
THE NEXT DAY EFFECTS OF A NORMAL NIGHT'S DRINKING ON COGNITION AND HUMAN PERFORMANCE

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I confirm that the word count of this thesis is less than 100,000 words

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Summary

This programme of PhD research aimed to extend the limited existing knowledge of the impact of the alcohol hangover on society. In particular, the aim was to gain a more comprehensive understanding of the next day effects of a normal night's drinking on cognition and human performance given the inconsistencies in methods and outcomes found in hangover research. In several literature reviews expectancy is considered a limitation of the naturalistic approach to cognitive and hangover research. To address this, a study was carried on two groups of participants, one where the true purpose of the study was disclosed, and in the other, the purpose was withheld. The results demonstrated little evidence to suggest that expectancy effects contaminated the outcome. This prompted the consideration of other variables that may contribute to inconsistencies in the findings.

The second study investigated performance in a non- student sample. In comparison to Study 1, similar findings were made in relation to response time measures and free recall, however drinking behaviour and non-response time measures did not mirror that of the previous study. A prominent aim of alcohol hangover research is to determine whether task performance is at the same level during hangover and no hangover testing sessions. This is useful at the onset of investigations, however to thoroughly understand the mechanisms at play, the processes underlying performance must be considered. Study 3 revealed important information relating to the way in which we process information with regards to signal detection. The results suggested that one's ability to accurately separate signal from noise is somewhat impaired during a hangover.

With regards to human performance, a scarcity of literature relating to physical activity led to the application of accelerometry methods to capture real time performance following a night of drinking. As expected the results revealed that a larger portion of the day was spent in sedentary activity. Sleep investigations also revealed disruption of sleep efficiency following a night's drinking.

Taken together, findings from this study indicate considerable implications for those working in high risk environments. All studies in this thesis employing cognitive tasks revealed impaired performance to some extent during an alcohol hangover. However, the complexity of the relationship between a hangover and cognitive performance was highlighted by the variation in results which showed that although most response time measured performance appeared to be impaired during a hangover, a blanket effect did not occur in that not all performance appeared was impaired during a hangover e.g. Divided Attention. This thesis has attempted to improve the methodological techniques used in hangover research and delineate the processes affected by a hangover.

1. Introduction

This thesis aims to explore the effects of an alcohol hangover on cognition and human performance; broadly defined as the unpleasant effects resulting from alcohol use (Swift & Davidson, 1998). To enable this understanding, this Chapter will first outline context examining alcohol use, and in particular consumption on a drinking occasion. Then it will explore what is currently known about the alcohol hangover, how it is defined, the biochemistry of alcohol consumption and the hangover, and some of the key challenges in the hangover field. The Chapter will then turn to issues of cognition more generally, and how these relate to hangover in the contemporary literature.

1.1 Alcohol Consumption

Global figures from census data of alcohol consumption in Ireland show that 11.46 litres of pure alcohol are consumed per person (over 15 years old) per year (World Health Organisation; WHO, 2018). This is the equivalent of 1,146 Irish alcohol units¹ (1432.5 UK units) of alcohol, 127.33 bottles of 12% wine or 498.26 568ml pints of Guinness (Drinkaware, 2018; calculated using algorithm cited by Brick, 2006). In the United Kingdom, 9.81 litres are consumed, this is the equivalent of 981 Irish units (1,226.25 UK units), 109 bottles of 12% wine or 426.52 pints of Guinness (Brick, 2006; Drinkaware, 2018; WHO, 2018).

According to the Health Research Board (HRB; 2009), 14% of 15 year olds, 21% of 16 year olds and 34% of 17 year olds consume alcohol weekly in Ireland indicating that 15, 16 and 17 year olds do not consume as much as those of 18+ years (69% of those that drank within the

¹ A unit in Ireland is 10g of alcohol; in the UK it is 8g of alcohol (Hope, 2009)

year reported consuming alcohol the week prior to a survey by Health Research Board; (Long and Mongan, 2014). Also, according to Mongan and Long (2016), 20.6% of the adult population (over 18 years) do not consume alcohol in Ireland. With this considered, the adult drinker is likely to consume much more than the figures cited above by WHO (2018). Similarly, 17% of men and 22% of women (aged 16 and over) in England reported that they did not consume alcohol within the year (2016). In Scotland, 17% of 15 year olds (2015) report drinking alcohol in the last week and 16% of adults (16+) report not consuming alcohol within the year (2016; Monitoring and Evaluating Scotland's Alcohol Strategy Report, 2018). In Wales, 17% of males and 14% of females between the ages of 11 and 16 report weekly alcohol consumption (Gartner et al., 2014); 10.47% of male and 16.7% of females of 16 years and over identify as abstainers (averaged across age groups from Gartner et al., 2014). More recently it has been argued that 20% of adults (18+) in Wales identify as abstainers (Angus, Holmes, Brennan & Meier, 2018). Finally, in Northern Ireland, 73% of adults (18+) consume alcohol which means that 27% do not (Health Intelligence briefing, 2011). Thus, it is likely that the figures estimated per capita in the UK are also subject to underestimation of alcohol consumers' true volume of consumption. In summation, it can be seen from the figures above that many people consume alcohol in both the UK and Ireland, and of those that do, alcohol is consumed in large quantities to put individuals at risk of harm, and at risk of hangover.

