommended level of saturated fat intake). Night shiftworkers consumed the most saturated fat of all shift schedules.

Table 6.7 Regression analysis for saturated fat as a percentage of energy intake

Independent variable	Parameter Estimate	SE	*p* value	95% CI Low	95% CI High	R^2 (Cum)
BMI (kg/m^2)	0.15	0.05	<0.01	0.03	0.26	0.04
Shift Schedule						
12h rotating	–2.28	2.69	0.39	–7.63	3.06	
8h rotating	–0.95	0.99	0.34	–2.93	1.03	
Night	2.76	0.76	<0.01	1.12	4.27	
Morning	0[a]					0.12
Sleep duration (hours)	0.54	0.25	0.04	–0.02	1.05	0.13
Age (years)	–0.05	0.02	0.05	–0.10	0.00	0.15
Industry						
Printing	–3.10	2.61	0.23	–8.29	2.09	
Postal	–3.48	2.64	0.19	–8.75	1.77	
Nursing	–1.13	2.50	0.65	–6.11	3.85	
Oil and gas	Reference					0.19
Marital status						
Married	1.19	0.74	0.11	–0.27	2.67	
Not married	Reference					0.21
Chronic fatigue (score: 10–50)	0.05	0.03	0.14	–0.01	0.11	0.29
Total hours worked (hours)	0.03	0.02	0.16	0.01	0.08	0.30

Note: Cum = cumulative; CI = confidence interval; SE = standard error; h = hour

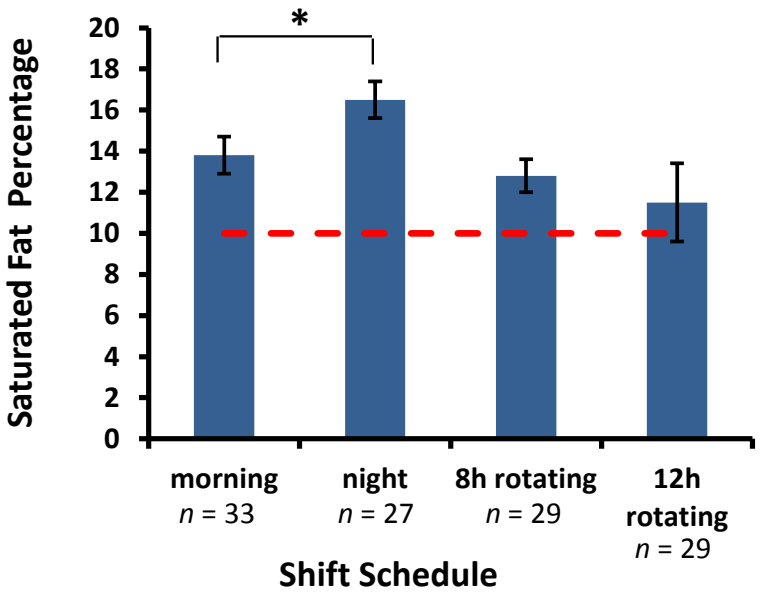


Figure 6.3 Shift schedule predicted saturated fat intake as a percentage of daily energy intake

Notes: Bars represent estimated marginal mean score ± standard error
Dotted lines show the recommended intake of saturated fat (10%)
** Indicates significant p <0.05*

6.3.5.5 Carbohydrate as a percentage of daily energy intake

The final model revealed that carbohydrate intake was significantly predicted by chronic fatigue, shift schedule and sleep duration (Table 6.8). Figure 6.4 shows that as sleep duration decreased the percentage of carbohydrates in the diet increased. Similarly, as chronic fatigue decreased, the percentage of carbohydrates in the diet increased. All shiftworkers were not consuming recommended levels of carbohydrate intake (as indicated by the dotted lines). Chronic fatigue explained 4% of the variance in carbohydrate intake. Additionally, working a 12h rotating shift schedule predicted a lower consumption of carbohydrate compared to working a morning shift schedule. Shift schedule explained a further 3% of the variance in carbohydrate in the diet. Sleep duration explained an additional 5% of the variance in carbohydrate intake in the diet.

Table 6.8 Regression analysis for carbohydrates as a percentage of energy intake

Independent variable	Parameter estimate	SE	*p* value	95% CI Low	95% CI High	R^2 (Cum)
Chronic fatigue	–0.19	0.08	0.02	–0.37	–0.02	0.04
Shift schedule				-		
12h rotating	–5.26	1.88	<0.01	–9.00	–1.15	
8h rotating	–0.83	1.74	0.63	–4.28	2.61	
Night	–1.21	1.89	0.52	–4.97	2.55	
Morning	Reference					0.07
Sleep duration (hours)	–1.59	0.64	0.01	–2.86	0.32	0.12

Notes: Cum = cumulative; CI = confidence interval; SE = standard error; h = hour

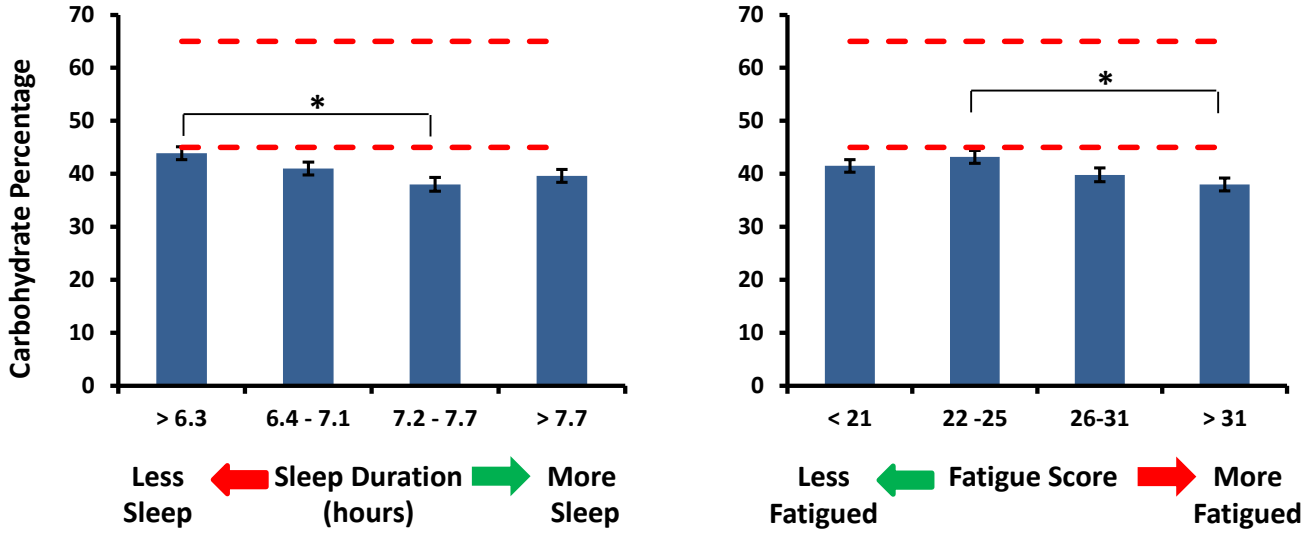


Figure 6.4 Sleep duration and fatigue significantly predicted carbohydrate intake as a percentage of daily energy intake

Notes: Bars represent estimated marginal mean score ± standard error
Dotted lines represent upper and lower acceptable macronutrient range
** Indicates significant p <0.05*
Sleep duration is reported in hours. The fatigue score represents participant's scores on the Chronic Fatigue Scale (scores range from 10 to 50)

6.3.5.6 Protein as a percentage of daily energy intake

The regression analysis indicated that the percentage of protein in the daily diet was significantly predicted by gender (Table 6.9). More specifically, females consumed a higher percentage of protein in the diet. Gender accounted for 3% of the variance in protein intake.

Table 6.9 Regression analysis for protein as a percentage of energy intake

Independent variable	Parameter Estimate	SE	*p* value	95% CI Low	95% CI High	R^2 (cum)
Gender						
Females	1.33	0.66	0.04	0.02	2.63	
Males	Reference					0.03

Notes: Cum = cumulative; CI = confidence interval; SE = standard error

6.3.5.7 Alcohol as a percentage of daily energy intake

The final regression model revealed that alcohol consumed as a percentage of daily energy intake was predicted by gender and total hours worked per week when controlling for industry, marital status and years worked shiftwork (Table 6.10). In particular, being a male predicted a higher percentage of alcohol as a percentage of daily energy intake when compared to females. Gender predicted 8% of the variance in alcohol intake. Working fewer hours per week indicated a higher percentage of alcohol in the daily diet, and predicted an additional 4% of the variance in alcohol intake.

Table 6.10 Regression analysis for alcohol as a percentage of daily energy intake

Independent variable	Parameter estimate	SE	*p* value	95% CI Low	95% CI High	R^2 (Cum)
Industry						
Printing	–1.45	2.49	0.56	–6.41	3.50	
Postal	–4.33	1.92	0.02	–8.14	0.51	
Nursing	–2.11	2.37	0.37	–6.83	2.59	
Oil and Gas	Reference					
Gender						
Female	–4.38	1.92	0.02	–8.20	–0.56	
Male	Reference					0.08
Marital Status						
Married	2.44	1.98	0.22	–1.49	6.37	
Not Married	Reference					0.08
Total Hours (hours)	–0.18	0.07	0.01	0.33	–0.04	0.12
Shiftwork (years)	–0.03	0.07	0.64	0.18	0.11	0.16

Notes: Cum= cumulative; CI = confidence interval; SE = standard error

6.4 Discussion

6.4.1 *Summary of findings*

Findings reported in this chapter suggest that factors related to shiftwork predict eating behaviour. In particular, shiftworkers with shorter sleep durations replaced their fat intake with carbohydrate intake. In contrast, fatigued shiftworkers replaced their carbohydrate intake with an

increased intake of fats. As expected, chronic fatigue and sleep duration were not correlated. Sleep restriction and fatigue are separate constructs (Shen, Barbera, Shapiro, 2006); therefore, it was not surprising to see that these factors impacted on eating behaviour in an opposing manner. Whilst all shiftworkers consumed a higher than recommended level of saturated fat (recommended level: <10% per day) (National Health & Medical Research Council, 2006), permanent night shiftworkers reported higher levels of saturated intake when compared to the other shift schedules. Shiftworkers on a 12h rotating shift schedule consumed less carbohydrates than morning shiftworkers. Shiftworkers who worked fewer hours reported a higher consumption of alcohol intake. The only factor to influence protein intake was gender, such that females demonstrated a higher intake of protein when compared to males. Factors related to shiftwork did not predict energy intake. Overall, results support the hypothesis that sleep duration, fatigue and work-related factors would predict alterations in eating behaviour. The findings are discussed in further detail below.

6.4.2 *Sleep duration predicts eating behaviour*

Shorter sleep durations predicted an increased consumption of carbohydrate at the cost of fat in the daily diet. However, contrary to previous research (Brondel et al., 2010; Spiegel, Tasali et al., 2004) shorter sleep durations did not predict an increase in energy intake in Study 3. Previous research suggesting that short sleep duration is linked to increased energy intake has largely compared individuals who were restricted to 4h of sleep per night and compared them to individuals who slept for 8h or 10h per night (Brondel et al., 2010; Spiegel, Tasali et al., 2004). Shiftworkers obtain varying amounts of sleep depending on the schedule and type of shift worked. Shiftworkers (apart from those on the 12h rotating shift schedule) in Study 3 reported obtaining the recommended levels of sleep on average (7–9 hours) (National Sleep Foundation, 2015). Sleep restriction may need to be severe to result in alterations in appetite hormones and changes in eating behaviour.

To our knowledge, no previous studies have examined sleep duration as a predictor of eating behaviour in shiftworkers. However, limited studies investigating the eating behaviour of shiftworkers have reported the sleep durations of their participants. One of the few studies that did report the sleep duration of their participants found that, similar to this study, while differences were found in food choice there was no difference in energy intake between shift types (morning, afternoon and night shift) (de Assis et al., 2003). In particular, afternoon shiftworkers consumed more starches and pastries (compared to morning and night shift).

Afternoon shiftworkers reported the longest sleep durations compared to the other two shift types (mean = 8.8h), whereas night shiftworkers obtained the least sleep (mean = 6.3h). These findings do not suggest that the alteration in eating behaviour seen in afternoon shiftworkers was due to short sleep durations. However, as no analyses were conducted it is not possible to understand the relationship between sleep duration and eating behaviour in the study conducted by de Assis et al. (2003).

A previous study investigating shiftworking nurses in France asked participants broad questions relating to whether sleep duration and energy intake had increased or decreased since beginning the shift schedule (day, afternoon or night shift) (Geliebter et al., 2000). Afternoon and night shiftworkers reported a decrease in sleep duration and an increase in energy intake since beginning work on these shifts. The decrease in sleep duration and increase in energy intake was not reported in measurement units (e.g. hours of sleep, energy and macronutrient intake). Therefore it is not possible to determine how much sleep restriction occurred and how eating behaviour altered for these individuals. Furthermore, participants in this study may have had difficulty recalling their food intake, as they did not keep a food record at the time of consumption (e.g. in a food diary). Participants completed a questionnaire, and were not asked questions to help with recall of food intake (as used in FFQs). It is possible that participants either overestimated or underestimated food intake. Nevertheless, the study conducted by Geliebter et al. (2000) was useful, as the findings suggested that sleep could be a predictor of eating behaviour in shiftwork populations. The current study improved on this previous study by utilising a validated FFQ to measure eating behaviour, therefore providing a more reliable measure of food intake. Study 3 used the SSI (Barton et al., 1995) to measure sleep. The measurement of sleep could be improved by using actigraphy, which combines sleep diaries with an activity monitor. Actigraphy has been found to be more reliable than methods (such as questionnaires and diaries) that ask participants to recall sleep episodes (Ancoli-Israel et al., 2003). Study 4 (reported in Chapter 7) measured sleep duration using actigraphy.

6.4.3 *Chronic fatigue predicts eating behaviour in shiftworkers*

As described above, increased fatigue predicted a higher intake of fat (as a percentage of daily energy intake). This finding is in line with previous studies that have suggested fatigue is associated with alterations in eating behaviour (Nishitani et al., 2009; Persson & Mårtensson, 2006). However, in contrast to findings from the current study, previous research has suggested that fatigue predicts an increase in carbohydrates as opposed to an increase in fat. These studies

suggested that carbohydrates are consumed by fatigued individuals due to the perception that carbohydrates can increase alertness and energy levels (Wurtman & Wurtman, 1989; Thayer, 1987). The motivation behind food choice was not examined in this chapter, but it is possible that the shiftworkers in the current study were consuming foods that they believed would boost their energy levels (e.g. foods high in fat but also containing sugar, such as cakes and biscuits). Shiftworkers experience not only high levels of fatigue, but many other alterations in mood such as increases in depression (Driesen et al., 2010; Geiger-Brown et al., 2004), anxiety (Srivastava, 2010), and stress (Nasrabadi et al., 2009; Srivastava, 2010). These aforementioned moods have also been associated with alterations in eating behaviour. For example, depressive moods have been linked to cravings and consumption of energy dense sweet foods (Jeffery et al., 2009; Willner et al., 1998), and stress can result in increased consumption of high-fat snack foods (Conner, Fitter, & Fletcher, 1999; Greeno & Wing, 1994). Study 4 (see Chapter 7) examined if alterations in these moods predict eating behaviour in shiftworkers.

6.4.4 *Work-related factors predict eating behaviour*

The results as reported in this chapter partially support the hypothesis that work-related factors predict eating behaviour. The findings from this chapter indicated that shiftwork schedule and total hours worked predicted eating behaviour such that night shiftworkers reported higher intakes of saturated fat, and 12h rotating shiftworkers consumed more carbohydrates compared to morning shiftworkers. Working fewer hours predicted a higher intake of alcohol. These findings are discussed below.

6.4.5 *Shiftwork history*

In contrast to findings from previous research suggesting shiftwork history predicts eating behaviour (Knutson et al., 1990; Morikawa et al., 2007), shiftwork history did not predict alterations in eating behaviour in Study 3. Morikawa et al.'s (2007) results showed that individuals who had participated in shiftwork for 10 years had a higher energy intake when compared to day workers, and individuals who had worked shiftwork for less than 10 years. Similarly, Knutson et al.'s (1990) longitudinal study found that shiftwork history predicted eating behaviour. Individuals who began working a shiftwork schedule reduced their intake of dietary fibre and increased their simple carbohydrate intake by 45% as a result of soft drink consumption after six months of participation in shiftwork. These findings suggest that eating behaviour may alter as the duration of shiftwork increases. Limited studies have investigated shiftwork history as a predictor of eating behaviour. The current study included shiftworkers who had been employed in shiftwork for

lengthy durations (>9 years on average). It has been postulated that shiftworkers who develop health disorders whilst working shiftwork revert back to day work (known as the 'healthy worker effect') (Wen et al., 1983). Many health disorders are associated with unhealthy eating behaviour. For example, diets low in fibre and diets with a higher GI (Salmeron et al., 1997) are associated with an increased risk of developing diabetes. It is possible that shiftworkers with unhealthy eating behaviours reverted back to day work and were not included in Study 3. A longitudinal study over a longer period of time that follows not only individuals who remain in shiftwork, but also those who revert back to day work, would be useful in understanding how eating behaviour alters over the years employed in shiftwork.

6.4.5.1 Shiftwork schedule

Similar to the study conducted by Morikawa et al. (2008) shift schedule did predict alterations in eating behaviour in the current study. Morikawa et al. (2008) found that shiftworkers employed on shifts that involved working over midnight had a higher energy intake than shiftworkers on other shift schedules investigated in the study (e.g. day shift, rotating shifts that did not involve midnight work). This chapter did not find that shift schedule predicted alterations in energy intake; however, alterations in the macronutrient content of food were seen between the shift types. In particular, night shiftworkers consumed the highest amount of saturated fat in this study when compared to other shift schedules. The finding that shiftworkers have a diet high in saturated fat are in line with previous research. For example, shiftworkers consume fried food more regularly than day workers (Harada et al., 2005), consume more butter (Puttonen et al., 2009) and report eating more saturated fats (Di Lorenzo et al., 2003) when compared to day workers. Results from this chapter suggest that mechanisms leading to higher saturated fat intake in shiftworkers require further investigation. It may be that shiftworkers are reaching for convenience foods high in fat due to fatigue and tiredness. The design of the current field study was useful, as it allowed for a broad understanding of typical eating behaviour of individuals on various shift types. The findings demonstrate that night shift alters eating behaviour. While shiftworkers on a 12h rotating shift also altered their eating behaviour, consuming less carbohydrates than morning shiftworkers, the methodology used does not explain if the 12h rotating shiftworkers are more likely to alter their eating behaviour on specific shift types. Eating behaviour on various shift types are explored in the following chapter.

6.4.5.2 Total hours worked

Findings from the current study showed that individuals who worked fewer hours consumed higher intakes of alcohol. This is in contrast to previous research demonstrating that long work hours are associated with increased alcohol intake (Shields, 1999; Trinkoff & Storr, 1998). In particular, a study investigating shiftwork schedule characteristics (e.g. shiftwork schedule and hours worked) and substance use (Trinkoff & Storr, 1998) found that shiftworking nurses who worked longer shifts (>8h) were more likely to report alcohol use than shiftworkers working shifts less than 8h in duration. It may be that the shiftworkers in the current study working fewer hours had more time to socialise than shiftworkers with more demanding work schedules. Indeed, studies have found that alcohol consumption increases on the weekends compared to working days (Haines, Hama, Guilkey, & Popkin, 2003). Not only shiftworkers who work fewer hours, but any individual with more free time may be more likely to increase their alcohol intake. Future research should investigate differences between part-time and full-time workers to determine how having more free time may impact on alcohol and food consumption.

6.5 Strengths and limitations

There has been limited research investigating predictors of eating behaviour in shiftworkers. Study 3 built on previous research by conducting analyses to understand if sleep duration, fatigue and work-related variables predict eating behaviour in shiftworkers. This study included shiftworkers on a variety of shift schedules employed in various industries, and used a validated dietary questionnaire to investigate eating behaviour as opposed to broad questions used in previous research.

There has been some investigation into predictors such as sleep (de Assis et al., 2003; Geliebter et al., 2000) and shiftwork history (Morikawa et al., 2007) and their effect on eating behaviour in shiftwork populations. However, to our knowledge sleep duration has not been analysed as predictor of eating behaviour in shiftworkers prior to the current study. In addition, this is the first study to investigate fatigue as a predictor of eating behaviour in shiftworkers. It has been demonstrated that sleep (Åkerstedt, 2003; Costa, 2010) and fatigue levels (Bohle & Tilley, 1993; Luna et al., 1997; Nasrabadi et al., 2009; Paterson et al., 2010) vary according to shift type, and therefore it is important to understand if variations in these factors alter eating behaviour.

Findings from this chapter show that sleep duration and fatigue alter eating behaviour. It used a measurement of general levels of fatigue as opposed to the current level of fatigue. It would be

interesting to understand the impact of current levels of fatigue on eating behaviour. This could be determined by measuring fatigue and eating behaviour on the same study day. In addition, sleep duration was measured as the average sleep duration between working days. This was particularly a limitation when determining the sleep duration of rotating shiftworkers, as they may have been experiencing different levels of sleep duration depending on the shift they were working. It would be useful to understand if the level of sleep duration experienced on the night prior to eating episodes impact on the eating behaviour of shiftworkers the following day. The current study employed an FFQ to measure usual food intake of the previous 12 months. FFQs are useful for comparing the average consumption of food over a period of time between groups (Erdman Jr et al., 2012), which was the aim of this chapter. However, it would be useful for future research to gain an understanding of how eating behaviour differs on a daily basis when individuals are working on differing shift types. This can be achieved by measuring food intake using food diaries.

This chapter includes one of the few studies investigating predictors of eating behaviour. However, there are many other predictor variables that could be investigated in future research. For example, de Assis et al. (2003) suggest that various environmental factors, such as food availability, could alter depending on shift type. The current study did include work site as a predictor variable to take the various locations into consideration. This could be investigated further when examining shiftworkers at various work sites to determine how cooking and food purchase facilities differ at each location, and if access to these facilities vary depending on shift type.

6.6 Conclusions

There has been limited research investigating predictors of eating behaviour in shiftworkers. The key findings from this chapter are listed below:

- Shorter sleep episodes predicted a higher carbohydrate intake.
- Increased fatigue predicted a higher intake of fat.
- Permanent night shift was associated with the highest intake of saturated fat.
- 12h rotating shift schedules were associated with lower consumption of carbohydrates compared to permanent morning shiftworkers.

In summary, the results from this chapter demonstrate that factors associated with shiftwork, such as sleep duration, fatigue and shift schedule, predict the eating behaviour of shiftworkers. Therefore, findings indicate that it is not simply the shift schedule, but the physiological and psychological factors associated with shiftwork, that can result in alterations in eating behaviour.

Chapter 7
A pathway to altered eating behaviour in shiftworkers (Study 4)

7.1 Introduction

A number of studies have been conducted to investigate the eating behaviour of shiftworkers. Studies have compared shiftworkers to day workers (Balieiro et al., 2014); investigated shiftworkers on various shift schedules (Esquirol et al., 2009; Morikawa et al., 2007; Pasqua & Moreno, 2004) and compared eating behaviour of shiftworkers on a variety of shift schedules (de Assis et al., 2003; Sudo & Ohtsuka, 2001; Suwazono et al., 2008). Findings from these studies have varied. Some studies have concluded shiftwork results in alterations in eating behaviour (Morikawa et al., 2007; Suwazono et al., 2008), whereas others have not found any differences in eating behaviour between shiftworkers and day workers, or between shiftworkers on a various shift schedules and shift types (de Assis et al., 2003) (see Section 1.5.4) for a detailed review of these studies.

As discussed in Chapter 6, a number of factors associated with shiftwork may predict alterations in the eating behaviour of shiftworkers. Factors associated with shiftwork such as sleep restriction (Bosy-Westphal et al., 2008; Brondel et al., 2010; St-Onge et al., 2011) and mood (Conner et al., 1999; Jeffery et al., 2009; Wardle et al., 2000), along with shift schedule and shift type (Morikawa et al., 2007; Suwazono et al., 2008) have been found to impact on hunger, food consumption and food choice. Despite the literature demonstrating the influence of these predictors on eating behaviour, very few studies have analysed these variables when investigating the eating behaviour of shiftworkers. The following sections discuss the impact of these factors on eating behaviour.

7.1.1 *Mood and eating behaviour*

Findings reported in Chapter 6 showed that fatigue predicted alterations in eating behaviour. In particular, shiftworkers who reported increased levels of chronic fatigue demonstrated a higher intake of fat. These findings are in line with previous research suggesting fatigue may influence food consumption and choice (Lieberman et al, 1986; Nishitani et al., 2009). In addition to fatigue, studies suggest that other moods may also impact on eating behaviour. For example, depressed mood has been associated with a low consumption of fruit and vegetables (Tanskanen et al., 2001) and increased consumption of sweet foods (Jeffery et al., 2009; Willner et al., 1998). Stress has also been found to result in increased consumption of high-fat snacks (Oliver et al., 2000; Wardle et al., 2000). These findings are of particular concern for shiftworkers as studies have demonstrated shiftworkers experience high levels of fatigue (Åkerstedt & Wright, 2009). Furthermore, shiftwork is also associated with negative mood states such as depression (Driesen

et al., 2010; Geiger-Brown et al., 2004), stress (Nasrabadi et al., 2009; Srivastava, 2010) and anxiety (Srivastava, 2010). Therefore, not only fatigue but also other moods should be investigated to examine if they also predict alterations in the eating behaviour of shiftworkers.

7.1.2 *Sleep and eating behaviour*

In addition to mood, sleep-related variables have been found to predict eating behaviour. Results reported in Chapter 3 showed that seven nights of sleep restriction resulted in increased hunger. The hunger levels prior to a buffet meal following sleep deprivation were compared at baseline with a control group receiving 8h of sleep per night. These findings are in line with previous studies demonstrating an increase in hunger following sleep restriction (Benedict et al., 2012; Hogenkamp et al., 2013; Schmid, Hallschmid, Jauch-Chara, Born, & Schultes, 2008).

Concurring with the above, results reported in Chapter 4 indicated that snack consumption increased when sleep was severely restricted to approximately 4h per sleep episode. These findings are comparable to a previous study that demonstrated an increase caloric intake from snacks when sleep was restricted to 5.5h per night (Nedeltcheva et al., 2009). Similarly, as reported in Chapter 6, a reduction in sleep was associated with increased carbohydrate consumption. Increased carbohydrate consumption following sleep restriction has also been found in previous studies (Markwald et al., 2013; Spaeth et al., 2013). Taken together, these findings suggest that shorter sleep episodes predict alterations in eating behaviour. This is also of relevance to shiftworkers as they frequently report sleep restriction (Åkerstedt, 2003).

Despite these findings and the consensus in the literature that shiftworkers are a population likely to experience sleep restriction (Åkerstedt, 2003), there has been limited investigation into the influence of sleep duration on eating behaviour in shiftworkers. A small number of studies have examined the sleep of their participants when investigating the eating behaviour of shiftwork populations (de Assis et al., 2003; Geliebter et al., 2000). However, these studies did not investigate sleep as a predictor of eating behaviour. Given the findings from Chapter 6, along with previous research suggesting eating behaviour may alter when sleep is restricted, sleep duration should be analysed when investigating the eating behaviour of shiftworkers.

7.1.3 *Shift type as a predictor of eating behaviour*

Shift schedule (e.g. permanent and rotating shifts) and shift type (e.g. morning, night and afternoon shifts) have been found to predict eating behaviour in previous studies (Balieiro et al., 2014; Morikawa et al., 2008). This was also demonstrated in Chapter 6, which reported findings

showing that permanent night shiftworkers consumed higher levels of saturated fat than other shift types, and 12h rotating shiftworkers had a higher carbohydrate intake (when compared to morning shiftworkers). Study 3, reported on in Chapter 6, did not allow for the examination of differences in eating behaviour on various shift types. Therefore, Study 4 built on the findings from Chapter 6, and examined the daily differences in eating behaviour between shift types in a sample of rotating shiftworkers.

7.1.4 *Work-related and demographic factors and eating behaviour*

In addition to mood and sleep there has been some investigation into other work-related variables that may predict alterations in the eating behaviour of shiftworkers. As discussed in Chapter 6, Morikawa et al. (2007) found that shiftworkers with a longer history of being employed in shiftwork had higher energy intakes than shiftworkers who reverted back to day work. Furthermore, results reported in Chapter 6 showed that shiftworkers who worked fewer hours had higher energy intakes. In particular, a higher energy intake from alcohol was found in shiftworkers who worked fewer hours. Other demographic variables have also been associated with alterations in eating behaviour. For example, individuals with higher BMI are more likely to have a higher intake of fat (Drewnowski & De Roos, 1992; Lissner & Heitmann, 1995). Indeed, BMI predicted a higher intake of fat in the shiftworkers analysed in Chapter 6. Therefore, factors typically associated with eating behaviour should be included as covariates when investigating eating behaviour. Study 4 included a number of demographic and work-related variables to ensure a comprehensive understanding of predictors of eating behaviour in shiftworkers.

7.1.5 *Pathway to altered eating behaviour*

Taken together, the above studies suggest that mood, sleep and shiftwork, along with other demographic and work-related variables influence eating behaviour. In addition to the relationship these factors have with eating behaviour it is likely mood, sleep and shiftwork have relationships with each other. These relationships are discussed below.

7.1.5.1 Sleep and mood

Sleep restriction has been found to result in alterations in mood (Dinges & Chugh, 1997; Haack & Mullington, 2005; Selvi et al., 2007). In particular, when sleep has been restricted to approximately 5h per night in a laboratory study, participants have reported increases in negative mood domains such as anger, fatigue, depression and confusion, and tension (Dinges et al., 1997; Haack & Mullington, 2005). Additionally, studies that have totally deprived participants of sleep

have found decreases in positive mood domains such as happiness, vigour and activation (Brendel et al., 1990; Paterson et al., 2011; Scott et al., 2006). These studies demonstrate that sleep duration may lead to alterations in both negative and positive moods.

7.1.5.2 Shiftwork and mood

Studies have demonstrated a relationship between shiftwork and mood. For instance, studies have shown that shiftwork is associated with negative mood states such as depression (Geiger-Brown et al., 2004), stress (Srivastava, 2010) and fatigue (Paterson et al., 2010). These mood disturbances may occur as a result of sleep-related factors (discussed above); however, it may be the shiftwork itself or other factors associated with the shift type or shift schedule. Therefore, in addition to exploring the relationship between sleep and mood, the relationship between shiftwork and mood should also be examined.

7.1.5.3 Shiftwork and sleep

Shiftwork not only influences mood, it has also been found to influence sleep. In particular shiftworkers on morning and night shift report obtaining less sleep than day workers and individuals on afternoon shift (Dorrian et al., 2008; Knauth et al., 1980). Additionally, night shiftworkers report poor sleep quality (Härmä, Sallinen, Ranta, Mutanen, & Müller, 2002). Night shiftworkers are working in direct opposition to their endogenous circadian system. Therefore, when individuals are working night shift it is likely that they will be attempting to sleep when their circadian system is promoting wake (Costa, 2010). In addition, environmental factors such as noise can result in increased sleep disturbances for night shiftworkers (Sallinen & Kecklund, 2010). Morning shiftworkers find it difficult to begin their sleep episode earlier, as early evening is also a time when the circadian system promotes wake. Furthermore, family and social commitments can interrupt the opportunity to attempt sleep earlier (Costa, 2010). These studies demonstrate that working various shift types can impact on sleep duration and sleep quality. Therefore this relationship will also be examined in this chapter.

7.1.6 *Summary and study aims*

There have been an increasing number of studies conducted to investigate eating behaviour in shiftworkers. However, few studies have investigated the role that factors such as mood, sleep and other work and demographic variables play in predicting eating behaviour. Health promotion strategies rely on an understanding of all mechanisms that contribute to unhealthy behaviours (Steptoe et al., 1995). Consequently, it is important to understand all pathways that can lead to

alterations in the eating behaviour of shiftworkers. Given the evidence to suggest that mood, sleep-related factors and shift type can predict eating behaviour, along with the studies demonstrating that these factors may have relationships with each other, Study 4 investigated a proposed pathway to explain alterations in eating behaviour (see Figure 7.1). The pathway includes mood, sleep- related factors (sleep duration, sleep efficiency and sleep quality) and mood domains such as tiredness, depression, stress, anxiety and happiness. Based on the evidence from previous studies discussed above, the following hypotheses were made:

- **Hypothesis 1**: Mood (tiredness, stress, anxiety, depression and happiness) will predict alterations in eating behaviour in shiftworkers.
- **Hypothesis 2:** Sleep duration will predict alterations in eating behaviour in shiftworkers.
- **Hypothesis 3:** Shift type will predict eating behaviour.
- **Hypothesis 4:** Sleep duration will predict mood.
- **Hypothesis 5:** Shift type will predict mood.
- **Hypothesis 6:** Shift type will predict sleep (sleep duration, sleep quality and sleep efficiency).

In addition to the above factors, demographic (e.g. gender, BMI) and other work-related variables (e.g. shiftwork history, hours worked per week) were entered into the model to understand how these factors impact on eating behaviour.

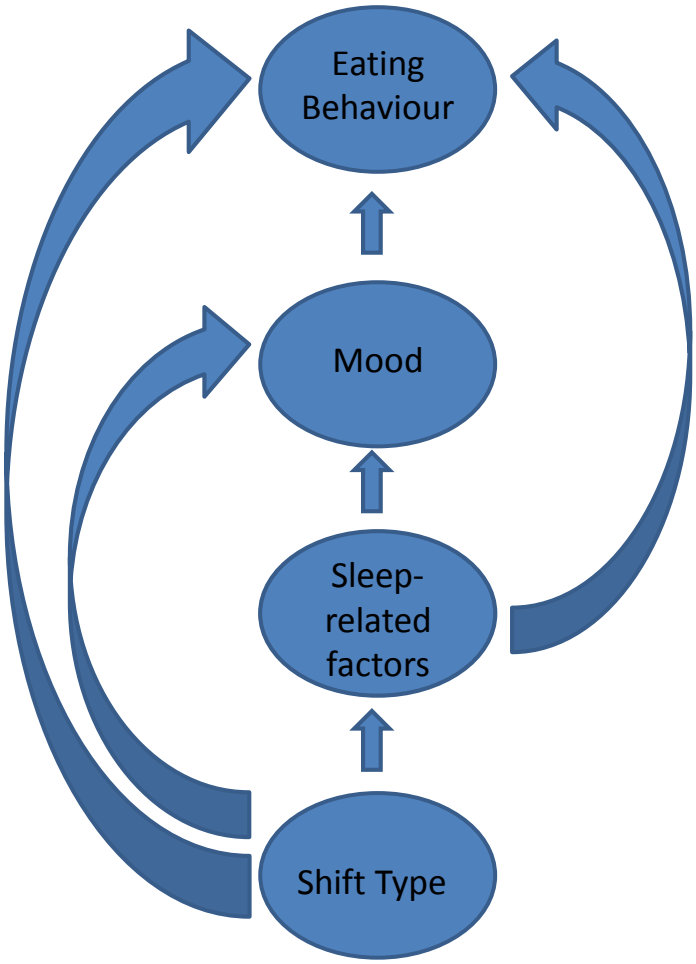


Figure 7.1 Proposed pathway leading to altered eating behaviour in shiftworkers

7.2 Methods

7.2.1 *Participants*

Participants in Study 4 (*n* = 52, 46 female) were volunteers recruited from three hospitals in the Adelaide metropolitan area. All participants were employed as nurses and worked full time or part time on one of the following shifts: morning (07:00–15:30), afternoon (13:00–21:30) or night (21:00–07:30) shift or a combination of these shifts.

Participants were included in the study if they were over the age of 18 and employed on a shiftwork schedule (described above) at one of the three hospitals. Participants were required to work a minimum of one shift type during the study period. Participants were excluded from the study if they were pregnant, as pregnancy can result in alterations to eating and sleeping behaviour. A variety of sleep disturbances and disorders have been associated with pregnancy (Pien & Schwab, 2004). Furthermore, pregnant women have demonstrated increased energy

intake (Godfrey, Robinson, Barker, Osmond, & Cox, 1996) and food cravings (e.g. sweets and desserts) (Flaxman & Sherman, 2000). Participants were also excluded if they reported a health condition affecting dietary intake, such as Crohn's disease. For example, individuals diagnosed with Crohn's disease are advised to avoid dietary fats and refined carbohydrates (Cashman & Shanahan, 2003).

7.2.2 *Ethics*

Ethics approval was obtained from the University of South Australia Human Research Ethics Committee and SA Health to cover each individual hospital in accordance with the guidelines of the National Health and Medical Research Council of Australia. Written informed consent was provided by each participant (see Appendix J)

7.2.3 *Study design*

The current study employed a within and between subjects repeated measures study design.

7.2.4 *Procedure*

Information sessions approximately 20 minutes in duration were held for potential volunteers in hospital wards at each site. The purpose of the study and procedure and were explained at these sessions, and volunteers had the opportunity to ask questions. Interested volunteers were provided with a study information sheet, which they were able to read in their own time (see Appendix G). If volunteers were interested in participating in the study they were asked to call or email a member of the research team to arrange a time for a second meeting. Alternatively, if volunteers were happy to proceed immediately following the information session, they were given the opportunity to discuss the study with a member of the research team following the information session.

The second meeting was conducted on a one-on-one basis to allow for a more detailed explanation of the study and the materials involved. If the volunteer wished to proceed, they were asked to sign the consent form and were given a study pack including a log book (containing all diaries and scales used in the study) (see Appendix K) and an activity monitor (Actiwatch 2, Respironics Inc., USA, 2009) (in order to determine sleep and wake periods).

Participants completed the study for a total of 14 consecutive days. During the 14-day period participants were asked to wear an activity monitor (Actiwatch 2, Respironics Inc, USA, 2009) around their wrist at all times, except in situations where the watch may get wet (e.g. showering

or swimming). Participants were also required to complete a sleep and work diary daily, and mood scales twice per day (at the start and end of each shift) (for details of log book see Appendix K). The diary and scales took approximately five minutes each day to complete. Additionally, participants were required to complete a food diary on three days per shift type and on one day off (as a comparison measure) taking approximately one minute to complete every time they consumed a meal or snack or beverage. As work schedules varied for each participant, the number of days the food diary was completed depended on the variety of shifts worked during the study period. Participants working three shift types (e.g. morning, afternoon and night shifts) during the 14-day study period completed the food diary for a minimum of 10 days (see Figure 7.2). Participants working only one shift type (e.g. morning shifts only) completed the food diary for a minimum of four days (Figure 7.3)

Study Day	Shift Type	Activity Monitor	Sleep Diary	Mood Diary	Food Diary
1	Afternoon	X	X	X	X
2	Afternoon	X	X	X	X
3	Morning	X	X	X	X
4	Morning	X	X	X	X
5	Day Off	X	X		X
6	Day Off	X	X		
7	Afternoon	X	X	X	X
8	Morning	X	X	X	X
9	Day Off	X	X		
10	Day Off	X	X		
11	Day Off	X	X		
12	Night	X	X	X	X
13	Night	X	X	X	X
14	Night	X	X	X	X

Measurement

Figure 7.2 Protocol: Maximum

Note: Example of a participant who worked shifts during the protocol requiring completion of the food diary the maximum amount of times possible

Study Day	Shift Type	Activity Monitor	Sleep Diary	Mood Diary	Food Diary
1	Morning	X	X	X	X
2	Morning	X	X	X	X
3	Day Off	X	X		X
4	Morning	X	X	X	X
5	Morning	X	X	X	
6	Morning	X	X	X	
7	Morning	X	X	X	
8	Day Off	X	X		
9	Day Off	X	X		
10	Morning	X	X	X	
11	Morning	X	X	X	
12	Morning	X	X	X	
13	Day Off	X	X		
14	Day Off	X	X		

Measurement

Figure 7.3 Protocol: Minimum

Note: Example of a participant who worked shifts during the protocol requiring completion of the food diary the minimum amount of times possible

Demographic information was recorded on a modified version of the General Information Questionnaire (GIQ) from the SSI (for further information see Section 2.7). Additionally, four other personality questionnaires (Eysenck Personality Inventory, Three Factor Eating Questionnaire, Health Locus of Control Questionnaire and a Morningness/Eveningness Questionnaire) were required to be completed on one occasion (findings from these questionnaires will be published as part of another study). The GIQ and questionnaires took approximately 20 minutes to complete. At the end of the 14-day study period a member of the research team returned to the hospital to collect the completed log book and activity monitor. If a mutually convenient time for collection was not possible a registered post envelope was sent to the participant to return the study materials.

7.2.5 *Materials*

7.2.5.1 Demographic information

The GIQ used in Study 4 was adapted from the SSI (Barton et al., 1995). The GIQ requires participants to complete demographic details (e.g. number of dependents, marital status). Additionally, questions relating to work (e.g. shiftwork history) and shift type (e.g. types of shifts

worked) are included. The GIQ also includes questions relating to health and lifestyle such as medications taken, smoking status and height and weight (to allow BMI to be calculated).

7.2.5.2 Sleep

Sleep was measured objectively for the entire duration of the study using a wrist activity monitor (Actiwatch 2, Respironics, USA, 2009). The wrist activity monitor was used to determine sleep duration and sleep efficiency. Sleep efficiency is calculated as: time asleep/divided by total time in bed * 100 (percentage). The wrist activity monitor and procedure is described in detail in Chapter 2 (Section 2.7). A sleep diary was also located within the participant log book, and this was used in conjunction with the wrist activity monitors. The sleep diary helped to determine sleep onset and offset, therefore improving the accuracy of the actigraphy data and determine a more accurate estimation of sleep duration. A measure of sleep quality was obtained from the sleep diary. Sleep quality was recorded on a scale of 1–6 with higher scores indicating a poorer quality of sleep. Therefore sleep-related variables were operationalised as follows:

- *Sleep duration*: total duration of sleep (in minutes) obtained between sleep onset and sleep offset.
- *Sleep efficiency*: total duration of sleep as a percentage of total time in bed from sleep onset to sleep offset.
- *Sleep quality*: subjective rating of sleep (score 1–6).

7.2.5.3 Mood

VAS were used to measure moods that have been found to affect eating behaviour (happiness, anxiety, depressive mood, stress and tiredness). A separate scale was used to assess each mood. Each VAS scale measures 100 mm and is anchored with 'not at all' on the far left-hand side of the scale and 'extremely' on the far right hand side of the scale (see Figure 2.9 in Chapter 2). Participants are instructed to place a vertical line on the scale representing how they feeling twice per working day during the study (directly prior to the beginning of their shift and directly following their shift). For further information on VAS scales see Section 2.7. The score for each mood domain was measured and a score ranging from 0 to 100 was obtained for each domain. Scores prior to the start of the shift and scores at the end of the shift for each mood domain were averaged to obtain a daily mood score for each mood domain per study day. Mood has been averaged across study days in previous research in order to obtain daily mood scores (Paterson et

al., 2010). Therefore, mood was operationalised as a daily score (ranging from 0 to 100) for happiness, anxiety, depression, stress and tiredness.

7.2.6 *Eating behaviour*

Eating behaviour in Study 4 was operationalised as energy intake (kJ) and percentage of total energy from macronutrients (fat, carbohydrate, protein) and alcohol as a percentage of total energy intake. For further discussion of measurement of eating behaviour refer to Section 1.1.3.

Participants were asked to keep a record of all food and drink consumed on three days per shift type and one day off in their issued food diaries. Participants were asked to record the method of cooking (e.g. boiled pasta), the type of food consumed (e.g. wholemeal bread) and the quantity of food (e.g. two teaspoons of white sugar or the weight in grams). Participants were asked to measure food using weights and common household measurements. In addition participants were asked to provide the brand names of foods where possible. If a recipe was used to prepare a meal during the data collection period, participants were asked to provide a copy of the recipe where possible.

Foodworks nutrient analyses software (Version 7.00, Xyris Software Australia, Kenmore Hills, QLD, Australia) was used to determine daily energy intake (kJ) and macronutrients (in grams). The database selected was NUTTAB 2010 (Food Standards Australia, New Zealand) which provided the most up to date nutrient information about foods in Australia. Any assumptions made in relation to food were entered into a spreadsheet that could be referred to by all individuals entering data. For example, if the participant reported 'consumed a glass of water' in their food diary it was assumed that 250 ml of water was consumed. If foods reported by participants were not listed in Foodworks, a food with a close description was used. For example, specific cola flavoured soft drink brands were not available as an option, and therefore all cola soft drink (regardless of brand) was entered as soft drink, cola flavour.

7.2.7 *Demographic variables*

A number of demographic variables were identified from previous literature and included in the study. The demographic variables and evidence of their impact on eating behaviour are listed in Table 7.1.

Table 7.1 Demographic variables and their effect on eating behaviour

Variable	Effect on eating behaviour
Age (years)	An individual's age can impact on eating behaviour. For example, life experiences occurring across the lifespan may alter food choices. It has been suggested that food and cooking skills are more common amongst older individuals (Devine, Wolfe, Frongillo Jr, & Bisogni, 1999)
Gender (male or female)	Research suggests there are gender differences in eating behaviour. In particular, men have a higher energy intake compared to women (Rolls, Fedoroff, & Guthrie, 1991)
Body mass index (kg/m^2)	Individuals with higher body mass index are more likely to consume energy-dense foods and have a high intake of dietary fats (Drewnowski, Kurth, Holden-Wiltse, & Saari, 1992; Lissner & Heitmann, 1995)
Dependents (number of children living at home)	Having dependents at home has been identified as factor that may impact on eating behaviour. For example, mothers have been found to place children's well-being above their own nutritional needs. In contrast, parents may make positive nutritional changes as they wish to set a good example for their children (Devine & Olson, 1992)
Marital status (married/not married)	Individuals living with a partner with whom they share food preparation and meal times may alter their eating behaviour. For example, if a partner alters their diet due to health reasons both partners may decide to make those changes to co-operate or ease the burden of food preparation (Devine & Olson, 1992)
Work site (hospital)	The place of work can have an effect on eating behaviour, particularly food choices. Norms for eating may alter from site to site. Some working individuals have discussed subtle pressure to consume healthier options whilst at work (Devine & Olson, 1992)

7.2.8 *Statistical analysis*

There were no clear patterns in missing data between participants or variables. Less than 5% of data was missing for all variables except for BMI (18% missing), sleep quality (8% missing) and sleep efficiency (6% missing). The literature suggests that statistical data is not likely to be biased when less than 10% of data are missing (Bennett, 2001; Schafer, 1999). All data were screened for normality. Boxplots were used to test for extreme scores. Upon inspection of the boxplots no outliers were identified (Field, 2013).