1.1.1 Alcohol on Occasion

Daily alcohol consumption in 2010 was estimated at 31.7 grams of pure alcohol per capita in Ireland and 29.8 grams in the United Kingdom per day (WHO, 2018). The density of

alcohol has been considered to be 0.789kg/m^3 (Vogel et al., 2011; Weast, 1983; Zin, Ross, Jones & Dupont, 2011) which can be used to convert daily consumption to 1.68 pints of Guinness at (4.2%) or almost half a bottle of wine (0.48; 12%) per day in Ireland and 1.58 pints of Guinness or 0.45 bottles of wine per day in the UK². However, conversion values from grams to units of alcohol vary across countries and researchers. As mentioned above, Hope (2009) cites that 8 grams in the UK and 10 grams in Ireland are equal to one unit of alcohol. With this considered, unit values of consumption in Ireland can be valued at 3.96 UK units or 3.17 Irish units per day. UK consumption levels equate to 3.73 UK units or 2.98 Irish units. These units are to standardise drinks for the ease of comparison across types, and to help individuals make choices around their alcohol use with views to recommended limits for alcohol. Moreover, the calculations carried out by the WHO were done so using a value of $.793\text{ kg/m}^3$ of alcohol density which contrasts slightly from that calculated by Weast (1974). Therefore, daily consumption equivalent calculations may vary.

Using a different methodology to the WHO studies, a diary survey report whereby respondents were required to report details pertaining to weekly type, quantity, frequency and location of alcohol consumption was carried out in Ireland (Long & Mongan, 2013). Out of all respondents (5,991), 16.2% reported drinking once a week, 21% reported consuming alcohol 2-3 times a week and 5.1% reported consuming alcohol 4 or more times a week. Of note, 20.6% had not consumed alcohol within the past year. Of those that consumed alcohol within the past year, 41.9% reported consuming 6 or more drinks per occasion, where each drink was 10g of

² Computed using the formula- Density x Volume=Mass to calculate total mass of drink, divided by 100 and multiplied by percentage of alcohol content to calculate grams of alcohol per drink. Amount per capita divided by grams calculated the number of drinks per capita.

alcohol per drink. This was double the average daily amount from the WHO studies. Moreover, 44.2% reported consuming 9 or more drinks as the most drinks consumed in one occasion over the past year (Long & Mongan, 2013), almost three times the daily amount from the WHO studies. As such, the estimation of typical amount consumed per occasion depends on how it is measured, and how it is interpreted by the drinker themselves.

In Northern Ireland, a report by the Department of Health, Social Services and Public Safety (DHSSPS; 2011) found that out of 2022 respondents, 78% reported reaching or exceeding the recommended daily limit (4+ UK units for males, 3+ UK units for females) of alcohol on at least one day the week prior to the survey. Moreover, 52% of males and 40% of females reported consuming alcohol at least once the week before. A further 8% of males and 5% of females consumed alcohol daily or most days. A more recent study by DHSSPS (2014) revealed similar results to the 2011 survey, 50% of males and 43% of females reported consuming alcohol at least once a week and a further 8% of males and 5% of females reported consuming alcohol daily or almost every day. Indicating that consumption levels have remained the same. The report also found a considerable increase in alcohol consumption among 60-75 year olds which changed from a prevalence of 49% to 58% from 1999 to 2013. Daily drinking was also more common among 60-75 year olds with 18% of males and 14% of females consuming alcohol almost every day. Also, 10% of males and 7% of females between the ages of 45-59 consumed alcohol daily. In contrast just 2% of males and 1% of females aged 18-29 reported consuming alcohol almost daily. These results indicate a difference in drinking behaviours across age and gender.

The benefits of surveys such as those by Long and Mongan (2013) and DHSSPS (2014) include the categorisation of adults as 18+ years as section 1.1 highlights the differences in alcohol consumption of those below and above the legal age of consumption. However, varying questions are used across surveys which makes comparisons between countries difficult. In contrast, data collected from the WHO (2018) in 2010 provides a standard set of questions which can be compared across countries. For example, using the same age (15+) and conversion algorithm ($\text{g/day} = \text{APC} \times 1000 \times 0.793/365 \text{ days}$; WHO, 2018) weekly alcohol consumption in Ireland and the UK can be compared to many countries including France (11.74), Estonia (15.35), Australia (9.71) and Germany (10.9). According to the WHO (2018), Ireland was the 6th and the UK was the 17th largest consumer of alcohol in 2010.

Surveys which measure alcohol consumption are limited by respondents' ability to accurately recall the number of drinks or units consumed in the previous week, month or year. It is challenging for individuals to average their own consumption, and this is particularly the case where some individuals drink few drinks during the working week, but drink heavily at the weekend (McClatchley, Shorter, and Chalmers, 2015). Moreover, one's ability to identify a standard drink or unit may also threaten the validity of the data. In an Irish study by the Health Research Board (IPSOS MORI, 2012), only 58% of the sample (n=1020) had heard of the term 'standard drink', only 24% were aware that 200 millilitres of wine contains two standard drinks and 51% were aware that a half pint of Guinness contains around one standard drink. Answers were given in a multiple choice structure with three options (1, 2, or 3 standard drinks) per question. Knowledge of standard drinks measures across wine, Guinness, lager and spirits were known by just 9% of respondents.

Definitions pertaining to binge drinking and recommended weekly units also vary considerably. The National Institute on Alcohol Abuse and Alcoholism (NIAAA; 2004) define a binge drinking episode as consuming alcohol to reach a Blood Alcohol Concentrations (BAC) value of 0.08%, or five or more standard drinks for male or four or more for a female (Kuntsche, Kuntsche, Thrul & Gmel, 2017; NIAAA; 2004). However, this is problematic as the definition of a standard drink varies across countries. For example, the amount per standard drink in America=14g, in New Zealand=10g, in Australia=10g, in Germany=12g, or in Canada=13.6g, which makes international comparison more difficult (Kalinowski & Humphreys, 2016). Also, the strength of beer varies considerably, for example, a half pint of beer is often characterised as one standard drink in both Ireland and the UK, however, the volume of pure alcohol in beer can vary considerably by brand; for example, Karpackie beer is 9% alcohol (Van Pur, 2018) and Beck's Premier Light is 2.3% alcohol (Chen & Sheih, 2016).

Prevalence reports of binge drinking in Ireland suggest 75% of alcohol consumed in Ireland is done so at a binge level (defined as four or more drinks for a female, five or more drinks for a male; Long & Mongan, 2013). In a survey based in Great Britain, binge drinking was categorised as eight or more units for a male or six or more units for a female. The results showed that 26.8% of respondents binged on their heaviest drinking day prior to the survey (National Statistics, 2017). In contrast, a Northern Ireland study by Health and Social Care (HSC; 2011) using a definition of binge as 10 or more units for males or seven or more for females found that 32% of those that consumed alcohol the week before the survey had done so at a binge level. Thus, evidence suggests that higher levels of binge drinking may occur in Ireland than in the UK. Finally, despite the limitations relating to the accuracy of prevalence measures of

alcohol consumption, the results indicate high levels of alcohol consumption in Ireland and the UK, and certainly drinking to a level which increases the likelihood of individuals experiencing a hangover.

As testing in Chapters 3 and 5 were carried out in Northern Ireland, it was decided a table provided by the National Health Service (NHS; 2012) would be used to convert alcohol beverages to UK units in all studies within this thesis in order to maintain consistency. Type and volume of drink would also be collected in order for alternative conversions to be carried out at a later time if needed. A definition of binge drinking as six or more drinks was also be implemented throughout this thesis for both males and females (NHS, 2017). Whilst definitions may vary depending on country, or circumstance, we adopt this single figure here.

1.2 Alcohol Hangover

1.2.1 The Importance of Studying Hangover

It is estimated that over 520,000 people go to work with an alcohol hangover each day in the UK, equating to 17 million working days lost due to a hangover (Alcohol in Moderation, 2010; Institute of Alcohol Studies 2017). In addition, the alcohol hangover is valued at costing the economy around £6.4 billion a year (Prime Minister's Strategy Unit, 2004). The Department of Health, Social Services and Public Safety in Northern Ireland estimates that the social costs of alcohol misuse in Northern Ireland reaches over £679.8m per annum (DHSSPS; 2010).

Absenteeism due to alcohol misuse in Northern Ireland alone is estimated to cost £33.1m (DHSSPS, 2010) and in the Republic of Ireland it is estimated to cost more than €41,290,805 (Mongan & Long, 2016). This indicates that the alcohol hangover affects the work of a large number of individuals in the UK and Ireland which in turn results in a considerable cost to the economy. What is more difficult to calculate is the cost of presenteeism. It is likely that loss of productivity, lateness, disputes with colleagues, accidents and poorly executed tasks at work due to alcohol related impairment the morning after a nights' drinking are a considerable expense to our economy. For example, a surgeon may carry out an operation while experiencing an alcohol hangover as there are currently no rules pertaining to acceptable BAC or hangover levels for surgeons to operate (Kapoor, Das-Purkayastha & Harries, 2012; Royal College of Surgeons, 2018). Airline companies often impose an 8-12 hour 'bottle to the throttle' rule for their pilots (Civil Aviation Requirements India, 2015; FAA, 1971; Newman, 2004). However, this does not account for the cognitive impairment which occurs after BAC returns to zero and the alcohol hangover begins (Stephens, Grange, Jones, & Owen, 2014; Stephens, Ling, Heffernan, Heather, & Jones, 2008; Verster, 2008; Wiese, Shlipak, & Browner, 2000). Moreover, almost 20% of work-related accidents in the UK are linked to the operation of heavy machinery (Office for National Statistics, 2017). Despite this, almost 50% of heavy machinery workers report drinking the night before using heavy machinery (Censuswide, 2015). Alcohol related accidents in the work place are estimated at €450 million in Ireland (Byrne, 2010). Many of the activities carried out in a normal day's work involve various cognitive functions that are affected differently during a hangover (Stephen et al., 2008). Moreover, cognition is not made up of one system but rather it is made up many systems (Thelan & Smith, 1996). To fully

understand the hangover's impact on cognition and the dangers that it poses, exploration of the impact of hangovers on individual cognitive systems is required.

Furthermore, it is estimated each tax payer in Ireland contributes €3,318 per annum to alcohol related health and crime (Alcohol Action Ireland, 2011). In relation to health, regular alcohol hangovers are associated with poorer health including cardiovascular mortality in middle aged men (Kauhanen et al., 1997; Shorter, Murphy & Cunningham, 2017). Also, those who experience regular hangovers are more likely to develop alcohol dependence (Molbak, Schou & Tolstrup, 2017). These results indicate hangover has considerable cost to society, whether at work, in healthcare, or daily activities; cognitive impairments as a result of the alcohol hangover have considerable costs which are often overlooked. The alcohol hangover has received little attention despite the physical dangers, societal cost, and health consequences that may arise as a result of the alcohol hangover (See 1.1). This was raised in a key article by Verster (2010), in a special issue in *Current Drug Abuse Reviews*. The figures given in this paper were difficult to replicate in PubMed, so they were replicated below for the current day using both PubMed and Google Scholar as examples to reflect the current under-representation of this important research in contemporary literature. It is of note, that since Verster noted 406 publications in 2010, there has not been a significant increase in the number of papers published.