Similar to Chapter 6, marital status was categorised into 'married' and 'not married' (divorced, widowed or single) and dependents were categorised into 'yes' (dependent <18years) or 'no' in order to have cell sizes that were sufficient for the analysis.

Sleep duration was calculated as the total amount of sleep obtained in each 24h period prior to the beginning of a shift (including naps). Eating behaviour for each shift was analysed as the total energy and macronutrient content of food and drink consumed during the 24h period the shift fell

into (i.e. 12am–12am). Therefore, food consumed during a night shift was likely to fall over two study days.

A significance level of 0.05 was used to determine significance. SPSS version 21 (SPSS, Chicago, Illinois, USA) was used for statistical analysis. A series of statistical tests were performed to investigate the data. One-way ANOVA tests were conducted to determine differences in predictor variables and dietary intake by shift type. In addition, correlation analyses were conducted for all continuous variables to examine associations between dietary intakes, mood domains, sleep, work-related variables and demographic variables. Magnitudes of correlations were interpreted as trivial, 0.1; small, 0.3; moderate, 0.3–0.5 and large, >0.5 (Cohen, 1988). A series of linear mixed models were conducted in order to formulate the pathway of the effect of shift type on eating behaviour variables.

7.3 Results

Fifty-two shiftworkers were recruited to participate in the study; however, 10 were excluded from the final analyses. Two participants did not return their log books, four participants did not complete their food diaries correctly, one participant reported a health condition and one participant reported being pregnant. Additionally, two participants were excluded as their actigraphy data could not be retrieved. Therefore the final sample included 42 participants. It is not possible to determine the effect size of this study as standard measures of effect size are not associated with mixed effect linear regressions.

7.3.1 *Demographics*

Shiftworkers (*n* = 42) included in Study 4 were aged between 22 and 63 years and the majority of participants were female (see Table 7.2 for demographic information). On average participants were overweight according to BMI. The majority of participants did not smoke. Just over half of the participants were married with dependents. Participants reported that they had been employed in shiftwork for approximately 15 years on average and had worked approximately 38h per week. The majority of shiftworkers were employed at Lyell McEwin and Modbury hospitals (see Table 7.2).

Table 7.2 Demographic and work-related characteristics of Study 4

	Mean / per cent	SD
Demographic factors		
Age (years)	40.3	12.1
Gender %		
Male	12.8	n/a
Female	87.2	n/a
Marital status %		
Married	68.4	n/a
Not married	31.6	n/a
Hospital %		
Lyell McEwin	44.6	n/a
Modbury	45.7	n/a
Queen Elizabeth	9.3	n/a
BMI (kg/m^2)	27.3	n/a
Total hours worked (hours)	37.8	10.6
Years worked in shiftwork (years)	15.1	12.7
Years worked in present shift system (years)	10.0	11.7

Notes: BMI = body mass index; SD = standard deviation

7.3.2 *Mood*

Univariate analyses were conducted to determine significant differences for mood by shift type. Analyses revealed on average participants reported feeling happiest on afternoon shift. Participants reported feeling more anxious and stressed on morning shift, yet most tired and depressed on night shift). Participants were significantly more tired on night shift than morning and afternoon shift. There were no significant differences between shifts for all other variables (see Table 7.3).

Table 7.3 Mood by shift type

Variable	Morning	N	Afternoon	N	Night	N	F	df
Happiness	54.7 (18.3)	79	56.2 (16.2)	77	48.4 (16.3)	38	2.69	2,191
Anxiousness	25.0 (21.7)	79	24.4 (20.8)	78	22.4 (18.5)	38	0.19	2,191
Depression	24.4 (20.8)	79	24.0 (20.2)	78	26.1 (21.4)	38	0.13	2,191
Stress	29.9 (23.2)	79	27.9 (20.7)	78	27.7 (21.2)	38	0.21	2,191
Tiredness	55.4 (22.9)	79	22.9 (21.3)	77	64.8 (17.0)	38	11.0*	2,191

Note: mean (standard deviation)
**p<0.05*

Mood variable score relates to the score on visual analogue scales (scores range from 0 to 100), higher scores indicated a higher level of the mood

7.3.3 *Sleep*

On average, sleep duration in the 24h period prior to a shift was 6.9h. Figure 7.4 shows sleep duration (classified into four categories) as a percentage of study nights. Univariate analyses (Table 7.4) showed the least amount of sleep was achieved prior to morning shift and the longest sleep durations were obtained prior to afternoon shifts.

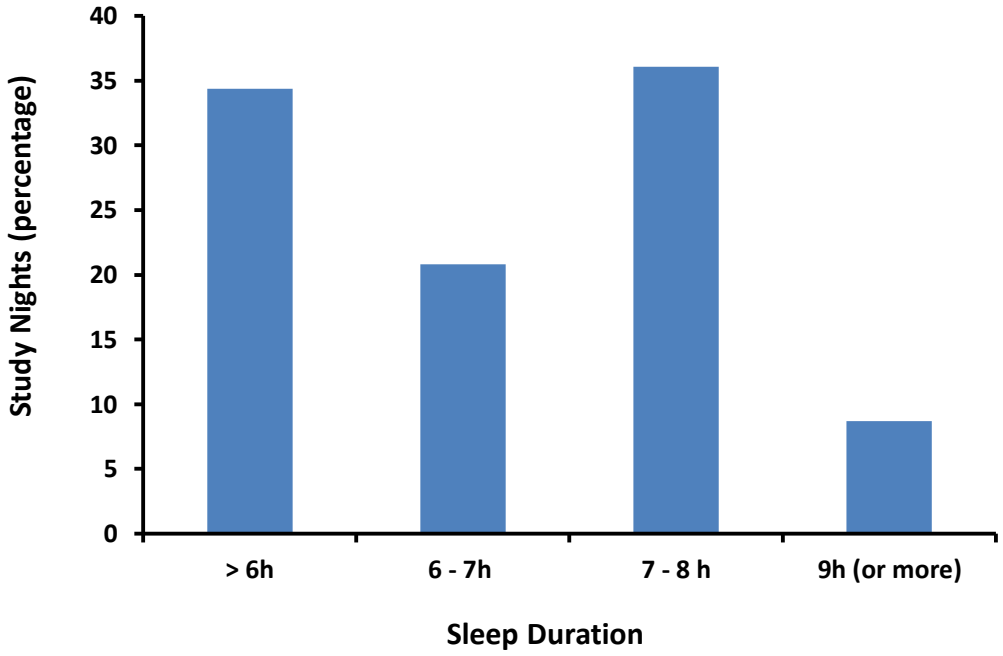


Figure 7.4 Frequency of sleep duration by study night (expressed as a percentage).

Note: It is recommended that adults obtain between 7 and 9h sleep per night (National Sleep Foundation, 2015)

Table 7.4 Sleep-related variables by shift type

Variable	Morning	N	Afternoon	N	Night	N	F	df
TST (hours)	5.8 (1.21)	79	7.4 (1.73)	77	7.2 (2.69)	37	17.48*	2,190
Sleep Eff. (%)	86.53 (7.57)	75	88.02 (6.85)	73	84.84 (7.67)	36	2.34	2,181
Sleep Quality	2.70 (1.09)	74	2.49 (0.97)	72	3.35 (2.37)	35	4.44*	2,178

Notes: mean (standard deviation)
TST = Total Sleep Time; Sleep Eff. = Sleep Efficiency; Sleep Quality = score on Sleep Quality Scale (scores range from 1–6, higher scores indicate poorer sleep quality)

7.3.4 *Dietary intake*

Eating behaviour variables (energy, and percentage of macronutrients and alcohol) in the diet were compared in a univariate analysis by shift type (Table 7.5). Results showed that the highest energy intakes were consumed on morning shifts. However, the highest percentage of fat, saturated fat and alcohol were consumed on days off. On average, the highest percentage of carbohydrate intake as a percentage of daily energy intake was reported on night shifts.

Table 7.5 Dietary intake by shift type

Variable	Morning	N	Afternoon	N	Night	N	F	df
Energy (kJ)	8409.6 (3905.1)	80	7222.7 (2839.5)	78	8243.3 (3,630.2)	39	2.54	2,194
Fat (%)	31.3 (7.3)	80	30.8 (8.9)	78	30.3 (8.5)	39	0.17	2,194
SFA (%)	12.8 (4.6)	80	11.5 (4.2)	78	11.8 (4.6)	39	0.17	2,194
CHO (%)	40.0 (11.0)	80	42.9 (12.4)	78	47.7 (12.7)	39	5.35*	2,194
Protein (%)	21.6 (7.7)	80	21.2 (7.8)	78	18.2 (8.1)	39	2.54*	2,194
Alcohol (%)	2.3 (4.0)	80	0.68 (2.9)	78	0.11 (0.6)	39	8.97	2,194

Notes: kJ = kilojoules; SFA = saturated fat; CHO = carbohydrate

In order to maintain health, it is recommended that the daily energy intake consists of between 45 and 65% carbohydrate, 15 and 25% protein, 20 and 35% fat, and saturated fat intake should be no more than 10% of daily energy intake (Australian National Health and Medical Research Council and the New Zealand Ministry of Health, 2006).

7.3.5 *Associations between dietary intake, mood, sleep-related, work-related and demographic factors*

Table 7.6 presents associations between dietary intake, mood, sleep-related, work-related and demographic variables. Energy showed a moderate positive correlation with fat intake. Fat and saturated fat demonstrated a large correlation. The mood variables were all correlated. Large negative correlations were seen between happiness and all other mood variables. Anxiousness, depression and stress also showed large correlations. Tiredness demonstrated a large negative correlation with happiness and large positive correlations with anxiousness, depression and stress.

Table 7.6 Associations between dietary intake, mood, sleep-related, work-related and demographic variables

	Age	BMI	Total hours worked	TST	SE	SQ	Energy (kJ)	Prot-ein	Fat	SFA	CHO	Alc	Happy	Anx	Depr	Stress	Tired
Age	1	–.095	–.265*	–.133	–.094	–.118	–.002	–.060	–.019	–.009	–.025	.196**	.118	.043	.050	.007	–.091
BMI	–.095	1	.223*	–.092	.013	.183*	–.051	.068	–.093	–.050	.076	–.140	.053	–.153	–.157*	–.088	–.130
Total hours worked	–.265*	.223*	1	.040	.085	.159*	.072	.239*	–.009	–.101	–.123	–.136	.117	–.116	–.151*	–.141	–.228**
TST	–.133	–.092	.040	1	.199*	–.110	–.094	.110	.017	–.125	–.037	–.132	–.064	.008	.017	.005	–.166*
SE	–.094	.013	.085	.199*	1	–.225*	–.041	.353*	.067	.027	–.296*	.020	.131	–.011	–.119	–.076	–.098
SQ	–.118	.183*	.159*	–.110	–.225*	1	.058	.124	–.028	–.008	–.049	–.032	–.056	.043	.074	.085	.090
Energy	–.002	–.051	.072	–.094	–.041	.058	1	–.028	.321*	.260*	–.226*	.132	–.152*	.228*	.194*	.190*	.151*
Protein	–.060	.068	.239*	.110	.353*	.124	–.028	1	.004	–.130	–.666*	–.004	.163*	–.159*	–.183*	–.184*	–.213*
Fat	–.019	–.093	–.009	.017	.067	–.028	.321*	.004	1	.612*	–.641*	–.072	.043	.098	.027	.108	–.010
SFA	–.009	–.050	–.101	–.125	.027	–.008	.260*	–.130	.612*	1	–.325*	.049	–.026	.144*	.149*	.139	.053
CHO	–.025	.076	–.123	–.037	–.296*	–.049	–.226*	–.666*	–.641*	–.32*	1	–.201*	–.132	–.007	.094	.031	.125
Alcohol	.196*	–.140	–.136	–.132	.020	–.032	.132	–.004	–.072	.049	–.201*	1	–.002	.141*	.149*	.098	.148*
Happy	.118	.053	.117	–.064	.131	–.056	–.152*	.163*	.043	–.026	–.132	–.002	1	–.449*	–.554*	–.587*	–.533*
Anxious-ness	.043	–.153	–.116	.008	–.011	.043	.228*	–.159*	.098	.144*	–.007	.141*	–.449*	1	.809*	.834*	.432*

	Age	BMI	Total hours worked	TST	SE	SQ	Energy (kJ)	Prot-ein	Fat	SFA	CHO	Alc	Happy	Anx	Depr	Stress	Tired
Depress-ion	.050	–.157*	–.151*	.017	–.119	.074	.194*	–.183*	.027	.149*	.094	.149*	–.554*	.809*	1	.810*	.475*
Stress	.007	–.088	–.141	.005	–.076	.085	.190*	–.184*	.108	.139	.031	.098	–.587**	.834**	.810**	1	.482**
Tired	–.091	–.130	–.228*	–.166*	–.098	.090	.151*	–.213*	–.010	.053	.125	.148*	–.533*	.432*	.475*	.482*	1

Notes: TST = total sleep time; SE = standard error; SQ = sleep quality; kJ = kilojoules; SFA = saturated fat; CHO = carbohydrate; Alc = alcohol; Anx = anxiousness; Depr = depression; BMI = body mass index
shaded numbers are significant correlations (p <.05)

7.3.6 *The pathways leading to altered eating behaviour in shiftworkers*

As depression, anxiety and stress were highly correlated (Cohen, 1988), only stress was used in the path analysis models.

Results of the final path analysis are depicted in Figures 7.5–7.10, which present all significant direct paths between external, shift, sleep and mood variables and eating behaviour. Appendix U provides tables for the models prior to the final significant pathways. Only factors that remained significant in the final models (as described below) have been included within this chapter.

First, the mood variables (happiness, stress and tiredness) were entered into the analyses with each eating behaviour variable (energy intake [kJ] and fat, protein, carbohydrate and alcohol as a percentage of energy intake) to test the hypotheses that mood would predict eating behaviour. The models showed that stress predicted a higher energy intake and a higher percentage of fat and saturated fat in the diet. Tiredness also predicted a higher energy intake, yet a lower percentage of protein in the diet (see Appendix U).

Second, sleep variables (total sleep time, sleep efficiency and subjective sleep quality) were entered into the analyses with each eating behaviour variable to test the hypotheses that sleep would predict eating behaviour. The models showed total sleep time predicted energy intake, such that the less time the shiftworkers in Study 4 spent asleep the more likely they were to have a greater energy intake. Sleep quality also predicted energy intake such that when sleep quality was poorer individuals reported a higher energy intake. A lower sleep efficiency percentage predicted a higher percentage of carbohydrate in the diet (see Appendix U).

In the next analyses all exogenous variables (demographics) and shift type were entered into the model.

The final model for energy shows that shift type, stress and gender predicted energy intake (Table 7.7, Figure 7.5). Individuals reported being significantly more stressed and consuming more energy on night and morning shifts compared to afternoon shift (Table 7.8). In addition, males consumed more energy than females. In the final model the only significant predictor of fat (Table 7.9, Figure 7.6) and saturated fat (Table 7.10, Figure 7.7) was stress. Higher levels of stress predicted higher levels of fat and saturated fat. A higher percentage of carbohydrates were consumed on morning shift compared to night shift and those with a lower percentage of sleep efficiency had a lower percentage of carbohydrate in their diet (Table 7.11, Figure 7.8). Individuals

consumed more protein on morning and afternoon shift when compared to night shift. Furthermore, males had a higher percentage of protein in the diet than females (Table 7.12, Figure 7.9). Final models revealed that a higher percentage of alcohol in the diet was demonstrated on morning and afternoon shifts compared to night shift (Table 7.13, Figure 7.10).

Table 7.7 Predictors of energy intake

Dependent variable	Predictor variable	Parameter Estimate	Std Err	*p*	95% CI Low	95% CI High
Energy	Stress	35.96	12.40	0.00	11.48	60.44
	Shift					
	Morning	397.06	531.10	0.45	–1445.11	650.97
	Afternoon	–1843.70	527.59	0.00	–2884.79	–802.62
	Night	Reference				
	Gender					
	Male	3341.01	1246.45	0.01	815.81	5866.20
	Female	Reference				

Std Err = standard error; CI = confidence interval

Table 7.8 Predictors of stress

Dependent variable	Predictor variable	Parameter estimate	Std. Err	*p*	95% CI Low	95% CI High
Stress	Shift					
	Morning	–0.74	2.89	0.79	–6.46	4.97
	Afternoon	–5.56	2.85	0.05	–11.20	0.07
	Night	Reference				

Std Err = standard error; CI, = confidence interval

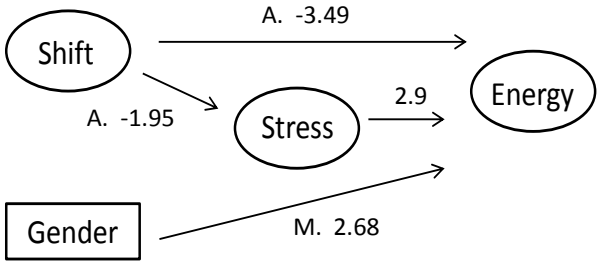


Figure 7.5 Final path analysis model of predictor variables on energy intake

Note: A = afternoon shift; M = morning shift; circles indicate endogenous variables, rectangles indicate exogenous variable, arrows represent significant pathways

Table 7.9 Predictors of fat intake

Dependent variable	Predictor variable	Parameter estimate	Std. Err	*p*	95% CI Low	95% CI High
Fat	Stress	0.07	0.03	0.02	0.01	0.13

Std Err = standard error; CI = confidence interval

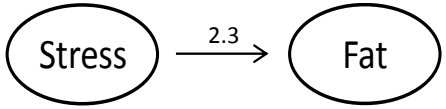


Figure 7.6 Final path analysis model of predictor variables on fat intake (as a percentage of daily energy intake)

Table 7.10 Predictors of saturated fat intake

Dependent variable	Predictor variable	Parameter estimate	Std Err	*p*	95% CI Low	95% CI High
Fat	Stress	0.04	0.01	0.00	0.01	0.08

Std Err = standard error; CI = confidence interval

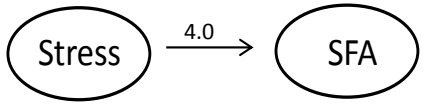


Figure 7.7 Final path analysis model of predictor variables on saturated fat intake (as a percentage of daily energy intake)

Note: SFA = saturated fat

Table 7.11 Predictors of carbohydrate intake

Dependent variable	Predictor variable	Parameter estimate	Std Err	*p*	95% CI Low	95% CI High
CHO	Sleep Eff	–0.39	0.11	0.00	0.62	0.16
	Shift					
	Morning	–6.18	2.19	0.00	–10.52	–1.84
	Afternoon	–2.51	2.20	0.25	–6.87	1.85
	Night	Reference				

Std Err = standard error; CI = confidence interval; Sleep Eff = sleep efficiency

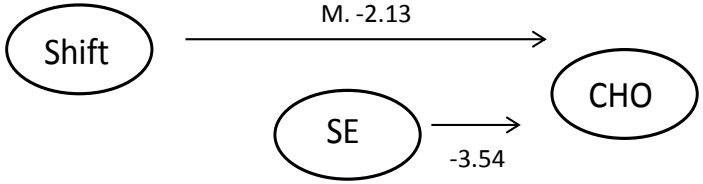


Figure 7.8 Final path analysis model of predictor variables on carbohydrate intake (as a percentage of daily energy intake)

Note: M = morning shift; SE = sleep efficiency; CHO = carbohydrate

Table 7.12 Predictors of protein intake

Dependent variable	Predictor variable	Parameter estimate	Std Err	*p*	95% CI Low	95% CI High
Protein	Shift					
	Morning	3.02	1.39	0.03	0.28	5.77
	Afternoon	2.54	1.38	0.06	–0.19	5.28
	Night	Reference				
	Gender					
	Male	6.36	2.52	0.01	1.22	11.51
	Female	Reference				

Std Err = standard error; CI = confidence interval

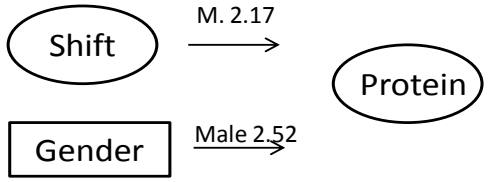


Figure 7.9 Final path analysis model of predictor variables on saturate fat intake (as a percentage of daily energy intake)

Note: M = morning shift

Table 7.13 Predictors of alcohol intake

Dependent variable	Predictor variable	Parameter estimate	Std Err	*p*	95% CI Low	95% CI High
Alcohol	Shift					
	Morning	3.02	1.39	0.03	0.28	5.77
	Afternoon	2.54	1.38	0.06	–0.19	5.28
	Night	Reference				
	Gender					
	Male	6.36	2.52	0.01	1.22	11.51
	Female	Reference				

Std Err = standard error; CI = confidence interval

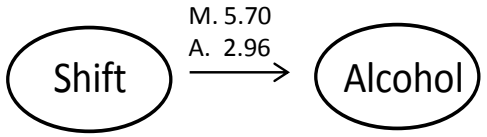


Figure 7.10 Final path analysis model of predictor variables on saturate fat intake (as a percentage of daily energy intake)

M = morning shift; A = afternoon shift

7.3.7 *The relationship between shift type, sleep-related factors and mood*

Results from the linear mixed models conducted as part of the path analysis (described above) demonstrated that shift type predicted stress (Table 7.14) and tiredness (Table 7.15). In particular, shiftworkers on afternoon shift were less stressed than night shiftworkers. However, night shiftworkers were more tired than both morning and afternoon shiftworkers.

Table 7.14 Predictors of stress

Dependent variable	Predictor variable	Parameter estimate.	Std. Err	*p*	95% CI Low	95% CI High
Stress	Shift					
	Morning	–0.74	2.89	0.79	–6.46	5.97
	Afternoon	–5.56	2.85	0.05	–11.20	0.07
	Night	Reference				

Note:Std. Err = standard error; CI = confidence interval

Table 7.15 Predictors of tiredness

Dependent Variable	Predictor Variable	Parameter Estimate.	Std. Err	*p*	95% CI Low	95% CI High
Tiredness	Shift					
	Morning	–6.39	3.17	0.04	–12.66	–0.12
	Afternoon	–17.10	3.13	0.00	23.29	–10.91
	Night	Reference				

Note: Std. Err = standard error; CI = confidence interval

7.3.8 *The relationship between shift type and sleep*

Findings from linear mixed models showed that shift type predicted sleep duration (Table 7.16) and sleep quality (Table 7.17). Morning shiftworkers had shorter sleep durations than night shiftworkers; however, the sleep quality of night shiftworkers was lower than morning and afternoon shiftworkers (higher scores on the scale indicate sleep quality was reduced).

Table 7.16 Predictors of sleep duration

Dependent variable	Predictor variable	Parameter estimate	Std. Err	P	95% CI Low	95% CI High
Sleep duration	Shift					
	Morning	–80.65	21.30	0.00	–122.68	–38.61
	Afternoon	13.15	21.32	0.53	–28.91	55.22
	Night	Reference				

Note:Std. Err = standard error; CI = confidence interval

Table 7.17 Predictors of sleep quality

Dependent variable	Predictor variable	Parameter estimate	Std. Err	*p*	95% CI Low	95% CI High
Sleep quality	Shift					
	Morning	–0.68	0.28	0.01	–1.25	–0.12
	Afternoon	–0.92	0.28	0.00	–1.48	–0.35
	Night	Reference				

Note:Std. Err = standard error; CI = confidence interval

7.4 Discussion

Findings from this study demonstrate that mood, sleep-related factors and shift type predicted eating behaviour. In particular, higher levels of stress resulted in increased energy and fat intake. Lower sleep efficiency predicted a higher carbohydrate intake. Additionally, night shiftworkers had higher energy, carbohydrate intakes, yet lower protein and alcohol intakes.

7.4.1 *Mood predicts eating behaviour (Hypothesis 1)*

There was support for Hypothesis 1 with the finding that stress predicted eating behaviour. Higher levels of stress predicted increased energy and fat intake. This finding is in line with previous research. For example, studies have demonstrated stress is associated with increased energy intake, particularly from foods high in fat and sugar (O'Connor et al., 2008; Wardle et al., 2000). As increased energy intake and foods high in fat are associated obesity (Bray & Popkin, 1998), this finding suggests that shiftworkers who are stressed may be at risk of weight gain.

Contrary to expectation, tiredness or happiness did not predict alterations in eating behaviour. Previous research has suggested that tiredness may influence eating behaviour. For example, shiftworking nurses have reported consuming sweet foods during night shift, as they perceived this type of food would help keep them awake (Persson & Mårtensson, 2006). Whilst Study 4 did allow for an overall determination of tiredness on a particular working day, mood levels were averaged across the study day. Therefore it is difficult to determine which foods were being consumed at peak levels of tiredness. Results reported in Chapter 5 suggested that fatigue levels tend to be higher around the circadian nadir and greater levels of fatigue were demonstrated with increasing levels of prior wake. Further research needs to be conducted to determine if shiftworkers alter their diet during times when they are at risk of feeling extremely tired and/or fatigued.

7.4.2 *Sleep-related factors predict eating behaviour (Hypothesis 2)*

Findings from the current study also showed support for Hypothesis 1b. Results showed that sleep efficiency predicted eating behaviour such that lower levels of sleep efficiency were associated with higher carbohydrate intakes. However, contrary to expectation, other sleep-related variables examined in this study (sleep duration and sleep quality) did not predict alterations in eating behaviour. Results reported in Chapters 3 and 6, along with previous research, demonstrate that restricting sleep can result in alterations to eating behaviour (Brondel et al., 2010; Schmid et al., 2009; St-Onge et al., 2011). For example, studies have demonstrated increased energy intake when sleep is restricted to around 4h per sleep episode (Brondel et al., 2010; St-Onge et al., 2011). Alterations in macronutrient consumption have been found when sleep is restricted to severe levels (around 4h) (Brondel et al., 2010; Schmid et al., 2009; St-Onge et al., 2011). According to the National Sleep Foundation (2015) individuals should obtain at least 7h sleep per night, therefore less than 7h sleep is considered sleep restriction. Participants in the current study did report restricting their sleep on just over half of their sleep periods during the study (see Figure 7.1). However, shiftworkers in this study only reported sleeping 4h or less on approximately 5% of sleep periods. It is possible that eating behaviour does not alter as a result of sleep restriction unless severe levels of sleep restriction are reached.

7.4.3 *Shift type predicts eating behaviour (Hypothesis 3)*

Results of the current study demonstrated that night shift was the shift type most likely to predict eating behaviour. In particular, night shifts were associated with increased energy intake (compared to afternoon shifts); increased carbohydrates (compared to morning shifts), decreased protein intake (compared to morning shifts) and decreased alcohol intake (compared to both morning and afternoon shifts). These findings are not surprising considering night shiftworkers are working in direct opposition to their circadian system (Åkerstedt, 2003). Previous studies have found night shifts are associated with increased carbohydrate intake (Reinberg et al., 1979) and a lower intake of fruit and vegetable (Balieiro et al., 2014).

The only factor examined in this study to mediate the relationship between shift type and eating behaviour was stress. Stress mediated the relationship between shift type and energy intake such that increased levels of stress resulted in increased energy intake. However, there may be various other factors associated with night shift that were not examined in Study 4 that also influence eating behaviour. For example, night shiftworkers often have limited healthy food choices and may resort to purchasing food from vending machines (Stewart & Wahlqvist, 1985).

Environmental factors may alter eating behaviour for night shiftworkers and therefore should be investigated in future studies.

7.4.4 *Work-related and demographic variables and eating behaviour*

Contrary to previous research demonstrating that work-related and demographic variables predict eating behaviour (Devine & Olson, 1992; Devine et al., 1999; Drewnowski, 1997), very few of these factors were associated with alterations to eating behaviour in the current study. In line with previous studies, results from the current study showed males consumed more energy than females (Rolls et al., 1991). Furthermore, males in this study had higher protein intakes. However, other work-related variables that have been found to impact on eating behaviour (e.g. shiftwork history) (Morikawa et al., 2007) were not associated with food consumption or choice in this study.

7.4.5 *Sleep-related factors and mood (Hypothesis 4)*

Contrary to expectation sleep duration and sleep quality did not predict alterations in mood. These findings are in contrast to previous research that suggest sleep restriction results in an increase in negative mood (Dinges & Chugh, 1997; Haack & Mullington, 2005; Selvi et al., 2007). Laboratory studies have typically restricted participant's sleep to severe levels (around 4–5h per night). Participants were only experiencing sleep durations of 4h or less on 5% of study nights. It may be that individuals do not experience alterations in mood unless they are experiencing severe levels of sleep restriction. Future research in the laboratory should examine the impact of moderate levels of sleep restriction (around 6h per sleep episode) on mood, particularly as findings from the current study (in addition to findings from Chapter 6) suggest that many shiftworkers may experience more moderate levels of sleep restriction.

7.4.6 *Shift type and mood (Hypothesis 5)*

Results from the current study indicate that shift type predicted mood. Night shiftworkers were more stressed than afternoon shiftworkers and more tired than both morning and afternoon shiftworkers. These findings concur with previous research suggesting shiftwork can impact on mood (Cavallo et al., 2002; Nasrabadi et al., 2009; Srivastava, 2010). The findings from both Study 4 and previous research suggest that mood and shiftwork is an area that could be explored further in future research. Thus far there has been limited research into predictors of altered mood in shiftworkers. Previous studies have indicated that various factors may result in increases in negative mood and reduced well-being in shiftworkers (Barnes-Farrell et al., 2008; Nasrabadi,

Yekta & Emami, 2004). For example, shiftwork may result in work-life conflict especially in family orientated countries such as Iran. Study 4 included predictor variables such as sleep along with other demographic variables (e.g. BMI, age and gender). However, these findings suggest it may be useful to examine predictors of mood in shiftworkers, particularly as positive mood in the workplace is beneficial for productivity in the workplace (Morgan et al., 2012) and improving motivation (Ilies & Judge, 2005).

7.4.7 *Shift type and sleep (Hypothesis 6)*

In line with previous research, findings from the current study demonstrate that shift type can impact on sleep (Knauth et al., 1980). In particular, morning shiftworkers had shorter sleep durations than night shiftworkers, and night shiftworkers had reduced sleep quality compared to both morning and afternoon shift. These findings concur with previous research suggesting morning shiftworkers may experience short sleep durations (Åkerstedt, 2003), and that night shift is associated with poor sleep quality (Sallinen & Kecklund, 2010). Whilst there is already a large body of research to suggest that shiftwork impacts on sleep (Dorrian et al., 2011; Knauth et al., 1980), it was important to investigate this relationship within Study 4 to ensure all aspects of the pathway were examined.

7.5 Strengths and limitations

Study 4 was one of the few studies to investigate predictors of eating behaviour in shiftworkers. Each shift type is associated with variations in factors that may predict eating behaviour. Therefore it is important to take these factors into consideration when investigating this area of research. The current study built on the study reported in Chapter 6, adding to the body of literature on shiftwork and eating behaviour. The design of the current study allowed for the examination of variables both within and between participants, and measures were repeated across the 14-day period of the study. Furthermore, sleep was measured objectively via actigraphy, which is a more accurate measure when compared to self-report (Ancoli-Israel et al., 2003). Moreover, eating behaviour was measured by using food diaries, which are considered gold standard when measuring eating behaviour in a field environment (Thomson & Subar, 2001).

Whilst the food diaries used in this study were gold standard, and allowed for the examination of macronutrient, alcohol and energy intake, it may have also been useful to assess the quality of the diet. For example, many foods contain carbohydrates; however, these foods vary in quality. Certain foods high in carbohydrates, such as white rice and white bread, have a higher GI and may

promote weight gain. However, consuming foods with a low GI (such as wholegrain foods) may help prevent weight gain (Roberts, 2000). Therefore, examining the quality of diet would allow for a more complete understanding of the impact of food choices on health.

Studies investigating eating behaviour are often subject to limitations. A detailed discussion on the limitations of measuring eating behaviour is discussed in Section 1.1.3. However, a few limitations in particular are of relevance to Study 4. Studies on eating behaviour often attract participants with an interest in health and nutrition and therefore results may be biased (Thomson & Subar, 2001). This sample bias may have occurred in the current study, as participants may have been interested in the nutritional report provided to participants upon completion of the study. This study included mostly female participants who were overweight on average. These two factors may have influenced findings, as females and individuals with higher BMI are more likely to under-report food intake. In addition, 18% of participants did not complete their height and weight measurements, and as a result BMI could not be determined for those participants.

Previous studies investigating mood in shiftworkers have averaged scores across the day (Paterson et al., 2010). However, future studies examining mood as a predictor of eating behaviour should consider measuring mood directly prior to the eating episode, as this would allow for a more accurate understanding of the effect of mood on food consumption and food choice. The study conducted within this chapter did not measure mood prior to eating episodes as participant burden was already relatively high, and measuring mood multiple times in addition to recording food and sleep would have increased the burden. However, it would be interesting to determine if food choices are poorer at times when mood has been found to deteriorate (e.g. around the circadian nadir, with lengthy durations of prior wake). Additionally, it may also be useful for future studies to assess trait levels of mood (e.g. depression). Future studies should consider controlling for trait moods or examine how trait moods may interact with current mood whilst on shift and eating behaviour.

7.6 Conclusions

Key findings from this chapter are listed below.

- Mood predicted eating behaviour:
    - increased stress predicted an increased intake of fat
- Sleep related factors predicted eating behaviour:
    - lower sleep efficiency predicted higher carbohydrate intakes
- Night shift altered eating behaviour. In particular, night shiftworkers:
    - consumed more carbohydrate compared to afternoon shiftworkers
    - consumed less protein than morning shiftworkers
    - consumed less alcohol compared to other shift types
    - demonstrated higher energy intakes compared to afternoon shiftworkers.
- Shift type predicted mood:
    - night shiftworkers were more stressed compared to afternoon shiftworkers and more tired than both morning and afternoon shiftworkers.
- Shift type predicted sleep:
    - morning shiftworkers had shorter sleep durations than night shiftworkers
    - night shiftworkers had a lower quality of sleep.

In summary, mood, sleep quality, and working nightshifts predicted eating behaviour in shiftworking nurses. In addition, shift type predicted mood and sleep quality. The current study provides insight to areas for future research. In particular, it may be important to assess mood at the time of the eating episode to determine if food choices are made as a result of mood. In addition, environmental factors (such as food availability and convenience) may be playing a role in the altered eating behaviour of night shiftworkers, and these should also be investigated as predictors of eating behaviour in shiftworkers. Overall, results from Study 4 demonstrated that there are many predictors of food consumption and food choice, and alterations in these predictors (along with others to be explored in the future) may explain mixed findings in the literature thus far.

Chapter 8
General discussion

8.1 Summary of research aims

The primary aim of this thesis was to determine predictors of eating behaviour in shiftworkers. In particular, it was hypothesised that mood, sleep-wake and shift-related factors would predict eating behaviour. In addition, the studies within this thesis aimed to examine the relationships these variables have with each other. The findings from the current thesis are discussed below and summarised in Table 8.1. Following this discussion the limitations of studies within this thesis and future directions are addressed.

8.2 Hypothesis 1: Factors related to shiftwork will predict eating behaviour

Hypothesis 1 was supported in the current thesis. Findings reported in Chapters 3 (Heath, Dorrian, Kosmadopoulos, & Sargent, 2011), 4 (Heath et al., 2012), 6 and 7 demonstrated that factors related to shiftwork predicted eating behaviour. The findings from these studies are discussed below.

8.2.1 *Hypothesis 1a: Mood will predict eating behaviour in shiftworkers*

8.2.1.1 Fatigue predicted eating behaviour in shifworkers

Findings reported in Chapters 6 and 7 concur with previous research suggesting mood is linked to alterations in eating behaviour (Greeno & Wing, 1994; Macht & Simons, 2000; Willner et al., 1998). In particular, fatigue has been associated with substitute eating (e.g. eating to avoid feelings such as irritability), eating style (e.g. fast eating) and motivation for eating (e.g. ordering a lot of food) (Nishitani et al., 2009). Previous studies suggest individuals are more likely to crave and consume carbohydrates when they are fatigued as they believe it will increase alertness, vigour (Wurtman & Wurtman, 1989) and energy levels (Thayer, 1987). A craving for carbohydrates and food high in sugar when fatigued has also been reported in a qualitative study of shiftworking nurses. The nurses stated that they believed carbohydrates and sugars helped keep them awake during night shifts (Persson & Mårtensson, 2006).

Findings discussed in Chapter 6 conflict with previous research, as participants reported an increased consumption of foods high in fat (rather than carbohydrate) with increased levels of fatigue. Conversely, shiftworkers demonstrated higher carbohydrate intakes with lower levels of fatigue. Studies within this thesis did not examine the quality of the diet. Therefore, the type of carbohydrates participants were consuming is not known. For example, participants may have been consuming carbohydrates high in sugar, or perhaps they were consuming higher quality

carbohydrates such complex carbohydrates (see Section 1.1.1 for further detail). Investigating the quality of the diet is important to understanding the effect of food consumed on health.

Participants from previous studies state that they consume or crave particular foods to alleviate negative mood states such as fatigue (Thayer, 1987; Wurtman & Wurtman, 1989). The results of this study along with findings from previous research suggest that shiftworkers may change their eating behaviour when feeling chronically fatigued.

Table 8.1 Summary of thesis findings

Outcome variable	Predictor variable	Study	Chap-ter	Specific findings
Eating behaviour	Mood	3	6	↑ Fatigue = higher fat intake
		4	7	↑ Stress = higher energy and fat intake
		3	6	↓ Fatigue = lower carbohydrate intake
	Sleep duration	1	3	↓ Sleep = higher hunger levels
		2	4	↓ Sleep = increased snacking overall
		2	4	↓ Sleep = increased consumption of sweet snacks
		3	6	↓ Sleep = higher carbohydrate intake
		3	6	↑ Sleep = higher fat intake
	Sleep efficiency	4	7	↓ Sleep efficiency = higher carbohydrate intake
	Shift schedule	3	6	Permanent night shift = higher saturated fat intake
		3	6	12h rotating shift = lower carbohydrate intake (compared to morning shift)
	Shift type	4	7	Night shift = higher carbohydrate intake (compared to afternoon shift)
		4	7	Night shift = lower protein intake (compared to morning shift)
		4	7	Night shift = lower alcohol intake (compared to morning and afternoon shift)
		4	7	Night shift = higher energy intake (compared to afternoon shift)
	Circadian phase	4	4	↓ Snacks during the biological night
Mood	Sleep duration	2	4	↓ Sleep = increase in negative mood domains and total mood disturbance ↓ Sleep = decrease in vigour-activity
	Prior wake	2	5	↑ Prior wake = increased total mood disturbance and increase in all negative mood domains except anger-hostility ↑ Prior wake = decrease in vigour-activity
	Shift type	4	7	Night shift =more stressed (compared to afternoon shift), more tired (than morning and afternoon shift)
	Circadian phase	2	5	Increase in total mood disturbance and all negative mood domains around the circadian nadir
		2	5	Decrease in vigour-activity around the circadian nadir
Sleep	Shift schedule	3	6	12h rotating shift = shorter sleep durations (compared to all other shift schedules)
	Shift type	4	7	Morning shiftwork = shorter sleep durations (compared to night shift)
	Shift type	4	7	Night shift = lower sleep quality

Note: ↑ = increase in variable, ↓ = decrease in variable; h = hours

8.2.1.2 Stress predicted eating behaviour in shiftworkers

Findings reported in chapter 7, showed shiftworkers were more likely to increase their fat and total energy intake when they experienced higher levels of stress. These findings concur with previous research demonstrating that stress contributed to overeating, such as increased snack consumption with particular preferences for high-fat foods (Greeno & Wing, 1994; O'Connor et al., 2008; Oliver et al., 2000; Wardle et al., 2000). Research suggests that comfort foods decrease physiological and behavioural responses to stress (Ulrich-Lai et al., 2010). Therefore, similar to motivation for altering eating behaviour when fatigued, shiftworkers may consume high-fat foods to alleviate stress.

8.2.1.3 Tiredness and happiness did not predict eating behaviour in shiftworkers

Contrary to expectation, not all mood states measured in the study reported on in Chapter 7 resulted in alterations in eating behaviour. Tiredness and happiness did not predict eating behaviour in shiftworkers. Previous research has found that tiredness is linked to alterations in eating behaviour. For example, tiredness has been associated with binge eating (Edelman, 1981). The mood scales participants completed in that study were completed at the beginning and end of each shift rather than at the time of food intake. Moods are typically longer in duration when compared to emotion, and can last up to six days (Santor & Patterson, 2004). However, results reported in Chapter 5 (Heath et al., 2010) along with previous research (e.g. Boivin et al., 1997) suggest that moods can vary in intensity across the day. From the study reported on in Chapter 7, it is not known if shiftworkers were tired when they were actually consuming food. This is a limitation of that study and is discussed in Section 8.3.2.

Chapter 7 only examined one positive mood state (happiness). Previous studies have demonstrated that positive mood and emotional states have been associated with enjoyment of food and hedonic eating (Macht, 2008). Studies suggest that weight may influence alterations in eating behaviour as a result of positive mood. For example, underweight individuals consumed more food when experiencing positive emotions than overweight individuals (Geliebter & Aversa, 2003). On average, the shiftworkers who participated in the study reported on in Chapter 7 were classified as overweight. Many studies have suggested that individuals who are overweight are more likely to increase food intake when experiencing negative mood (Baucom & Aiken, 1981; Lowe & Fisher Jr, 1983; McKenna, 1972; Plutchik, 1976; Ruderman, 1983; Slochower & Kaplan, 1980). Therefore, the shiftworking participants in this thesis may have been more likely to alter their eating behaviour as a result of negative rather than positive mood due to their weight status, and this may explain why happiness did not predict alterations in eating behaviour.

8.2.2 *Hypothesis 1b: Sleep-wake related factors will predict eating behaviour*

Hypothesis 1b is supported. Results of all studies investigating this hypothesis reported on in this thesis demonstrate that eating behaviour was predicted by sleep-wake related factors. Findings reported in Chapter 3, (Heath et al., 2011) show that hunger increased (compared to baseline and compared to a control condition) following seven nights of sleep restriction (4h per sleep opportunity). Findings reported in Chapter 4 (Heath et al., 2012), demonstrated that participants who were severely sleep restricted consumed more snacks and were more likely to choose sweet snacks when compared to moderately sleep-restricted participants. Results reported in Chapter 6

showed that shorter sleep durations predicted a higher intake of carbohydrate (as a percentage of daily energy intake). Additionally, findings reported in Chapter 7 indicate that lower sleep efficiency predicted a higher consumption of carbohydrate (as a percentage of daily energy intake). Taken together, these findings suggest that shorter sleep durations predicted an increase in hunger, an increased intake of snacks (particularly sweet snacks) and an increase in carbohydrates. Furthermore, lower sleep efficiency predicted a higher consumption of carbohydrate.

8.2.2.1 Sleep restriction predicts eating behaviour

The findings reported in this thesis are in line with previous studies examining sleep restriction and eating behaviour. Chapter 3 (Heath et al., 2011) demonstrated an increase in hunger following seven nights of sleep restriction. Participants' hunger levels were compared to baseline and a control condition receiving 8h of sleep per sleep opportunity. Previous research has demonstrated that hunger levels increase following sleep restriction (Spiegel et al., 2004). Whilst Chapter 3 showed hunger levels increased, contrary to expectation energy intake and macronutrient intake were not affected by sleep restriction. There has been evidence from previous research to suggest that energy and macronutrient intake are altered when sleep is restricted (Markwald et al., 2013; Spaeth et al., 2013; St-Onge et al., 2011). However, other studies have not noted differences in eating behaviour when sleep is restricted (Benedict et al., 2011). The review of the literature investigating sleep restriction and eating behaviour in Section 1.5.2 of the current thesis described how the methodology of the study should be considered when interpreting results. There were particular methodological issues that may have influenced the findings reported in Chapter 3 (e.g. a ceiling effect and the impact of a recovery sleep prior to testing). These methodological considerations and their potential impact on the findings of this study are discussed in detail in Section 8.3.1.

Findings reported in Chapter 4 (Heath et al., 2011) demonstrate that participants experiencing severe sleep restriction (approximately 4h sleep per 24h) consumed more snacks and were more likely to choose sweet snacks when compared to participants in a moderate sleep restriction condition (approximately 6h sleep per 24 hours). Results reported in Chapter 4 were similar to a previous study (Nedeltcheva et al., 2009), which showed that individuals subject to severe sleep restriction (5.5h per night for 14 days) consumed more energy from snacks during sleep restriction when compared to a control condition. These findings suggest that shiftworkers who are severely sleep restricted are likely to have a higher intake of snacks. They may be at particular

risk of developing health disorders related to eating behaviour as they are more likely to consume sweet snacks.

The studies reported in Chapters 6 and 7 were the first to our knowledge to examine sleep as a predictor of eating behaviour in shiftwork environments. Results in Chapter 6 showed that shorter sleep durations were associated with increases in carbohydrate consumption. Although macronutrient content of snacks reported on in Chapter 4 (Heath et al., 2012) were not examined, the sweet snacks are often high in carbohydrate, due to their high sugar content (Whitney, Rolfes, Crowe, Cameron-Smith, & Walsh, 2011). Therefore, the findings from Chapters 4 and 6 concur. Contrary to expectation, the study reported in Chapter 7 did not find shorter sleep durations to be associated with alterations in eating behaviour. Results in Chapter 7 found sleep efficiency was the only sleep-related factor to predict eating behaviour. Previous research has demonstrated that participants who are severely sleep restricted (to around 4h per sleep opportunity) are likely to crave carbohydrates (Spiegel et al., 2004) and alter their eating behaviour (Markwald et al., 2013; Nedeltcheva et al., 2009; Spaeth et al., 2013). However, participants reported on in Chapter 7 obtained 4h of sleep on only 4.9% of study nights. It is possible that only severe levels of sleep restriction alter eating behaviour. Shiftworkers who participated in the study reported on in Chapter 7 may not have been experiencing enough sleep restriction to impact their eating behaviour as a result.