Table 1.1. Number of articles available under a range of related health topics from PubMed and Google Scholar from August 2018

Search	No. of PubMed Articles	Google Scholar
Alcohol Hangover	384	1920
Hangover	610	78,200
Cognitive impairment	860,14	1,830,000
Workplace health	313,55	529,00
Alcohol	903,478	3,680,000
Dementia	185,752	203,000
Depression	395,834	3,470,000
Hay Fever	152,03	129,000
Cannabis	18,429	508,00

1.2.2 The Hangover Defined

“My first return of sense or recollection was upon waking in a strange and dismal-looking room, my head aching horridly, pains of a violent nature in every limb, and deadly sickness at the stomach”

William Hickey (1768) in Swift and Davidson (1998, p.54)

Despite a long history of alcohol consumption, the word hangover was not used until 1904 (Ayto, 2005). Before the 20th century, the alcohol hangover had many names including Katzenjammer (Katzen=cats, jammer= misery; Collins German Dictionary, 2018; The Guardian, 1849) and Paramada which was cited in a 3000 year old medical book in India (Schrojenstein Lantman, van de Loo, Mackus & Verster, 2017; Srikantha-Murthy, 2008). Today, there are many

slang terms (e.g. wasted, which suggests that the mind or body is ruined or devastated) for a hangover which relate to unpleasant mental and physical symptoms which often define the experience (Crystal, 2014).

An alcohol hangover occurs after alcohol intoxication and is thought to last around 18.4 hours or between 14 and 23 hours (Schrojenstein Lantman, Mackus, Roth & Verster, 2017; Schrojenstein Lantman, Mackus, Verster, 2018). Typically, definitions given in hangover papers are defined by the authors of the paper. Two such definitions include:

“Alcohol hangover refers to the set of adverse symptoms experienced following alcohol consumption once alcohol has been eliminated from the blood.” (Grange, Stephens, Jones & Owen, 2016; pp. 03)

Or

“...A constellation of unpleasant symptoms that emerge as the blood alcohol concentration approaches zero after excessive alcohol use.”

(Slutske, Piasecki, Nathanson, Statham & Martin, 2014; pp. 2027)

However, individual definitions may prove troublesome as a consensus on the phenomenon being examined is not clear (Schrojenstein Lantman, Mackus, Verster, van de Loo, Mackus & Verster, 2016). For example, the alcohol hangover is sometimes argued to be the acute withdrawal effects of alcohol (Prat, Adan, Sánchez-Turet, 2009; Swift and Davidson, 1998; Wiese et al., 2000).

The authors (Schrojenstein Lantman, Mackus, Verster, van de Loo, Mackus & Verster, 2016) conducted a survey of 1099 student respondents via Facebook ($M=20.9$ years, $SD=2.3$) where respondents were asked to type their best definition of a hangover. The most frequently reported symptoms were nausea (23.1%), headache (22.8), tiredness (9.6%) and apathy (5.4%). These 4 symptoms were then regarded as the four core symptoms of a hangover. The survey above was limited by the sample that was used. The age ranged from 18-30 years and included Dutch students only. As drinking behaviours differ with age, it is possible that the experience of an alcohol hangover may differ with age also (Verster et al., 2010). Using Dutch students only may also limit the results as not all ethnicities experience hangovers in the same way. For example, 560 million people of East Asian descent have an overactive alcohol dehydrogenase gene which causes Asian flush syndrome (Goedde, Harade & Agarwal, 1979). Not only do those of East Asian descent reach intoxication more easily, they also experience more severe hangovers (Wall, Horn, Johnson, Smith & Carr, 2000). In a study by Wall et al., (2000) Asian Americans who were either homozygous (mutations on both chromosomes), heterozygous (one mutated chromosome, one normal) or no mutations for aldehyde dehydrogenase genes were asked to answer a series of questions pertaining to demography, usual alcohol consumption, and hangover experience. A series of separate multiple regressions were performed on hangover questionnaires and predictor variables including gender, frequency of recent drinking, quantity of recent drinking and gene mutation type were applied. The results revealed a significant difference in reports of hangover severity and symptom scores in those with varying gene mutations with more intense hangovers occurring in those with the gene mutations. Moreover, those with two gene mutations experienced more severe hangovers

than those with one gene mutation. Although the differences in symptoms are not explored in this study, considerations of differences across ethnicities is warranted. The authors conclude that cross cultural explorations are needed in order to gain a better assessment of the alcohol hangover. Therefore, the definition by Schrojenstein Lantman, Mackus, Verster et al. (2017) may be limited to the experiences of young Dutch adults only. These symptoms did not correspond to the symptoms most commonly reported in hangover research; tiredness is often the most experienced symptom reported (Verster, van Herwijnen, Olivier and Kahler, 2009).

Further attempts at definition include the use of expert consensus. Link analysis which identified nine definitions composed of the most common factors used in the definition of hangovers by respondents e.g. intake of alcohol, symptoms and duration of hangover. From this, three definitions were created:

“The alcohol hangover is a combination of mental and physical symptoms, including headache, nausea, being tired and apathy, experienced the day after excessive alcohol consumption, which may negatively impact daily functioning and mood.”

“The alcohol hangover is a combination of mental and physical symptoms, including headache, nausea, being tired and apathy, experienced the day after excessive alcohol consumption.”

“The alcohol hangover is a combination of mental and physical symptoms, experienced the day after excessive alcohol consumption.”