8.2.3 *Hypothesis 1c: Shift-related factors will predict eating behaviour*

8.2.3.1 Circadian disruption affects eating behaviour

Shiftworkers often experience circadian disruption and are required to consume food at sub-optimal circadian phases. Findings reported in Chapter 4 (Heath et al., 2012) indicated that all participants snacked less during the biological night. These findings are in line with studies that suggest that appetite decreases during the night (Waterhouse et al., 2003). However, some studies investigating shiftworkers have found that night shiftworkers are more likely to snack across their shifts (Reinberg et al., 1979). It is important to note that participants who took part in the laboratory study reported on in Chapter 4 were fed three healthy meals each study day throughout the study, and were also provided with healthy snack choices. This may have resulted in less need to snack throughout the night than shiftworkers who have not consumed a meal prior to the commencement of their shift. Consuming healthy meals may protect shiftworkers from feeling the need to snack across the night. Educating shiftworkers on how to prepare quick healthy meals to take to work may be a useful health-promotion tool for this population.

However, it is important to remember that as the study reported on in Chapter 4 was a laboratory study, external validity is limited (this is discussed further in Section 8.3.1). Participants in the laboratory environment are not subject to environmental factors that may influence eating behaviour. For example, shiftworkers may be more likely to purchase foods from vending machines (Stewart & Wahlqvist, 1985).

8.2.3.2 Shift type and shift schedule predict eating behaviour

Findings from the current thesis support Hypothesis 1c. The field studies reported on in Chapters 6 and 7 examined if shift schedule and shift type predicted eating behaviour. Specifically, Chapter 6 examined shiftworkers on various shift schedules (permanent morning and night shift and rotating 8h and 12h shiftworkers). The findings reported in Chapter 6 demonstrate that permanent night shiftworkers had a higher intake of saturated fat (as a percentage of daily energy intake), whereas permanent morning shiftworkers had a higher intake of carbohydrate. Shift type was investigated in Chapter 7, and results showed that when the rotating shiftworkers in this study worked a night shift they had higher energy intakes, lower carbohydrate intakes, and consumed a lower daily percentage of alcohol. Overall night shifts were associated with more alterations in eating behaviour than other shift types.

Findings from previous studies have demonstrated differences in energy and macronutrient intakes between various shift schedules (Attia et al., 1985) and between shiftworkers on various shift types (Balieiro et al., 2014; Lennernäs et al., 1995; Reinberg et al., 1979). The studies investigating shiftworkers and eating behaviour have examined shiftworkers on a variety of shift schedules and shift types, and not surprisingly results have been varied. As each shift schedule and shift type affects predictors of eating behaviour differently, it is very important to understand these predictors and pathways in further detail, and for future research to look beyond the effect of shiftwork (as a whole) on eating behaviour.

8.3 Hypothesis 2: Factors related to shiftwork will predict mood

Hypothesis 2 is supported in the findings reported in Chapters 5 and 7. However, Hypothesis 2 was not supported by the findings in Chapter 6. Mood was not examined in Chapters 3 and 4. Results are discussed below.

8.3.1 *Hypothesis 2a: Sleep-wake related factors will predict mood*

Chapter 5 showed that when sleep was restricted to the equivalent of approximately 4h sleep opportunity per 24h in an FD study, all except one of the mood domains examined (A-H) deteriorated with increasing prior wake. Additionally, TMD increased with increasing levels of prior wake.

8.3.1.1 Sleep restriction predicts increases in negative mood and decreases in positive mood

Findings from the current thesis concur with previous studies that have demonstrated sleep restriction results in an increase in negative mood states (Dinges et al., 1997; Haack & Mullington, 2005; Taub & Berger, 1973). For example, participants restricted to approximately 5h of sleep per night for seven nights reported increased feelings of fatigue, confusion and tension (Dinges et al., 1997). Results of a later study also showed that when participants were restricted to 4h sleep per night for 12 nights, increases in tiredness and fatigue levels were reported, particularly during the first few days of sleep restriction when results were compared to a control condition obtaining 8h sleep per night (Haack & Mullington, 2005). Similar to findings from Chapter 5 (Heath et al., 2010), Haack and Mullington (2005) also noted a decrease in positive mood states, such as optimism and sociability, when participants were restricted of sleep. The findings of the current thesis, along with previous research, suggest that when sleep is severely restricted to around 4 or 5h per night individuals are more likely to experience increases in negative mood states and decreases in positive mood states.

8.3.1.2 Lengthy durations of prior wake predicts increases in negative mood and decreases in positive mood

Previous research employing an FD protocol has found that prior wake influences mood (Boivin et al., 1997; Koorengevel et al., 2003). However, previous FD studies investigating mood have not employed a measure of sleep restriction in their protocol. Study days in FD studies are generally 20h or 28h in duration (to ensure circadian rhythms are outside of circadian entrainment; see Section 1.3.3 for further detail). Sleep episodes in prior FD studies are typically the equivalent of 8h per 24h day (a ratio of 1:3). Therefore, participants are not awake as long as participants in the laboratory study reported in Chapter 5 (Heath et al., 2010). Chapter 5 showed that mood was most disturbed at the longest duration of prior wake (22h). This is relevant for shiftworkers, particularly those employed on night shifts. Night shiftworkers report that at times they do not sleep prior to the beginning of their shift (Knauth et al., 1980) and as a result are awake for long

durations. Therefore, mood is likely to be most disturbed on the first night shift if shiftworkers have not slept prior to their shift.

8.3.1.3 Sleep duration did not predict alterations in mood in shiftworkers

Results from Chapters 6 and 7 did not support the above hypothesis. Chapter 6 showed sleep duration was not correlated with chronic fatigue, and sleep duration did not predict alterations in mood (Chapter 7). Previous field studies have demonstrated links between sleep duration and mood. For example a 14-day study examining healthy employed individuals aged between 20 and 59 years reported decreased mood was correlated shorter sleep durations (Totterdell, Reynolds, Parkinson, & Briner, 1994). A later field study investigating older adults (m = 72.81 years) sleep variables (measured by actigraphy) were not associated with mood (McCrae et al., 2008). However, subjective sleep measures (measured by self-report diary) did demonstrate an association with daily functions in mood. More specifically, participants who had longer durations of total wake time (total unwanted wake time whilst in bed) reported higher levels of negative mood and lower levels of positive mood. Similar results were seen when participants reported lower ratings of subjective sleep quality. These findings from previous studies suggest that shorter sleep durations and poorer sleep quality result in increased negative mood and decreased positive mood.

Laboratory studies investigating the relationship between sleep restriction and mood have typically used protocols that subject participants to severe sleep restriction (4–5h per night). However, as noted previously, participants in the studies reported on in this thesis were not regularly experiencing severe sleep restriction. The shiftworkers in the field studies within this thesis reported mostly moderate levels of sleep restriction (6–7h per night). It may be that the studies within the current thesis did not include enough participants experiencing severe levels of sleep restriction to see any effects of sleep duration on mood. Very few studies have investigated alterations to mood when sleep is moderately restricted. The FD study included within this thesis (reported on in Chapters 4 and 5) did include a moderate sleep restriction condition. The effect of moderate sleep restriction on mood for this condition has been published by Hampton et al. (2010) (see Appendix V). Results were similar to the findings for the severe sleep restriction condition. Hampton et al. (2010) found that similar to the findings reported on in Chapter 5 (Heath et al., 2010) negative mood domains such as fatigue and confusion became more disturbed with increasing prior wake and V-A decreased with increasing durations of prior wake. A comparison of the two conditions was beyond the scope of this thesis (as results for the moderate

sleep restriction condition had been published separately). Further analyses of these two conditions may help with the understanding of any differences in mood between severe and moderately sleep-restricted individuals (this is discussed further in Section 8.4.3).

Previous research suggests shiftworkers report experiencing increases in negative moods (Cavallo et al., 2002; Driesen et al., 2010). Shiftwork is not only associated with sleep restriction, shiftwork also results in circadian disruption (Åkerstedt, 2003). Circadian disruption has been associated with increased negative mood in the current thesis and in previous research (Boivin et al., 1997; Koorengevel et al., 2003). The effect of circadian disruption and shiftwork on mood is discussed below. In addition, other variables may be predicting negative mood in shiftworkers (this is also discussed below). Overall the results of this thesis did not demonstrate sleep duration predicted mood in shiftworkers.

8.3.2 *Hypothesis 2b: Shift-related factors will predict mood*

Chapters 5 and 7 show support for the above hypothesis. As night shiftworkers are likely to be awake and at work at the time of the circadian nadir, circadian phase is a shift-related factor that may affect the mood of night shiftworkers in particular. Findings reported in Chapter 7 demonstrate that shiftworkers experienced higher levels of stress on night shift (compared to afternoon shift) and show that shiftworkers were more tired on night shift (when compared to both morning and afternoon shift).

Research investigating mood in shiftwork populations is limited; however, findings suggest that shiftwork is more likely to be associated with negative rather than positive mood. Rotating shiftworkers and night shiftworkers have reported high levels of stress (Cavallo et al., 2002; Nasrabadi, Seif, Latifi, Rasoolzadeh, & Emami, 2009; Srivastava, 2010). Furthermore, it has been demonstrated that night shiftworkers are likely to experience fatigue (Bohle & Tilley, 1993; Luna et al., 1997; Nasrabadi et al., 2009; Paterson et al., 2010). Results reported in Chapter 6 did not find any differences in chronic fatigue across shift types. Shiftworkers (on all shift types) reported higher levels of chronic fatigue (according to the Chronic Fatigue Scale) than a previous study measuring chronic fatigue in a large sample shiftworking nurses (n = 530) employed on night and rotating shifts (Barton, 1994). All shiftworkers participating in the study reported in Chapter 6 may have been experiencing chronic fatigue and this may be why no differences were seen between the shift types.

Shiftwork disrupts many lifestyle factors. As mentioned above, the mood of shiftworkers may vary depending on a number of variables. Demographic and confounding variables have not been included in many other studies investigating shiftwork and mood. However, a previous study suggested cultural background may impact on the shiftworkers' experiences. For example, shiftworkers in family-orientated countries report experiencing work-life conflict and therefore suffer from negative mood states, such as depression and anxiety (Nikbakht Nasrabadi, Parsa Yekta, & Emami, 2004). In addition, work stress has been found to be a predictor of negative mood in shiftworkers who reported increased levels of stress, anxiety, anger and tension (Srivastava, 2010). On the other hand, there are factors that have been associated with positive mood in the workplace, such as job satisfaction (Fisher, 2002) and social interactions (Clark & Watson, 1988). Therefore, numerous factors may play a role in mood experienced by shiftworkers. The studies reported in Chapters 6 and 7 did include a variety of demographic factors and some of these did predict mood (e.g. BMI was associated with depression). Circadian disruption has also been found to predict mood in the current thesis and in previous research (Boivin et al., 1997). The impact of circadian disruption on mood is discussed below.

Shiftworkers in the current thesis reported increased levels of tiredness whilst on night shift. However, Chapters 6 and 7 did not report increased levels of chronic fatigue, stress, anxiety and depression in the participants. These results conflict with previous findings (Bohle & Tilley, 1993; Cavallo et al., 2002; Driesen, Jansen, Kant, Mohren, & van Amelsvoort, 2010a; Luna et al., 1997; Nasrabadi, Seif, Latifi, Rasoolzadeh, & Emami, 2009). It may be that other factors (mentioned above) were confounding results, or there may have been limitations in the design of the study. Limitations are discussed in more detail in Section 8.3.

Results reported in Chapter 5 (Heath et al., 2010) show that severely sleep-restricted participants experienced more mood disturbance around the circadian nadir. These findings were in line with Hampton et al. (2010) (Appendix V) who reported on the moderately sleep-restricted condition within the same study. The findings suggest that night shiftworkers may be at greater risk of poor mood than shiftworkers on morning or afternoon shift, as they are more likely to be awake around the circadian nadir. Whilst shiftworkers in the study reported in Chapter 7 reported increases in tiredness whilst working a night shift, they did not report alterations in other mood domains. Mood was only tested on two occasions (and was not measured at the circadian nadir). This is discussed further in the limitations; however, it may explain inconsistent findings.

8.4 Hypothesis 3: Shift-related factors will predict sleep

Findings from the field studies in the current thesis suggest that shift-related factors predicted sleep and therefore provide support for Hypothesis 3. Rotating shiftworkers (Chapter 7) had shorter sleep durations prior to a morning shift (compared to night shiftwork). However, night shiftworkers reported experiencing lower sleep quality. Additionally, 12h rotating shiftworkers (Chapter 6) had shorter sleep durations than all other shift types.

As mentioned previously, the sleep of shiftworkers who participated in studies within this thesis were more likely to be considered moderate (6–7h sleep per night) rather than severe (around 4h sleep per night). As reported in Chapter 6, approximately 35% of shiftworkers reported obtaining 7h or less sleep on average. However, in Chapter 7, where sleep was measured objectively) shiftworkers reported obtaining less than 7h sleep on just over half (approximately 53%) of study nights. Overall results from the current thesis concur with findings suggesting that shiftworkers do not obtain adequate sleep (Åkerstedt, 2003; Costa, 2010).

Previous research suggests that night and morning shiftworkers are most at risk of sleep restriction (Åkerstedt, 2003; Costa, 2010). Indeed, Chapter 7 reported that shiftworkers participating in the study obtained the least amount of sleep prior to working a morning shift. However, Chapter 6 reported that permanent morning shiftworkers did not report experiencing sleep restriction on average. The 12h rotating shiftworkers investigated in Chapter 6 had been employed in shiftwork for approximately 18 years. Previous research suggests that individuals who work longer are more likely to experience sleep restriction (Ribet & Derriennic, 1999). This may have contributed to the shorter sleep episodes reported by the 12h rotating shiftworkers in Chapter 6. Previous research has also showed variables related to work such as overtime, amount of physical strain and pace of work environment (e.g. hectic work) are associated with the sleep duration of shiftworkers (Åkerstedt, Fredlund, Gillberg, & Jansson, 2002). Investigating these factors was beyond the scope of the current thesis; however, it is important to note that differences in the characteristics of shiftworkers and factors related to the work environment may influence the sleep of shiftworkers. Nevertheless, many of the shiftworkers in the current thesis reported moderate levels of sleep restriction. Therefore, results reported in the current thesis concur with previous findings suggesting the shiftworkers often experience sleep restriction.

8.5 Limitations

The findings of this thesis increased the body of knowledge on shiftwork and eating behaviour. However, the studies reported on within this thesis contain limitations that should be addressed in future research. The limitations of the laboratory and field studies included in this thesis are outlined below.

8.5.1 *Chapters 3, 4 and 5: Laboratory studies (Studies 1 and 2)*

Limitations of the laboratory study reported within Chapter 3 (Heath et al., 2011) included the sample size, measurement of eating behaviour and aspects relating to the design of the protocol. The laboratory studies within all of the above mentioned chapters had limitations in external validity and generalisation to shiftworkers along with some issues with the measurement of eating behaviour that should be taken into consideration.

The laboratory study reported on in Chapter 3 (Heath et al., 2011) was a pilot study and therefore the sample size was small (n = 12). Consequently, results of this study should be interpreted with caution. The characteristics of participants reported on in Chapters 3, 4 and 5 make it difficult to generalise results to shiftworkers in the field. The participants in both laboratory studies included healthy young males within the normal weight range (according to BMI). In addition, participants were not shiftworkers, and were not experiencing any mood or sleep-related disorders. Studies suggest shiftworkers are more likely to be overweight (Biggi et al., 2008; Esquirol et al., 2009; Lin et al., 2009) and may already be experiencing mood (Cavallo et al., 2002; Geiger-Brown et al., 2004; Srivastava, 2010) and sleep disturbances (Dorrian et al., 2008; Knauth et al., 1980). Overweight individuals may be at greater risk of consuming foods high in fat and sugar, as there is an association between high-fat and high-sugar diets and increased body weight (Lissner & Heitmann, 1995). Therefore, the food choices of shiftworkers may differ from the healthy young males who participated in the laboratory studies conducted within this thesis.

The FD design reported on in Chapters 4 and 5 had the advantage of analysing homeostatic and circadian influences separately. However, the rotating schedule of this study does not correspond with rotating shiftwork schedules in the field. Although generalisability is a limitation of these laboratory studies, the limitation was addressed by including two field studies in shiftwork populations within this thesis.

In addition to the above, the choice of eating behaviour measures may have impacted on results in both laboratory studies. First, using a buffet meal to measure eating behaviour may have

limited the findings reported on in Chapter 3. Whilst buffet meals are commonly used to measure eating behaviour (Allirot et al., 2014; Brondel et al., 2010; Wren et al., 2001), it is possible the novelty of the first buffet meal in the laboratory may have produced a ceiling effect and resulted in a higher than usual intake of food. This may have made it difficult for participants to consume more food at the buffet meal following sleep restriction, even though they reported higher levels of hunger. Furthermore, the knowledge that only healthy meals and snacks would be provided during the study may have influenced results reported in Chapter 3. In particular, participants may have been more likely to choose unhealthy food at the first buffet, making it less likely to notice any effect of sleep restriction.

Chapter 4 (Heath et al., 2012) measured snack choice; however, only a narrow range of snack choices was offered to participants. Nevertheless, even with the limited snack choices participants were still more likely to choose sweet snacks when they were severely sleep restricted. In both laboratory studies, participants were provided with healthy meals and snacks during the study. The availability of healthy meals may have resulted in participants being too full to snack throughout the night. Furthermore, participants also had the opportunity to consume healthy snacks without needing to prepare or purchase them. This does not mimic the real world, as shiftworkers have reported not having the energy to prepare healthy meals or having the time to take meal breaks (Persson & Mårtensson, 2006) Furthermore, shiftworkers are often exposed to environmental factors such as vending machines (Stewart & Wahlqvist, 1985). Food purchasing options are also limited during the night and shiftworkers may be relying on convenience foods. Therefore, food choices may differ in shiftwork environments when compared to the laboratory environment. It is also important to note that a number of other factors motivate food choice (these factors are discussed in detail in section 1.1.2).

In addition to the above limitations, the protocol of Chapter 3 could have been improved by measuring eating behaviour prior to the recovery sleep and/or measuring mood prior to the buffet meal. It is not known if the impact of sleep restriction (e.g. alterations in fatigue, alterations in appetite hormones) was still present following sleep restriction. The impact of recovery sleep is discussed in Section 8.4.4.

8.5.2 *Chapters 6 and 7: Field studies (Studies 3 and 4)*

Limitations of the field studies in this thesis include measurement of variables and study design. The factors examined in Chapter 6 were all measured via self-report. Collecting data using self-

report has its advantages as there is very little burden to participants. However self-report measures are subject to biases. For example sleep diaries have been found to result in gender and age biases (Reyner, Horne, & Reyner, 1995). Additionally, there are many biases associated with the collection of dietary intake (e.g. underreporting in specific populations—see Section 1.1.3 for further details). Chapter 6 assessed dietary intake by using a dietary questionnaire. Dietary questionnaires are useful as they allow for an estimation of habitual consumption of foods (Erdman Jr et al., 2012); however, the questionnaires did not allow for an understanding of daily variations in food depending on shift type. Similarly, only an average estimate of sleep duration was obtained in the study reported on in Chapter 6. The design of the questionnaire did not allow for an understanding of sleep obtained on various shift types. This was particularly a limitation for the participants on rotating shift schedules. The study conducted within Chapter 6 was cross sectional in design and therefore it is difficult to determine if food consumed had an impact on sleep duration. It is important to note that the nutritional content of meals prior to sleep may effect sleep duration. For example, a meal high in carbohydrates has been found to increase sleep duration (Nehme et al., 2014). Chapter 7 addressed some of the limitations of Chapter 6; its study used actigraphy to measure sleep and food diaries to measure food intake. Food diaries do have their limitations (discussed in detail in Section 1.1.3); however, they are considered gold standard when measuring self-reported eating behaviour (Thomson & Subar, 2001). The study in Chapter 7 was longitudinal and therefore addresses limitations associated with the cross sectional design used in Chapter 6.

As discussed previously, the log book used in the field study reported on in Chapter 7 asked participants to report their mood on only two occasions. Mood was not collected at various time points, and therefore it was difficult to compare results from Chapter 7 with the laboratory study reported on in Chapter 5 (Heath et al., 2010). Night shiftworkers may be at increased risk of experiencing negative mood. For example, Chapter 5 showed that mood is lowest around the circadian nadir. Many mood domains were not affected in the field studies; this may have been due to having only two time points where mood was measured. The examination of mood across various time points (particularly around the circadian nadir) would have provided a greater understanding of the effect of prior wake and circadian disruption in shiftworkers. In addition, the log book used in Study 4 (Chapter 7) could have been improved by asking participants to report their mood prior to eating episodes. This would have allowed for a more in depth understanding of the direct impact of mood on eating behaviour.

8.6 Future directions

Results from studies reported on in this thesis demonstrate that mood, sleep-wake and shift-related factors predict eating behaviour. However, findings within this thesis raise questions and identify areas that could be expanded in future studies to improve the understanding of eating behaviour in shiftworkers. Findings could also be investigated to determine if they apply to day workers as well as shiftworkers. The questions raised from this thesis are discussed below.

8.6.1 *How do the findings from this thesis apply to day workers?*

Many of the factors within this thesis not only apply to shiftworkers, they are also experienced by day workers. Day workers may be less likely to experience circadian disruption; however, they may be subject to other factors examined, such as sleep restriction. Similar to shiftworkers, many day workers report experiencing moderate levels of sleep restriction (National Sleep Foundation, 2015). In order to understand how factors within this pathway apply to day workers in comparison to shiftworkers, a sample of day workers should be investigated.

8.6.2 *When should meal breaks occur for night shiftworkers?*

The findings from the laboratory study reported in Chapter 5 (Heath et al., 2010) identified that mood was at its lowest point around the circadian nadir, and when individuals were awake for long periods of time. Night shiftworkers are at work during the circadian nadir and are more likely to be awake for long durations. Therefore, these results suggest that night shiftworkers may be most at risk of mood disturbance. However, field studies within the current thesis did not examine mood at the times when night shiftworkers are most at risk of mood deterioration. Future studies should examine mood across a night shift to determine if mood whilst at work coincides with mood findings in the laboratory. Furthermore, to gain a more complete understanding of the effect of mood on eating behaviour, mood should be measured directly prior to eating episodes. Determining if individuals on night shift are making poorer food choices at specific times (as a result of mood) will help organisations plan and determine the best times for meal breaks. Meal breaks could be planned at times when shiftworkers are at decreased risk of experiencing mood disturbance. Alternatively, organisations could increase factors associated with positive mood. For example, social interaction has been associated with positive mood (Clark & Watson, 1988). Employers could implement strategies such as ensuring meal breaks are social occasions and something employees can enjoy. Helping maintain a positive mood in the workplace may not only have positive impacts on eating behaviour, but will be likely to assist many other work-related factors.

8.6.3 *How does moderate sleep restriction affect mood and eating behaviour?*

Findings from Chapter 4 (Heath et al., 2012) show that snacking behaviour was increased and sweet snacks were more likely to be consumed when sleep restriction was severe (approximately 4h per 24h) compared to moderate (approximately 6h per 24h). Many of the shiftworkers in the current thesis reported experiencing moderate levels of sleep restriction as opposed to more severe levels. The results from Chapter 5 (Heath et al., 2010) show that mood deteriorated with increasing prior wake and the mood was at lower levels around the circadian nadir for individuals who were severely sleep restricted. The moderate sleep restriction condition was investigated by Hampton et al. (2010) (see Appendix V). Whilst results appeared to be in a similar direction for both the severe and moderate conditions, an analysis needs to be conducted to determine differences. Furthermore, it would be useful to understand how moderate sleep restriction affects both mood and eating behaviour compared to a control condition (obtaining around 8h sleep in a 24h period) in an FD study. An exploration of moderate sleep restriction will have not only implications for shiftworkers, it will also be useful for the general population. As mentioned above, many individuals (not only shiftworkers) report moderately restricting their sleep. Therefore findings of studies investigating moderate sleep restriction will have implications for the wider population.

8.6.4 *What is the impact of recovery sleep on eating behaviour?*

Chapter 3 (Heath et al., 2011) examined eating behaviour after a period of sleep restriction and a recovery sleep. Many individuals attempt to recover from restricting sleep during work days by extending their sleep episodes on weekends (Valdez, Ramírez, & García, 1996). In particular, it is a common strategy for night shiftworkers to extend their sleep following their last night shift (Åkerstedt, 1998). Shiftworkers have reported that they still crave and consume sweet foods the day after their night shift (Persson & Mårtensson, 2006), presumably after they have had time to have a recovery sleep opportunity. Therefore, it appears that one recovery sleep may not protect shiftworkers from alterations to eating behaviour, particularly the consumption of sweet foods. Previous research has demonstrated factors, such as performance, take some time return to baseline levels following a period of sleep restriction (Jay et al., 2007; Lamond et al., 2007). On the other hand, a recent study has demonstrated that mood states such as depression returned to baseline levels following one recovery sleep (Wehrens, Hampton, Kerkhofs, & Skene, 2012). However, the impact of recovery from sleep restriction on eating behaviour has not been investigated. Whilst this thesis did not focus on recovery sleep, it was interesting to note that

participants still remained hungrier than baseline levels even following a recovery sleep. Although mood may return to baseline levels following a recovery sleep and therefore may not be influencing eating behaviour, there are other factors that affect eating behaviour when individuals are sleep restricted. For example, previous research has shown alterations in appetite hormones following sleep restriction (Spiegel et al., 2004; Taheri et al., 2004). The period of time hormones take to return to baseline following a recovery sleep is an area for investigation in future research.

8.7 Concluding remarks

This thesis reports on some of the few studies to examine predictors of eating behaviour in shiftworkers, and has therefore contributed to the current body of knowledge on shiftwork and eating behaviour. In particular, this thesis identified that it is not simply shift type and shift schedule that affect eating behaviour, there are many factors associated with shiftwork that have implications for eating behaviour. Mechanisms behind the development of health disorders related to eating behaviour are complex. It is important to acknowledge that the pathway investigated within this thesis is one of many that lead to the development of health disorders in shiftworkers. Therefore, consideration of other factors and continued exploration into mechanisms is imperative.

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Hello Georgina,

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Best wishes,
Charli.

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Little Clock, Big Clock:
Molecular to Physiological Clocks

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Chapter 4

Food consumption and food choice following one week of sleep restriction: A pilot study

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Aims: There is evidence to suggest that restricting sleep may result in overconsumption of food and poor food choices. This has been attributed to disruption in appetite hormones following sleep restriction (SR). The aim of this study was to investigate food consumption and food choices before and after either one week of SR or a control condition consisting of one week of 8 h time in bed (TIB).

Methods: Twelve healthy males [age: 24.6 ± 3.1 years; BMI: 22.9 ± 1.3 kg/m^2, mean ± SD] completed either a SR (n=6) or a control condition (n=6). The protocol began with an adaptation and two baseline days (8 h TIB), seven SR days (4 h TIB) or seven control days (8 h TIB) and one recovery day (8 h TIB). On the first baseline and recovery days, participants were served an identical buffet meal (7,943 Kcal in total). All food was weighed and measured before, and immediately after the buffet meal. The calorie and macronutrient content of food was calculated using a nutritional database (CalorieKing). Prior to each buffet participants reported their subjective hunger.

Results: Mann-Whitney tests were conducted to examine the difference between conditions in total calories consumed, macronutrient content and self-reported hunger. There were no significant differences in calories or macronutrients consumed (p > .05). However, there was a significant difference in self-reported hunger (p = .02) such that participants who were sleep restricted reported feeling hungrier than control participants.

Discussion: Although self-reported hunger was higher on the recovery day when the SR condition was compared to the control condition, there was no difference in food consumption or food choices between conditions. A ceiling effect may have prevented participants from consuming more food despite increased hunger. Examining food consumption over an entire day following SR may provide a clearer understanding of how SR effects food consumption and food choice.

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Introduction

Obesity rates have more than doubled in Australia over the past two decades [5]. Over the same period of time, sleep duration has decreased [3]. Epidemiological studies which have demonstrated a relationship between sleep restriction (SR) and obesity [8] do not appear to be coincidental.

Laboratory studies suggest that hunger increases following SR due to altered levels of endocrine hormones that regulate appetite [10, 12]. In addition, there is some evidence to suggest poor food choice may occur when sleep is restricted. For example, heightened cravings for calorie rich foods were reported following two nights of sleep restriction (4 h TIB) compared to two nights of sleep extension (10 h TIB) [12].

Although the above findings suggest SR may influence food consumption and food choice, very few studies have examined objective measures of food intake following or during a period of SR. Results from a recent experimental study demonstrated increased food consumption and a higher percentage of fat consumption following a single night of SR (4 h TIB) [4]. Two previous studies examining the influence of SR on food intake did not find

differences in total food consumption [7, 11]; however, one of these studies did show an increase in calories from snacks during SR [7]. The disparity in results from previous studies may have occurred due to participants' calorie intake surpassing energy demands prior to testing in both the SR and control condition. To ensure energy balance remains constant, participants in the current study will follow a calorie controlled diet.

The aim of the current study was to examine participants' self-reported hunger, food consumption and food choice in a buffet meal before and after one week of SR (4 h TIB) and a control condition (8 h TIB) for the same time period. It was hypothesised that hunger and food consumption would be higher in the SR compared to the control condition following the experimental period. In addition, it was hypothesised that the SR condition would show a preference for high fat and high carbohydrate foods following the experimental period when compared to the control condition.

Methods

Participants

Twelve healthy males (24.6 ± 3.1 years, mean ± SD) completed the current study. Participants had normal sleep patterns, were not dieting, had no food allergies and were of a healthy weight range (body mass index: 22.9 ± 1.3 kg/m^2). Participants were excluded from the study if they were taking medication known to affect sleep or had a medical condition, if they consumed high levels of alcohol or caffeine, or if they had undertaken transmeridian travel or shiftwork in the 3 months prior to the start of the study. Ethics approval for this study was obtained from the University of South Australia Human Research Ethics Committee. Written informed consent was obtained from all participants and the research methods conformed to the guidelines established by the National Health and Medical Research Council of Australia.

Protocol

Participants were randomly assigned to either a SR condition (*n*=6) or a control condition (*n*=6) for 12 consecutive days in a sleep laboratory at the Centre for Sleep Research. In both conditions, the first three days (one adaptation and two baseline days) consisted of 8 h TIB (00:00 h – 08:00 h). During the next 7 days the SR condition were provided with 4 h TIB (04:00 h – 08:00 h) and the control condition were provided with 8 h TIB (00:00 h – 08:00 h). On the final night in the laboratory, participants in both conditions were provided with an 8 h recovery sleep opportunity (00:00 h – 08:00 h).

Participants in both conditions were served an identical buffet meal on two occasions during the study. The first buffet meal was served at 13:00 h after the first 8 h sleep opportunity in the laboratory (baseline day) and following a 17 h fast. The buffet was served again on the final day of the study (recovery day) at 13:00 h, again after a 17 h fast. The buffet meal was more than double the recommended daily intake (7,943 kcal in total). Participants could choose from a variety of different foods with varying levels of macronutrients (i.e. fat, protein, carbohydrate). Participants consumed the buffet individually in their own private living area and were given 1 hour to consume food *ad libitum*. During the hour in which the buffet was served, participants were instructed to remain quietly in their living areas with their televisions off. At 14:00 h all food was removed from the participants' living areas. Food from the buffet was weighed and measured to the nearest 1 g before and after consumption. Self-reported hunger was measured 45 minutes prior to each buffet meal.

During the remainder of the study, participants consumed a calorie controlled diet following the nutrient reference values of Australia and New Zealand and to suit sedentary males with normal BMI [2]. Throughout the experimental period of the study participants completed glucose tolerance tests, blood draws and neurobehavioural test batteries as part of a larger study. When not completing these tasks, participants were given free time to complete quiet activities such as reading or watching DVDs. Participants were monitored by a closed circuit television system to ensure compliance to the protocol.

Measures

Food consumption was measured by calculating the total number of calories consumed during the buffet meal. Food choice was measured by determining the macronutrient content (fat, protein and carbohydrate) of the food consumed during the buffet. Calorie and macronutrient content of food was ascertained by a nutritional database (CalorieKing).

Self-reported hunger was measured using a visual analogue scale. Participants were asked "how hungry do you feel right now" and asked to rate their hunger by drawing a line through the scale. The scale ranged from 0 mm ("I am not at all hungry") to 100 mm ("I have never been more hungry").

Data analysis

Data screening revealed non-normal distributions for all variables except for fat. Therefore, the difference between recovery and baseline data for each participant was computed to obtain a new variable (difference: recovery-baseline). A series of Mann-Whitney *U* tests were then performed to analyse differences in ranked position of scores between the two conditions [6].

Results

The difference (recovery-baseline) in calorie intake for the sleep restricted participants (*Median* = -89.85 kcal) did not significantly differ from control participants (*Median* = 36.82 kcal), Mann-Whitney $U = 17.0$, $z = -0.16$, $p > .05$ (Fig 1).

Similarly, the difference (recovery-baseline) in macronutrient intake for the sleep restricted participants (Fat: *Median* = -0.15, Protein: -1.15, Carbohydrate: 5.89) did not significantly differ from control participants (Fat: *Median* = 5.47, -7.96, 9.81). Fat: $U = 17.0$, $z = -.16$, $p > .05$; Protein: Mann Whitney $U = 16.0$, $z = -0.32$, $p > .05$; Carbohydrate: $U = 17.0$, $z = -0.16$, $p > .05$ (Fig 1).

The difference (recovery-baseline) in self-reported hunger for sleep restricted participants (*Median* = 10) was significantly different when compared to the control condition (*Median* = 4.5) Mann Whitney $U = 4.5$, $z = -2.17$, $p = .03$ The participants in the sleep restriction condition reported feeling hungrier than the control condition before the buffet on recovery day compared to before the buffet on baseline day (Fig 1).

Discussion

Contrary to expectation, the results of the present pilot study showed that participants in the SR condition did not increase their food consumption or make poorer food choices following SR.

Furthermore, food consumption and food choice was not different when the SR was compared to a control condition. However, similar to previous studies [10, 12], participants who were sleep restricted reported feeling hungrier following SR when compared to control participants who had been provided with 8 h TIB for 1 week.

Although sleep-restricted participants reported feeling hungrier, contrary to expectation there was no increase in food consumption or

Table 1. Number of subjects in the Sleep Restriction (SR) (n=6) and Control (n=6) Conditions showing increases, decreases or no change in each dependent variable (DV). There were no individuals in the SR condition for whom no change was recorded.

DV	SR Condition		Control Condition		
	n increase	*n* decrease	*n* increase	*n* decrease	*n* no change
Energy (kcal)	3 ↑	3 ↓	3 ↑	3 ↓	0
Fat (g)	3 ↑	3 ↓	3 ↑	3 ↓	0
Protein (g)	3 ↑	3 ↓	3 ↑	3 ↓	0
CHO (g)	3 ↑	3 ↓	4 ↑	2 ↓	0
Hunger (VAS)	5 ↑	1 ↓	1 ↑	3 ↓	2

↑ = number of subjects (n) showing an increase from baseline to recovery, ↓ = number of subjects (n) showing a decrease in variable from baseline to recovery. DV = Dependent Variable, SR = Sleep Restriction, kcal = kilocalories, g = grams, CHO = Carbohydrate, VAS = Visual analogue scale.

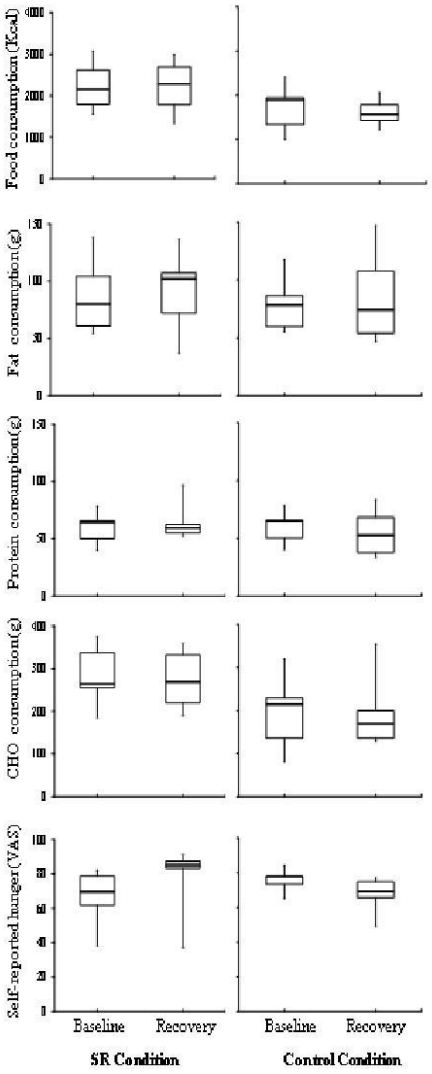


Fig. 1 Comparison of dependent variables by condition. The bottom and top of the boxes represent the 25th and 75th percentiles respectively. The median is shown by the line inside the box. The whiskers represent the distance between the lowest and highest values. DV = Dependent variable, VAS = Visual analogue scale, SR = Sleep restriction, CHO = Carbohydrate, Kcal = Kilocalorie, g = grams.

alteration in food choice following sleep restriction. It is possible that a ceiling effect may have prevented the sleep restricted participants from consuming more food following SR. In addition, it is possible the novelty of the first buffet meal in the laboratory may have resulted in higher than usual food consumption. Furthermore, the participants were aware they would not have access to unhealthy foods during the study, so this may have resulted in food choices they would not normally make on a day-to-day basis during the baseline buffet meal.

The current study is a pilot study and the small number of participants is a limitation. Consequently results must be interpreted with caution. In addition, if this study was to be replicated, the protocol could be improved by holding the second buffet prior to the recovery sleep opportunity to ensure the effect of SR is still evident. If appetite hormones do become disrupted as a result of SR, we do not know the duration it takes for the body to readjust hormone levels. In addition, any psychological variables that may result from increased food consumption and choice, such as mood or feelings of fatigue, may have returned to normal levels following the recovery sleep. However, a study examining eating habits of nurses reported participants craved and consumed sweet foods even after a recovery sleep following night shift work. [9] Night shift work is commonly associated with SR and feelings of fatigue [1].

As there is evidence from previous studies to suggest factors associated with SR may influence food consumption and food choice (e.g. altered appetite hormones, psychological factors) [10, 12], future studies in this area should be conducted. Due to the large individual differences seen in participants from this study, other factors (e.g. health, locus of control, eating style) that may moderate food consumption and food choice when sleep is restricted should also be investigated. Obesity is now considered a global epidemic; therefore, it is important to explore all mechanisms which may lead to the development of this chronic health condition.

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The effect of sleep restriction on snacking behaviour during a week of simulated shiftwork

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ABSTRACT

Due to irregular working hours shiftworkers experience circadian disruption and sleep restriction. There is some evidence to indicate that these factors adversely affect health through changes in snacking behaviour. The aim of this study was to investigate the impact of sleep restriction, prior wake and circadian phase on snacking behaviour during a week of simulated shiftwork. Twenty-four healthy males (age: 22.0 ± 3.6 years, mean ± SD) lived in a sleep laboratory for 12 consecutive days. Participants were assigned to one of two schedules: a moderate sleep restriction condition ($n = 10$) equivalent to a 6-h sleep opportunity per 24 h or a severe sleep restriction condition ($n = 14$) equivalent to a 4-h sleep opportunity per 24 h. In both conditions, sleep/wake episodes occurred 4 h later each day to simulate a rotating shiftwork pattern. While living in the laboratory, participants were served three meals and were provided with either five (moderate sleep restriction condition) or six (severe sleep restriction condition) snack opportunities daily. Snack choice was recorded at each opportunity and assigned to a category (sweet, savoury or healthy) based on the content of the snack. Data were analysed using a Generalised Estimating Equations approach. Analyses show a significant effect of sleep restriction condition on overall and sweet snack consumption. The odds of consuming a snack were significantly greater in the severe sleep restriction condition ($P < 0.05$) compared to the moderate sleep restriction condition. In particular, the odds of choosing a sweet snack were significantly increased in the severe sleep restriction condition ($P < 0.05$). Shiftworkers who are severely sleep restricted may be at risk of obesity and related health disorders due to elevated snack consumption and unhealthy snack choice. To further understand the impact of sleep restriction on snacking behaviour, future studies should examine physiological, psychological and environmental motivators.

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1. Introduction

Traditionally there has been considerable focus on obesity as a major public health concern. Recently there has been increasing interest as to how obesity affects performance in the workplace. Obesity has been associated with reduced productivity and higher rates of absenteeism (Narbro et al., 1996) and in America the annual cost of obesity on full time employment is estimated to be $73.1 billion (Finkelstein et al., 2010). This is of significant concern to industry and organisations, as obesity rates have risen dramatically throughout the world over the past 15 years (World Health Organisation, 2009).

According to the World Health Organisation, the rising rates of obesity can be attributed to behavioural and lifestyle changes in society (World Health Organisation, 2009). Over the past two decades there has been a shift to a "24-h society". In turn, the demand for industry, organisations and services to operate round-the-clock has lead to an increase in shiftwork in recent years (Australian Bureau of Statistics, 2010; U.S. Department of Labour, 2005). Shiftwork is associated with lifestyle and behavioural factors that may predispose shiftworkers to obesity. Therefore it is not surprising that when compared to day workers shiftworkers are more overweight and obese (Atkinson et al., 2008) and suffer from numerous chronic health conditions related to obesity such as cardiovascular disease (Boggild and Knutsson, 1999) and type 2 diabetes (Kawachi et al., 1995).

Shiftworkers experience circadian disruption and sleep restriction and there is emerging evidence to suggest these two factors may contribute to the increased incidence of obesity seen in shiftwork populations. Due to irregular working hours, shiftworkers sleep and eat at sub optimal circadian phases consequently affecting the quality, quantity and distribution of food intake.

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One of the first studies to examine eating behaviour in shiftworkers (Reinberg et al., 1979) found night shiftworkers consume snacks throughout their shift and recent studies concur with these findings (Waterhouse et al., 2003). Furthermore, studies suggest shiftworkers have poor dietary habits (Di Lorenzo et al., 2003; Harda et al., 2005). A number of factors may contribute to the snacking behaviour seen in shiftwork populations. Appetite hormones display a circadian rhythm (Cummings et al., 2001; Simon et al., 1998) and altered metabolic responses to eating at night suggest the body is not designed to consume and process food during this time (Atkinson et al., 2008). Therefore, shiftworkers may not be as hungry at night and thus prefer to snack rather than consuming heavy meals (Waterhouse et al., 2003). Additionally, the work place environment may contribute to snack choice during night shift. Shiftworkers have limited access to canteen facilities when working night shift and often rely on vending machines to obtain food (Stewart and Wahiqvist, 1985). Although it is clear that shiftworkers consume snacks at inappropriate circadian phases, there are limited controlled studies investigating the influence of circadian processes on snacking behaviour.

Along with circadian disruption, sleep restriction may also contribute to the high incidence of obesity seen in shiftworkers. Shiftworkers report poor quality and quantity of sleep when compared to day workers (Akerstedt, 2003). This is of concern as a relationship between shorter sleep durations (<8 h) and obesity has been found in shiftwork populations (Moreno et al., 2006). Laboratory studies have begun to investigate causal pathways to help understand the link between sleep restriction, obesity and related diseases. Participants in these studies have reported an increase in appetite and cravings for calorie rich foods following sleep restriction (Spiegal et al., 2005). Additionally, there is evidence to suggest hormones involved in appetite regulation are disturbed as a result of sleep restriction. Studies have shown that levels of ghrelin (an appetite stimulating hormone) increase, while levels of leptin (an appetite reducing hormone) decrease when individuals are deprived of sleep (Knutson et al., 2007; Spiegal et al., 2005), indicating sleep restriction may result in increased hunger. However, a laboratory study investigating energy intake following sleep restriction found that sleep restriction resulted in increased energy from snacks but not meals. In addition, there was no difference in leptin and ghrelin levels when the two conditions were compared (Nedeltcheva et al., 2009). This finding suggests snacking may be a result of processes other than hunger (i.e. non homeostatic) and snacking should be investigated separately to other eating episodes such as meals.

Overall, snacking behaviour may be influenced by both circadian and homeostatic (i.e. prior wake/sleep) components. Additionally there is evidence to suggest sleep restriction impacts on snacking behaviour. Therefore a protocol which allows for examination of all three factors is required. A forced desynchrony protocol extends or shortens the waking day outside the range of entrainment of the circadian pacemaker. This protocol desyncronises homeostatic and circadian processes and allows for the examination of variables at all possible levels of prior wakefulness and circadian phase (see Kleitman and Kleitman, 1953 for further detail). Thus far, only one study (Waterhouse et al., 2004) has investigated the separate influences of circadian and homeostatic processes on eating behaviour, concluding food intake was governed more by the wake period rather than circadian processes. However; participants lived on a normal sleep:wake ratio of 1:2 (the equivalent of an 8-h sleep opportunity per 24-h day). The current study will expand on previous research by employing a forced desynchrony protocol which will simulate a rotating shiftwork schedule with two levels of sleep restriction (moderate and severe). As it is unclear if the level of sleep restriction affects snack consumption and snack choice, the current study aims to investigate the effect of both moderate and severe sleep restriction on snacking behaviour. Furthermore, the study will examine the separate effects of prior wake and circadian phase on snack consumption and choice.

2. Materials and methods

2.1. Participants

Twenty-four healthy males participated in this study. Fourteen participants (age: 21.8 ± 3.8 years, mean ± SD) were randomly allocated to a severe sleep restriction condition and ten participants (age: 22.3 ± 3.5 years) were allocated to a moderate sleep restriction condition. Participants were of a healthy weight range (body mass index: 22.2 ± 1.9 kg/m^2), did not smoke and had normal sleeping patterns. Participants were excluded from the study if they were suffering from a medical condition or using medication known to affect sleep, if they had undertaken shiftwork or transmeridian travel in the three months prior to the start of the study and if they consumed high levels of caffeine or alcohol. Ethics approval for this study was obtained from the University of South Australia Human Research Ethics Committee. Written informed consent was obtained from all participants and the research methods conformed to the guidelines established by the National Health and Medical Research Council of Australia.

2.2. Protocol

Participants spent 12 consecutive days in a purpose built, time isolation laboratory at the Centre for Sleep Research. In both conditions, the first three days were 24 h in length (16 h of wake and an 8-h sleep opportunity at night). These days allowed participants to familiarise themselves with the laboratory environment and train on the performance tasks they were required to complete as part of a larger study. After the third night, participants in both conditions began the rotating shiftwork schedule which consisted of seven 28-h 'days'. The severe sleep restriction condition consisted of a 23,3-h wake episode and 4.7-h sleep opportunity (this is equivalent to a 4-h sleep opportunity per 24-h day). The moderate sleep restriction condition consisted of a 21-h wake episode and 7-h sleep opportunity (this is equivalent to a 6-h sleep opportunity per 24-h day).

Throughout the study, participants were restricted from eating *ad libitum*. Participants were served standardised meals (i.e. breakfast, lunch, dinner) at the same elapsed time into each wake period (i.e. 0.5 h, 7.5 h, 15 h). Breakfast consisted of a choice of toast, fruit, yoghurt and cereal; lunch consisted of a choice of salad and cold meats for sandwiches, soup and noodles; and dinner consisted of a hot meal of rice or pasta served with meat and/or vegetables. Snack opportunities were also provided at the same elapsed time into each wake period (i.e. 2.5 h, 5 h, 10 h, 12.5 h, 17.5 h) in each condition. Participants in the severe sleep restriction condition were provided with an extra snack opportunity at 20 h. Water was made available at all times. Participants chose and consumed their snack separately to ensure their decision was not influenced by others.

As part of a larger study participants completed neurobehavioral test batteries 1.5 h after waking and every 2.5 h thereafter during wake periods. The results of these test batteries have been reported elsewhere (Darwent et al., 2010; Sargent et al., 2010; Zhou et al., 2010, 2011a,b). When not completing test batteries participants were able undertake low intensity activities such as reading or watching DVDs. To ensure compliance to the protocol participants were monitored by a closed circuit television system.

2.3. Snacking

Snacks were assigned to one of three categories according to the content of the snack: (1) Sweet (1 × 31.3 g muesli bar, 2 × 18 g sweet biscuits), (2) Savoury (1 × 19 g packet of potato chips, or 1 × 25 g packet of savoury crackers) and (3) Healthy (1 × piece of seasonal fresh fruit, 1 × 40 g packet of dried fruit and nuts). Participants could choose one snack only from one of the three snack categories per snack opportunity; alternatively, they could choose not to snack. If participants chose to snack, they were given 30 min to consume the snack. If the snack was not consumed within this time, it was removed by a member of the research team.

2.4. Sleep

Sleep was monitored using a standard polysomnography montage which involved electrodes being attached to the scalp and face prior to each sleep opportunity. Sleep was scored in 30-s epochs in accordance with accepted criteria (Iber et al., 2007). Sleep efficiency was calculated as percentage of time in bed spent asleep. Average sleep efficiency during the forced desynchrony phase of the protocol for the moderate sleep restriction condition was 94.4 ± 2.4% and average sleep efficiency for severe sleep restriction condition was 95.9 ± 1.9%.

2.5. Core body temperature

Core Body Temperature (CBT) was recorded continuously in 1-min epochs with indwelling rectal thermistors (Steriprobe 491B; Cincinatti Sub-Zero Products, Cincinnati, Ohio). The thermistors were connected to a Mini-Mitter datalogger (Bend, Oregon).

2.6. Phase estimates

CBT data from six of the experimental days (2–7) were used to generate circadian phase estimates for each participant. Following the cleaning of the raw CBT data, the data were de-masked for sleep/wake differences and physical activity. A cosine equation was then fitted to the de-masked CBT data. The data were assigned a circadian phase estimate (i.e. 0–360 degrees) to each minute of the experimental period of the study using a resultant cosine equation (for more details regarding this process see Darwent et al., 2010).

2.7. Statistical analyses

Each snack opportunity was assigned a circadian phase (six bins with a width of 60 degrees, ~4 h) and a level of prior wakefulness (five levels: 2.5 h, 5 h, 10 h, 12.5 h, 17.5 h of prior wakefulness). The snack opportunity at 20 h of prior wakefulness (provided to the 4-h condition only) was excluded from the analysis to allow for equal comparisons between the conditions.

Logistic regression for a snack (yes/no) was conducted using a Generalised Estimating Equations (GEE) approach with exchangeable correlation structure and robust standard errors accounting for clustering over subjects. Initial models included main and two-way interaction terms. Where effects were significant within condition, planned repeated contrasts (Wald statistics) were conducted for prior wake and core body temperature bins were compared to zero degrees (circadian nadir) (see Fig. 1). Since interactions were not significant, final models included main effects only. In order to further investigate main effects of prior wake and phase, separate models were run for each condition.

3. Results

3.1. Overall snack consumption

Significant main effects were found for overall snack consumption. There was a significant effect of condition, prior wake and circadian phase ($P < .05$). There was a 40% reduction in the odds of choosing a snack in the moderate sleep restriction condition compared to the severe sleep restriction condition (95% CI = 0.36–0.95) (Table 1). Fewer snacks were consumed following a meal in both conditions (Fig. 1). All circadian phases were significantly different to the circadian nadir in the severe sleep restriction condition such that there were higher frequencies of snack consumption during the biological day compared to the biological night (Fig. 1). There were no significant differences between the phases in the moderate sleep restriction condition.

3.2. Sweet snack consumption

Significant main effects were found for the consumption of sweet snacks. A significant main effect was found for condition ($P < .05$), and prior wake was approaching significance ($P = 0.06$) (Table 1). Separate models were then run for each condition. Where effects were significant within condition, Wald comparisons were conducted to test the effect of prior wake (planned contrasts) and circadian phase (compared to bin zero) on sweet snack consumption for each condition. The odds of choosing a sweet snack were reduced during the snack opportunity following lunch and dinner. Overall, the odds of choosing a sweet snack increased across the day in the severe sleep restriction condition. No significant effects were found for circadian phase on sweet snack consumption.

3.3. Savoury snack consumption

A significant effect was found for prior wake on savoury snack consumption ($P < 0.05$) (Table 1). Wald comparison showed that there were reduced odds of consuming a savoury snack at 17.5 h of prior wakefulness compared to 12 h of prior wakefulness. No significant effects were found for condition or circadian phase on savoury snack consumption.

3.4. Healthy snack consumption

No significant effects were found for condition, prior wake or circadian phase on healthy snack consumption (Table 1).

4. Discussion

The current study investigated the influence of sleep restriction (severe and moderate) on snacking behaviour. Furthermore, the design of the study allowed for separate examination of homeostatic (prior sleep/wake) and circadian processes on snacking behaviour. Results suggest that individuals who are severely sleep restricted to the equivalent of 4 h sleep opportunity per 24 h had greater odds of consuming a snack when compared to individuals restricted to the equivalent of 6 h of sleep per 24 h. Moreover, when snack choice was examined, odds of choosing a sweet snack were increased when sleep was severely restricted. No significant differences were found between the two conditions for the consumption of savoury or healthy snacks. The lowest frequencies of snack consumption were around the circadian nadir.

The above findings concur with results from a previous laboratory study in which participants who were restricted to 5.5 h of sleep per night consumed more energy from snacks than when they were provided with an 8.5 h sleep opportunity per night (Nedeltcheva et al., 2009). The study concluded that the increased

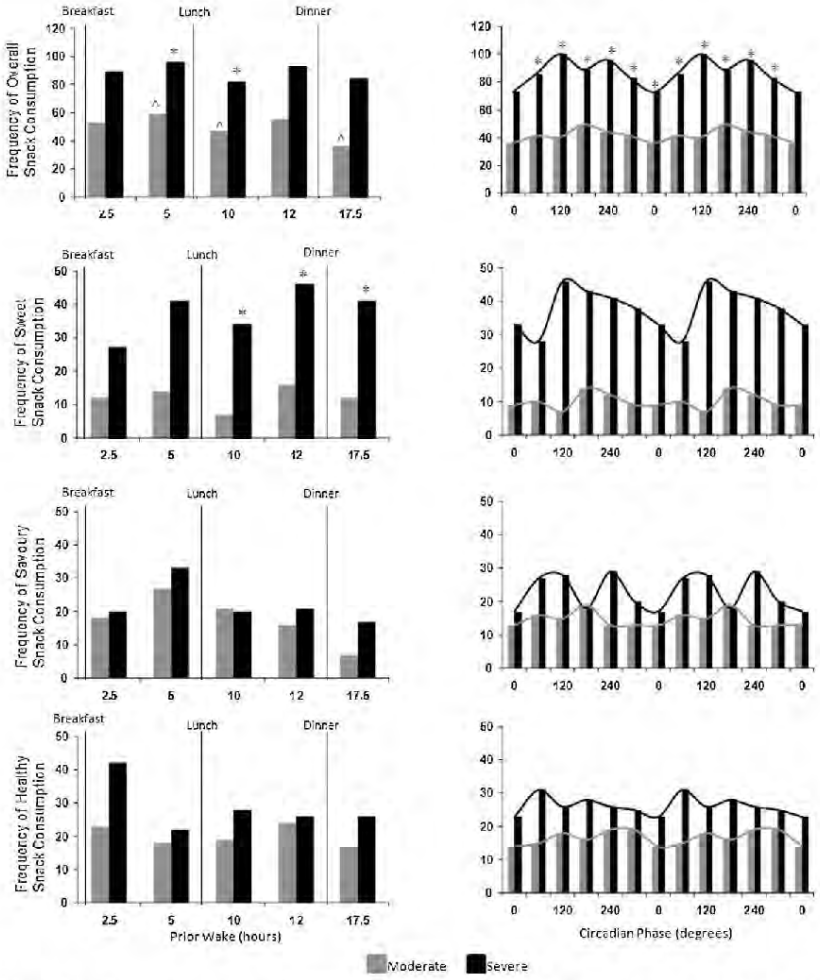


Fig. 1. Frequency of overall, sweet, savoury and healthy snacks by condition. Prior wake data were analysed using planned repeated contrasts. Circadian phase data (double plotted) were compared to zero degrees (circadian nadir). *Represents significant difference ($P < 0.05$) for severe sleep restriction condition. ^Represents significant difference ($P < 0.05$) for moderate sleep restriction condition.

consumption of snacks was not due to increased energy needs. In contrast to the present study, Nedeltcheva et al. (2009) found that the increase in snacking was more likely to occur at night rather than during the day. An advantage of the current study was that the forced desynchony protocol allowed for examination of homeostatic and circadian processes separately. When these processes were separated, we found that snacks were consumed more frequently during the biological day compared to the biological night. These contrasting findings demonstrate the need to separate homoeostatic and circadian processes to ensure results are not confounded.

Interestingly, shiftworkers consume more snacks at work when compared to day workers (Waterhouse et al., 2003). This behaviour may be due to the severe sleep restriction often reported by night shift workers. Indeed, nurses working night shift have reported they consume sweet snacks as they perceive it will help keep them awake (Persson and Martensson, 2006). Furthermore environmental factors may influence the snacking behaviour of shiftworkers. There are limited food options available at night and shiftworkers may not have the time to prepare healthy meals before their shift. Furthermore the investigation of reasons behind snack consumption and choice in shiftwork populations will demonstrate the role environmental factors may play.

In the current study only limited snack choices were offered to participants, however, even with the narrow range of choice we found significantly increased odds of choosing snacks from the sweet category when sleep was severely restricted. Furthermore, these findings concur with previous research suggesting the

Table 1
Main effects of condition (moderate/severe), prior wake and circadian phase for overall, sweet, savoury and healthy snack consumption.

Dependent variable	Independent variable	Odds ratio (OR)	St error of OR	Z	P	95% CI lower	95% CI upper
Snacking (overall)	Condition	0.58	0.12	−2.17	0.03	0.36	0.95
	Prior Wake	0.82	0.07	−2.29	0.02	0.69	0.97
	Circadian Phase	1.25	0.11	2.59	0.01	1.06	1.48
Sweet Snack	Condition	0.54	0.12	−2.81	0.01	0.35	0.83
	Prior Wake	1.13	0.07	1.86	0.06	0.99	1.28
	Circadian Phase	1.07	0.06	0.18	0.18	0.97	1.19
Savoury Snack	Condition	0.87	0.15	−0.78	0.44	0.62	1.22
	Prior Wake	0.86	0.06	−2.37	0.02	0.75	0.97
	Circadian Phase	0.99	0.03	−0.05	0.96	0.93	1.07
Healthy Snack	Condition	1.16	0.26	0.65	0.52	0.75	1.79
	Prior Wake	0.94	0.05	−1.16	0.25	0.84	1.05
	Circadian Phase	1.03	0.03	1.10	0.27	0.97	1.10

St error, standard error. CI, confidence interval.

energy from snack consumption in sleep restricted individuals was more likely to come from carbohydrates (Nedeltcheva et al., 2009). Although macronutrient content was not analysed in the current study, the snack choices in the sweet category had a high percentage of carbohydrate. Interestingly, carbohydrate cravings are associated with depressed mood (Lieberman et al., 1986) and both shiftworkers and severely sleep deprived individuals are reported to experience mood disturbances (Dinges et al., 1997; Gordon et al., 1986). This further demonstrates the need for future research to investigate psychological motivations behind snack choice as mood may mediate the relationship between sleep restriction and snack choice.

The forced desynchrony protocol, which allowed for separate analysis of homeostatic and sleep related processes on snacking behaviour, has built on previous sleep restriction studies. However, it is important to note there were some limitations of the current study which may reduce external validity and generalisation to shiftworkers. For example, to ensure a homogenous sample, the current study only included healthy young males; future studies should investigate snacking behaviour in females and older age groups during sleep restriction. Although the current protocol allowed for examination of snacking behaviour at all possible levels of prior wake and at all circadian phases, the rotating schedule applied in this study does not correspond with a typical rotating shift schedule. Furthermore, as the protocol was relatively short, the long-term effects of sleep restriction on snacking behaviour cannot be determined. Nonetheless, our findings suggest that when individuals are severely sleep restricted they are more likely to snack on sweet foods. As a result, individuals who are severely sleep restricted may be at risk of weight gain due to poor food choices. This finding has implications for shiftwork populations as they often report severe sleep restriction (Akerstedt, 2003) and compared to day workers, shiftworkers are more overweight and obese (Atkinson et al., 2008). Future research should focus on understanding the mechanisms involved in unhealthy snack choice and consumption when sleep is severely restricted including: psychological (i.e. mood, perception of alertness) physiological (i.e. appetite as a result of hormonal disruption), and environmental factors (i.e. time constraints, facilities available). A greater understanding of shiftworkers' snack consumption and choice will allow for the preparation of health promotion strategies, which will in turn be beneficial for both individuals and organisations.

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Hello Georgina,

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Best wishes,
Charli.

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Living in a 24/7 World:
The impact of circadian disruption on sleep, work and health

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Chapter 2

Subjective mood is influenced by sleep-related and circadian processes in a forced desynchrony protocol with severe sleep restriction

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Aims: Studies show subjective mood declines when sleep is severely restricted to 4-5h per night. In addition, mood follows a circadian rhythm such that subjective mood is lowest around the circadian nadir. These findings are important for shiftworkers who often report severe sleep restriction and are subject to circadian disruption. The current study aims to examine the effect of prior wake and circadian phase on subjective mood when sleep is severely restricted to the equivalent of 4h of sleep opportunity per 24-h day.
Methods: 14 healthy males (21.8 ± 3.8yr) lived in a time isolation laboratory for 12 consecutive days. Participants were scheduled to 3 x 24-h adaptation days (16-h wake, 8-h sleep opportunity), followed by 7 x 28-h forced desynchrony days (23.3-h wake, 4.7-h sleep opportunity). Total Mood Disturbance (TMD) was assessed every 2.5h during wake using the Profile Of Mood States scale. Core body temperature was continuously recorded with rectal thermistors and used to determine circadian phase.
Results: A significant effect of prior wake was found for TMD (p = <.001). Scores for TMD increased with duration of wakefulness. A significant effect of circadian phase was found for TMD (p = <.001). TMD scores were highest around the circadian nadir and lowest around the circadian acrophase. No interaction effects were found.
Discussion: These findings suggest mood is influenced by sleep-related and circadian processes separately in a controlled laboratory environment when sleep is severely restricted. Field based research investigating sleeping patterns and mood in shiftworkers would provide further understanding of how other factors such as work and family mediate between sleep restriction/circadian disruption and mood in an external environment.
Contact: Georgina Heath (georgina.heath@postgrads.unisa.edu.au)

Introduction

It is generally accepted that sleep plays a restorative role in general well-being and daily functioning.[1,1] Forced desynchrony studies (FD) have shown that the duration of prior wake and circadian phase affect mood.[2,7] Mood tends to decline with increasing duration of prior wake and reaches its lowest point around the circadian nadir. In these studies the ratio of sleep and wake was kept within a normal range (i.e. the equivalent of 8h sleep per 24-h day), however, there is evidence to suggest that sleep dose also alters mood. For example, participants who are subject to severe sleep restriction (i.e. 4-5h sleep opportunity per night) for one week report higher levels of anxiety, depression, fatigue and confusion than controls provided with a normal sleep opportunity of 8h per night for one week.[5] To date there have been no studies

employing an FD protocol to assess mood when sleep is severely restricted. Therefore, the current study examined the influence of prior wake and circadian phase in an FD protocol with severe sleep restriction (i.e. 4h per 24-h day).

Methods

Participants

Fourteen healthy males (age: 21.8 ± 2.5 yr, mean ± SD) participated in this study. All participants were in the healthy weight range (BMI 22.4 ± 2.3 kg/m^2), were non-smokers, with normal sleeping patterns. Participants did not have any medical conditions and were not taking any medications. Participants were excluded from the study if they were shiftworkers, had recently travelled through time zones or reported a high caffeine or alcohol intake. Ethics approval for this study was obtained from the University of South Australia Human Ethics Committee. Written informed consent was obtained from all participants and the research methods conform to the guidelines established by the National Health and Medical Research Council of Australia

Measures

Mood was assessed using the Profile of Mood States (POMS) [9]. POMS assesses transient mood states by asking participants to respond to 65 adjectives. Participants completed a 5- point Likert-type scale ranging from 'not at all' to 'extremely'. POMS measures five negative mood domains: Tension-Anxiety (T-A), Depression-Dejection (D-D), Anger-Hostility (A-H), Fatigue-Inertia (F-I) and Confusion-Bewilderment (C-B) and one positive mood domain, Vigour-Activity (V-A). A Total Mood Disturbance (TMD) score is computed by summing the negative domain scores and subtracting the positive domain score. Higher scores indicate greater mood disturbance.

Core body temperature (CBT) was recorded continuously in 1-min epochs with indwelling rectal thermistors (Steriprobe 491B; Cincinatti Sub-Zero Products, Cincinnati, Ohio, USA). The thermistors were connected to a Mini-Mitter datalogger (Bend, OR).

Sleep was monitored using polysomnography. Prior to each sleep opportunity, electrodes were attached to the face and scalp using a standard montage. Sleep was scored in 30-s epochs in accordance with accepted criteria.[10] Sleep efficiency was calculated as the percentage of time in bed spent asleep.

Protocol

The participants were required to live in a time isolation laboratory for 12 consecutive days. The first three days were 24h in length and consisted of a 16-h wake episode during the day followed by an 8-h sleep opportunity at night. These days were used to train participants on the POMS and to allow participants to familiarise themselves with the laboratory environment. The FD protocol began upon waking after the third night and consisted of seven 28-h 'days', each with a 23.3-h wake episode and 4.7-h sleep opportunity (this is equivalent to a 4-h sleep opportunity per 24-h day). During the wake episodes the POMS was administered every 2.5h as part of a 1-h test battery (i.e. 9 test batteries in total). The first test battery began 1.5h after scheduled wake up time.

Data reduction and statistical analysis

CBT data from six FD days (2-7) were used to generate circadian phase estimates for each participant. The generation of phase estimates from CBT data was a 4-step process: (i) clean the raw CBT data, (ii) de-mask for physical activity and sleep/wake, (iii) fit a cosine equation to the de-masked CBT data, and (iv) assign a circadian phase estimate (i.e. 0-360 degrees) to each minute of the FD portion of the protocol using a resultant cosine equation.[4]

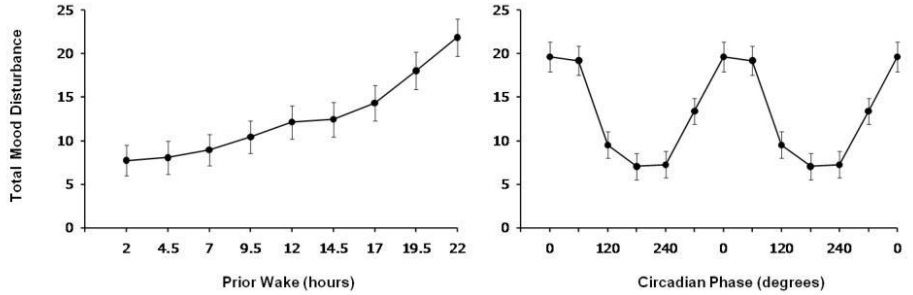


Figure 1. Main effects of prior wake (left) and circadian phase (right) on Total Mood Disturbance. Circadian phase data are double plotted. Values are mean ± SEM.

Individual data points were grouped according to circadian phase and level of prior wakefulness. For analysis of the circadian component, a bin width of 60 degrees (~4h) was selected. For analysis of the prior wake component, nine levels of prior wake were identified that corresponded to the midpoint of each test battery. The main and interaction effects of prior wake and circadian phase on TMD and the six mood domains were analysed using linear mixed model analysis. To control for any differences in sleep duration across the study days, sleep efficiency was included as a covariate in all analyses.

Results

Total Mood Disturbance

There was a significant main effect of prior wake for TMD, $F_{(8,\ 118)} = 18.6$, $p = <.001$ (Figure 1). TMD scores rose progressively with increasing duration of prior wake. There was a significant main effect of circadian phase for TMD, $F_{(5,171)} = 37.7$, $p = <.001$ (Figure 1). TMD was greatest at the circadian nadir and lowest at the acrophase.

Negative mood domains

There was a significant main effect of prior wake for all negative mood domains except A-H (Table 1). Scores on the negative mood scales were lowest at the first testing session and increased over the wake period. A significant main effect of circadian phase was found for all of the negative mood domains (Table 1). Scores on the negative mood scales were highest at, or just after, the circadian nadir and lowest at, or just after, the acrophase.

Positive mood domains

There was a significant main effect of prior wake for the positive mood domain of V-A (Table 1). Scores for V-A were highest at the first testing session and reduced over the wake period. There was a significant effect of circadian phase for V-A, such that scores were highest around the circadian acrophase and lowest around the circadian nadir.

Table 1. Main effects of prior wake and circadian phase on mood domains.

Mood Domain	Prior Wake			Circadian Phase		
	F	df	*p*	F	df	*p*
Tension-Anxiety (T-A)	4.1	8,91	<.001	10.6	5,146	<.001
Depression-Dejection (D-D)	3.1	8,90	<.01	6.3	5,149	<.001
Anger-Hostility (A-H)	2.5	8,68	.053	3.8	5,104	<.01
Fatigue-Inertia (F-I)	20.3	8,97	<.001	42.5	5,183	<.001
Confusion-Bewilderment (C-B)	14.0	8,123	<.001	30.2	5,171	<.001
Vigour-Activity (V-A)	12.3	8,112	<.001	38.3	5,190	<.001

Note: Denominator degrees of freedom are displayed as adjusted by SPSS using a Satterthwaite correction.

Discussion

The current study revealed mood is affected by sleep-related and circadian processes independently when sleep is severely restricted. Participants became increasingly anxious, depressed, confused, more fatigued and felt less active with increasing duration of prior wake and around the circadian nadir; however, the level of mood disturbance found did not reach clinical significance.[9] No interactions of prior wake and circadian phase on mood were found.

In contrast to previous FD studies, the current study included severe sleep restriction in the protocol. Participants in this study remained awake for 23.3h and were given a sleep opportunity of 4.7h, which is equivalent to 4h of sleep per 24-h day. A previous FD study found that mood (cheerfulness and happiness) was not significantly affected by prior wake; however there was a trend for mood to decline over the wake period.[2] A subsequent FD study found depression was not significantly affected by duration of prior wake.[7] However in both of these studies participant's sleep/wake was kept in line with a normal sleep ratio of 1:2 (i.e. the equivalent of 8h sleep per 24-h day). The severe sleep restriction and lengthy duration of prior wake in the current study may explain why we found a significant deterioration in mood and the previous studies did not. In addition, the previous FD studies used measures other than POMS to assess mood. Future studies should assess mood with POMS in an FD protocol with a normal sleep/wake ratio as this would allow for a direct comparison between the sleep doses.

In line with previous research,[2,7] the current study found mood displayed a circadian rhythm. Participants reported feeling more depressed, anxious, confused, angry and fatigued around the circadian nadir than they felt around the acrophase. Feelings of activity were lowest around the circadian nadir. Therefore, individuals who are required to remain awake throughout the biological night such as shiftworkers are likely to find their mood deteriorates during the early hours of the morning. The deterioration in mood may be compounded for shiftworkers due to the severe sleep restriction they often experience.[1] Indeed, shiftworkers often report mood disturbances such as anxiety and depression.[6]

The results of this study suggest severe sleep restriction, duration of prior wake and circadian phase impact on mood. Therefore, the current study has practical significance not only for shiftworkers who report severe sleep deprivation and circadian disruption[1] but also for any individuals who are deprived of sleep and have long durations of wakefulness. Mood states have been associated with various outcomes. Negative mood states have been found to influence job attitudes and behaviours[3] and psychological well-being.[11] In contrast, positive mood such as happiness and thinking optimistically may play a role in the prevention of cardiovascular disease.[8] A limitation of laboratory studies is that participants are not in their natural environment. Laboratory studies are unable to ascertain if other factors such as social, family and work pressures mediate the relationship between sleep restriction, circadian disruption and mood disturbances. Field studies investigating the mood of shiftworkers may enhance our understanding of how sleeping patterns and circadian disruption effect mood in this population.

Acknowledgements

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Appendix D: Participant information sheet (Study 1)

Participant Information Sheet

Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

The impact of chronic sleep loss on diabetes and obesity

You have been invited to participate in a research study. Before agreeing to participate in the study, it is important that you read and understand the following explanation of the study and the procedures. This form describes the purpose, procedures, benefits, risks, discomforts and alternative procedures that are available to you. If you choose to participate, you have the right to withdraw from the study at any time.

What is the study about?

The number of Australians with diabetes and obesity has dramatically increased in the last 30 years. It is commonly thought that the main causes are poor diet and lack of exercise, but recent evidence shows that poor sleep is also a causal factor. This study will examine the impact of poor sleep on two major aspects of diabetes and obesity – the ability to process glucose, and the ability to control appetite. The results of this study will be used to design effective intervention and treatment programs.

Who can participate and how does the study work?

Healthy, non-smokers who are aged between 18 to 35 years old, taking no medication and have a regular sleep pattern are eligible to participate in this study. Before commencing the study, potential participants will be required to attend a screening interview where they will complete a general health questionnaire. Participants will also be required to complete a 7-night sleep/wake diary and wear a wrist activity monitor (small device the same size as a wrist watch). These two measures will allow us to assess your sleep patterns.

What happens during the study?

All investigations will be carried out at the Centre for Sleep Research at the University of South Australia. If you are eligible to participate, you will be asked to attend the laboratory for twelve consecutive nights/days: four baseline nights and days, followed by eight study nights and days.

On the first baseline day, you will be required to arrive at the lab no later than 7:00 pm. At this time, you will begin training on a number of performance tasks that will be used throughout the study (for e.g. reaction time, mood, appetite/hunger scales). For the three baseline nights, your bedtime will be scheduled at midnight and you will be woken at 8:00 am the following morning.

Following the baseline period, you will then undergo seven study nights and days. On these nights and days, you will get a different amount of sleep than you would in a normal 24 h day. Sleep laboratory staff will instruct you when it is time to go to sleep and when it is time to wake up. During the study, we will monitor your sleep, your performance during the day, your body's tolerance for glucose, and your eating behaviour and appetite.

How will my sleep be monitored?
During all sleep periods, your sleep will be monitored using standard polysomnography. This involves placing small leads on your face and head. The leads will be held in position with a small piece of tape. The leads will be attached to you just before you go to bed and will be removed once you wake up.

How will my daytime performance be assessed?
During the daytime, you will be asked to complete a series of performance tasks at set times. In these tasks, we will measure your alertness, your sleepiness levels, and your mood. Most of these tasks are in the form of written scales but some tasks will be performed on a computer.

How will my glucose tolerance be assessed?
We will assess your glucose tolerance each day using a standard oral glucose tolerance test. The oral glucose tolerance test measures the body's ability to use a type of sugar, called glucose, that is the body's main source of energy. The oral glucose tolerance test involves drinking a glucose sugar drink after an overnight fast. The glucose drink consists of 75 g of sugar dissolved in 200 ml of water. Once you have finished the drink, you will be asked to remain seated for 180 minutes. You will be able to read or watch movies during this time. We will then monitor your blood glucose levels for 2 h using a tiny sensor, which will be placed just under the surface of the skin on your stomach before the test begins. This procedure is essentially painless as the sensor is very tiny. The sensor transmits a signal to a small monitor pack that you will wear around your waist. We will also take blood samples from a vein in your forearm before and after the glucose drink for measurement of blood insulin levels. Insulin is a hormone found in the body that helps to control the levels of glucose in the blood. Until the test is over, you will not be able to eat but you will be able to have sips of water.

How will my eating behaviour and appetite be monitored?
We will monitor your eating behaviour and appetite by recording the amount of food you eat, as well as asking you a series of questions each day about how hungry you feel and the types of foods you are craving to eat. In addition, we will collect blood samples each day to measure the level of appetite hormones in your blood.

What can I do in my free time during the study?
When you are not completing the daytime performance tasks or glucose tolerance tests, you may read, watch movies, or listen to music etc. Your movement and activity during wake and sleep periods will be recorded using small, visible cameras that are located in the ceiling of each bedroom and living area. These cameras will not located in any of the bathrooms. The Research Staff conducting this study will be the only group that will have access to this data to ensure your privacy and confidentiality.

What will I eat during the study?
All of your meals will be supplied during the study, and you will not be allowed to bring any food with you. If you have any special dietary requirements, please let the staff know so that we can accommodate you. It is important to remember that throughout the study, and in the 24h prior to the first baseline night, you will be asked to refrain from consuming any alcohol, caffeine or medication.

Are there any risks?
Because of these changes to your sleep and wake schedule, you may experience a range of symptoms, including excessive sleepiness and fatigue, irritability, and mild queasiness. You may also experience minor skin irritation from the small electrodes that will be used to monitor your sleep. These are placed on your temples (next to your eyes), your chin, your forehead and your collarbone

and are taped to your skin. Attempts will be made to minimize any discomfort by alternating the position of these leads.

You will be required to fast for 10 h overnight prior to every morning's glucose tolerance test. Whilst fasting, you may experience feelings of hunger and irritability. A meal will be served immediately after each glucose tolerance test. The glucose drink that is used for the oral glucose tolerance test is very sweet and on rare occasions makes people feel nauseous. The tiny sensor that will be used to monitor your blood glucose may also irritate your skin.

Each day during the study, we will obtain multiple blood samples from a vein in your forearm. To avoid multiple punctures each day, an experienced medical practitioner will insert a catheter into your arm. To minimize the discomfort associated with this procedure, a local anesthetic will be used to numb the skin surrounding the catheter insertion site. In total, we will draw 450 ml of blood during the study -- this is less than the amount taken for a Red Cross blood donation (470ml). To maintain your blood volume, we will replace the withdrawn blood with an equivalent amount of normal saline immediately after each blood sample. Veins vary in size from one person to another and from one side of the body to the other. Obtaining a blood sample from some people may be more difficult than from others. Other risks associated with having blood drawn are slight but may include excessive bleeding, fainting or feeling light-headed, hematoma (blood accumulating under the skin), or infection (a slight risk any time the skin is broken).

What do I need to bring?

You will be staying in the sleep laboratory for 10 days and nights, so you will need to bring enough clothes and toiletries to cover this time. Although the laboratory is kept at a constant temperature (21°C), you might feel cold at different times during the study so it is a good idea to bring a warm, comfortable tracksuit with you. We will provide you with all of your linen (sheets, blankets, towels, pillows etc) but you may wish to bring your own pillow from home. You will have your own room and living area for the duration of the study but you will be sharing shower and toilet facilities with other people who are participating in the study. Because there will be periods of spare time throughout the study, please feel free to bring along your own music, books or movies.

What happens at the end of the study?

Following completion of the study, you will be given a taxi voucher to cover your transport home. You will not be allowed to drive yourself home. We also advise that you avoid the following activities [driving a car, riding a bike, and/or operating heavy machinery] until you have obtained at least one full night's sleep (uninterrupted for 9 hours or more) following completion of the study. In the 24h following completion of the study, or if you have withdrawn from the study early, staff at the Centre for Sleep Research will contact you via telephone for follow-up. Following completion of the study, should you need to get in contact with study staff at any time, they can be reached on **(08) 8302 6624.**

What happens to the results?

All data from this study will be stored on computers at the Centre for Research, with CD or floppy disks as backups in lockable filing cabinets. All information collected, as part of the study, will be destroyed at the end of seven years. Summarized results will be stored as hard copies at the Centre for Sleep Research and may be used in theses, journal publications and conferences. All records containing personal information will remain STRICTLY CONFIDENTIAL no information that would lead to the identification of any individual will be released.

What will you get out of the study?

While you will not directly benefit from this study, you will be compensated for the inconvenience and loss of time associated with your participation. You will be reimbursed at a rate of $5 per hour,

but if for some reason you do no complete the entire protocol, you will receive a pro rata payment based on the number of hours that you spent in the sleep laboratory. Upon request, you will be provided with a copy of the final research report.

Voluntary participation - what happens if I say no?

Before deciding whether or not to take part in this trial, you may wish to discuss the matter with a relative, friend or your local doctor. You should feel free to do this. It is important that you understand that your participation in this trial is voluntary, as is the case with all research projects at the Centre for Sleep Research. If you do not wish to take part you are under no obligation to do so. If you decide to take part but later change your mind, you are free to withdraw from the project at any stage. Your decision to take part, not to take part, or to withdraw, will not affect your routine medical treatment or your relationship with those treating you or your relationship with the Centre for Sleep Research.

How do I become a participant?

If you are interested in participating or have any questions, please call Georgina Heath on (08) 8302 9946 or by email: Georgina.Heath@.unisa.edu.au

UniSA Human Research Ethics Committee Contact Details

This study has been approved by the University of South Australia's Human Research Ethics Committee. Should you wish to speak to a person not directly involved in the study, particularly in relation to matters concerning policies, information about the conduct of the study or your rights as a participant, or should you wish to make a confidential complaint, you may contact the Executive Officer the University of South Australia's Human Research Ethics Committee on (08) 8302 3118 or by email Vicki.Allen@unisa.edu.au

Appendix E: Participant information sheet (Study 2)

Participant Information Sheet

Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

The influence of sleep, wake, and the internal body clock on neurobehavioural function

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You have been invited to participate in a research study. Before agreeing to participate in the study, it is important that you read and understand the following explanation of the study and the procedures. This form describes the purpose, procedures, benefits, risks, discomforts and alternative procedures that are available to you. If you choose to participate, you have the right to withdraw from the study at any time.

What is the study about?

The aim of this study is to improve our understanding of how sleep loss affects neurobehavioural function. That is, how sleep loss affects our memory, alertness and performance. The results we obtain from this study will help us to design better shiftwork schedules.

Who can participate and how does the study work?

Healthy, non-smokers who are aged between 18 to 35 years old, taking no medication and have a regular sleep pattern are eligible to participate in this study. Before commencing the study, potential participants will be required to attend a screening interview where they will complete a general health questionnaire. Participants will also be required to complete a 7-night sleep/wake diary and wear a wrist activity monitor (small device the same size as a wrist watch). These two measures will allow us to assess your sleep pattern.

What happens during the study?

All investigations will be carried out at the Centre for Sleep Research at the University of South Australia. If you are eligible to participate, you will be asked to attend the laboratory for twelve consecutive nights/days: three baseline nights and days, followed by nine study nights and days. During this period, you will not have access to clocks, telephones (mobile phones/internet) or live television/radio so you will be unaware of the time.

On the first baseline day, you will be required to arrive at the lab no later than 12:00pm. At this time, you will begin training on a number of performance tasks that will be used throughout the study (memory, concentration, alertness, performance tests) until your performance reaches a plateau. For the three baseline nights, your bedtime will be scheduled at 11:00pm and you will be woken at 7:00am the following morning.

Following the baseline period, you will then undergo nine study nights and days. On these nights and days, your sleep and wake periods will be set at times that are different to those in a normal 24h cycle. You will get a different amount of sleep than you would in a normal 24h day. Sleep laboratory staff will instruct you when it is time to go to sleep and when it is time to wake up. Because of these

changes to your sleep and wake schedule, you may experience a range of symptoms, including excessive sleepiness and fatigue, irritability, and mild queasiness.

During all sleep periods (baseline and study nights) your sleep will be monitored using standard polysomnography, which involves placing electrodes on your face (taped to the skin) and scalp. During the daytime (baseline and study days), you will also be asked to complete a series of performance tasks at set times. When you are not completing these tasks, you may read, watch TV (DVDs/Videos), talk, or listen to music etc. Your movement and activity during wake and sleep periods will be recorded using small, visible cameras that are located in the ceiling of each bedroom and living area. These cameras will not located in any of the bathrooms. The Research Staff conducting this study will be the only group that will have access to this data to ensure your confidentiality.

Throughout the study, we will be monitoring your body temperature continuously and collecting saliva samples to measure melatonin levels. Body temperature will be measured using two devices: (1) a rectal thermometer and; (2) a tiny capsule (which contains a temperature sensor) that you will be asked to swallow (about the size of a multi-vitamin). The capsule transmits a signal to a small monitor pack that will be worn around the waist. At all times, you will have one capsule traveling through your digestive system. The capsules take approximately two days to pass through your system (although this may very between individuals) and you will be required to swallow approximately 10 capsules (1-2 capsules every second day depending on your bowel activity) over the course of the study.

On one of the baseline days and one of the study days we will also measure your blood glucose levels. This will involve placing a tiny sensor just under the surface of the skin on your stomach. This procedure is essentially painless as the sensor is very tiny. The sensor transmits a signal to a small monitor pack that will be worn around the waist. When you wake up on these two days, we will ask you to drink a glass of water that has been mixed with 75g of glucose. This called a glucose tolerance test and measures how well your body can use glucose. Once you have finished the drink, you will be asked to remain seated for 180 minutes. You will be able to read or watch TV (DVDs/Videos) during this time. Until the test is over, you will not be able to eat but you will be able to have sips of water.

All of your meals will be supplied during the study, and you will not be allowed to bring any food with you. If you have any special dietary requirements, please let the staff know so that we can accommodate you. It is important to remember that throughout the study, and in the 24hr prior to the first baseline night, you will be asked to refrain from consuming any alcohol, caffeine or medication.

Are there any risks?

The ingestible capsule that we are asking you to swallow (to record your body temperature) and the tiny sensor that we are using to record your blood glucose levels transmit data via low power radio frequency. This produces a small level of electromagnetic radiation, but it will be at level of exposure that is considered safe for you. For example, mobile phones also produce electromagnetic radiation, reaching peak levels of ~2000 milliwatts. The peak level produced by the ingestible capsule and the glucose sensor is approximately 1000 times lower than the level produced by a mobile phone. It is important however, to notify Research Staff if you have been exposed to radiation in other research projects or as a part of investigation (X-Rays) or treatment (Radiotherapy) in the past year.

In rare instances, you may experience some gastrointestinal discomfort following ingestion of the temperature capsule, or it may become lodged in the intestines. We will be monitoring you closely at all times during the study, and it is important for you to let Research Staff now if you are

experiencing any untoward symptoms so that the appropriate action and treatment can be initiated. You may experience some difficulty when swallowing the capsule, which could result in a potential choking hazard. At all times, the capsules will be administered to you according to the manufacturer's recommendation (i.e. the capsule will always be swallowed with water or other suitable liquid) and you will be instructed not to chew the capsule before swallowing.

You may also experience minor skin irritation from the small electrodes that will be used to monitor your sleep. These are placed on your temples (next to your eyes), your chin, your forehead and your collarbone and are taped to your skin. Attempts will be made to minimize any discomfort by alternating the position of these leads. The tiny sensor that will be used to monitor your blood glucose may also irritate your skin.

How does my family get in touch with me if there is an emergency?

An important part of the study protocol is that while you are living in the sleep laboratory, you are unaware of the time of day. This means you will not have access to telephones. Should your family need to get in touch with you at any time, they can contact the sleep laboratory (staff will be present 24hr a day) on the following number: **(08) 8302 6624.**

What do I need to bring?

You will be staying in the sleep laboratory for 12 days and nights, so you will need to bring enough clothes and toiletries to cover this time. We will provide you with all of your linen (sheets, blankets, towels, pillows etc) but you may wish to bring your own pillow from home. You will have your own room and living area for the duration of the study but you will be sharing shower and toilet facilities with other subjects participating in the study. Because there will be periods of spare time throughout the study, please feel free to bring along your own music, books or movies.

What happens at the end of the study?

Following completion of the study, you will be given a taxi voucher to cover your transport home. You will not be allowed to drive yourself home. We also advise that you avoid the following activities [driving a car, riding a bike, and/or operating heavy machinery] until you have obtained at least one full nights sleep (uninterrupted for 9 hours or more) following completion of the study. In the 24h following completion of the study, or if you have withdrawn from the study early, staff at the Centre for Sleep Research will contact you via telephone for follow-up. Following completion of the study, should you need to get in contact with study staff at any time, they can be reached on **(08) 8302 6624.**

What happens to the results?

All data from this study will be stored on computers at the Centre for Research, with CD or floppy disks as backups in lockable filing cabinets. All information collected, as part of the study, will be destroyed at the end of seven years. Summarized results will be stored as hard copies at the Centre for Sleep Research and may be used in theses, journal publications and conferences. All records containing personal information will remain STRICTLY CONFIDENTIAL no information that would lead to the identification of any individual will be released.

What will you get out of the study?

While you will not directly benefit from this study, you will be compensated for the inconvenience and loss of time associated with your participation. If you complete the study, you will receive $1440 ($960 participation payment + $480 completion payment). If for some reason you do no complete the whole study, you will receive a pro rata participation payment based on the number of hours that you spent in the sleep laboratory. Upon request, you will be provided with a copy of the final research report.

Voluntary participation - what happens if I say no?

Before deciding whether or not to take part in this trial, you may wish to discuss the matter with a relative, friend or your local doctor. You should feel free to do this. It is important that you understand that your participation in this trial is voluntary, as is the case with all research projects at the Centre for Sleep Research. If you do not wish to take part you are under no obligation to do so. If you decide to take part but later change your mind, you are free to withdraw from the project at any stage. Your decision to take part, not to take part, or to withdraw, will not affect your routine medical treatment or your relationship with those treating you or your relationship with the Centre for Sleep Research.

How do I become a participant?

If you are interested in participating or have any questions, please call Xuan Zhou, Raymond Matthews, or Gemma Paech on (08) 8302 6624 or by email Xuan.Zhou@unisa.edu.au, Raymond.Matthews@unisa.edu.au, or Gemma.Paech@unisa.edu.au

UniSA Human Research Ethics Committee Contact Details

This study has been approved by the University of South Australia's Human Research Ethics Committee. Should you wish to speak to a person not directly involved in the study, particularly in relation to matters concerning policies, information about the conduct of the study or your rights as a participant, or should you wish to make a confidential complaint, you may contact the Executive Officer the University of South Australia's Human Research Ethics Committee on (08) 8302 3118 or by email Vicki.Allen@unisa.edu.au

Appendix F: Participant information sheet (Study 3)

Participant Information Sheet

Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

The impact of work on sleeping patterns, eating behavior and health

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You are invited to participate in a research study collecting data on sleep patterns, eating behavior and health. Before agreeing to participate in the study, it is important that you read and understand the following explanation of the study and procedures. This sheet describes the purpose, procedures, and benefits. If you choose to participate it is important to understand that you have the right to withdraw from the study at any time.

Data will be collected from Australian workers in order for us to:

- learn more about the **sleep patterns, eating behavior and health** of Australian workers;
- understand how **work** (shiftwork and day work) may impact **sleep patterns**, **eating behavior** and **health**.

How will we collect information?

To learn more about your **work**, **sleep patterns**, **eating behavior** and **health** you will be required to answer an anonymous questionnaire. This questionnaire should take approximately 40 minutes to complete.

Who is involved in running this study?

This study is being conducted by the University of South Australia, Centre for Sleep Research. Dr Charli Sargent and Dr Jill Dorian and PhD student, Georgina Heath are the primary researchers who will be managing the study. If you are interested in participating or have any further questions, you should feel free to contact Charli, Jill or Georgina on (08) 8302 6624 at the Centre for Sleep Research.

What happens to the results?

All data from this study will be stored on computers at the Centre for Sleep Research with CD or USB devices as backups in lockable filing cabinets. All data will be stored for 5 years. Summarised results will be stored as hard copies at the Centre for Sleep Research and may be used in journal publications and at conferences. All questionnaires will be completed anonymously therefore participants in this study will not be able to be identified.

What will I get out of the study?

You will not directly benefit from this study. Upon request, you will be provided with a copy of the final research report and/or a nutritional analysis please email Georgina Heath at the email address below or call Georgina on 08) 8302 9946. If you would like a copy of your analysis you will need to provide your dietary questionnaire code which is located at the bottom of your questionnaire.

Georgina.Heath@unisa.edu.au

Voluntary participation - What happens if I say no?

Before deciding whether or not to take part in this study, you may wish to discuss the matter with a relative, friend or work colleague. You should feel free to do this. It is important that you understand that your participation in this study is voluntary, as is the case with all research projects associated with the University of South Australia. If you do not wish to take part you are under no obligation to do so. If you decide to take part but later change your mind, you are free to withdraw from the study at any stage.

What if I have a question about the study?

This study has been approved by the University of South Australia's Human Research Ethics Committee. Should you wish to speak to a person not directly involved, in particular in relation to matters concerning policies, information about the conduct of the study or your rights as a participant, or should you wish to make a confidential complaint, you may contact the Executive Officer the University of South Australia's Human Research Ethics Committee, Vicki Allen, on (08) 8302 3118 or by email vicki.allen@unisa.edu.au.