(Schrojenstein Lantman, Mackus, Verster, van de Loo, Mackus & Verster, 2017; pp.151)

These definitions were then presented to the Alcohol Hangover Research Group³ (AHRG, n=35) for feedback. The Alcohol Hangover Research Group was established in 2009 (Verster, 2010), to increase the quality and quantity of research in the hangover field. Of these 35, 16 (45.7%) members replied and the concluding definition reads as:

“The alcohol hangover refers to the combination of mental and physical symptoms, experienced the day after a single episode of heavy drinking, starting when blood alcohol concentration approaches zero”.

(Schrojenstein Lantman, Mackus, Verster, van de Loo, Mackus & Verster, 2017, pp.153)

Expert responders highlighted concerns around the use of ‘excessive’ drinking and as a result this was replaced by the word ‘heavy’. Heavy episodic drinking is sometimes referred to as binge drinking. As discussed above in Section 1.1.1, the definition varies, however it is likely to be around six or more drinks (NHS, 2017). Chapman (1970) argues a peak BAC of .11% or .12% is necessary to create a hangover. BAC levels can also vary depending on sex, weight, water consumption, beverage type, food consumption and time taken to drink beverages (Rohesnow & Marlatt, 1981; Verster et al., 2010). According to a BAC calculator by Healthstatus.com and used by U.S Department of Transport (Department of Transport, 1992; Healthstatus, 2018), a female aged 25 and weighing 8 stone (112 lbs) will reach a BAC level of

³ Note: Author is a current member and contributor to AHRG

.13% after consuming 3 drinks of whiskey within 1 hour. It can therefore be argued that heavy episodic drinking may not be required for a hangover to occur, and other factors including timing and composition of both drinks and the person are important to consider.

In summation, the definition of an alcohol hangover from Schrojenstein Lantman, Mackus, Verster et al., (2016). will be used within this thesis. However, excessive or heavy drinking will not be required for hangover categorisation in studies within this thesis.

1.2.3 Measuring an Alcohol Hangover

Moving beyond the conceptual definition of a hangover, for research, it is important to be able to understand what a hangover is and thus measure a hangover. The most comprehensive list of symptoms identified was compiled by Penning, McKinney and Verster (2012). These 47 included mental symptoms such as dizziness and confusion; and physical symptoms such as fatigue and nausea. The full list of symptoms were (in order of frequency):

1. Fatigue (being tired)
2. Thirst
3. Drowsiness
4. Sleepiness
5. Headache
6. Dry mouth
7. Nausea
8. Weakness
9. Reduced alertness
10. Concentration problems
11. Apathy (lack of interest/concern)
12. Increased reaction time
13. Reduced appetite
14. Clumsiness
15. Agitation
16. Vertigo
17. Memory problems
18. Gastrointestinal complaints
19. Dizziness
20. Stomach pain
21. Tremor
22. Balance problems
23. Restlessness
24. Shivering
25. Sweating
26. Disorientation
27. Audio-sensitivity
28. Photo-sensitivity
29. Blunted affect
30. Muscle pain
31. Loss of taste
32. Regret
33. Confusion
34. Guilt
35. Gastritis
36. Impulsivity
37. Hot/cold flashes
38. Vomiting
39. Heart pounding
40. Depression
41. Palpitations
42. Tinnitus
43. Nystagmus
44. Anger
45. Respiratory problems
46. Anxiety
47. Suicidal thoughts

Whilst these symptoms attempt an exhaustive list, it is not practical to assess all of these symptoms reported in research. Similarly, whilst some may be characteristic of hangover, others could be associated with different factors; for example, anxiety may be the result of hangover, or could be a common experience for the person. A consensus on best practice in hangover research highlighted two alcohol hangover scales as most useful to measure the symptoms (Verster et al., 2010). The Hangover Severity Scale measures the frequency of 13 validated symptoms experienced (Slutske, Piasecki & Hunt-Carter (2003; $\alpha = .84$) and the Acute Hangover Scale (AHS; $\alpha = .84$) measures the severity of nine hangover symptoms using a Likert scale (Rohsenow, Howland, Minsky, Greece, Almeida & Roehrs (2007). The overlap between these three scales is given in Table 1.2.

Table 1.2. Hangover symptoms included in AHS, AHSS, and HSS

Hangover Symptoms shared between questionnaires	AHS	HSS	AHSS
Fatigue	*	*	*
Thirst	*	*	*
Headache	*	*	
Nausea	*	*	*
Weakness		*	
Concentration problems		*	*
Apathy (lack of interest/concern)			*
Reduced appetite	*		
Clumsiness			*
Dizziness	*		*
Stomach pain	*		*
Shivering		*	*
Sweating		*	*
Audio-sensitivity		*	
Photo-sensitivity		*	
Confusion			
Vomiting		*	*
Heart pounding (racing)	*		*
Depression		*	
Palpitations			
Anxiety		*	

This table is based on the findings by Penning et al., (2012).

Since the AHS and HSS were developed and recommended by Verster (2010), there has been one additional scale created. The Alcohol Hangover Severity Scale (AHSS) was developed by Penning, McKinney, Bus, Olivier, Slot and Verster (2013) containing 12 symptoms from the 47 identified by Penning et al., (2012; fatigue, clumsiness, dizziness, sweating, shivering, nausea, heart-pounding, confusion, stomach pain, concentration problems and thirst). These were measured as present/absent/on a five-point Likert scale. However, this scale had not been developed when the first empirical Chapter was designed. HSS was created using survey data and is more widely used across longer time reference periods (e.g. it can capture the nature of a hangover in the past year). The AHS was developed using an experimental approach and measured hangover symptoms as well as severity closer to the time the hangover occurred. With this in mind, the AHS was selected for measuring both frequency and severity of alcohol hangovers throughout the thesis as testing occurred around the time of the hangover.