Appendix G: Participant information sheet (Study 4)

Participant Information Sheet

Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

The effect of shift type on sleeping patterns, mood and eating behaviour

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You are invited to participate in a research study collecting data on sleeping patterns, mood and eating behavior. Before agreeing to participate in the study, it is important that you read and understand the following explanation of the study and procedures. This sheet describes the purpose, procedures, and benefits. It is important to understand that participants are free to withdraw from the research project at any stage without affecting their status now or in the future.

Data will be collected from Australian shift workers in order for us to:

- learn more about the **sleep patterns, mood and eating behaviours** of Australian shift workers.
- understand how shift work may influence sleep patterns and mood, and in turn, how this influences eating behavior.

How will we collect information?

Participation in this study will initially require the completion of a general information questionnaire which should take approximately 20 minutes. Additionally, to participate in this study you will be required to wear an activity monitor around your wrist to measure sleeping patterns and to complete a work, sleep diary and mood scales daily (this should take approximately five minutes per day for a period of two weeks). In addition to this participation will also require the completion of a food diary on two days per shift type and on one day off. This food diary should take approximately two to five minutes to complete per eating episode (i.e. an extra 15-35 minutes per day).

Who is involved in running this study?

This study is being conducted by the University of South Australia, Centre for Sleep Research. Dr Alison Coates, Dr Jill Dorrian and PhD student, Georgina Heath from the University of South Australia and Dr Charli Sargent from CQ University are the primary researchers who will be managing the study. If you are interested in participating or have any further questions, you should feel free to contact Georgina Heath (PhD student) on (08) 8302 9946 or by email at Georgina.Heath@unisa.edu.au. Georgina's supervisors are also available to contact by telephone or email:

- Dr Alison Coates on 08) 8302 2313 (email: Alison.Coates@unisa.edu.au)
- Dr Jill Dorrian on 8302 6624 (email: Jill.Dorrian@unisa.edu.au).

What happens to the results?

All data from this study will be stored on computers at the Centre for Sleep Research (University of South Australia, City East Campus). CD or USB devices will be used to backup data and will be stored in lockable filing cabinets at the Centre for Sleep Research. All data will be stored for 5 years. Summarised results will be stored as hard copies at the Centre for Sleep Research and may be used in journal publications and at conferences. Participants will be assigned an identification code at the beginning of the study, and therefore no identifiable information will be recorded in our data.

What will I get out of the study?

You will not directly benefit from this study. Upon request, you will be provided with a copy of the final research report and/or feedback on your sleeping patterns and a nutritional analysis. If you wish to receive any of these documents please email Georgina Heath at the email address below or call Georgina on 08) 8302 9946. To obtain these you will need to provide your study code which is located on the front page of your study booklet.

Georgina.Heath@unisa.edu.au

Voluntary participation - What happens if I say no?

Before deciding whether or not to take part in this study, you may wish to discuss the matter with a relative, friend or work colleague. You should feel free to do this. It is important that you understand that your participation in this study is voluntary, as is the case with all research projects associated with the University of South Australia. If you do not wish to take part you are under no obligation to do so. As mentioned above, participants are free to withdraw from the research project at any stage without affecting their status now or in the future.

What if I have a question about the study?

This study has been approved by the The Human Research Ethics Committee (TQEH/LMH/MH) and University of South Australia's Human Research Ethics Committee. Should you wish to speak to a person not directly involved, in particular in relation to matters concerning policies, information about the conduct of the study or your rights as a participant, or should you wish to make a confidential complaint, you may contact:

- Executive Office of The Human Research Ethics Committee (TQEH/LMH/MH) on (08) 8222 6841.

- Executive Officer the University of South Australia's Human Research Ethics Committee, Vicki Allen, on (08) 8302 3118 or by email vicki.allen@unisa.edu.au.

Thank you for your time

Appendix H: Participant consent form (Study 1)

Subject Consent Form



Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

Project Title:
The impact of chronic sleep loss on diabetes and obesity

Principal Researchers' names:
Dr Charli Sargent, Dr Greg Roach, Dr Jill Dorrian, A/Prof Jon Buckley, A/Prof Garry Scroop

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I have read the information sheet, and the nature and the purpose of the research project has been explained to me. I understand and agree to take part.

I understand that I may not directly benefit from taking part in the study.

I understand that I will be videotaped during the study.

I understand that the tape will be stored in digital format for 7 years in a lockable filing cabinet at the Centre for Sleep Research. The named researchers above will have access to this tape during this period.

I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential.

I understand that I can withdraw from the study at any stage and that this will not affect my status now or in the future.

I understand the statement concerning compensation for taking part in the study, which is contained in the information sheet.

I acknowledge that the results of the study are unknown and that I may suffer a range of symptoms including excessive sleepiness and fatigue, irritability, and mild queasiness. This list of symptoms is not exhaustive.

I acknowledge that I have been advised that I should avoid the following activities until I have obtained at least one full nights sleep (uninterrupted for 9 hours or more) following the completion of the study: driving a car, riding a bike, and/or operating heavy machinery.

I release and indemnify the University, its employees, students and agents against liability in respect of all claims, costs and expenses and for all loss, damage, injury or death to persons or property caused or contributed by me in connection with my failure to follow the after study instructions.

Name of Subject .....

Signed .....

Dated .....

I have explained the study to subject and consider that he/she understands what is involved.

Researcher .....

Signed .....

Dated .....

Appendix I: Participant consent form (Study 2)

Participant Information Sheet

Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

The influence of sleep, wake, and the internal body clock on neurobehavioural function

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You have been invited to participate in a research study. Before agreeing to participate in the study, it is important that you read and understand the following explanation of the study and the procedures. This form describes the purpose, procedures, benefits, risks, discomforts and alternative procedures that are available to you. If you choose to participate, you have the right to withdraw from the study at any time.

What is the study about?

The aim of this study is to improve our understanding of how sleep loss affects neurobehavioural function. That is, how sleep loss affects our memory, alertness and performance. The results we obtain from this study will help us to design better shiftwork schedules.

Who can participate and how does the study work?

Healthy, non-smokers who are aged between 18 to 35 years old, taking no medication and have a regular sleep pattern are eligible to participate in this study. Before commencing the study, potential participants will be required to attend a screening interview where they will complete a general health questionnaire. Participants will also be required to complete a 7-night sleep/wake diary and wear a wrist activity monitor (small device the same size as a wrist watch). These two measures will allow us to assess your sleep pattern.

What happens during the study?

All investigations will be carried out at the Centre for Sleep Research at the University of South Australia. If you are eligible to participate, you will be asked to attend the laboratory for twelve consecutive nights/days: three baseline nights and days, followed by nine study nights and days. During this period, you will not have access to clocks, telephones (mobile phones/internet) or live television/radio so you will be unaware of the time.

On the first baseline day, you will be required to arrive at the lab no later than 12:00pm. At this time, you will begin training on a number of performance tasks that will be used throughout the study (memory, concentration, alertness, performance tests) until your performance reaches a plateau. For the three baseline nights, your bedtime will be scheduled at 11:00pm and you will be woken at 7:00am the following morning.

Following the baseline period, you will then undergo nine study nights and days. On these nights and days, your sleep and wake periods will be set at times that are different to those in a normal 24h cycle. You will get a different amount of sleep than you would in a normal 24h day. Sleep laboratory staff will instruct you when it is time to go to sleep and when it is time to wake up. Because of these

changes to your sleep and wake schedule, you may experience a range of symptoms, including excessive sleepiness and fatigue, irritability, and mild queasiness.

During all sleep periods (baseline and study nights) your sleep will be monitored using standard polysomnography, which involves placing electrodes on your face (taped to the skin) and scalp. During the daytime (baseline and study days), you will also be asked to complete a series of performance tasks at set times. When you are not completing these tasks, you may read, watch TV (DVDs/Videos), talk, or listen to music etc. Your movement and activity during wake and sleep periods will be recorded using small, visible cameras that are located in the ceiling of each bedroom and living area. These cameras will not located in any of the bathrooms. The Research Staff conducting this study will be the only group that will have access to this data to ensure your confidentiality.

Throughout the study, we will be monitoring your body temperature continuously and collecting saliva samples to measure melatonin levels. Body temperature will be measured using two devices: (1) a rectal thermometer and; (2) a tiny capsule (which contains a temperature sensor) that you will be asked to swallow (about the size of a multi-vitamin). The capsule transmits a signal to a small monitor pack that will be worn around the waist. At all times, you will have one capsule traveling through your digestive system. The capsules take approximately two days to pass through your system (although this may very between individuals) and you will be required to swallow approximately 10 capsules (1-2 capsules every second day depending on your bowel activity) over the course of the study.

On one of the baseline days and one of the study days we will also measure your blood glucose levels. This will involve placing a tiny sensor just under the surface of the skin on your stomach. This procedure is essentially painless as the sensor is very tiny. The sensor transmits a signal to a small monitor pack that will be worn around the waist. When you wake up on these two days, we will ask you to drink a glass of water that has been mixed with 75g of glucose. This called a glucose tolerance test and measures how well your body can use glucose. Once you have finished the drink, you will be asked to remain seated for 180 minutes. You will be able to read or watch TV (DVDs/Videos) during this time. Until the test is over, you will not be able to eat but you will be able to have sips of water.

All of your meals will be supplied during the study, and you will not be allowed to bring any food with you. If you have any special dietary requirements, please let the staff know so that we can accommodate you. It is important to remember that throughout the study, and in the 24hr prior to the first baseline night, you will be asked to refrain from consuming any alcohol, caffeine or medication.

Are there any risks?

The ingestible capsule that we are asking you to swallow (to record your body temperature) and the tiny sensor that we are using to record your blood glucose levels transmit data via low power radio frequency. This produces a small level of electromagnetic radiation, but it will be at level of exposure that is considered safe for you. For example, mobile phones also produce electromagnetic radiation, reaching peak levels of ~2000 milliwatts. The peak level produced by the ingestible capsule and the glucose sensor is approximately 1000 times lower than the level produced by a mobile phone. It is important however, to notify Research Staff if you have been exposed to radiation in other research projects or as a part of investigation (X-Rays) or treatment (Radiotherapy) in the past year.

In rare instances, you may experience some gastrointestinal discomfort following ingestion of the temperature capsule, or it may become lodged in the intestines. We will be monitoring you closely at all times during the study, and it is important for you to let Research Staff now if you are

experiencing any untoward symptoms so that the appropriate action and treatment can be initiated. You may experience some difficulty when swallowing the capsule, which could result in a potential choking hazard. At all times, the capsules will be administered to you according to the manufacturer's recommendation (i.e. the capsule will always be swallowed with water or other suitable liquid) and you will be instructed not to chew the capsule before swallowing.

You may also experience minor skin irritation from the small electrodes that will be used to monitor your sleep. These are placed on your temples (next to your eyes), your chin, your forehead and your collarbone and are taped to your skin. Attempts will be made to minimize any discomfort by alternating the position of these leads. The tiny sensor that will be used to monitor your blood glucose may also irritate your skin.

How does my family get in touch with me if there is an emergency?

An important part of the study protocol is that while you are living in the sleep laboratory, you are unaware of the time of day. This means you will not have access to telephones. Should your family need to get in touch with you at any time, they can contact the sleep laboratory (staff will be present 24hr a day) on the following number: **(08) 8302 6624.**

What do I need to bring?

You will be staying in the sleep laboratory for 12 days and nights, so you will need to bring enough clothes and toiletries to cover this time. We will provide you with all of your linen (sheets, blankets, towels, pillows etc) but you may wish to bring your own pillow from home. You will have your own room and living area for the duration of the study but you will be sharing shower and toilet facilities with other subjects participating in the study. Because there will be periods of spare time throughout the study, please feel free to bring along your own music, books or movies.

What happens at the end of the study?

Following completion of the study, you will be given a taxi voucher to cover your transport home. You will not be allowed to drive yourself home. We also advise that you avoid the following activities [driving a car, riding a bike, and/or operating heavy machinery] until you have obtained at least one full nights sleep (uninterrupted for 9 hours or more) following completion of the study. In the 24h following completion of the study, or if you have withdrawn from the study early, staff at the Centre for Sleep Research will contact you via telephone for follow-up. Following completion of the study, should you need to get in contact with study staff at any time, they can be reached on **(08) 8302 6624.**

What happens to the results?

All data from this study will be stored on computers at the Centre for Research, with CD or floppy disks as backups in lockable filing cabinets. All information collected, as part of the study, will be destroyed at the end of seven years. Summarized results will be stored as hard copies at the Centre for Sleep Research and may be used in theses, journal publications and conferences. All records containing personal information will remain STRICTLY CONFIDENTIAL no information that would lead to the identification of any individual will be released.

What will you get out of the study?

While you will not directly benefit from this study, you will be compensated for the inconvenience and loss of time associated with your participation. If you complete the study, you will receive $1440 ($960 participation payment + $480 completion payment). If for some reason you do no complete the whole study, you will receive a pro rata participation payment based on the number of hours that you spent in the sleep laboratory. Upon request, you will be provided with a copy of the final research report.

Voluntary participation - what happens if I say no?

Before deciding whether or not to take part in this trial, you may wish to discuss the matter with a relative, friend or your local doctor. You should feel free to do this. It is important that you understand that your participation in this trial is voluntary, as is the case with all research projects at the Centre for Sleep Research. If you do not wish to take part you are under no obligation to do so. If you decide to take part but later change your mind, you are free to withdraw from the project at any stage. Your decision to take part, not to take part, or to withdraw, will not affect your routine medical treatment or your relationship with those treating you or your relationship with the Centre for Sleep Research.

How do I become a participant?

If you are interested in participating or have any questions, please call Xuan Zhou, Raymond Matthews, or Gemma Paech on (08) 8302 6624 or by email Xuan.Zhou@unisa.edu.au, Raymond.Matthews@unisa.edu.au, or Gemma.Paech@unisa.edu.au

UniSA Human Research Ethics Committee Contact Details

This study has been approved by the University of South Australia's Human Research Ethics Committee. Should you wish to speak to a person not directly involved in the study, particularly in relation to matters concerning policies, information about the conduct of the study or your rights as a participant, or should you wish to make a confidential complaint, you may contact the Executive Officer the University of South Australia's Human Research Ethics Committee on (08) 8302 3118 or by email Vicki.Allen@unisa.edu.au

Appendix J: Participant consent form (Study 4)

Participant Consent Form

Centre for Sleep Research
School of Psychology
Division of Arts, Education, Social Sciences

Project Title:
The effect of shift type of sleeping patterns, mood and eating behaviour

Researchers' names:
Georgina Heath, Dr Alison Coates, Dr Jillian Dorrian, Dr Tim Olds, Dr Alex Rowlands, Violetta Prauza and Dr Charli Sargent

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I have read the information sheet, and the nature and the purpose of the research project has been explained to me. I understand and agree to take part.

I understand that I may not directly benefit from taking part in the study.

I understand that while information gained during the study may be published, I will not be identified and my personal results will remain confidential and will not be released unless required by a tribunal or court of law.

I understand that I can withdraw from the study at any stage and that this will not affect my status now or in the future.

Name of Participant .....

.....

Signed .....

Dated .....

I have explained the study to the participant and consider that he/she understands what is involved.

Researcher .....

Signed .....

Dated .....

This project has been approved by The Human Research Ethics Committee (TQEH/LMH/MH) and The University of South Australia's Human Research Ethics Committee. Should you wish to speak to a person not directly involved in the study in relation to matters concerning policies, information about the conduct of the study, your rights as a participant or should you wish to make a confidential complaint you may contact:
The Executive Office of The Human Research Ethics Committee (TQEH/LMH/MH), Tel: +61 8 8222 684.
The Executive Officer of University of South Australia Committee, Tel: +61 8 8302 3118; Email: Vicki.Allen@unisa.edu.au

Appendix K: Participant log book(Study 4)

The effect of shift type on sleeping patterns, mood and eating behaviour

Participant Logbook

Date: ……

Participant ID Number:

Activity Monitor Serial Code: ……..

This logbook contains questions concerning your work hours, sleep and mood. Please complete your sleep and work diaries daily. Please complete your mood diary at the beginning and end of each shift. It should take approximately five minutes to fill this part of your log book.

Additionally, you will find a food diary. Please complete this food diary on the pre-determined dates.

The days you will need to complete the food diary are:

Shift type:_____ Shift type:_____

Date 1: _____ Date 1: _____

Date 2: _____ Date 2: _____

Date 3: _____ Date 3: _____

Shift Type:_____ Day Off:

Date 1: _____ Date 1:_____

Date 2: _____

Date 3: _____

Please also complete an extra mood, hunger and food enjoyment scales before and after each meal and snack on the days that you are completing the food diary.

Please wear your **Activity Monitor** <u>every day</u> when possible.

If you have any questions about how to complete this log book please contact Georgina Heath at the Centre for Sleep Research on (08) 8302 9946. Alternatively you can email Georgina at : Georgina.Heath@unisa.edu.au.

Thank you for your participation!

General Information Questionnaire

Date: _____

Participant ID: _____

Activity Monitor Number: _____

The information collected in the following section will be used to investigate the impact of different demographic variables on sleep, mood and eating behaviour. Plgease note that within this questionnaire the terms “Morning”, “Afternoon”, “Day” and “Night” shifts are used. Please ignore the fact that these terms may differ from the ones used in your organisation. For example, you may call your “Morning” shift and “Early” shift, while your “Afternoon” shift may be referred to as a “Late”, “Evening” or “Swing” shift. If you do not wish to answer a particular question, please leave it blank. This section should take approximately 20 minutes to complete.

1: Age: _____

2: Gender (please circle): Male Female

3. Weight (kg):_____

4. Height (cm):_____

5. Postcode:_____

6. Marital Status (please circle):

   A: Married/Living with a partner

   B: Separated/Divorced

   C: Widowed

   D: Single

7. Do you have any children living at home with you (please circle):

   Yes No

   A: If yes, how many?_____

B: How old are they? 1)___ 2)____ 3)___ 4)___ 5)___

8. Do you care for any other dependents (e.g. parents)? (please circle)

Yes No

9. Do you smoke? (please circle)

Yes No

If yes, on average, how many cigarettes do you smoke per day? (please specify)

_____

10. On average, how many units of alcohol do your drink per week? (e.g. 1 unit = ½ pint lager/bitter or 1 glass of wine or 1 measure of spirit (please specify):

_____

11. How long have you worked in your present shift system?

_____ Years _____ Months

12. How long altogether have you been working shifts?

_____ Years _____ Months

13. Excluding overtime, approximately how many hours do you work each week?

_____ Hours _____ Minutes

14. On average, how many hours of overtime do you work each week?

_____ Hours _____ Minutes

15. Do you have a second paid job in addition to your main one? (please circle)

Yes No

16. For each of the shifts that you normally work, at what time do they start and finish? (please use 24 hour clock format e.g. midnight = 00:00, 8.30am = 08:30, 1.00pm = 13:00, 6.15pm = 18:15):

a. Morning shift Start: _____ Finish:_____

b. Afternoon shift Start: _____ Finish:_____

c. Day shift Start: _____ Finish:_____

d. Night shift Start: _____ Finish:_____

e. Other (please specifiy)_____

17. For each shift type that you normally work, on average how many successive shifts of the same kind do you normally work before changing to another shift or have some days off? (please state):

a. Number of successive Morning shifts _____

b. Number of successive Afternoon shifts _____

c. Number of successive Day shifts _____

d. Number of successive Night shifts _____

e. Total number of successive shifts

(of any kind before days off) _____

f. Other:_____

18. What is the maximum number of shifts of any kind you have worked between days off on the past month? (please state): _____

19. On average, how many days off in succession do you normally have? (please state)

_____

20. In general, when changing from one type of shift to another, what type of shift is each shift Or day off followed by? (please state):

    a. Morning shifts are normally followed by: _____

    b. Afternoon shifts are normally followed by: _____

    c. Day shifts are normally followed by: _____

    d. Night shifts are normally followed by: _____

    e. Other…… are normally followed by: _____

    f. Days off are normally followed by: _____

21. Does your organisation provide access to food and beverages (such as tea, coffee, chocolate or other snacks and meals) in the way of (please circle all appropriate options):

    a. Staff room equipped with food and beverage making facilities

    b. Canteen, open selective hours

    c. Canteen, open 24 hours

    d. Vending machines

    e. Café nearby

    f. Other:_____

22. Medications

    Are you required to take any prescription medications? If so, please detail which medications and dosages you are currently taking in the spaces provided below:

    _____

    _____

    _____

    _____

    _____

    _____

Eysenck Personality Inventory (EPI)

The EPI Instructions

Here are some questions regarding the way you behave, feel and act.

Try to decide whether YES or NO represents **your usual way** of acting or feeling. Then circle either YES or NO in the adjoining columns. Work quickly, and don't spend too much time over any question, we want your first reaction, not a long drawn-out though process. The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions.

Start now, work quickly and remember to answer every question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

1	Do you often long for excitement?	YES	NO
2	Do you often need understanding friends to cheer you up?	YES	NO
3	Are you usually carefree?	YES	NO
4	Do you find it very hard to take no for an answer?	YES	NO
5	Do you stop and think things over before doing anything?	YES	NO
6	If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so?	YES	NO
7	Do your moods go up and down?	YES	NO
8	Do you generally do and say things quickly without stopping to think?	YES	NO
9	Do you ever feel 'just miserable' for no good reason?	YES	NO
10	Would you do almost anything for a dare?	YES	NO
11	Do you suddenly feel shy when you want to talk to an attractive stranger?	YES	NO
12	Once in a while do you lost your temper and get angry?	YES	NO
13	Do you often do things on the spur of the moment?	YES	NO
14	Do you often worry about things you should have done or said?	YES	NO
15	Generally do you prefer reading to meeting people?	YES	NO
16	Are your feelings rather easily hurt?	YES	NO
17	Do you like going out a lot?	YES	NO
18	Do you occasionally have thoughts and ideas that you would not like other people to know about?	YES	NO
19	Are you sometimes bubbling over with energy and sometimes very sluggish?	YES	NO
20	Do you prefer to have few but special friends?	YES	NO
21	Do you daydream a lot?	YES	NO
22	When people shout at you do you shout back?	YES	NO
23	Are you often troubled about feelings of guilt	YES	NO
24	Are all your habits good and desirable ones?	YES	NO
25	Can you usually let yourself go and enjoy yourself a lot at a liv27ely party?	YES	NO

26	Would you call yourself tense or 'highly strung'?	YES	NO
27	Do other people think of you as being very lively?	YES	NO
28	After you have done something important, do you come away feeling you could have done better?	YES	NO
29	Are you mostly quiet when you are with other people?	YES	NO
30	Do you sometimes gossip?	YES	NO
31	Do ideas run through your head so that you cannot sleep?	YES	NO
32	If there is something you want to know about, would you rather look it up in a book than talk to someone about it?	YES	NO
33	Do you get palpitations or thumping in your heart?	YES	NO
34	Do you like the kind of work that you need to pay close attention to?	YES	NO
35	Do you get attacks of shaking or trembling?	YES	NO
36	Would you always declare everything at customs, even if you knew you could never be found out?	YES	NO
37	Do you hate being with a crown who plays jokes on one another?	YES	NO
38	Are you an irritable person?	YES	NO
39	Do you like doing things in which you have to act quickly?	YES	NO
40	Do you worry about awful things that might happen?	YES	NO
41	Are you slow and unhurried in the way you move?	YES	NO
42	Have you ever been late for an appointment or work?	YES	NO
43	Do you have many nightmares?	YES	NO
44	Do you like talking to people so much that you never miss a chance of talking to a stranger?	YES	NO
45	Are you troubled by aches and pains?	YES	NO
46	Would you be very unhappy if you could not see lots of people most of the time?	YES	NO
47	Would you call yourself a nervous person?	YES	NO
48	Of all the people you know, are there some whom you definitely do not like?	YES	NO
49	Would you say that you were fairly self-confident?	YES	NO
50	Are you easily hurt when people find fault with you or your work?	YES	NO
51	Do you find it hard to really enjoy yourself at a lively party?	YES	NO
52	Are you troubled by feelings of inferiority?	YES	NO
53	Can you easily get some life into a dull party?	YES	NO
54	Do you sometimes talk about things you know nothing about?	YES	NO
55	Do you worry about your health?	YES	NO
56	Do you like playing pranks on others?	YES	NO
57	Do you suffer from sleeplessness?	YES	NO

Health Locus of Control

Instructions:

- Each item below is a belief statement with which you may agree or disagree.
- Beside each statement is a scale which ranges from strongly disagree (1) to strongly agree (6).
- For each item we would like you to circle the number that represents the extent to which you agree or disagree with that statement. The more you agree with a statement, the higher will be the number you circle. The more you disagree with a statement, the lower will be the number you circle.
- Please make sure that you answer **EVERY ITEM** and that you circle **ONLY ONE** number per item. This is a measure of your personal beliefs; obviously, there are no right or wrong answers.
-

1=STRONGLY DISAGREE **(SD)** 2=MODERATELY DISAGREE **(MD)** 3=SLIGHTLY DISAGREE **(D)**	4=SLIGHTLY AGREE **(A)** 5=MODERATELY AGREE **(MA)** 6=STRONGLY AGREE **(SA)**

		SD	MD	D	A	MA	SA
1	If I get sick, it is my own behavior which determines how soon I get well again.	1	2	3	4	5	6
2	No matter what I do, if I am going to get sick, I will get sick.	1	2	3	4	5	6
3	Having regular contact with my physician is the best way for me to avoid illness.	1	2	3	4	5	6
4	Most things that affect my health happen to me by accident.	1	2	3	4	5	6
5	Whenever I don't feel well, I should consult a medically trained professional.	1	2	3	4	5	6
6	I am in control of my health.	1	2	3	4	5	6
7	My family has a lot to do with my becoming sick or staying healthy.	1	2	3	4	5	6
8	When I get sick, I am to blame.	1	2	3	4	5	6
9	Luck plays a big part in determining how soon I will recover from an illness.	1	2	3	4	5	6
10	Health professionals control my health.	1	2	3	4	5	6
11	My good health is largely a matter of good fortune.	1	2	3	4	5	6
12	The main thing which affects my health is what I myself do.	1	2	3	4	5	6
13	If I take care of myself, I can avoid illness.	1	2	3	4	5	6
14	Whenever I recover from an illness, it's usually because other people (for example, doctors, nurses, family, friends) have been taking good care of me.	1	2	3	4	5	6
15	No matter what I do, I 'm likely to get sick.	1	2	3	4	5	6
16	If it's meant to be, I will stay healthy.	1	2	3	4	5	6
17	If I take the right actions, I can stay healthy.	1	2	3	4	5	6
18	Regarding my health, I can only do what my doctor tells me to do.	1	2	3	4	5	6

Three Factor Questionnaire (Based on Stunkard & Messick, 1985)

Part I

Directions: Please answer true or false to following questions:

1.	When I smell a sizzling steak or see a juicy piece of meat I find it very difficult to keep from eating, even if I have just finished a meal	T	F
2.	I usually eat too much at social occasions, like parties and picnics	T	F
3.	I am usually so hungry that I eat more than three times a day	T	F
4.	When I have eaten my quota of calories, I am usually good about not eating any more	T	F
5.	Dieting is so hard for me because I just get too hungry	T	F
6.	Deliberately take small helpings as a means of controlling my weight	T	F
7.	Sometimes things just taste so good that I keep on eating even when I am no longer hungry	T	F
8.	Since I am often hungry, I sometimes wish that while I am eating, an expert would tell me that I have had enough or that I can have something more to eat	T	F
9.	When I feel anxious, I find myself eating.	T	F
10.	Life is too short to worry about dieting	T	F
11.	Since my weight goes up and down, I have gone on reducing diets more than once	T	F
12.	I often feel so hungry that I just have to eat something	T	F
13.	When I am with someone who is overeating, I usually overeat too	T	F
14.	I have a pretty good idea of the number of calories in common food	T	F
15.	Sometimes when I start eating, I just can't seem to stop	T	F
16.	It is not difficult for me to leave something on my plate	T	F
17.	At certain times of the day, I get hungry because I have gotten used to eating then	T	F
18.	While on a diet, if I eat food that is not allowed, I consciously eat less for a period of time to make up for it	T	F
19.	Being with someone who is eating often makes me hungry enough to eat also	T	F
20.	When I feel blue, I often overeat	T	F
21.	I enjoy eating too much to spoil it by counting calories or watching my weight	T	F
22	When I see a real delicacy, I often get so hungry that I have to eat right away	T	F
23.	I often stop eating when I am not really full as a conscious means of limiting the amount that I eat	T	F
24.	I get so hungry that my stomach often seems like a bottomless pit	T	F
25.	My weight has hardly changed at all in the last ten years	T	F
26.	I am always hungry so it is hard for me to stop eating before I finish the food on my plate	T	F
27.	When I feel lonely, I console myself by eating	T	F
28.	I consciously hold back at meals in order not to gain weight	T	F
29.	I sometimes get very hungry late in the evening or at night	T	F
30.	I eat anything I want, any time I want	T	F
31.	Without even thinking about it, I take a long time to eat	T	F
32.	I count calories as a conscious means of controlling my weight	T	F
33.	I do not eat some foods because they make me fat	T	F
34.	I am always hungry enough to eat at any time	T	F
35.	I pay a great deal of attention to changes in my figure	T	F
36.	While on a diet, if I eat a food that is not allowed, I often then splurge and eat other high calorie foods	T	F

Part II

Directions: Please answer the following questions by circling the number above the response that is appropriate to you.

37. How often are you dieting in a conscious effort to control your weight?

1	2	3	4
Rarely	Sometimes	Usually	Always

38. Would a weight fluctuation of 5 lbs affect the way you live your life?

1	2	3	4
Not at all	Slightly	Moderately	Very much

39. How often do you feel hungry?

1	2	3	4
Only at Mealtimes	Sometimes between meals	Often between meals	Almost always

40. Do your feelings of guilt about overeating help you to control your food intake?

1	2	3	4
Never	Rarely	Often	Always

41. How difficult would it be for you to stop eating halfway through dinner and not eat for the next four hours?

1	2	3	4
Easy	Slightly difficult	Moderately difficult	Very difficult

42. How conscious are you of what you are eating?

1	2	3	4
Not at all	Slightly	Moderately	Extremely

43. How frequently do you avoid 'stocking up' on tempting foods?

1	2	3	4
Almost never	Seldom	Usually	Almost always

44. How likely are you to shop for low calorie foods?

1	2	3	4
Unlikely	slightly unlikely	Moderately likely	Very likely

45. Do you eat sensibly in front of others and splurge alone?

1	2	3	4
Never	Rarely	Often	Always

46. How likely are you to consciously eat slowly in order to cut down on how much YOU eat?

1	2	3	4
Unlikely	Slightly likely	Moderately likely	Very likely

47. How frequently do you skip dessert because you are no longer hungry?

1	2	3	4
Almost Never	Seldom	at least once a week	Almost every day

48. How likely are you to consciously eat less than you want?

1	2	3	4
Unlikely	Slightly likely	Moderately likely	Very likely

49. Do you go on eating binges though you are not hungry?

1	2	3	4
Never	Rarely	Sometimes	At least once a week

50. On a scale of 0 to 5, where 0 means no restraint in eating (eating whatever you want, whenever you want it) and 5 means total restraint (constantly limiting food intake and never 'giving in'), what number would you give yourself?

    0 Eat whatever you want, whenever you want it

    1 Usually eat whatever you want, whenever you want it

    2 Often eat whatever you want, whenever you want it

    3 Often limit food intake, but often 'give in'

    4 Usually limit food intake, rarely 'give in'

    5 Constantly limiting food intake, never 'giving in'

51. To what extent does this statement describe your eating behaviour? 'I start dieting in the morning, but because of any number of things that happen during the day, by evening I have given up and eat what I want, promising myself to start dieting again tomorrow.'

1	2	3	4
Not like me	A little like me	Pretty good description of me	Describes me perfectly

Morningness-Eveningness Questionnaire

Instructions:

- Please read each question very carefully before answering.
- Please answer each question as honestly as possible.
- Answer ALL questions
- Each question should be answered independently of others. Do NOT go back and check your answers.

1. What time would you get up if you were entirely free to plan your day?

5:00 – 6:30 AM	☐
6:30 – 7:45 AM	☐
7:45 – 9:45 AM	☐
9:45 – 11:00 AM	☐
11:00 – 12 Noon	☐
12 Noon – 5:00 AM	☐

2. What time would you go to bed if you were entirely free to plan your evening?

8:00 – 9:00 PM	☐
9:00 – 10:15 PM	☐
10:15 – 12:30 AM	☐
12:30 – 1:45 AM	☐
1:45 – 3:00 AM	☐
3:00 AM – 8:00 PM	☐

3. If there is a specific time at which you have to get up in the morning, to what extent do you depend on being woken up by an alarm clock?

Not all dependent	☐
Slightly dependent	☐
Fairly dependent	☐
Very dependent	☐

4. How easy do you find it to get up in the morning (when you are not woken up unexpectedly)?

Not all easy	☐
Not very easy	☐
Fairly easy	☐
Very easy	☐

5. How alert do you feel during the first half-hour after you wake up in the morning?

Not all alert	☐
Slightly alert	☐
Fairly alert	☐
Very alert	☐

6. How hungry do you feel during the first half hour after you wake up in the morning?

Not all hungry	☐
Slightly hungry	☐
Fairly hungry	☐
Very hungry	☐

7. During the first half-hour after you wake up in the morning, how tired do you feel?

- Very tired ☐
- Fairly tired ☐
- Fairly refreshed ☐
- Very refreshed ☐

8. If you have no commitments the next day, what time would you go to bed compared to your usual bedtime?

- Seldom or never later ☐
- Less than one hour later ☐
- 1 – 2 hours later ☐
- More than two hours later ☐

9. You have decided to engage in some physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 7:00 – 8:00 am. Bearing in mind nothing but your own internal "clock", how do you think you would perform?

- Would be in good form ☐
- Would be in reasonable form ☐
- Would find it difficult ☐
- Would find it very difficult ☐

10. At what time of day do you feel you become tired as a result of need for sleep?

- 8:00 – 9:00 PM ☐
- 9:00 – 10:15 PM ☐
- 10:15 PM – 12:45 AM ☐
- 12:45 – 2:00 AM ☐
- 2:00 – 3:00 AM ☐

11. You want to be at your peak performance for a test that you know is going to be mentally exhausting and will last for two hours. You are entirely free to plan your day. Considering only your own internal "clock", which ONE of the four testing times would you choose?

- 8:00 AM – 10:00 AM ☐
- 11:00 AM – 1:00 PM ☐
- 3:00 PM – 5:00 PM ☐
- 7:00 PM – 9:00 PM ☐

12. If you got into bed at 11:00 PM, how tired would you be?

- Not at all tired ☐
- A little tired ☐
- Fairly tired ☐
- Very tired ☐

13. For some reason you have gone to bed several hours later than usual, but there is no need to get up at any particular time the next morning. Which ONE of the following are you most likely to do?

- Will wake up at usual time, but will NOT fall back asleep ☐
- Will wake up at usual time and will doze thereafter ☐

Will wake up at usual time but will fall asleep again ☐
Will NOT wake up until later than usual ☐

14. One night you have to remain awake between 4:00 – 6:00 AM in order to carry out a night watch. You have no commitments the next day. Which ONE of the alternatives will suite you best?

Would NOT go to bed until watch was over ☐
Would take a nap before and sleep after ☐
Would take a good sleep before and nap after ☐
Would sleep only before watch ☐

15. You have to do two hours of hard physical work. You are entirely free to plan your day and considering only your own internal "clock" which ONE of the following time would you choose?

8:00 AM – 10:00 AM ☐
11:00 AM – 1:00 PM ☐
3:00 PM – 5:00 PM ☐
7:00 PM – 9:00 PM ☐

16. You have decided to engage in hard physical exercise. A friend suggests that you do this for one hour twice a week and the best time for him is between 10:00 – 11:00 PM. Bearing in mind nothing else but your own internal "clock" how well do you think you would perform?

Would be in good form ☐
Would be in reasonable form ☐
Would find it difficult ☐
Would find it very difficult ☐

17. Suppose that you can choose your own work hours. Assume that you worked a FIVE hour day (including breaks) and that your job was interesting and paid by results). Which FIVE CONSECUTIVE HOURS would you select?

5 hours starting between 4:00 AM and 8:00 AM ☐
5 hours starting between 8:00 AM and 9:00 AM ☐
5 hours starting between 9:00 AM and 2:00 PM ☐
5 hours starting between 2:00 PM and 5:00 PM ☐
5 hours starting between 5:00 PM and 4:00 AM ☐

18. At what time of the day do you think that you reach your "feeling best" peak?

5:00 – 8:00 AM ☐
8:00 – 10:00 AM ☐
10:00 AM – 5:00 PM ☐
5:00 – 10:00 PM ☐
10:00 PM – 5:00 AM ☐

19. One hears about "morning" and "evening" types of people. Which ONE of these types do you consider yourself to be?

Definitely a "morning" type ☐
Rather more a "morning" than an "evening" type ☐
Rather more an "evening" than a "morning" type ☐
Definitely an "evening" type ☐

Sleep Diary

Instructions:

1. Please complete a single line of the sleep diary for each attempted/actual sleep period (i.e. major sleeps and naps), even if you do not actually fall asleep.
2. Record start date/time immediately prior to 'lights out'. Start time is the time that you start attempting to sleep (i.e. 'lights out'), not the time that you fall asleep. **Note:** start /end times should not include time spent reading, watching TV, etc.
3. Rate the quality of your sleep compared to a **'normal' sleep period**.

Sleep Quality
1. Very good
2. Good
3. Average
4. Poor
5. Very poor
6. Did not sleep

	Start Date	**Start Time**	**End Date**	**End Time**	**Sleep Quality (1-6)**	**Sleep Time Awakenings**
E.g.	*05.04.12*	*22:30*	*06.04.12*	*08:30*	*3*	*Woke up 2 times*
1						
2						
3						
4						
5						
6						
7						
8						
9						

Sleep Diary Continued…….

10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						

Comments (Please make any relevant comments, for example, regarding the sleep environment, interruptions, ambient noise etc.)

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Mood Diary 1 (please complete before your shift)

Date:_____ **Time**:_____

Instructions:
These scales are to be completed directly before the start of your shift. For each scale, please rate how you feel right now by placing a mark along the horizontal line between the two statements.

How happy do you feel?

_____

I am not happy at all — I have never been more happy

How anxious do you feel?

_____

I am not anxious at all — I have never been more anxious

How depressed do you feel?

_____

I am not depressed at all — I have never been more depressed

How stressed do you feel?

_____

I am not stressed at all — I have never been more stressed

How tired do you feel?

_____

I am not tired at all — I have never been more tired

Work Diary

Start Date	Scheduled Start Time	Actual Start Time	Did you have a break? Yes/No If yes Time & Duration	End Date	Scheduled End Time	Actual End Time

Mood Diary 2 (please complete after your shift)

Date:_____ **Time**:_____

Instructions:
These scales are to be completed at the end of your shift. For each scale, please rate how you feel right now by placing a mark along the horizontal line between the two statements.

How happy do you feel?

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How depressed do you feel?

_____

I am not depressed at all — I have never been more depressed

How stressed do you feel?

_____

I am not stressed at all — I have never been more stressed

How tired do you feel?

_____

I am not tired at all — I have never been more tired

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How depressed do you feel?

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I am not depressed at all — I have never been more depressed

How stressed do you feel?

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I am not stressed at all — I have never been more stressed

How tired do you feel?

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I am not tired at all — I have never been more tired

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Start Date	Scheduled Start Time	Actual Start Time	Did you have a break? Yes/No If yes Time & Duration	End Date	Scheduled End Time	Actual End Time

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How stressed do you feel?

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I am not stressed at all — I have never been more stressed

How tired do you feel?

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I am not tired at all — I have never been more tired

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Start Date	Scheduled Start Time	Actual Start Time	Did you have a break? Yes/No If yes Time & Duration	End Date	Scheduled End Time	Actual End Time

Mood Diary 2 (please complete after your shift)

Date:_____ **Time**:_____

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I am not depressed at all — I have never been more depressed

How stressed do you feel?

_____

I am not stressed at all — I have never been more stressed

How tired do you feel?

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I am not tired at all — I have never been more tired

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Date:_____ **Time**:_____

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How stressed do you feel?

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How tired do you feel?

_____

I am not tired at all — I have never been more tired

Work Diary

Start Date	Scheduled Start Time	Actual Start Time	Did you have a break? Yes/No If yes Time & Duration	End Date	Scheduled End Time	Actual End Time

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How tired do you feel?

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I am not tired at all — I have never been more tired

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How stressed do you feel?

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I am not stressed at all — I have never been more stressed

How tired do you feel?

_____

I am not tired at all — I have never been more tired

Work Diary

Start Date	Scheduled Start Time	Actual Start Time	Did you have a break? Yes/No If yes Time & Duration	End Date	Scheduled End Time	Actual End Time

Mood Diary 2 (please complete after your shift)

Date:_____ **Time**:_____

Instructions:
These scales are to be completed at the end of your shift. For each scale, please rate how you feel right now by placing a mark along the horizontal line between the two statements.

How happy do you feel?

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I am not happy at all — I have never been more happy

How anxious do you feel?

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I am not anxious at all — I have never been more anxious

How depressed do you feel?

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I am not depressed at all — I have never been more depressed

How stressed do you feel?

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I am not stressed at all — I have never been more stressed

How tired do you feel?

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How tired do you feel?

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FOOD DIARY

The effect of shift type on sleeping patterns mood and eating behaviour

To allow us to assess your dietary intake we will need you to keep a record of everything you eat and drink for three days per shift type and on one day off. It is important that these days be as normal as possible. Please do not change any eating patterns on the days that you record. Remember we are only interested in your usual dietary intake, not the perfect diet!

If you have any question regarding how to complete the food record, please do not hesitate to contact the study team on **8302 9946**.

General Guidelines:

- Please keep the diary for three days per shift type and on one day off,.
- Write down all food and drinks eaten both at home and away from home and include all vitamins, minerals or other supplements taken.
- Beverages of all kinds, including water and alcohol must be recorded. For juices and cordials please record how these were made (strength).
- For packaged foods record the brand name and the weight or volume. Attach product labels with your record if possible, this is very useful.
- For home made foods please provide the recipe with all the ingredients and number of serves made and the portion or fraction of the recipe you ate
- Record amounts (in grams) as accurately as possible using the scales provided.
- Remember to record the amounts of left overs as well.
- If you are out and unable to measure the food, describe what is eaten as fully as possible and make the best guess you can for the quantity.
- If you do not eat a particular meal or snack, simply draw a line across the page at this point, to show that you have definitely not eaten anything for this meal.

Guidelines for Describing Foods and Beverages:

- Remember to include any toppings or fillings likes spreads consumed with foods, eg. sauces, dressings, gravy, stuffing, sugar, pesto, margarine, syrups
- When describing foods, provide as many details as possible, for example:
  - Cooking methods (eg. fried, steamed, grilled, roasted, poached, boiled)
  - Regular or low fat (eg. skim or full cream milk, Diet lite yoghurt, Flora Light Margarine, Salt reduced tomato paste, coke zero)
  - Describe if the food has been trimmed of all fat or skin removed (eg. skinless chicken breast, bacon, trimmed)

Guidelines for Describing the Quantity of Foods and Beverages:

Household Measurements – **For foods such as vegetables, cereals and canned fruits, a household measurement (eg. tsp, cup) is adequate. However, state whether the spoons are level, rounded or heaped eg. 1 level cup of cooked rice**

Weight on packaging – **the weights on packaging is a convenient way to determine the amount eaten eg. half of a can of 425g baked beans.**

Bread – **indicate the size of the slice (eg. sandwich, toast slice) and indicate whether it was eaten raw or toasted.**

Cheese, meat and fish – **If possible weigh the portions for these foods. If not possible, please estimate as best you can (use comparisons)**

Use comparisons – **for describing portion sizes by comparing it to objects (eg. potato the same size as an egg, or a square of cheese, the same size as a matchbox)**

EXAMPLE

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
- QUANTITY OF FOOD (eg. 6 heaped tsp white sugar or weight (g))
- BRAND NAMES (eg Nestle diet lite) if possible

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING	250ml	Apple Juice Fruitbox
	1	Multivitamin tablet
6:00		
BREAKFAST	3	Sanitarium Weetbix
	½ cup	Dairy Farmers Skim milk (fat free) (for weetbix)
	2 tsp	White Sugar (for weetbix)
	1 large glass (~400ml)	Daily Juice Pulp Free Orange Juice
	1 toast slice	Molenberg Multigrain toast
	14g	IXL Apricot Jam
8:00		
DURING MORNING	1 Large Cup (450ml)	Cappuccino from café
	31g	Uncle Tobys Choc Chip Chewy Muesli Bar
	250ml	Water
	72g	Apple – Granny Smith
10:00		
MIDDAY	2 slices	Wonder White, White bread
	1 slattering	Butter (enough to cover surface of 1 slice of bread)
	2 slices (20g)	Tomato
	1 leaf (5g)	Lettuce
12:30	2 slices (40g)	Cheese – regular fat
	1 cup	Fries from café
	300ml	Water

EXAMPLE CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON 15:00	1 small handful	Mixed Salted Nuts
EVENING MEAL 18:30	261g (2)	small lamb chops, fat cut off, grilled
	1 (med size)	Baked potato
	1tbs	Butter
	1cup	Mixed frozen Heinz vegetables (including corn, carrot, beans) – boiled
	200g (1 tub)	Strawberry yoghurt 99% fat free
	2 glasses (200ml)	Red wine
DURING EVENING / SUPPER 21:00	1 cup (250ml)	Whole fat plain milk
	5	Home made chocolate chip cookies ~5cm diameter
	200ml	Water

DAY ONE – MORNING SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY ONE – MORNING SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY TWO – MORNING SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
- QUANTITY OF FOOD (eg. 6 heaped tsp white sugar or weight (g))
- BRAND NAMES (eg Nestle diet lite) if possible

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY TWO – MORNING SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY THREE – MORNING SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
- QUANTITY OF FOOD (eg. 6 heaped tsp white sugar or weight (g))
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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY THREE – MORNING SHIFT CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY ONE – AFTERNOON SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY ONE – AFTERNOON SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY TWO – AFTERNOON SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY TWO – AFTERNOON SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY THREE – AFTERNOON SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY THREE – AFTERNOON SHIFT CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY ONE – NIGHT SHIFT

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
- QUANTITY OF FOOD (eg. 6 heaped tsp white sugar or weight (g))
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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY ONE – NIGHT SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

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Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

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TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY TWO – NIGHT SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

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Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

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EARLY MORNING		
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DAY THREE – NIGHT SHIFT - CONTINUED

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

DAY OFF

Record ALL food and drink consumed during the date including sweets, snacks, nibbles, sauces and dressings, water and supplements (vitamins).

Please remember to record:

- METHOD OF COOKING (eg. boiled pasta)
- TYPE OF FOOD (eg. wholemeal bread)
- QUANTITY OF FOOD (eg. 6 heaped tsp white sugar or weight (g))
- BRAND NAMES (eg Nestle diet lite) if possible

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
EARLY MORNING		
BREAKFAST		
DURING MORNING		
MIDDAY		

DAY OFF

TIME	QUANTITY EATEN	DETAILS OF FOOD & DRINK
DURING AFTERNOON		
EVENING MEAL		
DURING EVENING / SUPPER		

ADDITIONAL INFORMATION

If you have made any major changes to your eating habits during the past few months, please describe them here:

On completion of this record, please return it to us at the centre.

THANK YOU FOR YOUR CO-OPERATION IN COMPLETING SUCH A DETAILED FORM. WE ARE VERY GRATEFUL FOR YOUR TIME AND EFFORT.

If you have any comments or suggestions, please write them below.

Appendix L: General health and background information questionnaire (Study 1)

GENERAL HEALTH & BACKGROUND INFORMATION QUESTIONNAIRE

Name: _____Date: _____ Subject No: _____

All of the information you give is completely confidential

Section One: General

Address: _____ Ph (H): _____

_____ Ph (M): _____

_____

_____

Email: _____

DOB: _____ Age: _____ yr Gender: male ☐ female ☐

Weight: _____ kg Height: _____ cm left-handed ☐ right-handed ☐

Highest Level of Education Completed: Primary ☐ Secondary ☐ Tertiary ☐ Post grad ☐

Occupation: _____

Approximate traveling time to work: _____ minutes

Mode of transportation: _____ (bus, train, car, etc)

1. Have you traveled through time zones in the last 3 months? YES ☐ NO ☐

If yes, please provide trip details: -

_____

_____

_

2. Are you, or have you ever been involved in shift work? YES ☐ NO ☐

   If so: how long ago? _____ yr_____ months

   for how long ? _____ yr_____ months

3. Please list the average amount of caffeine you consume per day *(e.g. cups of tea/coffee, cans of caffeinated soft drink and chocolate bars)*

   _____

   _

   _____

_

4. Do you smoke? YES ☐ NO ☐
   If so, how many cigarettes/cigars? _____ per day

5. Do you have any children living with you at home? YES ☐ NO ☐
   If so, how many? _____

Section Two: Sleep

6. What time do you normally wake up? _____ week _____ weekend

7. What time do you normally go to sleep? _____ week _____ weekend

8. Do you normally nap during the day? YES ☐ NO ☐
   If so, how often does this occur? _____

9. How well do you usually sleep?

   very poorly_____very well

   1 2 3 4 5

10. On average, how many times per night do you wake up?

    Never ☐ hardly ever ☐ 1 or 2 ☐ < 5 ☐ 5 – 10 ☐ >10 ☐ don't know ☐

Section Three: General Health

11. Have you had any serious accidents, head injuries, or concussion? YES ☐ NO ☐

12. Are you currently on any medication? YES ☐ NO ☐
    If yes, please give details:
_____

13. Have you been on any medication in the past week? YES ☐ NO ☐
    If so, what medication:
_____

14. What exercise do you do?

15. How much exercise do you do, on average per week? _____ hours

16. On average, how much alcohol do you drink per week? _____ beer/cider _____ spirits

17. Have you ever experienced any of the following medical conditions, and if so, when?

Don't know = 0 No = 1 Yes in the past = 2 Yes, sometimes = 3 Yes, at present = 4

(a)	Asthma _____	(b)	Hay fever _____
(c)	Eczema _____	(d)	Allergies _____
(e)	Thyroid Problems _____	(f)	Undue anxiety _____
(g)	Sleepwalking _____	(h)	Loud snoring _____
(I)	Nightmares _____	(j)	Bruxism _____
(k)	Difficulty reading/writing _____	(l)	Arthritis/Rheumatism _____
(m)	Depression _____	(n)	Heart problems _____
(o)	Stomach problems _____	(p)	Waking with a jolt _____
(q)	Waking up excessively early _____	(r)	Difficulty falling asleep _____
(s)	Stress/anxiety at home/work _____	(t)	Epilepsy _____
(u)	Migraine _____	(v)	Colour blindness _____
(w)	Hepatitis _____	(x)	HIV _____
(y)	Blood disorders (i.e. Hemophilia)_____		

18. This project involves collecting blood samples:

(a) Have you ever given blood before? YES ☐ NO ☐

(b) Have you ever had any problems giving blood? YES ☐ NO ☐

19. Do you have any food allergies e.g. lactose intolerance (please list)

_____

20. Have you currently dieting? YES ☐ NO ☐

21. Have dieted in the past month? YES ☐ NO ☐

22. Are you a vegetarian? YES ☐ NO ☐

Section Four: Stress and Workload

23. Do you have exams/assignments due/other tests scheduled for one week before or during the study? YES ☐ NO ☐

24. Are you currently experiencing a greater than your normal amount of stress? (e.g. sick relative, relationship break-up, getting married, moving house) YES ☐ NO ☐

Comments:

_____

Section 5: Pittsburgh Sleep Quality Index

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month.

1. During the past month, when have you usually gone to bed at night?

   Usual Bedtime

   _____

2. During the past month, how long (in minutes) has it usually taken you to fall asleep each night?

   Number of Minutes_____

3. During the past month, when have you usually gotten up in the morning?

   Usual getting up time

   _____

4. During the past month, how many hours of *actual sleep* did you get at night? (This may be different to the number of hours you spend in bed)

   Hours of sleep per night_____

5. For each of the remaining questions, check the one best response:

During the past month, how often have you had trouble sleeping because you…

(a) Cannot get to sleep within 30 minutes:

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(b) Wake up in the middle of the night or early morning

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(c) Have to get up to use the bathroom

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(d) Cannot breathe comfortably

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(e) Cough or snore loudly

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(f) Feel too cold

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(g) Feel too hot

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(h) Had bad dreams

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(i) Have pain

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

(j) Other reason(s), please describe:

_____

How often during the past month have you had trouble sleeping because of this?

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

6. During the past month, how would you rate your sleep quality overall?

very good ☐ fairly good ☐ fairly bad ☐ very bad ☐

7. During the past month, how often have you taken medicine (prescribed or over the counter) to help you sleep?

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

8. During the past month, how often have you had trouble staying awake while driving, eating meals or engaging in social activity?

not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week ☐

9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?

not a problem at all ☐ only a very slight problem ☐ somewhat of a problem ☐ a very big problem ☐

Section 6: Epworth Sleepiness Scale

How likely are you to fall asleep or doze off in the following situations, rather than just feeling tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation.

0 = would *never* doze
1 = *slight* chance of dozing
2 = *moderate* chance of dozing
3 = *high* chance of dozing

Sitting and reading _____

Watching TV _____

Sitting inactive in a public place (e.g. theatre/meeting) _____

As a passenger in a car for an hour without a break _____

Lying down in the afternoon when circumstances permit _____

Sitting and talking to someone _____

Sitting quietly after lunch without alcohol _____

In a car, while stopped for a few minutes in the traffic _____

TOTAL

Appendix M: General health and background information questionnaire (Study 2)

GENERAL HEALTH & BACKGROUND INFORMATION QUESTIONNAIRE

Name: _____Date: _____ Subject No: _____

All of the information you give is completely confidential

Section One: General
Address:_____ Ph(H):_____
_____ Ph(M):_____

Email:_____

DOB: _____ Age: _____ yr Gender: male ☐ female ☐

Weight: _____ kg Height:____ cm left-handed ☐ right-handed ☐

Highest Level of Education Completed: Primary ☐ Secondary ☐
Tertiary ☐ Post grad ☐

Occupation: _____

Approximate traveling time to work: _____ minutes

Mode of transportation:_____ (bus, train, car, etc)

1. Have you traveled through time zones in the last 3 months? ☐ YES ☐ NO
If yes, please provide trip details:
_____

2. Are you, or have you ever been involved in shift work? ☐ YES ☐ NO
If so: how long ago? _____ yr _____ months
for how long ? _____ yr _____ months

3. Please list the average amount of caffeine you consume per day *(e.g. cups of tea/coffee, cans of caffeinated soft drink and chocolate bars)*
_____
_____

4. Do you smoke? ☐ YES ☐ NO
If so, how many cigarettes/cigars? _____ per day

5. Do you take illicit drugs (e.g., Marijuana)? ☐ YES ☐ NO

6. Do you have any children living with you at home? ☐ YES ☐ NO
If so, how many? _____

Section Two: Sleep
7. What time do you normally wake up? _____ week _____ weekend

8. What time do you normally go to sleep? _____ week _____ weekend

9. Do you normally nap during the day? ☐ YES ☐ NO
If so, how often does this occur? _____

10. How well do you usually sleep?

very poorly_____very well
1 2 3 4 5

11. On average, how many times per night do you wake up?

☐ never ☐ hardly ever ☐ 1 or 2 ☐ < 5 ☐ 5 – 10 ☐ >10 ☐ don't know

Section Three: General Health

12. Have you had any serious accidents, head injuries, or concussion? ☐ YES ☐ NO

13. Are you currently on any medication? ☐ YES ☐ NO

If yes, please give details: _____

14. Have you been on any medication in the past week? ☐ YES ☐ NO

If so, what medication:_____

15. What exercise do you do?

16. How much exercise do you do, on average per week? _____ hours

17. On average, how much alcohol do you drink per week? ___beer/cider ___spirits

18. Have you ever experienced any of the following medical conditions, and if so, when?

Don't know = 0 No = 1 Yes in the past = 2 Yes, sometimes = 3 Yes, at present = 4

(a) Asthma	_____	(b) Hay fever	_____
(c) Eczema	_____	(d) Allergies	_____
(e) Thyroid Problems	_____	(f) Undue anxiety	_____
(g) Sleepwalking	_____	(h) Loud snoring	_____
(I) Nightmares	_____	(j) Bruxism	_____
(k) Difficulty reading/writing	_____	(l) Arthritis/Rheumatism	_____
(m) Depression	_____	(n) Heart problems	_____
(o) Stomach problems	_____	(p) Waking with a jolt	_____
(q) Waking up excessively early	_____	(r) Difficulty falling asleep	_____
(s) Stress/anxiety at home/work	_____	(t) Epilepsy	_____
(u) Migraine	_____	(v) Colour blindness	_____

Section Four: Stress and Workload

19. Do you have exams/assignments due/other tests scheduled for one week before or during the study? ☐ YES ☐ NO

20. Are you currently experiencing a greater than your normal amount of stress? (e.g. sick relative, relationship break-up, getting married, moving house) ☐ YES ☐ NO

Comments:_____

Section 5: Pittsburgh Sleep Quality Index

The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month.

During the past month, when have you usually gone to bed at night?

Usual Bedtime_____

During the past month, how long (in minutes) has it usually taken you to fall asleep each night? Number of Minutes _____

During the past month, when have you usually gotten up in the morning?

Usual getting up time_____

During the past month, how many hours of *actual sleep* did you get at night? (This may be different to the number of hours you spend in bed)

Hours of sleep per night_____

For each of the remaining questions, check the one best response:

During the past month, how often have you had trouble sleeping because you…

Cannot get to sleep within 30 minutes:

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Wake up in the middle of the night or early morning

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Have to get up to use the bathroom

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Cannot breathe comfortably

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Cough or snore loudly

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Feel too cold

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Feel too hot

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Had bad dreams

☐ not during the past month ☐ less than once/week ☐ once or twice/week ☐ 3 or more times/week

Have pain
☐ not during the past month ☐ less than once/week ☐ once or twice/week
☐ 3 or more times/week

Other reason(s), please describe:

_____

How often during the past month have you had trouble sleeping because of this?

☐ not during the past month ☐ less than once/week ☐ once or twice/week
☐ 3 or more times/week

During the past month, how would you rate your sleep quality overall?
☐ very good ☐ fairly good ☐ fairly bad ☐ very bad

During the past month, how often have you taken medicine (prescribed or over the counter) to help you sleep?
☐ not during the past month ☐ less than once/week ☐ once or twice/week
☐ 3 or more times/week

During the past month, how often have you had trouble staying awake while driving, eating meals or engaging in social activity?
☐ not during the past month ☐ less than once/week ☐ once or twice/week
☐ 3 or more times/week

During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?
☐ not a problem at all ☐ only a very slight problem ☐ somewhat of a problem
☐ a very big problem

Section 6: Epworth Sleepiness Scale

How likely are you to fall asleep or doze off in the following situations, rather than just feeling tired? This refers to your usual way of life in recent times. Even if you have not done some of these things recently try to work out how they would have affected you. Use the following scale to choose the most appropriate number for each situation.

0	=	would *never* doze
1	=	*slight* chance of dozing
2	=	*moderate* chance of dozing
3	=	*high* chance of dozing

Sitting and reading _____

Watching TV _____

Sitting inactive in a public place (e.g. theatre/meeting) _____

As a passenger in a car for an hour without a break _____

Lying down in the afternoon when circumstances permit _____

Sitting and talking to someone _____

Sitting quietly after lunch without alcohol _____

In a car, while stopped for a few minutes in the traffic _____

TOTAL _____

Appendix N: Buffet food items (Study 4)

BUFFET SELECTION
Throughout the study there will be two buffet meals. Please let us know if you like the following foods by ticking the box next to foods you like to eat.

Name:_____ Date:_____

Bread:

- White ❑
- Wholemeal ❑
- Multigrain ❑

Luncheon Meats:

- Turkey ❑
- Ham ❑
- Tuna ❑
- Salami ❑
- Kabana ❑

Vegetables and Fruits:

- Lettuce ❑
- Tomato ❑
- Cucumber ❑
- Corn (tinned) ❑
- Chick Peas ❑
- Dried Fruit (e.g. sultanas) ❑
- Tinned Fruit (peaches) ❑
- Tinned Fruit (pears) ❑
- Tinned Fruit (apricots) ❑
- Grapes ❑
- Rockgelon ❑
- Strawberries ❑
- Apple ❑

Condiments:

- Mayonnaise ❑
- Butter ❑
- Margarine ❑
- Dip (e.g. French onion) ❑
- Jam (strawberry) ❑
- Jam (apricot) ❑
- Tomato Sauce ❑

Other:

- Baked Beans ❑
- Potato Chips ❑
- Nuts ❑
- Meat Pies ❑
- Sausage Rolls ❑
- Lollies ❑

Biscuits:

- Cracker (Jatz) ❑
- Savoury Biscuits (shapes) ❑
- Sweet Biscuits ❑

Dairy:

- Cheese ❑
- Yogurt (strawberry) ❑
- Yoghurt (vanilla) ❑

Sweets:

- Lollies ❑
- Chocolate ❑
- Muffin (banana) ❑
- Muffins (chocolate chip) ❑
- Muffins (chocolate) ❑
- Cheesecake ❑
- Donuts (chocolate) ❑
- Donuts (strawberry) ❑
- Jelly (strawberry) ❑
- Jelly (lime) ❑
- Jelly (orange) ❑

Drinks:

- Coke ❑
- Flavoured milk:
  - Chocolate ❑
  - Strawberry ❑
  - Banana ❑
- Fruit Juice
  - Orange ❑
  - Apple ❑
  - Apple and Raspberry ❑

Appendix O: Study food items (Study 4)

Dinner: Beef and Black Bean with Rice Noodles
Beverage: Orange Juice
Dessert: Yoghurt and Fruit Salad

Snow Peas	❑
Zucchini	❑
Red Capsicum	❑
Bean Sprouts	❑
Cashew Nuts	❑
Rump Steak	❑
Black Bean Sauce	❑
Soy Sauce	❑
Thai Rice Noodles	❑
(Olive Oil)	❑
(Cornflour)	❑
Orange Juice	❑
Vanilla Yoghurt	❑
Fruit Salad (apple, banana, watermelon, strawberries, pineapple)	❑

Dinner: Tuna Mornay
Beverage: Strawberry Nesquik
Dessert: Yoghurt

Pasta	❑
Béchamel Sauce	❑
Parmesan Cheese	❑
Tuna	❑
Peas	❑
Carrots	❑
Corn	❑
White Bread Roll (with Margarine)	❑
Strawberry Nesquik	❑
Passionfruit Yoghurt	❑

Dinner: Spaghetti Bolognaise
Beverage: Strawberry Nesquik
Dessert: Fruit Salad and Ice-Cream

Pasta	❑
Beef Mince	❑
Red Capsicum	❑
Mushrooms (Button)	❑
Carrots	❑
Onions	❑
Garlic	❑
Napolitano Sauce	❑
Parmesan Cheese	❑
Country Grain Bread Roll (with Margarine)	❑
(Olive Oil)	❑
Strawberry Nesquik	❑
Fruit Salad (1 apple, banana, watermelon, strawberries, pineapple)	❑
Vanilla Ice-Cream	❑

Dinner: Chicken Burgers (x2)
Beverage: Orange Juice
Dessert: Ice-Cream with Jelly

White Bread Roll (with Margarine) ❑
Chicken Breast Fillet ❑
Mayonnaise ❑
Tomato ❑
Avocado ❑
Onions ❑
Cucumber ❑
Cheese ❑
(Olive Oil) ❑
❑

Orange Juice

Vanilla Ice-Cream ❑
Orange Jelly ❑

Dinner: Thai Green Chicken Curry
Beverage: Strawberry Nesquik
Dessert: Frozen Yoghurt

White Rice	❑
Chicken Breast Fillet	❑
Onion	❑
Green Capsicum	❑
Zucchini	❑
Cashew Nuts	❑
Thai Green Curry Sauce	❑
Garlic Pappadums	❑
(Olive Oil)	❑
Strawberry Nesquik	❑
Strawberry Frozen Yogurt	❑

Lunch: Chicken Caesar Salad
Beverage: Apple Juice
Dessert: Peach

Chicken Breast Fillet	❑
Baby Spinach Leaves	❑
Gourmet Lettuce Mix (Rocket and Cos)	❑
Bacon	❑
Croutons	❑
Caesar Salad Dressing	❑
Lebanese Bread (with Margarine)	❑
(Olive Oil)	❑
Apple Juice	❑
Peach	❑

Lunch: Scrambled Eggs with Vegetables
Beverage: Orange Juice
Dessert: Honey and Banana Muffin

Eggs	❑
Chives	❑
Bacon	❑
Mushrooms (Button)	❑
Red Capsicum	❑
(Margarine)	❑
(Milk)	❑
(Olive Oil)	❑
Lebanese Bread (with Margarine)	❑
Orange Juice	❑
Honey and Banana Muffin	❑

Lunch: Pizza Pockets (x2)
Beverage: Orange Juice

Pita Bread Pockets	❑
Red Capsicum	❑
Cheddar Cheese	❑
Hungarian Salami	❑
Baby Spinach Leaves	❑
Tomato and Onion Relish	❑
Orange Juice	❑

Lunch: Beef Yiros
Beverage: Apple Juice
Dessert: Vanilla Yoghurt and Honey and Banana Muffin

Yiros bread (Pita)	❑
Rump steak	❑
Lettuce	❑
Onion	❑
Tomato	❑
Tzatziki	❑
Grated Mainland Light Cheddar Cheese	❑
(Olive oil)	❑
Apple Juice	❑
Vanilla yoghurt	❑
Honey and banana muffin	❑

Dinner: BBQ Chicken, Mashed Potato, Sweet Corn and Salad
Beverage: Orange Juice
Dessert: Jelly

1/4 Chicken	❑
Potato	❑
(Milk)	❑
(Margarine)	❑
(Parmesan Cheese)	❑
Gravy	❑
Lettuce	❑
Tomato	❑
Onion	❑
Cucumber	❑
Red Capsicum	❑
Carrots	❑
French Salad Dressing	❑
Sweet Corn on the cob	❑
Orange Juice	❑
Vanilla Ice-cream	❑
Fruit Salad (apple, banana, watermelon, strawberries, pineapple)	❑
Orange Jelly	❑

Lunch: Ham, Cheese and Tomato Toasted Sandwiches with Soup
Beverage: Orange juice
Dessert: Yoghurt and Strawberries

Helga's Wholemeal Bread (with Margarine)	❑
Cheddar Cheese	❑
Shaved Leg Ham	❑
Tomato	❑
Tomato Soup	❑
Orange Juice	❑
French Cheesecake Yoghurt	❑
Strawberries	❑

Dinner: Hamburgers with Cheese (x2)
Beverage: Orange Juice
Dessert: Ice-cream, Fruit Salad and Jelly

- [ ] Minced Beef
- [ ] (Onion)
- [ ] (Egg)
- [ ] (Olive Oil)
- [ ] (Breadcrumbs)
- [ ] Lettuce (iceberg)
- [ ] Tomato
- [ ] Beetroot
- [ ] Cheddar Cheese
- [ ] Hamburger Rolls (with Margarine)
- [ ] Mayonnaise
- [ ] Tomato Ketchup

- [ ] Orange Juice

- [ ] Raspberry Jelly
- [ ] Vanilla Ice-Cream
- [ ] Fruit Salad (apple, banana, watermelon, strawberries, pineapple)

Lunch: Turkey Breast and Salad Sandwiches (x2)
Beverage: Orange Juice
Dessert: Yoghurt and Fruit Salad

Helga's Wholemeal Grain Bread (with Margarine)	❑
Shaved Turkey Breast	❑
Avocado	❑
Tomato	❑
Cucumber	❑
Mayonnaise	❑
Orange Juice	❑
Strawberry Yoghurt	❑
Fruit Salad (apple, banana, watermelon, pineapple, strawberries)	❑

Lunch: Chicken and Salad Wrap (x2)
Beverage: Strawberry Nesquik
Dessert: Strawberries and Yoghurt

White Wraps	❑
Shaved Chicken Breast	❑
Grated Carrot	❑
Tomato	❑
Cucumber	❑
Grated Cheddar Cheese	❑
Mayonnaise	❑
Milk	❑
Strawberry Nesquik	❑
Strawberry Yoghurt	❑
Strawberries	❑

Lunch: Ham and Salad Rolls (x2)
Beverage: Apple and Blackcurrant Juice
Dessert: Yoghurt and Banana

Wholemeal Rolls (with Margarine)	❑
Shaved Leg Ham	❑
Grated Carrot	❑
Tomato	❑
Lettuce (Iceberg)	❑
Grated Cheddar Cheese	❑
Mayonnaise	❑
Apple and Blackcurrant Juice	❑
French Cheesecake Yoghurt	❑
Banana	❑

Dinner: Lamb Rogan Josh
Beverage: Apple and Blackcurrant Juice
Dessert: Apple and Ice-Cream

Lamb	❑
Rogan Josh Sauce	❑
White Rice	❑
(Olive Oil)	❑
Pappadums	❑
Apple and Blackcurrant Juice	❑
Apple Pie	❑
Vanilla Ice-Cream	❑

Dinner: Honey and Chilli Chicken Stir-Fry
Beverage: Apple and Blackcurrant Juice
Dessert: Ice-Cream and Fruit Salad

Chicken Breast Fillet	❑
White Rice	❑
Honey and Chilli Sauce	❑
Mushrooms (Button)	❑
Broccoli	❑
Sweet-Corn	❑
Carrots	❑
Red Capsicum	❑
Cashew Nuts	❑
(Olive Oil)	❑
Apple and Blackcurrant Juice	❑
Fruit Salad (apple, banana, watermelon, strawberries, pineapple)	❑
Vanilla Ice-Cream	❑

Dinner: Chicken and Vegetable Pasta
Beverage: Orange Juice
Dessert: Fruit Salad and Ice-Cream

Chicken Breast Fillet	❑
Pasta	❑
Grated Carrot	❑
Mushrooms (Button)	❑
Broccoli	❑
Napolitano Sauce	❑
Parmesan Cheese	❑
(Olive Oil)	❑
Wholemeal Roll (with Margarine)	❑
Orange Juice	❑
Fruit Salad (apple, banana, watermelon, strawberries, pineapple)	❑
Vanilla Ice-Cream	❑

Snacks:

Tiny Teddies (Honey)	❑
Tiny Teddies (Hundreds and Thousands)	❑
Thin Cut Potato Chips	❑
Barbeque Shapes	❑
Mixed Nuts (Dry Roasted No Salt)	❑
Dried Fruit and Nut Mix	❑
Orange Juice	❑

Appendix P: Sleep diary (Studies 1 & 2)

SLEEP DIARY INSTRUCTIONS

STEP ONE: Record the time you go to bed and the time that you get out of bed. Also record the time you that you actually went to sleep and at what time you finally wake up. This should be done for ANY and EVERY sleep period, including short naps.

Also record how many times you woke up during the sleep period, and the TOTAL amount of time you were awake for after you add each of these awakenings together.

STEP TWO: The second step involves rating how sleepy/awake you feel just before you go to bed and as soon as you wake up. Do this using the SLEEPINESS SCALE below. Choose the statement which best describes your state of sleepiness immediately BEFORE and AFTER the sleep period.

SLEEPINESS SCALE
1 = Feeling active and vital. Alert and wide awake
2 = Functioning at a high level but not at peak. Able to concentrate.
3 = Relaxed, awake, responsive, not at full alertness.
4 = A little foggy. Not at peak. Let down.
5 = Fogginess. Beginning to lose interest in remaining awake. Slowed down.
6 = Sleepy. Prefer to be lying down. Fighting sleep. Woozy.
7 = Almost in reverie. Sleep onset will be soon. Lost struggle to remain awake.

STEP THREE: The third step requires a subjective evaluation to be made about how well you slept. Simply select a number from the following scale, and record it in the column marked "SLEEP QUALITY":

HOW YOU SLEPT
1 = Very Well
2 = Well
3 = Average
4 = Poorly
5 = Very Poorly

STEP FOUR: Finally, first thing after waking, please record how many hours of sleep it felt like you obtained. Accuracy is not important – we are more interested in your subjective estimate.

SLEEP DIARY

Name:	Study ID:	

		SLEEP PERIOD[1]						SLEEPINESS[2]		SUBJECTIVE RATINGS[3-4]	
DATE (dd/mm/yy)	DAY (Mon-Sun)	*BED TIME* (hh:mm)	*SLEEP ONSET TIME (hh:mm)*	*WAKE TIME* (hh:mm)	GET UP TIME (hh:mm)	No. OF AWAKENINGS	TOTAL TIME AWAKE (minutes)	BEFORE (1-7)	AFTER (1-7)	SLEEP QUALITY (1-5)	HOURS OF SLEEP

Appendix Q: Standard Shiftwork Index (Study 3)

QUESTIONNAIRE FOR SHIFTWORKERS

1. Your General Information

Please answer the following questions as accurately as possible. Please note that the information you give will be treated in strictest confidence.

1.1 Today's Date: _____

1.2 Age: _____

1.3 Sex: Female Male
(circle one)

1.4. Highest level of education: *(circle one)*

Post graduate
Undergraduate
Vocational
High school completion
Some secondary school completion
Some primary school completion

1.5 Which industry are you employed in? _____

Your Domestic Situation

1.6 Are you: *(tick one)*

(a) Married/Living with a partner _____
(b) Separated/Divorced _____
(c) Widowed _____
(d) Single _____

1.7 How many persons in your household are in each of the following age groups (excluding yourself)?

(a) 0 to 5 years _____
(b) 6 to 12 years _____
(c) 13 to 18 years _____
(d) 19 to 24 years _____
(e) 25 to 60 years _____
(f) 60 years + _____

1.8 How many of these need looking after by **you**? _____

Your General Work Information

1.9 How long have you worked altogether? _____ years

1.10 How long have you worked in your **present** shift system? _____ years_____ months

1.11 How long **altogether** have you been working shifts? _____ years_____ months

1.12 On average, how many hours do you work each week excluding overtime? _____ hours _____ minutes

1.13 On average, how many hours **paid** overtime do you work each week?_____ hours _____minutes

1.14 On average, how many hours unpaid overtime do you work each week, (e.g. over-run of shifts)? _____ hours_____ minutes

1.15 Do you have a second paid job in addition to your main one? _____ yes_____ no
(tick one)

Your Shift Details

1.16 For each of the shifts that **you normally work**, at what time do they start and finish? (Please use 24h time, e.g. 21:30 or clearly indicate "am" or "pm").

		START	**FINISH**
(a)	Morning (or early) shift	_____	_____
(b)	Afternoon (or late, evening or swing) shift	_____	_____
(c)	Half-day shift	_____	_____
(d)	Night shift	_____	_____
(e)	Other ..... *(please specify)*	_____	_____

1.17 For each of the shifts that **you normally work**, on average how many successive shifts of **the same kind** do you normally work before changing to another shift or having some days off?

		NUMBER
(a)	Number of successive morning shifts	_____
(b)	Number of successive afternoon shifts	_____
(c)	Number of successive night shifts	_____
(d)	Total number of successive shifts (of any kind) before days off	_____
(e)	Other ..... *(please specify)*	_____

1.18 What is the maximum number of shifts of any kind you have worked **between** days off in the past month? _____

1.19 On average, how many days off in succession do you normally have? _____

1.20 In general, when changing from one type of shift to another, what type of shift is each shift or day off followed by?

(a) Morning shifts are normally followed by: _____

(b) Afternoon shifts are normally followed by: _____

(c) Night shifts are normally followed by: _____

(d) Other ..... are normally followed by: _____

(e) Days off are normally followed by: _____

1.21 If you work night shifts how are they organised?
(please tick the <u>one</u> which best describes your night work)

(a) permanent nightshift _____
(b) a single block of night duty per year _____
(c) occasional blocks of night duty per year _____
(d) a block of nights each month _____
(e) one or two nights each week _____
(f) any other? (*please specify)* _____

1.22 How regular is the shift system you work?
(please tick one)

(a) **REGULAR** i.e. a fixed roster which is repeated when the cycle of shifts finishes, even if occasional variations occur to meet special requests. _____

(b) **IRREGULAR** i.e. the duty roster does not cycle or repeat in any regular manner and individual preferences are not taken into account. _____

(c) **FLEXIBLE** i.e. where the individuals concerned are consulted about their preferred duty hours before the duty roster is drawn up. _____

1.23 If your shift system is **regular**, over how many weeks does the cycle run before it is repeated? _____

1.24 Use the numbers 1 - 5 to rate **your** workload in comparison to the **average** workload of other people performing a similar job in other parts of your organisation:

Where: 1 = Extremely light
2 = Quite light
3 = About the same

4 = Quite heavy
5 = Extremely heavy
(Insert one number for each type of workload on each shift)

		Morning	**Afternoon**	**Night**
(a)	Physical workload	_____	_____	_____
(b)	Mental workload	_____	_____	_____
(c)	Time pressures	_____	_____	_____
(d)	Emotional stress	_____	_____	_____

1.25 What are your main reasons for working shifts?
(please circle one number for each)

		Not a reason for me		**Partly a reason for me**		**Very much a reason for me**
(a)	It is part of the job	1	2	3	4	5
(b)	It was the only job available	1	2	3	4	5
(c)	More convenient for my domestic responsibilities	1	2	3	4	5
(d)	Higher rates of pay	1	2	3	4	5
(e)	Other ..... *(please give your reasons)*	1	2	3	4	5

2. Your Sleep and Fatigue

2.1 At what time do you normally fall asleep and wake up at the following points within your shift system? **Please note that, depending on your shift system, some of the sleeps listed may be the same as one another. If so, please indicate this by writing "same as e"; "same as g", etc.** Please use 24h time (e.g. 22:30) or clearly indicate "am" or "pm".

		FALL ASLEEP	**WAKE UP**
EARLY SHIFT			
(a)	Before your first morning shift	_____	_____
(b)	Between two successive morning shifts	_____	_____
(c)	After your last morning shift	_____	_____
LATE SHIFT			
(d)	Before your first afternoon shift	_____	_____

(e) Between two successive afternoon shifts _____ _____

(f) After your last afternoon shift _____ _____

NIGHT SHIFT

(g) Before your first night shift _____ _____

(h) Between two successive night shifts _____ _____

(i) After your last night shift _____ _____

DAY OFF

(j) Before your first day off _____ _____

(k) Between two successive days off _____ _____

(l) After your last day off _____ _____

2.2 If you normally take a nap/naps in addition to your main sleep, either at work or at home, at what time do you take it/them?

(a) On morning shifts from _____ to _____ and from _____ to _____
(b) On afternoon shifts from _____ to _____ and from _____ to _____
(c) On night shifts from _____ to _____ and from _____ to _____
(d) On days off from _____ to _____ and from _____ to _____

2.3 How many hours sleep do you feel you usually need per day, irrespective of which shift you are on?

_____ hours _____ minutes

2.4 How do you feel about the amount of sleep you normally get? *(Circle one number for each)*

		Nowhere near enough	**Could do with a lot more**	**Could do with a bit more**	**Get the right amount**	**Get**
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.5 How well do you normally sleep? *(Circle one number for each)*

		Extre-mely badly	Quite badly	Moder-ately well	Quite well	Extre-mely well
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.6 How rested do you normally feel after sleep? *(Circle one number for each)*

		Definite-ly not rested	Not very rested	Moder-ately rested	Quite rested	Extre-mely rested
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.7 Do you ever wake up earlier than you intended? *(Circle one number for each)*

		Almost never	Rarely	Some-times	Frequ-ently	Almost always
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.8 Do you have difficulty in falling asleep? *(Circle one number for each)*

		Almost never	Rarely	Some-times	Frequ-ently	Almost always
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.9 Do you take sleeping pills? *(Circle one number for each)*

		Almost never	Rarely	Some-times	Frequ-ently	Almost always
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.10 Do you use alcohol to help you to sleep? *(Circle one number for each)*

		Almost never	Rarely	Some-times	Frequ-ently	Almost always
(a)	Between successive morning shifts	1	2	3	4	5
(b)	Between successive afternoon shifts	1	2	3	4	5
(c)	Between successive night shifts	1	2	3	4	5
(d)	Between successive days off	1	2	3	4	5

2.11 Do you ever feel tired on: *(Circle one number for each)*

		Almost never	Rarely	Some-times	Frequ-ently	Almost always
(a)	Morning shifts	1	2	3	4	5
(b)	Afternoon shifts	1	2	3	4	5
(c)	Night shifts	1	2	3	4	5
(d)	Days off	1	2	3	4	5

2.12 The following items relate to how tired or energetic **you generally feel**, irrespective of whether you have had enough sleep or have been working very hard. Some people appear to "suffer" from permanent tiredness, even on rest days and holidays, while others seem to have limitless energy. Please indicate the degree to which the following statements apply to your own normal feelings. *(Circle one number for each).*

		Not at all		**Some-what**	**Very much so**	
(a)	I generally feel I have plenty of energy	1	2	3	4	5
(b)	I usually feel drained	1	2	3	4	5
(c)	I generally feel quite active	1	2	3	4	5
(d)	I feel tired most of the time	1	2	3	4	5
(e)	I generally feel full of vigour	1	2	3	4	5
(f)	I usually feel rather lethargic	1	2	3	4	5
(g)	I generally feel alert	1	2	3	4	5
(h)	I often feel exhausted	1	2	3	4	5
(i)	I usually feel lively	1	2	3	4	5
(j)	I feel weary much of the time	1	2	3	4	5

2.13 Do you have any other comments or observations relating to your sleep and fatigue that have not been covered in the above section? If so, please try to describe them here:-

.....

.....

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3. Your Health and Well-Being

3.1 Please indicate how frequently you experience the following, by circling the appropriate number:

		Almost never	Quite seldom	Quite often	Always
(a)	How often is your appetite disturbed?	1	2	3	4
(b)	How often do you have to watch what you eat to avoid stomach upsets?	1	2	3	4
(c)	How often do you feel nauseous?	1	2	3	4
(d)	How often do you suffer from heartburn or stomach-ache?	1	2	3	4
(e)	How often do you complain of digestion difficulties?	1	2	3	4
(f)	How often do you suffer from bloated stomach or flatulence?	1	2	3	4
(g)	How often do you suffer from pain in your abdomen?	1	2	3	4
(h)	How often do you suffer from constipation or diarrhoea?	1	2	3	4
(i)	How often do you suffer from heart palpitations?	1	2	3	4
(j)	How often do you suffer from aches and pains in your chest?	1	2	3	4
(k)	How often do you suffer from dizziness?	1	2	3	4
(l)	How often do you suffer from sudden rushes of blood to your head?	1	2	3	4
(m)	Do you suffer from shortness of breath when climbing the stairs normally?	1	2	3	4
(n)	How often have you been told that you have high blood pressure?	1	2	3	4
(o)	Have you ever been aware of your heart beating irregularly?	1	2	3	4
(p)	Do you suffer from swollen feet?	1	2	3	4
(q)	How often do you feel "tight" in your chest?	1	2	3	4
(r)	Do you feel you have put on too much weight since beginning shiftwork?	1	2	3	4
(s)	Do you feel you have lost too much weight				

since beginning shiftwork? 1 2 3 4

3.2 Have you suffered from any of the following (diagnosed by your doctor)?

		Before starting shiftwork	**Since starting shiftwork**	**Never**
(a)	Chronic back pain	.....	.....	.....
(b)	Gastritis, duodenitis	.....	.....	.....
(c)	Gastric or duodenal ulcer	.....	.....	.....
(d)	Gall stones	.....	.....	.....
(e)	Colitis	.....	.....	.....
(f)	Sinusitis, tonsillitis	.....	.....	.....
(g)	Bronchial asthma	.....	.....	.....
(h)	Angina	.....	.....	.....
(i)	Severe heart attack (myocardial infarction)	.....	.....	.....
(j)	High blood pressure	.....	.....	.....
(k)	Cardiac arrhythmias	.....	.....	.....
(l)	Hypercholesterolaemia	.....	.....	.....
(m)	Diabetes	.....	.....	.....
(n)	Cystitis	.....	.....	.....
(o)	Kidney stones	.....	.....	.....
(p)	Eczema	.....	.....	.....
(q)	Chronic anxiety	.....	.....	.....
(r)	Depression	.....	.....	.....
(s)	Arthritis	.....	.....	.....
(t)	Haemorrhoids	.....	.....	.....
(u)	Varicose veins	.....	.....	.....
(v)	Anaemia	.....	.....	.....
(w)	Headaches	.....	.....	.....
(x)	Others	.....	.....	.....
	.....	.....	.....	.....

3.3 Have you taken any of the following medications for prolonged periods (more than three months)?

		Before starting shiftwork	Since starting shifwork	Never
(a)	Tranquillizers	.....	.....	.....
(b)	Sleeping tablets	.....	.....	.....
(c)	Anti-depressants	.....	.....	.....
(d)	Antacids	.....	.....	.....
(e)	Antispasmodics	.....	.....	.....
(f)	Laxatives	.....	.....	.....

		Before starting shiftwork	Since starting shifwork	Never
(g)	Drugs to control high blood pressure	.....	.....	.....
(h)	Diuretics	.....	.....	.....
(i)	Heart medicines	.....	.....	.....
(j)	Vasodilators	.....	.....	.....
(k)	Bronchodilators	.....	.....	.....
(l)	Vitamins, tonics	.....	.....	.....
(m)	Pain killers	.....	.....	.....
(n)	Steroids	.....	.....	.....
(o)	Anti-inflammatory medicines	.....	.....	.....
(p)	Hormones (except contraceptive pills)	.....	.....	.....
(q)	Others	.....	.....	.....
	.....	.....	.....	.....

		Before starting shiftwork	Since starting shiftwork
3.4	On average, how many cigarettes have you smoked per week?	.....	.....
3.5	On average, how many units of alcohol have you drunk per week? (e.g. 1 unit = 1/2 pint lager/ bitter **or** 1 glass of wine **or** 1 measure of spirit)	.....	.....

			Small	Medium	Large
3.6	On average, how many cups of caffeinated coffee Do you drink each day? *(please state type and size)*	**Instant**	…….	……..	……
		Espresso	…….	……..	……...
		Brewed	…….	……..	……

		Weak	Medium	Strong
	On average, how many cups of black tea Do you drink each day? *(please state strength and size)*	……..	……	……

		375ml	600ml
	On average, how many energy drinks Do you drink each day? *(please indicate the size)*	……	……
	On average, how many soft drinks Do you drink each day? *(please indicate the size)*	……	……

	On average, how many other drinks Do you drink each day? Eg milk drinks (iced coffee) *(please indicate the type of drink and size)*	Drink: …….. **Size:……..ml/glasses**

		Bars	Pieces
	On average, how many bars or pieces of chocolate Do you eat each day?	……	……

3.7 If appropriate, and you are not taking a birth control pill, has your menstrual cycle been:

		Extremely irregular	Fairly irregular	Fairly regular	Extremely regular
(a)	Before starting shiftwork	1	2	3	4
(b)	Since starting shiftwork	1	2	3	4

3.8 The following questions deal with **how you have felt in general over the past few weeks.** Please circle the most appropriate answer for each question. Remember to concentrate on present and recent complaints, not those that you have had in the distant past.

Have you recently:

(a)	been able to concentrate on what you are doing?	Better than usual	Same as usual	Less than usual	Much less than usual
(b)	lost much sleep over worry?	Not at all	No more than usual	Rather more than usual	Much more than usual
(c)	felt that you are playing a useful part in things?	More so than usual	Same as usual	Less than usual	Much less than usual
(d)	felt capable of making decisions about things?	More so than usual	Same as usual	Less than usual	Much less than usual
(e)	felt constantly under strain?	Not at all	No more than usual	Rather more than usual	Much more than usual
(f)	felt you could not overcome your difficulties?	Not at all	No more than usual	Rather more than usual	Much more than usual
(g)	been able to enjoy your normal day to day activities?	More so than usual	Same as usual	Less than usual	Much less than usual
(h)	been able to face up to your problems?	More so than usual	Same as usual	Less than usual	Much less than usual
(i)	been feeling unhappy and depressed?	Not at all	No more than usual	Rather more than usual	Much more than usual
(j)	been losing confidence in yourself?	Not at all	No more than usual	Rather more than usual	Much more than usual
(k)	been thinking of yourself as a worthless person?	Not at all	No more than usual	Rather more than usual	Much more than usual
(l)	been feeling reasonably happy all things considered?	More so than usual	About the same	Less so than usual	Much less than usual

3.9 What is your height in cm? _____

3.10 What is your weight in kg? _____

3.11 How many hours of physical activity do you participate in per week? _____

3.12 Below are listed some descriptions of **symptoms of anxiety.**

Please indicate the degree to which you **generally** or **typically** experience the symptom when **you are feeling anxious.**

		Not at all		**Some-what**		**Very much so**
(a)	I perspire	1	2	3	4	5
(b)	My heart beats faster	1	2	3	4	5
(c)	I worry too much over something that doesn't really matter	1	2	3	4	5
(d)	I feel jittery in my body	1	2	2	4	5
(e)	I imagine terrifying scenes	1	2	3	4	5
(f)	I get diarrhoea	1	2	3	4	5
(g)	I can't keep anxiety provoking pictures out of my mind	1	2	3	4	5
(h)	I feel tense in my stomach	1	2	3	4	5
(i)	Some unimportant thought runs through my mind and bothers me	1	2	3	4	5
(j)	I nervously pace	1	2	3	4	5
(k)	I feel like I am losing out on things because I can't make up my mind soon enough	1	2	3	4	5
(l)	I feel physically immobilised	1	2	3	4	5
(m)	I can't keep anxiety provoking thoughts out of my mind	1	2	3	4	5
(n)	I find it difficult to concentrate because of uncontrollable thoughts	1	2	3	4	5

4. Your choice of food

Several different factors influence our choice of food. For every person, there will be a different set of factors that is important. In the next set of questions, we are interested in finding out what factors influence *your choice of food*. Listed below are a series of factors that may be relevant to your choice of foods. Read each item carefully and decide how important the item is to you.

Put a **tick in the box** that best reflects your feelings. Remember, there are no right or wrong answers - we are interested in *what is important to you*.