In recent years, some deliberation has been made around the level of alcohol and its metabolites in the body when the hangover begins. Traditionally, when a BAC level is above 0% it is assumed to reflect acute intoxication (Verster et al., 2010). However, a more recent study claims to demonstrate that when Breath Alcohol Concentration (BrAC) levels return to zero, alcohol metabolites may still be present in urine and have an active effect (Verster, Mackus, van de Loo, Garssen & Scholey, 2017). Thus, the authors argue that cognitive tests carried out when BrAC levels are zero do not ensure hangover testing and may reflect residual intoxication effects. However, detection of alcohol in urine can often be delayed; urine detection may not signify the effects of intoxication are still in the body, rather, the effects of intoxication may be removed from the body but excreted as waste product through urine for some time after

(Murphy, 2015). Moreover, if the bladder is not emptied before, during or after alcohol consumption, indicators of alcohol use in the urine may be inaccurate (Murphy, 2015).

Breath analysis of alcohol functions through the exchange of air in the alveoli within the lungs. As oxygen is inhaled through the alveoli, carbon dioxide is exhaled through the alveoli through the blood. Thus, if alcohol is present in the blood it will be detected through the breathalyser measurement of alcohol concentration in the air according to Henry's Law⁴(Saferstein, 2007).

Furthermore, it is estimated that 23% of drinkers never experience a hangover (Howland, Rohesnow & Edwards, 2008). However, this review applied data that was collected from a laboratory setting using a pre-set dose to reach a peak BAC of around 100mg/dl - 120mg/dl (.1 or .12%) which is considerably lower than that consumed in a naturalistic setting (Hesse & Tutenges, 2010; Jones, 2010; Kruisselbrink, Bervoets, de Klerk, van de Loo & Verster, 2017; Verster, de Klerk, Bervoets, & Kruisselbrink, 2013). In a survey of Canadian adult drinkers, it was reported that 43% of drinkers had few or minimal symptoms of a hangover (Shorter et al., 2017). These differing figures illustrate issues of both attribution (e.g. was the tiredness caused by the hangover) and sample measurement (experimental vs survey methods).

A more recent study by Verster et al., (2015) suggests that hangover immunity may not exist and that those who claim to be hangover immune may not be consuming enough alcohol to create a next day hangover state. In support of this, a study by Kruisselbrink, Bervoets, de

⁴ "At a constant temperature, the amount of a given gas that dissolves in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with that liquid." (Chemistry Libre Texts, 2018; Henry, 1803)

Klerk, van de Loo and Verster (2017), recruited a student sample to take part in a survey where they were asked about alcohol consumption and hangover experiences. Respondents reported their heaviest drinking session in the previous month and estimated peak BAC levels were calculated and analysed along with hangover severity reports. The results showed that when one looks at respondents that reported BAC levels of 80mg% or above, just 5.8% of females and 5.1% of males reported hangover resistance. Despite differences in reported hangover symptoms, the way in which alcohol is metabolised does not appear to differ across those who claim to be hangover resistant and those who do not (Mackus, Schrojenstein Lantman, Mackus, Verster, van de Loo, Kraneveld, Garsson, Brookhuis & Verster, 2018). Of note, those of East Asian decent report hangover symptoms after low levels of alcohol consumption therefore, it cannot be assumed that those who report hangover resistance are not consuming enough alcohol (Wall, Horn, Johnson, Smith & Carr, 2000).

Whilst the AHS, HSS, and AHSS measure individual symptoms, and the consensus definitions can summarise the general nature of the hangover, it is noted that alcohol hangover symptoms can differ from person to person (Penning, McKinney, Bus, Olivier, Slot & Verster, 2013). For example, a study by Shorter, Murphy & Cunningham (2017) used latent class analysis to identify patterns around alcohol consumption and hangover symptoms. Participants were an online community (n=579) that were asked to report on previous year's hangover symptoms and drinking behaviour. Four classes were identified, Class 1, included participants that experienced multiple hangover symptoms; class 2 experienced thirst, tiredness, nausea and vomiting; Class 3 experienced thirst, tiredness and headache and class 4 were symptoms free. Differences in drinking behaviours, flushing/blushing, perceived harm from drinking and

AUDIT scores across groups were used to explain the variation in symptom profiles, however, a number of individuals did not experience hangover at all (class 4) whilst drinking similar amounts to those in the other groups (Classes 1-3). This research highlighted the importance of gaining a better understanding of alcohol hangover symptoms as experienced together. Other attempts to group symptoms have not been at the personal level, but at the level of symptoms. For example, Swift and Davidson (1998) grouped symptoms into classes of *pain*, *gastrointestinal irritation*, *disturbance of sleep*, *sensory system imbalance*, *sympathetic hyperactivity*, *mood disruption* and *cognitive impairment*. Each of these will be considered in turn.

1.2.4 The Biochemistry of Alcohol Hangover Symptoms

1.1.1.1 Pain

Symptoms of *pain* such as headaches can be caused by dehydration. For example, alcohol is a diuretic and therefore leads to an increased production of urine which in turn causes the release of fluids from the body (Eggleton, 1942). It also decreases the body's production of vasopressin which is an antidiuretic hormone that is secreted by cells in the nuclei of the hypothalamus and is stored in the pituitary glands. Vasopressin controls water retention in the kidneys and therefore, when alcohol slows down the production of vasopressin, the body becomes dehydrated through increased urination (Ylikahri, Pösö, Huttunen & Hillbom, 1974). Electrolytes such as sodium, magnesium, potassium and calcium

become depleted as a result of the over production of urine (Swift and Davidson, 1998). This contributes to physical pain such as muscle ache (Bergeron, 2008). For this reason, researchers often recommend drinking beverages and foods rich in electrolyte ions alongside, before or after alcohol consumption (Hecht, 1986). Although Strauss, Rosenbaum and Nelson's study (1950) suggests that hydration diminishes alcohol symptoms by 50%, the study is unclear about how it reaches this conclusion, it does not state how many participants were recruited and furthermore, it is inconsistent with more recent studies which suggest that rehydration does not significantly decrease hangover symptoms (Verster, 2015). In this study 826 Dutch and Canadian participants were asked if they consumed food or water after alcohol consumption and hangover symptoms and severity were measured. The results showed that hangover symptoms and severity did not differ significantly when water or food were consumed (Verster, 2015). However, the study was carried out in the form of a survey whereby participants were asked to report on the last hangover that they experienced. Retrospective recall of alcohol, water and food consumption may be subject to inaccuracies thus the role of hydration during alcohol consumption or a hangover remains uncertain and should be interpreted with caution.

1.1.1.2 Gastrointestinal Irritation

The *gastrointestinal symptoms* of a hangover include vomiting and stomach pain (Lieber, 1995). Here, cells and tissues in the gastrointestinal tract can become damaged as a result of alcohol consumption (Swift & Davidson, 1998). Alcohol is a toxin that irritates the stomach lining. This creates the stomach pain or cramps which may be associated with an alcohol hangover (Batmanghelidj & Page, 2012). An inflamed stomach lining also prevents the

stomach from producing acids and enzymes that aid digestion, as a result, the stomach churns its contents to help the movement of its contents from the stomach into the intestines (Hunt et al, 2014).

Alcohol may prompt the secretion of hydrochloric acids in the stomach. This causes the body to get rid of the stomach contents through vomiting (Chari, Teyssen & Singer, 1993). Vomiting as a result of alcohol consumption can then result in the development of oesophageal varices and Mallory-Weiss syndrome (tear in mucose membrane; Bujanda, 2000). Acid regurgitation can be experienced after large amounts of alcohol is consumed, it occurs as a result of lowered pressure on the oesophageal sphincter and the slowing of oesophageal propulsive motor activity and gastric emptying (Bujanda, 2000).

Teyssen et al. (1997) found differences in acid secretion among drink types during alcohol consumption. The authors found that fermented beverages such as wine, prosecco, beer and sherry stimulated acid secretion but fermented and distilled beverages such as whiskey, rum, and Cointreau had no effect on acid secretion. In addition to this, gastric emptying appears to differ across alcohol doses with low doses appearing to increase gastric emptying and high doses decreasing gastric emptying (Bor, Bor-Caymaz, Tobey, Abdulnour & Orlando, 1999; Bujanda, 2000). Therefore, in addition to individual differences of hangover symptoms, gastrointestinal problems may vary due to the dose and type of drink consumed.

1.1.1.3 Sleep Disturbance

Although, people often report falling asleep immediately after alcohol consumption (Finnegan, Hammersley & Cooper, 1998), the quality of *sleep* can be disturbed by the over production of glutamine. Glutamine is a natural stimulant and alcohol produces both stimulant and sedative effects (Hendler, Ramchandani, Gilman & Hommer, 2011). The stimulating effects of alcohol are thought to be associated with rising BACs (while drinking) whereas the sedative effects are associated with already high BAC levels (Martin et al., 1993). The stimulating effects are linked to the activation of dopamine release in the brain's 'reward circuitry' (Hendler, Ramchandani, Gilman & Hommer, 2011). During alcohol consumption glutamine production is suppressed, and when alcohol leaves the body, the body then attempts to recover lost levels of glutamine. The increased glutamine levels after consumption has ceased is referred to as Glutamine Rebound (Simpson, Resch, Millington & Myers, 1998).

There are two main types of sleep Non-Rapid Eye Movement Sleep (NREM) and Rapid Eye Movement Sleep (REM). NREM sleep refers to the first three stages of sleep (wakefulness, light sleep and deep sleep) and REM sleep occurs after NREM sleep. Here, the brain is active and dreaming can occur (Lu, Sherman, Devor & Saper, 2006). Reduced REM sleep has been observed in the first half of the sleep period after drinking (Williams and Salamy, 1972). When the Glutamine Rebound occurs (after alcohol leaves the system), Roehrs et al. (1991) found increased waking and light sleeping occurred during the second half of the sleep period. On a normal night NREM and REM sleep regulates throughout the night with an average of six to

seven cycles, however, after an evening of drinking this is reduced to two to three cycles (Drinkaware, 2015).

Alcohol also interferes with blood sugar levels controlled by the liver (Frienkel et al., 1965). When alcohol (ethanol) is ingested, it moves through the stomach and into the liver where it is transformed into acetaldehyde by the enzyme, alcohol dehydrogenase. Acetaldehyde is then converted into acetate by the acetaldehyde dehydrogenase enzyme (ALDH).

The metabolization of acetaldehyde to acetate occurs as illustrated below:



This results in the accumulation of nicotinamide adenine dinucleotide (NADH) which causes a build-up of lactic acid through the prevention of lactate oxidation (Swift & Davidson, 1998). Furthermore, NADH also inhibits the oxidation of fatty acid and as a result, a condition called fatty liver can occur in those who consume large amounts over time (Brooks & Zakhari, 2014; Swift & Davidson, 1998). Both excess lactic acid and the presence of fatty liver can inhibit the production of glucose in the body resulting in lowered blood sugars (Berg, Tymoczko & Stryer, 2002). Low blood sugars are associated with tiredness, crankiness and dizziness (Varni et al., 2018).