It is important to me that the food I eat on a typical day:		***Not important at all***	***A little important***	***Moderately important***	***Very importa***
1	is easy to prepare				
2	contains no additives				
3	is low in calories				
4	tastes good				
5	contains natural ingredients				
6	is not expensive				
7	is low in fat				
8	is familiar to me				
9	is high in fibre and roughage				
10	is nutritious				
11	is easily available in shops and supermarkets				
12	is good value for money				
13	cheers me up				
14	smells nice				
15	can be cooked very simply				
16	helps me cope with stress				
17	helps me control my weight				
18	has a pleasant texture				
19	is packaged in an environmentally friendly way				
20	comes from countries I approve of politically				
21	is like the food I ate when I was a child				
22	contains lots of vitamins and minerals				
23	contains no artificial ingredients				
24	keeps me awake and alert				
25	looks nice				
26	helps me relax				

It is important to me that the food I eat on a typical day:		*Not important at all*	*A little important*	*Moderately important*	*Very important*
27	is high in protein				
28	takes no time to prepare				
29	keeps me healthy				
30	is good for my skin/teeth/hair/nails etc				
31	makes me feel good				
32	has the country of origin clearly marked				
33	is what I usually eat				
34	helps me to cope with life				
35	can be bought in shops close to where I live or work				
36	is cheap				

Please make sure you have answered every item

Do you have any other comments or observations relating to your experiences as a shiftworker that have not been covered in this questionnaire? If so, please try to describe them here:

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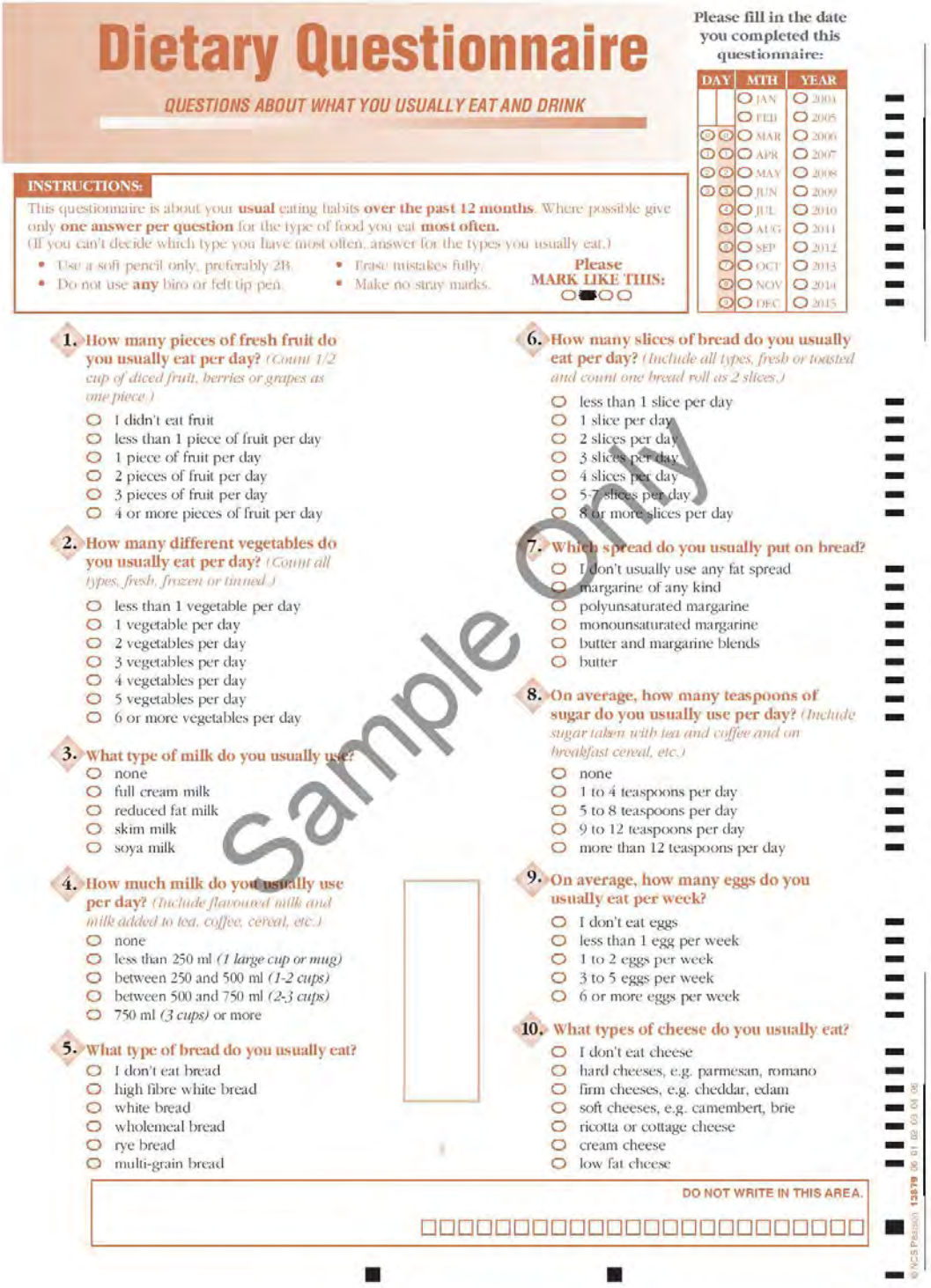
GENERAL INFORMATION

- Some people experience severe health, sleep or emotional problems as a result of working shifts. It is possible that completing this questionnaire may have drawn your attention to problems you experience as a result of shiftwork and/or other factors. If you feel that talking to someone might help with these problems we would strongly advise you to contact your GP. If they cannot help you they should be able to put you in contact with someone who can.

Can you please check that you have answered all the questions, but please do not alter any of your answers.

Thank you for filling in this questionnaire.

Appendix R: Dietary questionnaire (Study 3)



Dietary Questionnaire

QUESTIONS ABOUT WHAT YOU USUALLY EAT AND DRINK

Please fill in the date you completed this questionnaire:

DAY	MTH	YEAR
	○ JAN	○ 2004
	○ FEB	○ 2005
○ ○	○ MAR	○ 2006
○ ○	○ APR	○ 2007
○ ○	○ MAY	○ 2008
○ ○	○ JUN	○ 2009
	○ JUL	○ 2010
	○ AUG	○ 2011
	○ SEP	○ 2012
	○ OCT	○ 2013
	○ NOV	○ 2014
	○ DEC	○ 2015

INSTRUCTIONS:

This questionnaire is about your **usual** eating habits **over the past 12 months**. Where possible give only **one answer per question** for the type of food you eat **most often.**
(If you can't decide which type you have most often, answer for the types you usually eat.)

- Use a soft pencil only, preferably 2B.
- Do not use **any** biro or felt tip pen.
- Erase mistakes fully.
- Make no stray marks.

Please MARK LIKE THIS: ○■○○

1. How many pieces of fresh fruit do you usually eat per day? *(Count 1/2 cup of diced fruit, berries or grapes as one piece.)*

- ○ I didn't eat fruit
- ○ less than 1 piece of fruit per day
- ○ 1 piece of fruit per day
- ○ 2 pieces of fruit per day
- ○ 3 pieces of fruit per day
- ○ 4 or more pieces of fruit per day

2. How many different vegetables do you usually eat per day? *(Count all types, fresh, frozen or tinned.)*

- ○ less than 1 vegetable per day
- ○ 1 vegetable per day
- ○ 2 vegetables per day
- ○ 3 vegetables per day
- ○ 4 vegetables per day
- ○ 5 vegetables per day
- ○ 6 or more vegetables per day

3. What type of milk do you usually use?

- ○ none
- ○ full cream milk
- ○ reduced fat milk
- ○ skim milk
- ○ soya milk

4. How much milk do you usually use per day? *(Include flavoured milk and milk added to tea, coffee, cereal, etc.)*

- ○ none
- ○ less than 250 ml *(1 large cup or mug)*
- ○ between 250 and 500 ml *(1-2 cups)*
- ○ between 500 and 750 ml *(2-3 cups)*
- ○ 750 ml *(3 cups)* or more

5. What type of bread do you usually eat?

- ○ I don't eat bread
- ○ high fibre white bread
- ○ white bread
- ○ wholemeal bread
- ○ rye bread
- ○ multi-grain bread

6. How many slices of bread do you usually eat per day? *(Include all types, fresh or toasted and count one bread roll as 2 slices.)*

- ○ less than 1 slice per day
- ○ 1 slice per day
- ○ 2 slices per day
- ○ 3 slices per day
- ○ 4 slices per day
- ○ 5-7 slices per day
- ○ 8 or more slices per day

7. Which spread do you usually put on bread?

- ○ I don't usually use any fat spread
- ○ margarine of any kind
- ○ polyunsaturated margarine
- ○ monounsaturated margarine
- ○ butter and margarine blends
- ○ butter

8. On average, how many teaspoons of sugar do you usually use per day? *(Include sugar taken with tea and coffee and on breakfast cereal, etc.)*

- ○ none
- ○ 1 to 4 teaspoons per day
- ○ 5 to 8 teaspoons per day
- ○ 9 to 12 teaspoons per day
- ○ more than 12 teaspoons per day

9. On average, how many eggs do you usually eat per week?

- ○ I don't eat eggs
- ○ less than 1 egg per week
- ○ 1 to 2 eggs per week
- ○ 3 to 5 eggs per week
- ○ 6 or more eggs per week

10. What types of cheese do you usually eat?

- ○ I don't eat cheese
- ○ hard cheeses, e.g. parmesan, romano
- ○ firm cheeses, e.g. cheddar, edam
- ○ soft cheeses, e.g. camembert, brie
- ○ ricotta or cottage cheese
- ○ cream cheese
- ○ low fat cheese

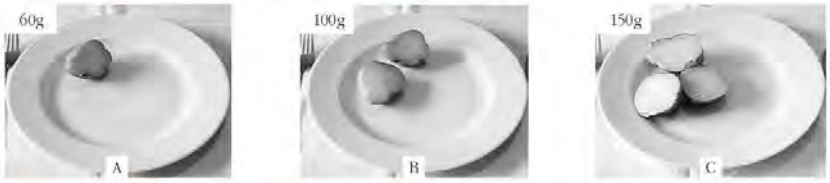
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Sample Only

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For each food shown on this page, indicate ***how much on average you would usually have eaten at main meals during the past 12 months.*** *When answering each question, think of the* ***amount*** *of that food you usually ate, even though you may rarely have eaten the food on its own.*
If you usually ate more than one helping, fill in the oval for the serving size closest to the ***total amount*** *you ate.*

11. When you ate potato, did you usually eat: ○ I never ate potato



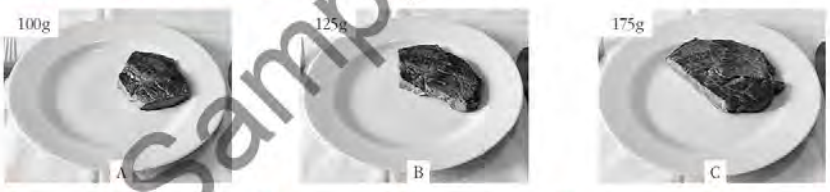
○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

12. When you ate vegetables, did you usually eat: ○ I never ate vegetables



○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

13. When you ate steak, did you usually eat: ○ I never ate steak



○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

14. When you ate meat *or* vegetable casserole, did you usually eat: ○ I never ate casserole



○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

Sample Only

15. **Over the last 12 months, on average, *how often* did you eat the following foods?** *Please completely fill one oval in every line.* Please MARK LIKE THIS: ● NOT LIKE THIS: ⊘ ⊗ ⊖

Times You Have Eaten		NEVER	less than once per month	1 to 3 times per month	1 time per week	2 times per week	3 to 4 times per week	5 to 6 times per week	1 time per day	2 times per day	3 or more times per day
CEREAL FOODS, SWEETS & SNACKS											
All Bran™	A1	○	○	○	○	○	○	○	○	○	○
Sultana Bran™, FibrePlus™, Branflakes™	A2	○	○	○	○	○	○	○	○	○	○
Weet Bix™, Vita Brits™, Weeties™	A3	○	○	○	○	○	○	○	○	○	○
Cornflakes, Nutrigrain™, Special K™	A4	○	○	○	○	○	○	○	○	○	○
Porridge	A5	○	○	○	○	○	○	○	○	○	○
Muesli	A6	○	○	○	○	○	○	○	○	○	○
Rice	A7	○	○	○	○	○	○	○	○	○	○
Pasta or noodles (include lasagne)	A8	○	○	○	○	○	○	○	○	○	○
Crackers, crispbreads, dry biscuits	A9	○	○	○	○	○	○	○	○	○	○
Sweet biscuits	A10	○	○	○	○	○	○	○	○	○	○
Cakes, sweet pies, tarts and other sweet pastries	A11	○	○	○	○	○	○	○	○	○	○
Meat pies, pasties, quiche and other savoury pastries	A12	○	○	○	○	○	○	○	○	○	○
Pizza	A13	○	○	○	○	○	○	○	○	○	○
Hamburger with a bun	A14	○	○	○	○	○	○	○	○	○	○
Chocolate	A15	○	○	○	○	○	○	○	○	○	○
Flavoured milk drink (cocoa, Milo™, etc.)	A16	○	○	○	○	○	○	○	○	○	○
Nuts	A17	○	○	○	○	○	○	○	○	○	○
Peanut butter or peanut paste	A18	○	○	○	○	○	○	○	○	○	○
Corn chips, potato crisps, Twisties™, etc.	A19	○	○	○	○	○	○	○	○	○	○
Jam, marmalade, honey or syrups	A20	○	○	○	○	○	○	○	○	○	○
Vegemite™, Marmite™ or Promite™	A21	○	○	○	○	○	○	○	○	○	○
DAIRY PRODUCTS, MEAT & FISH											
Cheese	B1	○	○	○	○	○	○	○	○	○	○
Ice-cream	B2	○	○	○	○	○	○	○	○	○	○
Yoghurt	B3	○	○	○	○	○	○	○	○	○	○
Beef	B4	○	○	○	○	○	○	○	○	○	○
Veal	B5	○	○	○	○	○	○	○	○	○	○
Chicken	B6	○	○	○	○	○	○	○	○	○	○
Lamb	B7	○	○	○	○	○	○	○	○	○	○
Pork	B8	○	○	○	○	○	○	○	○	○	○
Bacon	B9	○	○	○	○	○	○	○	○	○	○
Ham	B10	○	○	○	○	○	○	○	○	○	○
Corned beef, luncheon meats or salami	B11	○	○	○	○	○	○	○	○	○	○
Sausages or frankfurters	B12	○	○	○	○	○	○	○	○	○	○
Fish, steamed, grilled or baked	B13	○	○	○	○	○	○	○	○	○	○
Fish, fried (include take-away)	B14	○	○	○	○	○	○	○	○	○	○
Fish, tinned (salmon, tuna, sardines, etc.)	B15	○	○	○	○	○	○	○	○	○	○
FRUIT											
Tinned or frozen fruit (any kind)	C1	○	○	○	○	○	○	○	○	○	○
Fruit juice	C2	○	○	○	○	○	○	○	○	○	○
Oranges or other citrus fruit	C3	○	○	○	○	○	○	○	○	○	○
Apples	C4	○	○	○	○	○	○	○	○	○	○
Pears	C5	○	○	○	○	○	○	○	○	○	○
Bananas	C6	○	○	○	○	○	○	○	○	○	○
Watermelon, rockmelon (cantaloupe), honeydew, etc.	C7	○	○	○	○	○	○	○	○	○	○
Pineapple	C8	○	○	○	○	○	○	○	○	○	○
Strawberries	C9	○	○	○	○	○	○	○	○	○	○
Apricots	C10	○	○	○	○	○	○	○	○	○	○
Peaches or nectarines	C11	○	○	○	○	○	○	○	○	○	○
Mango or paw paw	C12	○	○	○	○	○	○	○	○	○	○
Avocado	C13	○	○	○	○	○	○	○	○	○	○

Sample Only

Times You Have Eaten CONTINUED

		NEVER	less than once per month	1 to 3 times per month	1 time per week	2 times per week	3 to 4 times per week	5 to 6 times per week	1 time per day	2 times per day	3 or more times per day
VEGETABLES (INCLUDING FRESH, FROZEN AND TINNED)											
Potatoes, roasted or fried (include hot chips)	D1	○	○	○	○	○	○	○	○	○	○
Potatoes cooked without fat	D2	○	○	○	○	○	○	○	○	○	○
Tomato sauce, tomato paste or dried tomatoes	D3	○	○	○	○	○	○	○	○	○	○
Fresh or tinned tomatoes	D4	○	○	○	○	○	○	○	○	○	○
Peppers (capsicum)	D5	○	○	○	○	○	○	○	○	○	○
Lettuce, endive, or other salad greens	D6	○	○	○	○	○	○	○	○	○	○
Cucumber	D7	○	○	○	○	○	○	○	○	○	○
Celery	D8	○	○	○	○	○	○	○	○	○	○
Beetroot	D9	○	○	○	○	○	○	○	○	○	○
Carrots	D10	○	○	○	○	○	○	○	○	○	○
Cabbage or Brussels sprouts	D11	○	○	○	○	○	○	○	○	○	○
Cauliflower	D12	○	○	○	○	○	○	○	○	○	○
Broccoli	D13	○	○	○	○	○	○	○	○	○	○
Silverbeet or spinach	D14	○	○	○	○	○	○	○	○	○	○
Peas	D15	○	○	○	○	○	○	○	○	○	○
Green beans	D16	○	○	○	○	○	○	○	○	○	○
Bean sprouts or alfalfa sprouts	D17	○	○	○	○	○	○	○	○	○	○
Baked beans	D18	○	○	○	○	○	○	○	○	○	○
Soy beans, soy bean curd or tofu	D19	○	○	○	○	○	○	○	○	○	○
Other beans (include chick peas, lentils, etc.)	D20	○	○	○	○	○	○	○	○	○	○
Pumpkin	D21	○	○	○	○	○	○	○	○	○	○
Onion or leeks	D22	○	○	○	○	○	○	○	○	○	○
Garlic (not garlic tablets)	D23	○	○	○	○	○	○	○	○	○	○
Mushrooms	D24	○	○	○	○	○	○	○	○	○	○
Zucchini	D25	○	○	○	○	○	○	○	○	○	○

16. **Over the last 12 months, how often did you drink beer, wine and/or spirits?**

Times That You Drank

		NEVER	less than once a month	1-3 days per month	1 day per week	2 days per week	3 days per week	4 days per week	5 days per week	6 days per week	every day
Beer (low alcohol)	1	○	○	○	○	○	○	○	○	○	○
Beer (full strength)	2	○	○	○	○	○	○	○	○	○	○
Red wine	3	○	○	○	○	○	○	○	○	○	○
White wine (include sparkling wines)	4	○	○	○	○	○	○	○	○	○	○
Fortified wines, port, sherry, etc.	5	○	○	○	○	○	○	○	○	○	○
Spirits, liqueurs, etc.	6	○	○	○	○	○	○	○	○	○	○

When answering the next two questions, please convert the amounts you drank into glasses using the examples given below. For spirits, liqueurs, and mixed drinks containing spirits, please count each nip (30 ml) as one glass.

1 can or stubby of beer = 2 glasses
1 large bottle beer (750 ml) = 4 glasses
1 bottle wine (750 ml) = 6 glasses
1 bottle of port or sherry (750 ml) = 12 glasses

17. **Over the last 12 months, on days when you were drinking, how many glasses of beer, wine and/or spirits altogether did you *usually* drink?**

TOTAL NUMBER OF GLASSES PER DAY	1	2	3	4	5	6	7	8	9	10 or more
	○	○	○	○	○	○	○	○	○	○

18. **Over the last 12 months, what was the *maximum* number of glasses of beer, wine and/or spirits that you drank in 24 hours?**

MAXIMUM NUMBER OF GLASSES PER 24 HOURS	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19 or more
	○	○	○	○	○	○	○	○	○	○

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Thank You for completing this questionnaire

DO NOT WRITE IN THIS AREA.

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Sample Only

Appendix S: Profile of Mood States (Studies 1 & 2)

SCANTRON® FORM NO. T-101256-POMS 4887-C011-5 4

NAME _____ DATE _____

SEX: Male (M) Female (F)

IDENTIFICATION

Below is a list of words that describe feelings people have. Please read each one carefully. Then fill in ONE circle under the answer to the right which best describes HOW YOU HAVE BEEN FEELING DURING THE PAST WEEK INCLUDING TODAY.

The numbers refer to these phrases.

0 = Not at all
1 = A little
2 = Moderately
3 = Quite a bit
4 = Extremely

Col (C) O.P. (O)

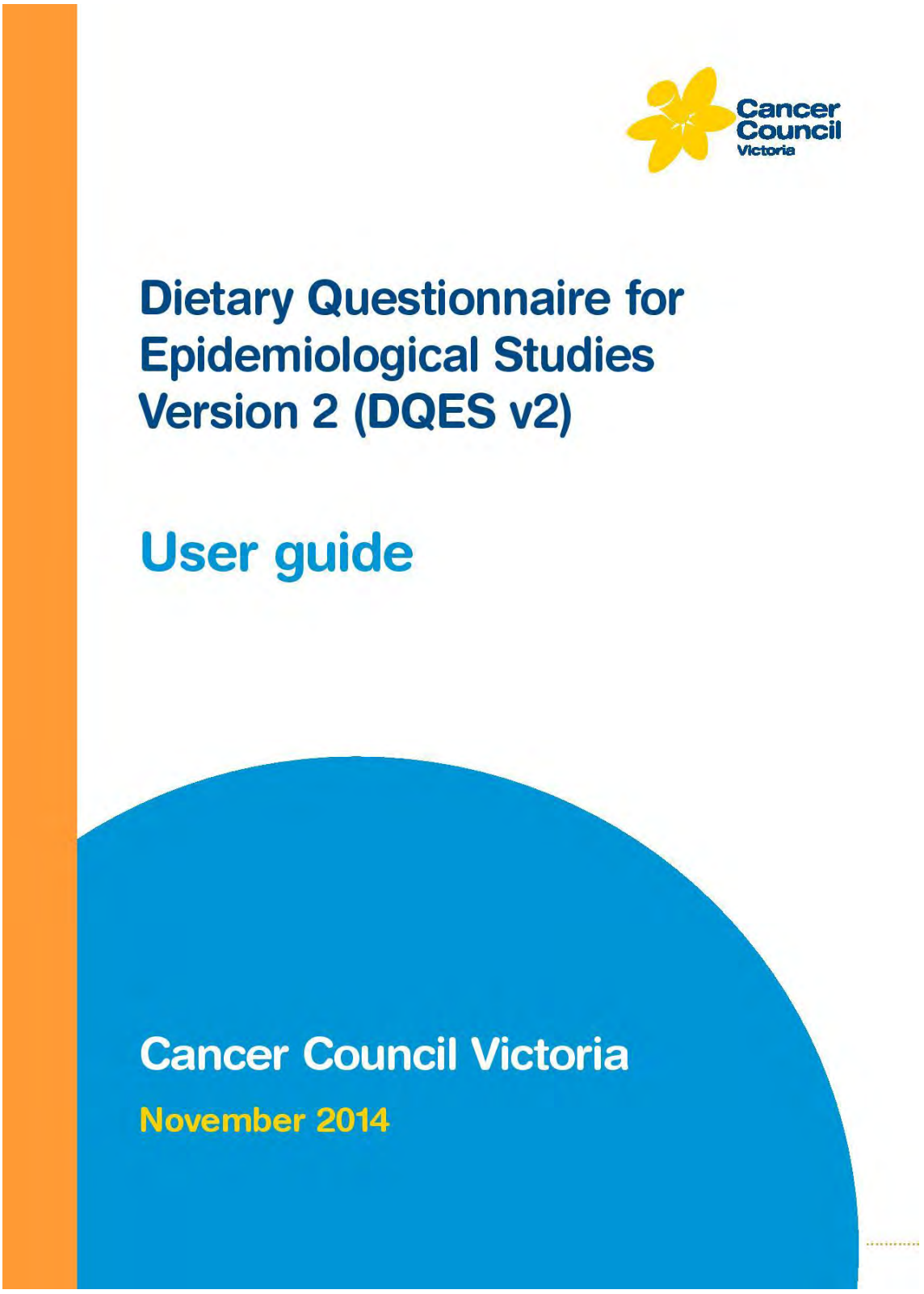
	NOT AT ALL	A LITTLE	MODERATELY	QUITE A BIT	EXTREMELY
1. Friendly	0	1	2	3	4
2. Tense	0	1	2	3	4
3. Angry	0	1	2	3	4
4. Worn out	0	1	2	3	4
5. Unhappy	0	1	2	3	4
6. Clear-headed	0	1	2	3	4
7. Lively	0	1	2	3	4
8. Confused	0	1	2	3	4
9. Sorry for things done	0	1	2	3	4
10. Shaky	0	1	2	3	4
11. Listless	0	1	2	3	4
12. Peeved	0	1	2	3	4
13. Considerate	0	1	2	3	4
14. Sad	0	1	2	3	4
15. Active	0	1	2	3	4
16. On edge	0	1	2	3	4
17. Grouchy	0	1	2	3	4
18. Blue	0	1	2	3	4
19. Energetic	0	1	2	3	4
20. Panicky	0	1	2	3	4
21. Hopeless	0	1	2	3	4
22. Relaxed	0	1	2	3	4
23. Unworthy	0	1	2	3	4
24. Spiteful	0	1	2	3	4
25. Sympathetic	0	1	2	3	4
26. Uneasy	0	1	2	3	4
27. Restless	0	1	2	3	4
28. Unable to concentrate	0	1	2	3	4
29. Fatigued	0	1	2	3	4
30. Helpful	0	1	2	3	4
31. Annoyed	0	1	2	3	4
32. Discouraged	0	1	2	3	4
33. Resentful	0	1	2	3	4
34. Nervous	0	1	2	3	4
35. Lonely	0	1	2	3	4
36. Miserable	0	1	2	3	4
37. Muddled	0	1	2	3	4
38. Cheerful	0	1	2	3	4
39. Bitter	0	1	2	3	4
40. Exhausted	0	1	2	3	4
41. Anxious	0	1	2	3	4
42. Ready to fight	0	1	2	3	4
43. Good natured	0	1	2	3	4
44. Gloomy	0	1	2	3	4
45. Desperate	0	1	2	3	4
46. Sluggish	0	1	2	3	4
47. Rebellious	0	1	2	3	4
48. Helpless	0	1	2	3	4
49. Weary	0	1	2	3	4
50. Bewildered	0	1	2	3	4
51. Alert	0	1	2	3	4
52. Deceived	0	1	2	3	4
53. Furious	0	1	2	3	4
54. Efficient	0	1	2	3	4
55. Trusting	0	1	2	3	4
56. Full of pep	0	1	2	3	4
57. Bad-tempered	0	1	2	3	4
58. Worthless	0	1	2	3	4
59. Forgetful	0	1	2	3	4
60. Carefree	0	1	2	3	4
61. Terrified	0	1	2	3	4
62. Guilty	0	1	2	3	4
63. Vigorous	0	1	2	3	4
64. Uncertain about things	0	1	2	3	4
65. Bushed	0	1	2	3	4

MAKE SURE YOU HAVE ANSWERED EVERY ITEM.

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Appendix T: Dietary Questionnaire for Epidemiological Studies Version 2 User Guide (Study 3)



Dietary Questionnaire for Epidemiological Studies Version 2 (DQESv2)

User guide

November 2014

Updated January 2015

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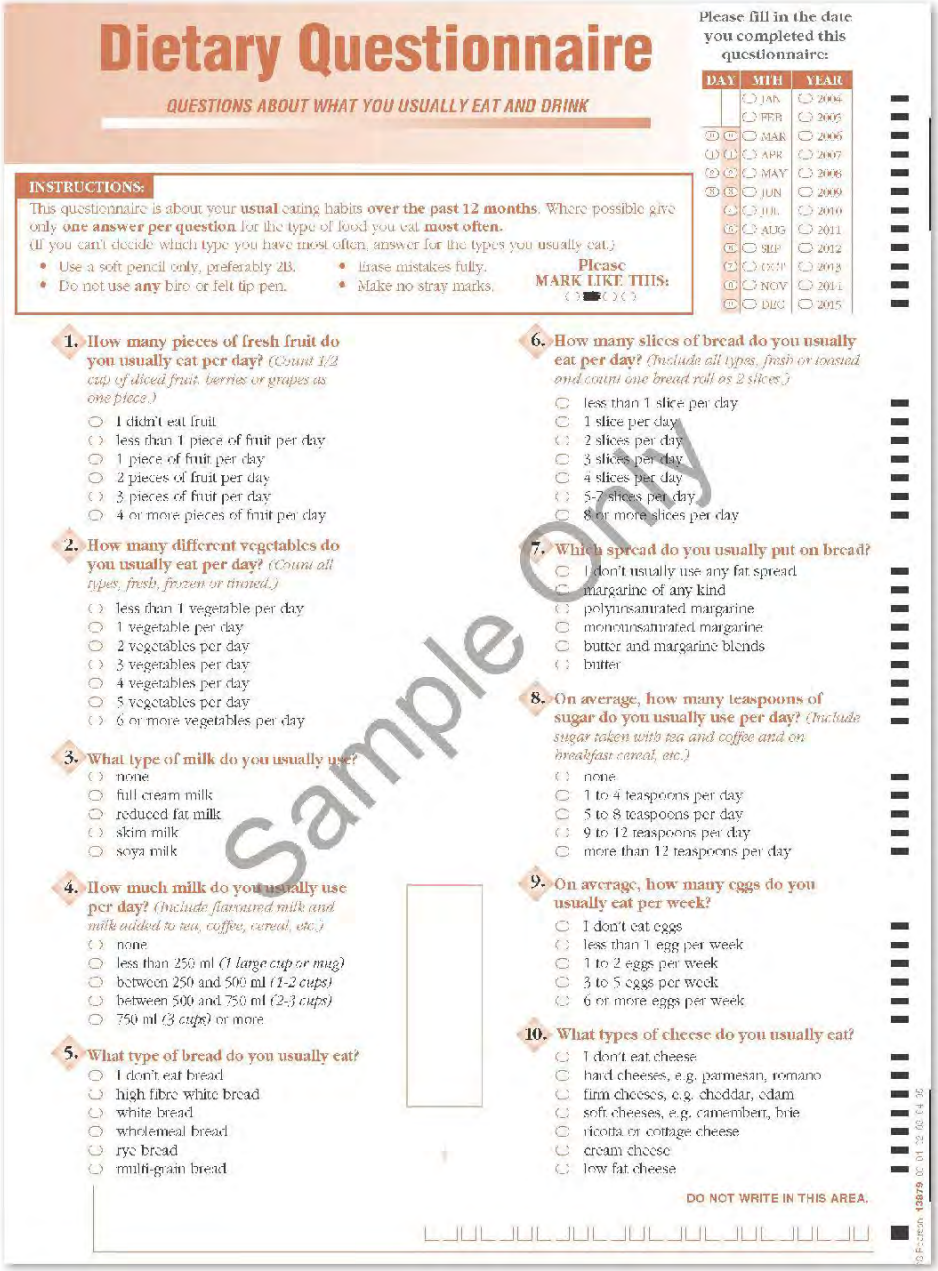
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1 Dietary Questionnaire for Epidemiological Studies Version 2 - sample



Dietary Questionnaire

QUESTIONS ABOUT WHAT YOU USUALLY EAT AND DRINK

Please fill in the date you completed this questionnaire:

DAY	MTH	YEAR
	○ JAN	○ 2004
	○ FEB	○ 2005
01	○ MAR	○ 2006
01	○ APR	○ 2007
02	○ MAY	○ 2008
03	○ JUN	○ 2009
	○ JUL	○ 2010
	○ AUG	○ 2011
	○ SEP	○ 2012
	○ OCT	○ 2013
	○ NOV	○ 2014
	○ DEC	○ 2015

INSTRUCTIONS:

This questionnaire is about your **usual** eating habits **over the past 12 months**. Where possible give only **one answer per question** for the type of food you eat **most often.**
(If you can't decide which type you have most often, answer for the types you usually eat.)

- Use a soft pencil only, preferably 2B.
- Do not use **any** biro or felt tip pen.
- Erase mistakes fully.
- Make no stray marks.

Please MARK LIKE THIS: ( ) (■) ( )

1. How many pieces of fresh fruit do you usually eat per day? *(Count 1/2 cup of diced fruit, berries or grapes as one piece.)*

- ○ I didn't eat fruit
- ○ less than 1 piece of fruit per day
- ○ 1 piece of fruit per day
- ○ 2 pieces of fruit per day
- ○ 3 pieces of fruit per day
- ○ 4 or more pieces of fruit per day

2. How many different vegetables do you usually eat per day? *(Count all types, fresh, frozen or tinned.)*

- ○ less than 1 vegetable per day
- ○ 1 vegetable per day
- ○ 2 vegetables per day
- ○ 3 vegetables per day
- ○ 4 vegetables per day
- ○ 5 vegetables per day
- ○ 6 or more vegetables per day

3. What type of milk do you usually use?

- ○ none
- ○ full cream milk
- ○ reduced fat milk
- ○ skim milk
- ○ soya milk

4. How much milk do you usually use per day? *(Include flavoured milk and milk added to tea, coffee, cereal, etc.)*

- ○ none
- ○ less than 250 ml *(1 large cup or mug)*
- ○ between 250 and 500 ml *(1-2 cups)*
- ○ between 500 and 750 ml *(2-3 cups)*
- ○ 750 ml *(3 cups)* or more

5. What type of bread do you usually eat?

- ○ I don't eat bread
- ○ high fibre white bread
- ○ white bread
- ○ wholemeal bread
- ○ rye bread
- ○ multi-grain bread

6. How many slices of bread do you usually eat per day? *(Include all types, fresh or toasted and count one bread roll as 2 slices.)*

- ○ less than 1 slice per day
- ○ 1 slice per day
- ○ 2 slices per day
- ○ 3 slices per day
- ○ 4 slices per day
- ○ 5-7 slices per day
- ○ 8 or more slices per day

7. Which spread do you usually put on bread?

- ○ I don't usually use any fat spread
- ○ margarine of any kind
- ○ polyunsaturated margarine
- ○ monounsaturated margarine
- ○ butter and margarine blends
- ○ butter

8. On average, how many teaspoons of sugar do you usually use per day? *(Include sugar taken with tea and coffee and on breakfast cereal, etc.)*

- ○ none
- ○ 1 to 4 teaspoons per day
- ○ 5 to 8 teaspoons per day
- ○ 9 to 12 teaspoons per day
- ○ more than 12 teaspoons per day

9. On average, how many eggs do you usually eat per week?

- ○ I don't eat eggs
- ○ less than 1 egg per week
- ○ 1 to 2 eggs per week
- ○ 3 to 5 eggs per week
- ○ 6 or more eggs per week

10. What types of cheese do you usually eat?

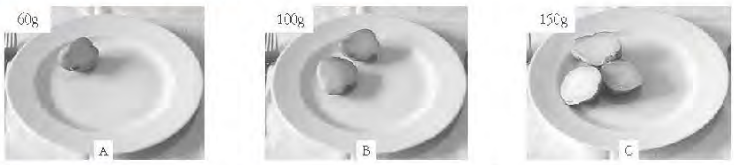
- ○ I don't eat cheese
- ○ hard cheeses, e.g. parmesan, romano
- ○ firm cheeses, e.g. cheddar, edam
- ○ soft cheeses, e.g. camembert, brie
- ○ ricotta or cottage cheese
- ○ cream cheese
- ○ low fat cheese

DO NOT WRITE IN THIS AREA.

Sample Only

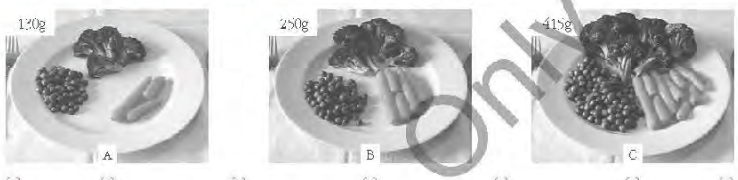
For each food shown on this page, indicate ***how much on average you would usually have eaten at main meals during the past 12 months.*** *When answering each question, think of the* ***amount*** *of that food you usually ate, even though you may rarely have eaten the food on its own.*
If you usually ate more than one helping, fill in the oval for the serving size closest to the ***total amount*** *you ate*

11. When you ate potato, did you usually eat: ○ I never ate potato



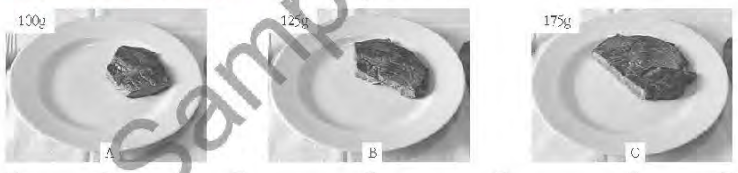
○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

12. When you ate vegetables, did you usually eat: ○ I never ate vegetables



○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

13. When you ate steak, did you usually eat: ○ I never ate steak



○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

14. When you ate meat *or* vegetable casserole, did you usually eat: ○ I never ate casserole



○ Less than A ○ A ○ Between A & B ○ B ○ Between B & C ○ C ○ More than C

Sample Only

15. Over the last 12 months, on average, *how often* did you eat the following foods? *Please completely fill one oval in every line.* Please MARK LIKE THIS: ⬬ NOT LIKE THIS: ✓ ✗ —

Times You Have Eaten		NEVER	less than once per month	1 to 3 times per month	1 time per week	2 times per week	3 to 4 times per week	5 to 6 times per week	1 time per day	2 times per day	3 or more times per day
CEREAL FOODS, SWEETS & SNACKS											
All Bran™	A1	○	○	○	○	○	○	○	○	○	○
Sultana Bran™, FibrePlus™, Branflakes™	A2	○	○	○	○	○	○	○	○	○	○
Weet Bix™, Vita Brits™, Weeties™	A3	○	○	○	○	○	○	○	○	○	○
Cornflakes, Nutrigrain™, Special K™	A4	○	○	○	○	○	○	○	○	○	○
Porridge	A5	○	○	○	○	○	○	○	○	○	○
Muesli	A6	○	○	○	○	○	○	○	○	○	○
Rice	A7	○	○	○	○	○	○	○	○	○	○
Pasta or noodles (include lasagne)	A8	○	○	○	○	○	○	○	○	○	○
Crackers, crispbreads, dry biscuits	A9	○	○	○	○	○	○	○	○	○	○
Sweet biscuits	A10	○	○	○	○	○	○	○	○	○	○
Cakes, sweet pies, tarts and other sweet pastries	A11	○	○	○	○	○	○	○	○	○	○
Meat pies, pasties, quiche and other savoury pastries	A12	○	○	○	○	○	○	○	○	○	○
Pizza	A13	○	○	○	○	○	○	○	○	○	○
Hamburger with a bun	A14	○	○	○	○	○	○	○	○	○	○
Chocolate	A15	○	○	○	○	○	○	○	○	○	○
Flavoured milk drink (cocoa, Milo™, etc.)	A16	○	○	○	○	○	○	○	○	○	○
Nuts	A17	○	○	○	○	○	○	○	○	○	○
Peanut butter or peanut paste	A18	○	○	○	○	○	○	○	○	○	○
Corn chips, potato crisps, Twisties™, etc.	A19	○	○	○	○	○	○	○	○	○	○
Jam, marmalade, honey or syrups	A20	○	○	○	○	○	○	○	○	○	○
Vegemite™, Marmite™ or Promite™	A21	○	○	○	○	○	○	○	○	○	○
DAIRY PRODUCTS, MEAT & FISH											
Cheese	B1	○	○	○	○	○	○	○	○	○	○
Ice-cream	B2	○	○	○	○	○	○	○	○	○	○
Yoghurt	B3	○	○	○	○	○	○	○	○	○	○
Beef	B4	○	○	○	○	○	○	○	○	○	○
Veal	B5	○	○	○	○	○	○	○	○	○	○
Chicken	B6	○	○	○	○	○	○	○	○	○	○
Lamb	B7	○	○	○	○	○	○	○	○	○	○
Pork	B8	○	○	○	○	○	○	○	○	○	○
Bacon	B9	○	○	○	○	○	○	○	○	○	○
Ham	B10	○	○	○	○	○	○	○	○	○	○
Corned beef, luncheon meats or salami	B11	○	○	○	○	○	○	○	○	○	○
Sausages or frankfurters	B12	○	○	○	○	○	○	○	○	○	○
Fish, steamed, grilled or baked	B13	○	○	○	○	○	○	○	○	○	○
Fish, fried (include take away)	B14	○	○	○	○	○	○	○	○	○	○
Fish, tinned (salmon, tuna, sardines, etc.)	B15	○	○	○	○	○	○	○	○	○	○
FRUIT											
Tinned or frozen fruit (any kind)	C1	○	○	○	○	○	○	○	○	○	○
Fruit juice	C2	○	○	○	○	○	○	○	○	○	○
Oranges or other citrus fruit	C3	○	○	○	○	○	○	○	○	○	○
Apples	C4	○	○	○	○	○	○	○	○	○	○
Pears	C5	○	○	○	○	○	○	○	○	○	○
Bananas	C6	○	○	○	○	○	○	○	○	○	○
Watermelon, rockmelon (cantaloupe), honeydew, etc.	C7	○	○	○	○	○	○	○	○	○	○
Pineapple	C8	○	○	○	○	○	○	○	○	○	○
Strawberries	C9	○	○	○	○	○	○	○	○	○	○
Apricots	C10	○	○	○	○	○	○	○	○	○	○
Peaches or nectarines	C11	○	○	○	○	○	○	○	○	○	○
Mango or paw paw	C12	○	○	○	○	○	○	○	○	○	○
Avocado	C13	○	○	○	○	○	○	○	○	○	○

Sample Only

Times You Have Eaten
CONTINUED

		NEVER	less than once per month	1 to 3 times per month	1 time per week	2 times per week	3 to 4 times per week	5 to 6 times per week	1 time per day	2 times per day	3 or more times per day
VEGETABLES (INCLUDING FRESH, FROZEN AND TINNED)											
Potatoes, roasted or fried (include hot chips)	D1	○	○	○	○	○	○	○	○	○	○
Potatoes cooked without fat	D2	○	○	○	○	○	○	○	○	○	○
Tomato sauce, tomato paste or dried tomatoes	D3	○	○	○	○	○	○	○	○	○	○
Fresh or tinned tomatoes	D4	○	○	○	○	○	○	○	○	○	○
Peppers (capsicum)	D5	○	○	○	○	○	○	○	○	○	○
Lettuce, endive, or other salad greens	D6	○	○	○	○	○	○	○	○	○	○
Cucumber	D7	○	○	○	○	○	○	○	○	○	○
Celery	D8	○	○	○	○	○	○	○	○	○	○
Beetroot	D9	○	○	○	○	○	○	○	○	○	○
Carrots	D10	○	○	○	○	○	○	○	○	○	○
Cabbage or Brussels sprouts	D11	○	○	○	○	○	○	○	○	○	○
Cauliflower	D12	○	○	○	○	○	○	○	○	○	○
Broccoli	D13	○	○	○	○	○	○	○	○	○	○
Silverbeet or spinach	D14	○	○	○	○	○	○	○	○	○	○
Peas	D15	○	○	○	○	○	○	○	○	○	○
Green beans	D16	○	○	○	○	○	○	○	○	○	○
Bean sprouts or alfalfa sprouts	D17	○	○	○	○	○	○	○	○	○	○
Baked beans	D18	○	○	○	○	○	○	○	○	○	○
Soy beans, soy bean curd or tofu	D19	○	○	○	○	○	○	○	○	○	○
Other beans (include chick peas, lentils, etc.)	D20	○	○	○	○	○	○	○	○	○	○
Pumpkin	D21	○	○	○	○	○	○	○	○	○	○
Onion or leeks	D22	○	○	○	○	○	○	○	○	○	○
Garlic (not garlic tablets)	D23	○	○	○	○	○	○	○	○	○	○
Mushrooms	D24	○	○	○	○	○	○	○	○	○	○
Zucchini	D25	○	○	○	○	○	○	○	○	○	○

16. **Over the last 12 months, how often did you drink beer, wine and/or spirits?**

Times That You Drank

		NEVER	less than once a month	1-3 days per month	1 day per week	2 days per week	3 days per week	4 days per week	5 days per week	6 days per week	every day
Beer (low alcohol)	1	○	○	○	○	○	○	○	○	○	○
Beer (full strength)	2	○	○	○	○	○	○	○	○	○	○
Red wine	3	○	○	○	○	○	○	○	○	○	○
White wine (include sparkling wines)	4	○	○	○	○	○	○	○	○	○	○
Fortified wines, port, sherry, etc.	5	○	○	○	○	○	○	○	○	○	○
Spirits, liqueurs, etc.	6	○	○	○	○	○	○	○	○	○	○

When answering the next two questions, please convert the amounts you drank into glasses using the examples given below. For spirits, liqueurs, and mixed drinks containing spirits, please count each nip (30 ml) as one glass.

1 can or stubby of beer 2 glasses
1 large bottle beer (750 ml) 4 glasses
1 bottle wine (750 ml) 6 glasses
1 bottle of port or sherry (750 ml) 12 glasses

17. **Over the last 12 months, on days when you were drinking, how many glasses of beer, wine and/or spirits altogether did you *usually* drink?**

TOTAL NUMBER OF GLASSES PER DAY	1	2	3	4	5	6	7	8	9	10 or more
	○	○	○	○	○	○	○	○	○	○

18. **Over the last 12 months, what was the *maximum* number of glasses of beer, wine and/or spirits that you drank in 24 hours?**

MAXIMUM NUMBER OF GLASSES PER 24 HOURS	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19 or more
	○	○	○	○	○	○	○	○	○	○

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Thank You for completing this questionnaire

DO NOT WRITE IN THIS AREA.

Sample Only

2 Introduction

The Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2) is a modification of a food frequency questionnaire (FFQ) that was developed by Cancer Council Victoria in the late 1980s to measure dietary intake of people taking part in the Melbourne Collaborative Cohort Study (MCCS). These were men and women, recruited for the study between 1990 and 1994, who at the time of recruitment were 40-69 years of age and resided in Melbourne, Victoria. The majority were born in Australia, Greece or Italy.

The DQES v2 was developed specifically for Australian adults and has been used in the Australian arm of the Breast Cancer Family Registry, Australian Prostate Cancer Family Study, Australian Longitudinal Study of Women's Health and numerous other epidemiological studies in Australia. The DQES v2 is a suitable tool for assessing intakes of foods and nutrients among adults in epidemiological studies, subject to the limitations common to all food frequency questionnaires. For other uses, where more detail about diet is required, or where a very different population is being studied, we cannot be confident about the suitability of this instrument.

DQES v2 is not recommended for use with children or younger people in general as it does not include some food types common to younger people. For example, it does not include soft drinks or electrolyte drinks which were found to make up 16-21% of sugar intakes for males and females aged 12-18 years (1995 National Nutrition Survey[1])

The food list on the MCCS food frequency questionnaire was based on weighed food records from 810 volunteers who were demographically similar to MCCS participants.

The DQES v2 comprises a food list of 74 items with 10 frequency response options ranging from 'Never' to '3 or more times per day' and a section covering intake of 6 types of alcoholic beverage with 10 frequency response options ranging from 'never' to 'every day'. The 74 food items are grouped into four food type categories: 1) cereal foods; sweets and snacks; 2) dairy products, meats and fish; 3) fruit and 4) vegetables.

3 Questionnaire evaluation

The performance of the Cancer Council Victoria's dietary questionnaire has been evaluated in studies comparing the results of the questionnaire with those from weighed food records[2,3] showing good agreement between methods.

In a validation study conducted in a group of women aged 16-48 years (mean 33 years), correlation coefficients for nutrient intakes comparable with those reported for other food frequency questionnaires[2].

A modification of the questionnaire has also been shown to reliably measure past dietary intake[4]. The questionnaire has also been found to be useful in assessment of fatty acids[5].

1. McLennan W, Podger A: National Nutrition Survey Nutrient Intakes and Physical Measurements Australia. Canberra, Australian Bureau of Statistics, 1998
2. Hodge A, Patterson AJ, Brown WJ, Ireland P, Giles G: The Anti Cancer Council of Victoria FFQ: relative validity of nutrient intakes compared with weighed food records in young to middle-aged women in a study of iron supplementation. *Aust NZ J Publ Heal* 24:576-583, 2000
3. Xinying Xie P, Noakes M, Keogh J. Can a food frequency questionnaire be used to capture dietary intake data in a 4 week clinical intervention trial? *Asia Pacific Journal of Clinical Nutrition* 2004;1(4):318-23
4. Ambrosini GL, van Roosbroeck SA, Mackerras D, Fritschi L, de Klerk NH, Musk AW.The reliability of ten-year dietary recall: implications for cancer research. *J Nutr*. 2003 Aug;133(8):2663-8
5. Woods RK, Stoney RM, Ireland PD, Bailey MJ, Raven JM, Thien FC, Walters EH, Abramson MJ. A valid food frequency questionnaire for measuring dietary fish intake. *Asia Pac J Clin Nutr*. 2002;11(1):56-61

4 Nutritional data

The data collected by DQES v2 is used to calculate nurient intakes. The calculation of the majority of the nutrients is based on Australian nutrient composition data from NUTTAB95 [6]. The remainder have been based on other data sources, and these are listed in Table 1.

Table 1 Nutrients calculated using other sources

Nutrient	Source of information
Vitamin E, folate	*Holland B, Welch AA, Unwin ID, Buss DH, Paul AA, and Southgate DAT. McCance and Widdowson's The Composition of Foods. 5th ed. 1993, Cambridge: Royal Society of Chemistry*
Carotenoids	USDA-NCC. *USDA-NCC Carotenoid Database for U.S.Foods.* 1998
Fatty acids	*RMIT Fatty Acid database of Australian foods.* Xyris software, Brisbane
Glycaemic index Glycemic load	Foster-Powell K, Holt HA, and Brand-Miller JC. International tables of glycemic index and glycemic load values: 2002. *Am J Clin Nutr.* 2002; 76: 5-56

The variable 'BetaCarotene', is a ß-carotene equivalent (mcg/d) from NUTTAB. ß-carotene equivalent is the sum of the ß-carotene and half the amounts of α-carotene and α- and ß-cryptoxanthins present.

Alpha-carotene through to lycopene are individual carotenoid intakes (mcg/d) calculated from the USDA data base. The value labelled 'Beta-Carotene' is total ß-carotene, and is not directly related to the 'BetaCarotene' from NUTTAB. There is no expectation of close agreement as the two variables come from databases from different time periods and countries, and may include different foods.

Variables FD40 to FD226N3N6, are intakes of individual fatty acids, based on a data set obtained from Professor Neil Mann, RMIT University, and now used in the FoodWorks nutrient analysis software. Some of these will have very low or zero intakes; all the variable columns from the original database have been retained, even if intakes are zero.

Individual food intakes are reported in grams per day and include all the adjustments as described in Section 5.

Folate calculation

The Australian Government has implemented the mandatory fortification of bread flour with folic acid (a form of folate) from September 13, 2009. The DQES v2 calculation of folate intake has not been modified to account for this.

5 Administration of the questionnaire

The DQES v2 is available electronically (online) or hardcopy (printed). The questionnaire is designed to be either self-administered or interviewer-administered.

5.1 Online version

The researcher is responsible for the distribution of IDs to participants, and for ensuring that all online questionnaires are completed within a reasonable time frame – typically this is the estimated project completion date as specified in the Memorandum of Understanding. An email reminder will be sent to determine the study status, prior to this date.

6. Lewis, J et al. NUTTAB 95 : nutrient data table for use in Australia. Commonwealth of Australian 1995

5.2 Printed version

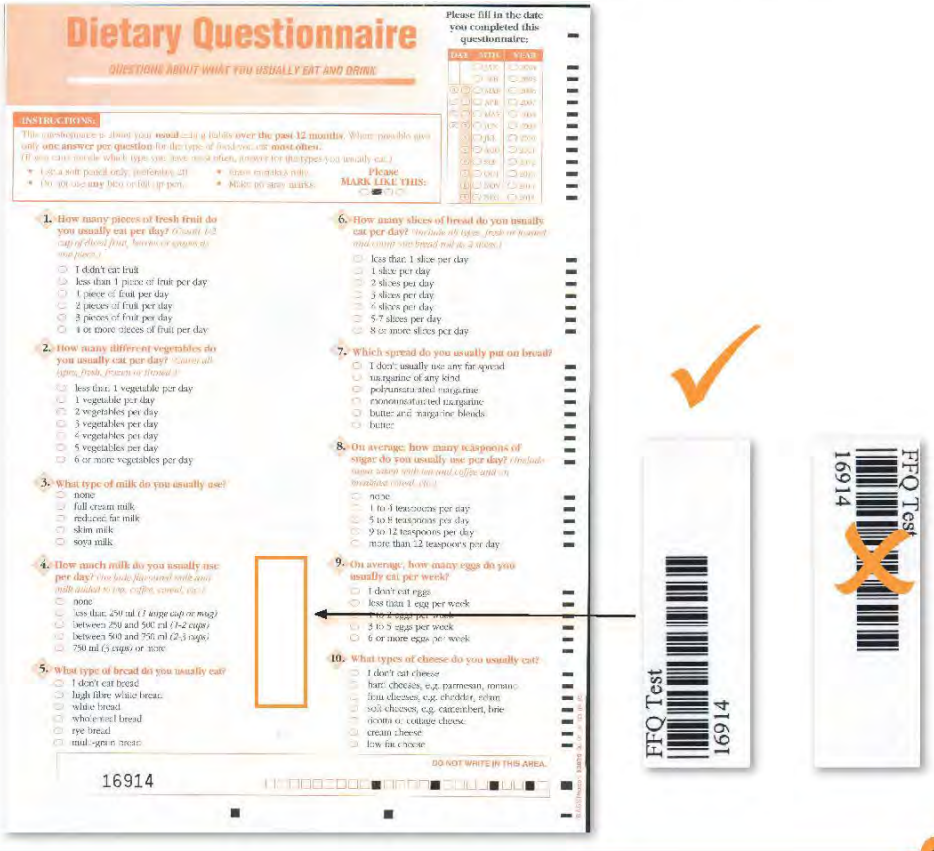
A soft pencil (2B) is preferred for completion of the printed questionnaires. Ink can be used but is not recommended. Ensure the box is completely covered. Do not tick, cross, strikethrough or circle the boxes.



Every question **MUST** be completed. It is the researcher's responsibility check that each question has been completed correctly before returning the questionnaire to Cancer Council Victoria for scanning and analysis. Incomplete questionnaires can delay processing or result in the use of default values which may impact on the quality of the results.

ID labels

To enable identification of individual questionnaires, self adhesive barcode labels are provided. The researcher needs to place the label in the empty box on the first page of the questionnaire. It is preferred that the label is oriented as shown below. If any other labels are added, please ensure that they do not obscure any of the marks on the edge of the questionnaire.



Separated pages

If the pages of the questionnaire become separated, use a paper clip to keep them together. Please do not use sticky tape or staples as we need to be able to separate the pages for scanning.

6 DQES v2 analysis

6.1 Errors

The questionnaire analysis software produces a report of all errors and inconsistencies in questionnaire responses. In some cases, default values will be assumed and the output will still be calculated. When the assumptions required for calculations are too great, no output will be produced. This will be detailed in the error report. It is up to the researcher to decide what to do about missing or inconsistent data.

6.2 Fruit and vegetable questions

The information obtained about fruit consumption in Question 15 is necessary to determine the relative contribution of different types of fruit to the person's total fruit intake. It is often found that food frequency questionnaires do not provide an accurate estimate of a person's total fruit intake; therefore Question 1 has been included to scale the responses to Question 15.

As with fruit, the information obtained about vegetables in Question 15 is essential for determining the relative contribution of different vegetables to a person's total vegetable intake. The response to Question 2 is used to scale the responses about frequency of specific vegetable consumption in Question 15.

Question 2 asks about how many different vegetables the person usually eats per day. We chose not to ask about the number of "serves" of vegetables because there is confusion about what constitutes a "serve" of vegetables. Moreover, we obtain information about vegetable serving sizes separately in Questions 11 and 12.

The program that calculates nutrient values from the questionnaire data uses responses to Questions 1 and 2 to adjust the answers about fruit and vegetable intake in Question 15. If either of these questions is left blank, the program will not calculate nutrients for that person.

Also if the responses to Questions 1 or 2 are completely inconsistent with the responses in Question 15, nutrients will not be calculated.

It is not expected that answers will match exactly, but if for example it were indicated in Question 1 that the respondent did not eat fruit, and in Question 15 they reported eating fruit, this would be rejected. Similarly, if some fruit were reported in Question 1 and none in Question 15, this would lead to rejection. The same logic applies to vegetables in Questions 2 and 15.

6.3 Multiple responses

For Questions 3, 5, 7 and 10, it is possible for multiple responses to be selected reflecting use of a variety of types of milk, bread, spread or cheese. When more than one response is selected, the calculation of nutrient intakes will assume that each type is consumed in equal quantities.

For Questions 1, 2, 4, 6, 8 & 9 only a single response is allowed. When multiple responses are given for questions requiring only a single response, only the first response is used in the analysis.

6.4 Portion size

Responses to the portion size questions (Questions 11-14) are used to calculate a single portion size factor (PSF) indicating whether on average a person eats median size serves (PSF=1), more than the median (PSF > 1), or less than the median (PSF < 1). The PSF is used to scale the standard portion size for different foods up or down. One response is required for each question. If more than 50% of the responses are 'NEVER', the questionnaire is not analysed.

6.5 Daily equivalent frequencies

For Questions 15 and 16, analysis of food intakes in terms of frequency requires conversion of the questionnaire responses to daily equivalent fequencies. The conversions used are shown in Table 2.

Table 2 Conversion of questionnaire responses to daily equivalent frequencies (DEF) for Questions 15 & 16

Question 15 - Foods

Frequency category	DEF
never	0
less than once per month	0.02
1-3 times per month	0.07
once per week	0.14
twice per week	0.28
3-4 times per week	0.5
5-6 times per week	0.78
once per day	1
twice per day	2
3 or more times per day	3

Question 16 - Alcohol

Frequency category	DEF
never	0
less than once a month	0.02
1-3 days per month	0.07
1 day per week	0.14
2 days per week	0.28
3 days per week	0.43
4 days per week	0.57
5 days per week	0.71
6 days per week	0.86
every day	1

6.6 Question 15

In Question 15, the 74 food items are grouped into four categories:

1. Cereal foods, sweets and snacks
2. Dairy products, meats and fish
3. Fruit
4. Vegetables

Certain foods such as sandwiches and salads are not listed because their composition varies. People should think about the separate ingredients that make up these foods and answer the questionnaire accordingly. For example, if a person ate a salad that included tomato once a week and a tomato sandwich once a week, the appropriate answer for tomato would be "2 times per week".

All foods, whether eaten at home, away from home or on holidays, need to be included.

If there are seasonal differences in dietary intake, the person completing the questionnaire will need to estimate their average intake over the whole year; for example, if they ate salad with lettuce 2 times per week in spring and summer (i.e. 6 months or half the

year) and never for the rest of the year, they should record this as once a week on the questionnaire.

One response is required for each question. If more than 50% of responses are 'NEVER', the questionnaire will not be analysed.

6.7 Alcohol questions

DQES v2 does not ask about beverage-specific frequency of consumption but an overall quantity of consumption, so assumptions have to be made in the calculation of nutrients. To estimate beverage-specific (and total) weekly consumption, we calculate a weighted average from two extreme methods of assigning quantity to consumption of individual beverages.

The first method assumes that people who consume more than one type of beverage always do so on the same days (subject to the constraints of the beverage-specific frequencies), while the second method assumes that people separate their beverages wherever possible. In both methods, on days when people drink more than one beverage, we apportion the total glasses consumed equally among all types consumed on that day. From the 3-day diary of the 1995 National Health Survey, we determined that people who drank more than one beverage were about two times as likely to drink them on separate days as on the same day. Therefore, the data from the second method are given two times the weight of the first method when we construct the weighted average.

Due to the assumptions required in the calculation of nutrients from alcoholic beverages, the results are less reliable than those for nutrients from food. Therefore, nutrients from alcoholic beverages are reported separately and it is up to the researcher to decide whether to include these nutrients in the totals. If you want to include alcohol, all nutrients in the alcohol file should be added to the nutrients in the main file.

Question 16

This question asks about average alcohol consumption over the past twelve months for each alcohol type separately. One response is required for each question. If **all** responses are 'NEVER', no further questions need to be answered.

Question 17

This question asks about the total number of glasses of all alcohol types usually drunk per day. This may require totalling all alcohol types usually consumed.

Question 18

This question asks the maximum number of glasses of alcohol drunk in any 24 hour period during the past year and is not used in the calculation of nutrients. Missing this question will not stop nutrients being calculated but creates a warning in the error report.

6.8 'Never' response - online questionnaire

When particpants respond 'Never' to Questions 11 to 14 or Questions 15A to 15C in the online questionnaire, they will receive a warning to review the questions. Without responses to these questions, nutrients cannot be calculated. If the participant does not review responses to these questions the questionnaire ends and the data will not be analysed.

6.9 Printed questionnaire

Incomplete questionnaire

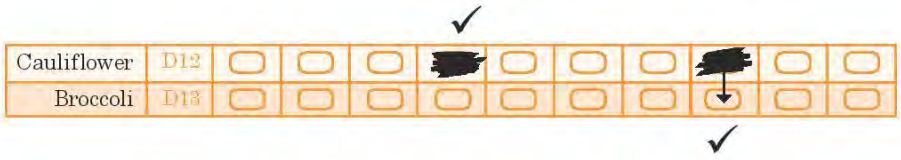
If more than 50% of the questionnaire has not been answered, the questionnaire will not be analysed.

Missing response - Questions 11 to 16

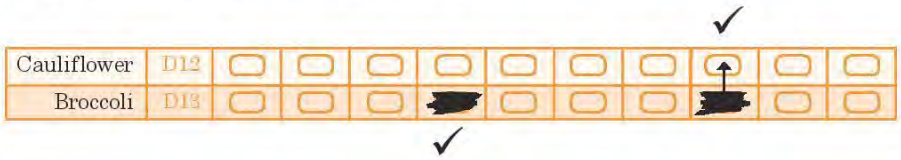
When a question has not been answered, it is assumed none of that food or drink item was consumed in the past 12 months.

Multiple/missing response - Questions 15 and 16

When two responses have been given to one question and the following question has been left unanswered, it is assumed that the response on the right hand side of the first line actually belongs to the second line.



When one question is left unanswered and the following question has two responses on the right hand side of the lower line is taken for the missing question.



6.10 New food types

The food types listed in DQES v2 were based on products that were in common use at the time when the questionnaire was developed. Since then, a number of other foods have appeared on the market and are now commonly used, for example soy and linseed bread, gluten free breads, cholesterol lowering margarines and milk substitutes based on nuts. If people report using foods that are not listed, the DQES cannot be analysed, so it is important for the researcher to decide how they wish to deal with this. It might be best to select one of the available options that best reflects the item. For example, with bread we are mostly interested in whether it is whole grain or made from refined flour so white sourdough would be recorded as white as would Turkish bread and sourdough rye as rye bread.

In order to account for these changes in the food types, Cancer Council Victoria is developing an updated version of the DQES that will reflect more recent food use patterns.

7 Output reports

Analysis of the questionnaires results in five types of output report, which are made available to researchers in *csv* format. These are listed in Table 3. Details of fields included in these reports are given in Tables 4-7. Examples of error report outputs are given in Table 8.

Table 3 Types of output report resulting from analysis of DQES v2

	Data type	Fields/example
Report 1.	Raw data	see Table 4
Report 2.	Nutrients from food (excluding alcoholic beverages)	see Table 5
Report 3	Nutrients from alcoholic beverages	see Table 6
Report 4	Food intakes	see Table 7
Report 5	Error messages	see Table 8

Table 4 Output fields for Report 1: Raw data

Field names				
Scan.no	Butter	Cakes	Fish.fried	Carrots
Id	Sugar.p.d	Pies/pastries	Fish.tinned	Cabbage
Date	Eggs.p.w	Pizza	Fruit.tin	Cauliflower
	Cheese.none	Hamburger	Fruit juice	Broccoli
Fruit.p.d	Cheese.hard	Chocolate	Oranges	Spinach
Veg.p.d	Cheese.firm	Flav.milk	Apples	Peas
Milk.none	Cheese.soft	Nuts	Pears	Green bean
Milk.full	Ricotta	Peanut butter	Bananas	Sprouts
Milk.red	Cream cheese	Chips	Melons	Bakes beans
Milk.skim	Lowf.cheese	Jam/honey	Pineapple	Soy bean
Milk.soy	Pot.eat	Vegemite	Strawberry	Other bean
Milk.p.d	Veg.eat	Cheese	Apricots	Pumpkin
Bread.none	Steak.eat	Icecream	Peaches	Onion
Bread.highf	Casserole.eat	Yoghurt	Mango	Garlic.fresh
Bread.white	Allbran	Beef	Avocado	Mushroom
Bread.whol	Other brans	Veal	Pot.roast/fried	Zucchini
Bread.rye	Weetbix	Chicken	Pot.not fat	Beer.low
Bread.multi	Cornflakes	Lamb	Tom sauce/paste	Beer.full
Bread.p.d	Porridge	Pork	Tom.tinned	Red wine
Spread.none	Muesli	Bacon	Peppers	White wine
Marg	Rice	Ham	Green salad	Port/sherry
Poly.marg	Pasta	Beef/salami	Cucumber	Spirits
Mono.marg	Dry biscuits	Sausages	Celery	Glass.p.d
Marg blends	Sweet biscuits	Fish.grill	Beetroot	Max.glass.p.d

Table 5 Output fields for Report 2: Nutrients from food (excluding alcoholic beverages)

Field name	Measure	Field name	Measure	Field name	Measure
Scan No.		Potassium	mg/day	FD200 arachidic	g/day
ID		Retinol	ug/day	FD220 behenic	g/day
Date		Retinol Equiv	ug/day	FD240 lignoceric	g/day
Portion	Standard	Riboflavin	mg/day	FD141 myristoleic	g/day
Energy	kJ/day	Sodium	mg/day	FD151 pentadecenoic	g/day
All Fat	g/day	Thiamin	mg/day	FD161 palmitoleic	g/day
SatFat	g/day	VitaminC	mg/day	FD161T trans palmitoleic	g/day
PolyFat	g/day	VitaminE	mg/day	FD171 heptadecenoic	g/day
MonoFat	g/day	Zinc	mg/day	FD181 oleic	g/day
Protein	g/day	Alpha-Carotene	ug/day	FD181T elaidic/trans vaccenic	g/day
Carbohydrate	g/day	Beta-Carotene	ug/day	FD201 eicosenic	g/day
Fibre	g/day	Lycopene	ug/day	FD182N6T trans linoleic	g/day
Alcohol	g/day	FD40 butyric	g/day	FD183N3 alpha-linoleic	g/day
BetaCarotene	ug/day	FD60 caproic	g/day	FD202N6 eicosadienoic	g/day
Calcium	mg/day	FD80 capricylic	g/day	FD203N6 dihomo-gamma-linolenic	g/day
Cholesterol	mg/day	FD100 capric	g/day	FD204N6 arachidonic	g/day
Folate	ug/day	FD120 lauric acid	g/day	FD205N3 eicosapentaenoic	g/day
Iron	mg/day	FD140 myristic	g/day	FD205N6 fatty acid	g/day
Magnesium	mg/day	FD150 pentadecanoic	g/day	FD224N6 adrenic	g/day
Niacin	mg/day	FD160 palmitic	g/day	FD225N3 clupanodonic	g/day
Niacin Equiv	mg/day	FD170 margaric	g/day	FD226N3 decosahexaenoic	g/day
Phosphorus	mg/day	FD180 stearic	g/day	Glycemic Load	
				Glycemic Index	

Table 6 Output fields for Report 3: Nutrients from alcoholic beverages

Field name	Measure	Field name	Measure	Field name	Measure
Scan No.		Alcohol	g/day	Niacin Equiv	mg/day
ID		BetaCarotene	ug/day	Thiamin	mg/day
Date		Calcium	mg/day	VitaminC	mg/day
Portion	Standard	Protein	g/day	VitaminE	mg/day
Energy	kJ/day	Carbohydrate	g/day	Zinc	mg/day
All Fat	g/day	Sugars	g/day	Phosphorus	mg/day
SatFat	g/day	Cholesterol	mg/day	Potassium	mg/day
PolyFat	g/day	Folate	ug/day	Retinol	ug/day
MonoFat	g/day	Iron	mg/day	Retinol Equiv	ug/day
Starch	g/day	Magnesium	mg/day	Riboflavin	mg/day
Fibre	g/day	Niacin	mg/day	Sodium	mg/day

Table 7 Output fields for Report 4: Food intakes

Field name	Measure	Field name	Measure	Field name	Measure
Scan No.		Sweet Biscuits	g/day	Apricots	g/day
ID		Cakes	g/day	Peaches	g/day
Date		Meat pies	g/day	Mango	g/day
Portion	Standard	Pizza	g/day	Avocado	g/day
Full cream milk	g/day	Hamburger	g/day	Chips	g/day
Reduced fat milk	g/day	Chocolate	g/day	Potatoes	g/day
Skim milk	g/day	Flavoured Milk Drink	g/day	Tomato sauce	g/day
Soya milk	g/day	Nuts	g/day	Tomatoes	g/day
High fibre white bread	g/day	Peanut butter	g/day	Capsicum	g/day
White bread	g/day	Crisps	g/day	Lettuce	g/day
Wholemeal bread	g/day	Jam	g/day	Cucumber	g/day
Rye bread	g/day	Vegemite	g/day	Celery	g/day
Multi-grain bread	g/day	Ice-cream	g/day	Beetroot	g/day
Margarine	g/day	Yoghurt	g/day	Carrots	g/day
Polyunsaturated margarine	g/day	Beef	g/day	Cabbage	g/day
Monounsaturated margarine	g/day	Veal	g/day	Cauliflower	g/day
Butter and margarine blends	g/day	Chicken	g/day	Broccoli	g/day
Butter	g/day	Lamb	g/day	Spinach	g/day
Hard cheese	g/day	Pork	g/day	Peas	g/day
Firm cheese	g/day	Bacon	g/day	Green beans	g/day
Soft cheese	g/day	Ham	g/day	Bean sprouts	g/day
Ricotta or cottage cheese	g/day	Salami	g/day	Baked beans	g/day
Cream cheese	g/day	Sausages	g/day	Tofu	g/day
Low fat cheese	g/day	Fish	g/day	Other beans	g/day
Sugar	g/day	Fried fish	g/day	Pumpkin	g/day
Eggs	g/day	Tinned fish	g/day	Onion	g/day
All Bran	g/day	Tinned fruit	g/day	Garlic	g/day
Branflakes	g/day	Fruit juice	g/day	Mushrooms	g/day
Weet Bix	g/day	Oranges	g/day	Zucchini	g/day
Cornflakes	g/day	Apples	g/day	Light beer	g/day
Porridge	g/day	Pears	g/day	Heavy beer	g/day
Muesli	g/day	Bananas	g/day	Red wine	g/day
Rice	g/day	Melon	g/day	White wine	g/day
Pasta	g/day	Pineapple	g/day	Fortified wines	g/day
Crackers	g/day	Strawberries	g/day	Spirits	g/day

Table 8 Examples of output of Report 5: Errors

ID	Warning/Rejection reasons
5	Intermediate warning - portion size factor (Q11-14) is based on only 2 foods.
10	Serious warning - portion size factor (Q11-14) is based on only 1 food or has defaulted to 1.
24	Intermediate warning - portion size factor (Q11-14) is based on only 2 foods.
78	Intermediate warning - portion size factor(Q11-14) is based on only 2 foods.
126	Trivial warning - cheese consumption indicated in (Q10) but frequency 'never' in (Q15).
140	Serious warning - (Q1) 'I don''t eat fruit' and fruit intake reported in (Q15).
140	Serious warning - portion size factor (Q11-14) is based on only 1 food or has defaulted to 1.
179	Intermediate warning - portion size factor (Q11-14) is based on only 2 foods.
255	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
275	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
276	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
283	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
294	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
305	Serious warning - consumption of alcoholic beverages indicated in (Q16) but number of glasses per day (Q17) is missing.
305	Trivial warning - missing maximum number of glasses (Q18).
311	Trivial warning - cheese consumption indicated in (Q10) but frequency 'never' in (Q15).
321	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
594	Serious warning - portion size factor (Q11-14) is based on only 1 food or has defaulted to 1.
600	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
612	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
636	Serious warning - (Q1) 'I don''t eat fruit' and fruit intake reported in (Q15).
1328	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
1347	Trivial warning - cheese consumption indicated in (Q10) but frequency 'never' in (Q15).
1347	Intermediate warning - portion size factor (Q11-14) is based on only 2 foods.
1353	Trivial warning - Milk type selected in (Q3) but 'none' used in (Q4).
1353	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
1373	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
1448	Trivial warning - portion size factor (Q11-14) is based on only 3 foods.
Processing was completed at 15/02/2011 11:56:06 AM	
Number of records processed : 383	
Number of records rejected : 0	

8 Interpretation of output

8.1 Raw data report

The output data in the raw data report need to be interpreted in the context of the questions and response options. The report shows the number of the response option selected, not the value that the option represents.

For example, for Question 1 (Fruit intake), a value of '4' in the raw data report does not mean that the participant eats 4 pices of fruit a day, but instead indicates that the participant has selected Option 4 which means that they eat '2 pieces of fruit a day'.

9 Processing questionnaires

A minimum of two weeks is required to process both online and printed questionnaires.

9.1 Online questionnaires

Processing of online questionnaires takes place upon requests from researchers. Requests for data processing should be emailed to ffq@cancervic.org.au

9.2 Printed questionnaires

Printed questionnaires are scanned and analysed upon return to the Nutritional Assessment Office.

It is important that questionnaires are completed correctly as re-scanning is subject to a minimum cost.

Please ensure that the *Dispatch & Receipt Form* is also returned with the questionnaires.

10 Ordering

The DQES v2 is made available for use on a fee-for-service basis.

The price per unit (as detailed in Table 9) includes questionnaires (printed or online), participant ID barcodes and scanning (for printed), analysis, postage and GST.

The DQES v2 remains the property of Cancer Council Victoria.

Table 9 Price per unit for Dietary Questionnaire for Epidemiological Studies Version 2 (DQES v2)

Quantity Minimum of 55	**Printed DQES v2** Includes scanning & analysis (GST included)	**Online DQES v2** Includes analysis (GST included)
55 to 99	$16.50	$15.60
100 to 499	$16.00	$11.90
500 to 999	$13.70	$10.30
1,000 plus	$11.90	$8.70

Please note: There is a minimum order size of 55 questionnaires.

Login details for online questionnaires or copies of printed questionnaires are dispatched within a week of receiving an order.

10.1 ID labels for printed questionnaires

Barcode labels are provided for printed questionnaires to enable unique identification. When you place an order for printed questionnaires, you will be asked to specify two elements to be used on the labels: a study reference name and a series of sequential numbers from which ID numbers will be drawn. These appear on the labels as shown below.



Study Reference
This could be an acronym or abbreviation of the study name and can be maximum of ten characters. The Study Reference will be the same on all labels.

Sequential Number
This will be unique for each questionnaire. It can be a maximum of ten digits. A capital letter can also be included if the same ID numbers are to be used for more than one stage of the study, e.g. 16914 for the main study and A16914 for the follow-up.

Additional or replacement barcode labels for printed questionnaires can be provided at the cost of $5 per sheet, to a maximum cost of $85.

Refunds are not available for any questionnaires that are not used.

10.2 Order form

DQES can be ordered by completing the *DQES v2 Order Form*, which includes a *Memorandum of Understanding*.

There are separate order forms for electronic and printed versions of DQES and these can be downloaded at www.cancervic.org.au\dqes

The completed *DQES v2 Order Form* and *Memorandum of Understanding* should be sent the Nutritional Assessment Office:

Email: ffq@cancervic.org.au

Mail: Nutritional Assessment Office
Cancer Epidemiology Centre
Cancer Council Victoria
615 St Kilda Road
Melbourne VIC 3004

10.3 Invoicing

Payment for DQES can be made with credit card or by invoice. Invoices and receipts for credit card payments are emailed by our Finance Department once the request or payment is received and processed.

11 Referencing DQES v2

Researchers referencing the DQES v2 should use the following citation:

Giles GG, Ireland PD. Dietary Questionnaire for Epidemiological Studies (Version 2), Melbourne: Cancer Council Victoria, 1996.

For more information, contact:

Nutritional Assessment Office
Cancer Council Victoria

Phone (03) 9514 6264
E-mail ffq@cancervic.org.au
Website www.cancervic.org.au\dqes

Appendix U: Models of significant pathways (Chapter 7)

Predictors of Energy Intake						
Dependent Variable	Predictors	Parameter Estimate	Standard Error	P	95% CI Low	95% CI Upper
Energy	Stress	43.81	12.94	0.00	18.27	69.35
	Tiredness	40.91	11.48	0.00	18.25	63.58
	TST	-4.35	1.72	0.01	-7.76	-0.94
	Shift Type					
	Morning	-465.92	536.39	0.38	-1524.39	-592.55
	Afternoon	-2065.54	531.93	0.00	-3115.28	-1015.80
	Night	Reference	0	-	-	-
	Gender					
	Male	3165.82	1215.09	0.01	702.69	5628.95
	Female	Reference		-	-	-

CI = confidence interval; TST = total sleep time

Predictors of Stress						
Dependent Variable	Predictors	Parameter Estimate	Standard Error	P	95% CI Low	95% CT Upper
Stress	Shift Type					
	Morning	-0.74	2.89	0.79	-6.46	5.97
	Afternoon	-5.56	2.85	0.05	-11.20	0.07
	Night	Reference		-	-	-
	Tiredness	0.35	0.05	0.00	0.23	0.46

CI = confidence interval

Predictors of Tiredness						
Dependent Variable	Predictors	Parameter Estimate	Standard Error	P	95% CI Lower	85% CI Upper
Tiredness	Shift Type					
	Morning	-6.39	3.17	0.04	-12.66	-0.12
	Afternoon	-17.10	3.13	0.00	23.29	-10.91
	Night	Reference		-	-	-
	Sleep Quality	2.30	0.82	0.00	0.68	0.39

CI = confidence interval

Predictors of Sleep Quality						
Dependent Variable	Predictors	Parameter Estimate	Standard. Error	P	95% CI Lower	95% CI Upper
Sleep Quality	Shift Type					
	Morning	-0.68	0.28	0.01	-1.25	-0.12
	Afternoon	-0.92	0.28	0.00	-1.48	-0.35
	Night	Reference		-	-	-

CI = confidence interval

Predictors of Total Sleep Time						
Dependent Variable	Predictors	Parameter Estimate	Standard. Error	P	95% CI Lower	95% CI Upper
TST	Shift Type					
	Morning	-80.65	21.30	0.00	-122.68	-38.61
	Afternoon	13.15	21.32	0.53	-28.91	55.22
	Night	Reference		.	.	.

Predictors of Fat Intake						
Dependent Variable	Predictors	Parameter Estimate	Std. Error	P	95% CI Lower	95% CI Upper
Fat	Stress	0.07	0.03	0.02	0.01	0.13

Predictors of Saturated Fat Intake						
Dependent Variable	Predictors	Parameter Estimate	Std. Error	P	95% CI Lower	95% CI Upper
SFA	Stress	0.04	0.17	0.00	0.01	0.08

SFA = saturated fat; CI = Confidence Interval

Predictors of Protein Intake						
Dependent Variable	Predictors	Parameter Estimate	Std. Error	P	95% CI Lower	95% CI Upper
Protein	Shift Type					
	Morning	3.23	1.40	0.02	0.47	6.00
	Afternoon	2.75	1.39	0.05	0.00	5.50
	Night	Reference		-	-	-
	Tiredness	-0.06	0.02	0.02	-0.11	-0.00
	Gender					
	Male	6.73	2.52	0.01	1.59	11.88
	Female	Reference		-	-	-

CI = confidence interval

Predictors of Carbohydrate Intake						
Dependent Variable	Predictors	Parameter Estimate	Std. Error	P	Lower	Upper
CHO	Shift Type					
	Morning	-6.48	2.15	0.00	-10.74	-2.22
	Afternoon	-3.47	2.14	0.10	-7.70	0.76
	Night	Reference		-	-	-
	Sleep Efficiency	-0.40	0.11	0.00	-0.62	-0.17

CHO = carbohydrate; CI = confidence interval

Predictors of alcohol intake						
Dependent Variable	Predictors	Parameter Estimate	Std. Error	P	95% CI Lower	95% CI Upper
Alcohol	Shift Type					
	Morning	3.08	0.54	0.00	2.01	4.16
	Afternoon	1.54	0.54	0.00	0.47	2.61
	Night	Reference	0	-	-	-

Appendix V: Hampton et al. (2010)

Living in a 24/7 World:
The impact of circadian disruption on sleep, work and health

Australasian Chronobiology Society
7th Annual Meeting

4 – 5 September 2010

University of South Australia, Adelaide, Australia



Citation
Hampton LK, Darwent D, Matthews RW, Heath G, Ferguson SA, Sargent C, Kennaway DJ, Roach GD (2010). The influence of circadian phase and prior wake on positive and negative mood during a sleep-restricted forced desynchrony protocol. In: Sargent C, Darwent D, Roach GD (Eds). *Living in a 24/7 world: The impact of circadian disruption on sleep, work and health.* Australasian Chronobiology Society, Adelaide, Australia, pp. 13-17.

Chapter 3

The influence of circadian phase and prior wake on positive and negative mood during a sleep-restricted forced desynchrony protocol

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Aims: To determine the effects of prior wake and circadian phase on subjective mood while employing a novel sleep restricted forced desynchrony (FD) protocol. It was hypothesised that positive mood (i.e. Vigour) would be influenced by a circadian and homeostatic process, whereas negative mood (i.e. Confusion, Tension, Anger, Depression, Fatigue) would not.
Methods: 10 healthy males, with a mean (± SD) age of 22.3 (± 3.5) years and a body mass index of 22.8 (± 1.8) kg/m² participated in a 28-h sleep restricted FD protocol. During the FD periods, participants were scheduled to 7h sleep and 21h wake (the equivalent of 6h sleep per solar day). Subjective mood was assessed using the Profile of Mood States (POMS) 1.5h after waking and every 2.5h thereafter. Circadian phase was assessed using the core body temperature rhythm that was sampled using a rectal thermistor (Steri-probe 491B).
Results: Separate linear mixed-model ANOVA were conducted on the total mood disturbance score and individual mood subscales. The positive mood scale of the POMS (Vigour) showed main effects for circadian phase and prior wake. The negative mood scales of Fatigue, Confusion and Tension were also influenced by both processes. No significant effects of circadian phase or prior wake were found for Anger or Depression.
Discussion: Very few studies have reported an influence of circadian phase or prior wake on negative mood states. No FD studies have yielded such results. Finding circadian and prior wake influences on 3 negative mood subscales within this FD study, could therefore be due to the use of the novel sleep restricted protocol, suggesting that negative mood is only influenced under reduced sleep. The findings from this study have practical implications as they give insight into how mood is affected when people receive 6h sleep per night which more closely mirrors that of today's society.
Contact: Laura Hampton (hamlk003@students.unisa.edu.au)

Introduction

Positive mood (affect) is influenced by a circadian and homeostatic process (i.e. prior sleep/wake).[3,7] Investigations in to whether negative affect follows this same pattern have yielded equivocal results.[3,5,6,7] Circadian phase influences on negative mood have been observed during an ultra-short sleep/wake cycle,[6] which only partially de-masks the influence of prior wake.[2] Additionally, homeostatic influences on negative mood have been noted during sleep restriction,[5] where results are confounded by the influence of circadian phase. In order to look at the influence of the circadian and

homeostatic process separately, a protocol that can remove the masking effect of the opposing process needs to be employed. A forced desynchrony (FD) protocol enables mood to be sampled across all possible combinations of circadian phase and prior wake, thus allowing for the effects of the two processes to be separated through data folding and averaging procedures.

Previous FD studies have employed a sleep/wake ratio of 1:2 (the equivalent of 8h sleep and 16h wake per solar day), giving insight into how mood is affected with the recommended 8h sleep per night. However, many people work varying or extended hours during both the biological day and biological night and consequently no longer receive 8h of sleep per night. Instead, many only obtain about 6h.[8] The independent influence of circadian phase and prior wake on mood under sleep-restricted conditions is unknown. It is under this premise that a novel sleep restricted FD protocol will be conducted whereby sleep/wake will be scheduled at a 1:3 ratio (the equivalent of 6h sleep and 18h wake per solar day).

The aim of this study is to use this novel approach to determine the influence of the circadian and sleep/wake homeostat on mood as measured by the Profile of Mood States (POMS).[9] Based on the findings of previous FD studies, which have only found circadian and prior wake effect on positive mood scales, it was hypothesised that positive mood would show circadian and homeostatic influences whereas negative mood would not. This study will provide information on how mood is influenced under conditions where individuals are receiving sleep which more closely parallels that routinely obtained by individuals.

Method

Participants

Twelve male volunteers were recruited; however two withdrew due to personal reasons. The remaining participants (n=10) had a mean (± SD) age of 22.3 (± 3.5) years and a body mass index of 22.8 (± 1.8) kg/m^2. Participants were non-smokers, drug and medication free, did not consume high levels of caffeine or alcohol and were of good physical and mental health as determined by a screening interview and a General Health Questionnaire. Participants wore a wrist activity monitor (Actiwatch-64, Philips-Respironics) and kept a sleep diary the week prior to the study to monitor sleep habits. Only those who maintained a nocturnal sleep/wake cycle and obtained 7 to 8h sleep per night were admitted as participants. Each participant provided written informed consent to partake in this study, which was granted ethics approval from the UniSA Human Research Ethics Committee and conforms to the guidelines established by the National Health and Medical Research Council of Australia.

Measures

Participants completed a battery of tests assessing various aspects of their neurobehavioural function of which the POMS was the first measure administered. The POMS is a 65 item assessment of transient mood state in which participants rate each item from 0=not at all to 4=extremely. It is a valid and reliable measure[9] frequently used in sleep studies[4,5,6] and provides a Total Mood Disturbance (TMD) score as well as a score on six individual subscales. The TMD score is the sum of the five negative mood subscales: Fatigue-Inertia (FI), Confusion-Bewilderment (CB), Tension-Anxiety (TA), Anger-Hostility (AH) and Depression-Dejection (DD) minus the positive mood subscale: Vigour-Activity (VA).

Core body temperature (CBT) was continuously recorded in 1-minute epochs using a rectal thermistor (Steri-probe 491B) inserted 10cm beyond the anal sphincter muscles. Circadian phase was determined by fitting a regression model for CBT with one fundamental (24h) and

one additional harmonic (12h) for the intrinsic circadian component. From this, an estimate of intrinsic period and clock time for the CBT rhythm was produced. Circadian phase was divided into 6 × 60° bins. The nadir of the fitted temperature rhythm was assigned circadian phase 0°.

Protocol

Participants lived in the time isolation laboratory for 12 consecutive solar (24h) days. During this time they had no access to time cues such as clocks, live television, the Internet or mobile phones. Ambient light was kept at 10-15 lux (dim indoor light) during wake periods and less than 0.03 lux (darkness) during sleep opportunities. Ambient temperature was set at 22±1°C.

The protocol consisted of two adaptation/training days and a baseline day where sleep was scheduled to begin at midnight and end at 8:00am. The FD period began upon waking after the baseline night. During this phase, the length of each 'day' was extended to 28h and the sleep/wake ratio was reduced to 1:3. Participants were scheduled to 7h sleep and 21h wake each 28h period (the equivalent of 6h sleep per solar day) and were scheduled to wake up 4h later each FD period. Test batteries were administered on 8 occasions each waking period, with the first being administered 1.5h after waking and then every 2.5h thereafter. Sleep was assessed using polysomnography (PSG) and scored according to the accepted criteria.[11]

Data Analyses

Separate linear mixed-model ANOVA were used to determine whether there were main effects of prior wake and circadian phase for TMD and the six individual subscales. Circadian phase and prior wake were entered into the model as fixed factors, with TMD, VA, FI, CB, TA, AH or DD entered as the dependent variable. Sleep efficiency (the percentage of time in bed spent asleep) was included as a covariate to take in to account variation in sleep length and time awake. Subject ID was entered as a random effect to account for the between-subjects variance. Post hoc comparisons, with Bonferroni corrections, were conducted to compare scores on the mood scales at each circadian phase with scores at circadian phase 0°. Scores at the varying prior wake categories were compared with scores at prior wake 1.5h. Significant differences are denoted in Figure 1 by asterisks.

Results

Linear mixed-model ANOVA revealed a main effect of circadian phase ($F_{(5,95)}$=18.0, p<.001) and prior wake ($F_{(7,72)}$=11.6, p<.001) for TMD. Participants experienced the greatest level of mood disturbance around the circadian nadir (0°) and the least at the acrophase of the CBT rhythm (180°). Mood disturbance increased with lengthened prior wake.

The main effects (and post hoc tests) of circadian phase and prior wake for the VA, FI, CB and TA subscales are plotted in Figure 1. Analyses of the positive subscale (VA) revealed a significant main effect of circadian phase ($F_{(5,115)}$=22.5, p<.001) and prior wake ($F_{(7,71)}$=12.4, p<.001). Vigour was highest at 180° and lowest at the circadian nadir. Vigour was inversely proportional to the level of prior wake.

Analyses of the negative subscales revealed significant main effects of circadian phase for FI ($F_{(5,85)}$=13.9, p<.001), CB ($F_{(5,83)}$= 8.4, p<.001) and TA ($F_{(5,77)}$=4.8, p=.001). FI and CB were at their highest at the circadian nadir. TA was highest at circadian phase 300° (on the upward arm of the CBT rhythm). FI and CB exhibited a persistent minimum from 120° to 240°, whereas TA was lowest at 180°. A significant effect of prior wake was also found for FI ($F_{(7,60)}$=10.1, p<.001), CB ($F_{(7,61)}$=7.5, p<.001) and TA ($F_{(7,61)}$=2.3, p<.05), wherein negative mood increased with prior wake. No main

effects of circadian phase or prior wake were found for AH and DD.

Discussion

While the results supported the hypothesis that positive mood would follow a circadian rhythm and show an effect of prior wake, the hypothesis that negative mood would not was only partially supported.

Significant main effects of circadian phase and prior wake were found for TMD. Participants showed greatest overall mood disturbance around 5am (circadian phase 0°) and the least amount of disturbance around 5pm (circadian phase 180°). Participants also reported a greater mood disturbance the longer they had been awake. However, while total mood disturbance worsened during these periods, none of the effects were clinically significant.[9]

The presence of significant main effects of circadian phase and prior wake for the positive mood subscale (Vigour) is congruent with the notion that positive affect is influenced by a circadian and homeostatic process.[3,7]

The negative subscales of Fatigue, Confusion and Tension were also influenced by circadian phase and prior wakefulness. Diurnal variation in negative affect has previously only been observed during an ultra-short sleep/wake cycle.[6] Although this protocol greatly diminishes homeostatic pressure, it only partially de-masks this influence.[2] Additionally, an effect of prior wake has been seen during sleep restriction[5] where results are confounded by the influence of circadian phase. In order to separate these two processes and assess their independent influence on mood, a FD protocol is required. FD studies have found that negative mood domains do not fluctuate across circadian phase or with prior wakefulness.[3,7] Hence, the findings of this FD study, which show a circadian and homeostatic influence for the

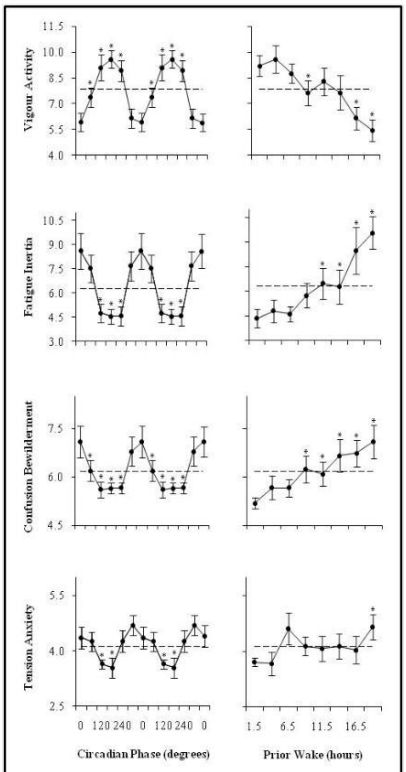


Figure 1. A double plot of circadian phase (left) and a plot of prior wake (right) for VA, FI, CB and TA. Plotted points represent mean scores for the different mood scales. The average score is represented by the dashed line. SE bars represent how different participants were from each other. Lower scores indicate less intensity. Asterisks denote significant post hoc differences from the first measure of prior wake (1.5h) or circadian phase 0°. *$p < .05$.

Fatigue, Confusion and Tension subscales, are novel. Previous FD studies have employed a 1:2 sleep/wake ratio (the equivalent of 8h sleep per night). In this study, participants were scheduled to a 1:3 ratio (the equivalent of 6h sleep per night). Therefore, the novelty of our observations may be attributed to the sleep restriction (or extended wakefulness) that was imposed on participants. That is, prior sleep history could be a mediating factor for the presence of circadian and homeostatic variation in the negative mood domains.

Previous FD studies have used visual analogue scales (VAS) to assess mood. However, most of these VAS measures are uni-polar and only measure one mood domain (i.e. happiness or cheerfulness). The POMS covers six mood subscales and also supplies a global measure of mood disturbance. Therefore, whilst a direct comparison between previous FD studies and the current study cannot be made, this study provides insight on the influence of circadian phase and prior wake on a wider range of mood scales than previously looked at in FD.

The observed results have practical implications for individuals engaged in shiftwork, as well as the companies which employ such working conditions. Mood has been linked with a variety of work related outcomes. For example, negative mood has been associated with increased absenteeism and turnover in the workplace, which can impact on productivity.[10] Positive mood, on the other hand is known to facilitate coping ability, creative problem solving and conflict reduction.[1] Consequently, those engaged in shifts which run during early hours of the morning, or involve extended hours of wakefulness, are more susceptible to diminished ability and performance. As laboratory studies are free from many external influences, which can impact on mood, field studies involving shift-workers should be conducted to determine whether these results are replicated in a less controlled environment.

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