Furthermore, the suppression of growth hormone after alcohol consumption impacts on sleep-wake rhythms (Swift & Davidson, 1998). The growth hormone is often secreted by the pituitary gland in the first few hours into a sleep period and plays an important role in the

growth, recuperation and repair of muscles, bones and other tissues in the body (Van Cauter & Play, 1996). As sleep is disrupted so too is the release of the growth hormone which in turn also contributes to the physically exhausted, 'jet lagged' type feeling experienced after a night's drinking (Prinz, Roehrs, Vitaliano, Linnoila & Weitzman 1980). Alcohol's impact on the biochemistry of the body during metabolism also contributes to the most commonly reported hangover symptom, tiredness (Verster, van Herwijnen, Olivier, Kahler, 2009).

1.1.1.4 Sensory Sensitivity

Increased *sensory sensitivity* is another commonly reported hangover characteristic (Swift and Davidson, 1998). Sensitivity to light and sound or vertigo symptoms can be attributed to mild alcohol withdrawal in nondependent drinkers. The toxins in the body created by alcohol can irritate sensory nerve cells. Sensitivity is lowered during intoxication and a rebound effect may occur during a hangover (Pinel and Mucha, 1980). As an evolutionary coping mechanism, the body then interprets the irritation as stress and the cells become overly active which causes the sensory system to become more delicate (Fink, 2010). Few researchers have explored the hypersensitivity that occurs during a hangover as a product of central nervous system changes, and this is an area for further examination.

1.1.1.5 Sympathetic Hyperactivity

Sympathetic Hyperactivity is an increased activity of the sympathetic nervous system which is a symptom of *veisalgia* (Swift & Davidson, 1998). As a result, sweating, tremors, and both increased heart rate and systolic blood pressure can occur (Howes & Reid, 1985; Tsai,

Gastfriend & Coyle, 1995). As mentioned above, alcohol dehydrogenase breaks ethanol into acetaldehyde (Zakhari, 2014). In large amounts acetaldehyde can have toxic effects which, similarly to sympathetic hyperactivity also include, sweating, vomiting, and increased pulse and temperature (Swift and Davidson, 1998; Ylikahri et al 1974). Nonetheless, acetaldehyde typically metabolises quickly and has left the body when BAC returns to zero (Zakhari, 2006). Despite this, some researchers suggest that acetaldehyde is responsible for the ill feeling of a hangover (Swift and Davidson, 1998; Wiese, Shlipak, & Browner, 2000). However, for those who have inactive alcohol dehydrogenase (ALDH) genes which are responsible for the production of enzymes that metabolise Acetaldehyde, the acetaldehyde remains in the body for a longer period of time at higher concentration, and the hangover effects are more severe and enduring at lower amounts of alcohol. Those of Asian ethnic origin are more likely to have inactive ALDH genes; for example, a study by Yokoyama, Yokoyama, Yokoyama et al. (2005) on 251 Japanese participants with active or inactive ALDH genes found those with inactive ALDH genes experienced a hangover at lower levels of alcohol consumption than those with active ALDH genes.

In contrast, Ylikahri, Pösö, Huttunen and Hillbom (1974) carried out a laboratory study on 19 participants that were required to fast for 10 hours before consuming 1.5g/kg body weight of ethanol. By analysing the blood, the authors found no correlation between acetaldehyde concentration and hangover severity. Moreover, levels of acetaldehyde in the body were low when hangover symptoms were most severe. The authors suggested this was evidence that acetaldehyde does not play a role in the symptomology of a hangover. However, this was one study, with a small sample size, and the differences in the simple rating scales used

to measure hangover severity may not have fluctuated in a way that correlated with the acetaldehyde concentration. It could also be considered that acetaldehyde may have a delayed or persistent effect on the body, rather than changing at the same time as the symptom severity ranking changed. Acetaldehydes impact on hangover symptomatology and severity remains inconclusive (Penning et al., 2010), and again, the lack of research in this area, and particularly contemporary research affects this conclusion.

Increased levels of gamma-aminobutyric acid (GABA; inhibitory neurotransmitter) occurs during alcohol intoxication (Proctor, Allan & Dunwiddie, 1992). Twenty percent of neurons in the brain release GABA, when GABA is released it lowers the firing of these neurons (Steffensen et al., 2008). As a result, increased levels of GABA (due to alcohol consumption) causes decreased levels of glutamate (excitatory neurotransmitter) which in turn results in lowered brain activity e.g. drowsiness, slurred speech and other sedative effects (Petroff, 2002). When alcohol leaves the system and the hangover begins, our body tries to make up for the decreased levels of glutamate in the body by producing more (Tsai & Coyle, 1995). Excessive release of glutamate transmitters can result in anxiety, stress, and restlessness (Swanson, Bures, Johnson, Linden, Monn & Schoepp, 2005). Glutamate also contributes to the sleep disturbances experienced in the second half of one's sleep after drinking and may also account for the early wake up time that is often reported after a night of drinking (Roehrs & Roth, 2001).

1.1.1.6 Mood Disruption

When alcohol is consumed, mood becomes instantly elevated as a result of the release of dopamine, norepinephrine, and serotonin. Dopamine is released as a result of alcohol's effect on the GABA system (Weiss, Lorang, Bloom & Koob, 1993). However, dopamine is not released throughout the brain in the same way that it is after the consumption of other drugs such as cocaine; instead it is only released in the reward pathway which contributes to the rewarding aspects of intoxication (Chiara, 1997). The reward pathway is an important pathway in the brain as it encourages reward through learning i.e. positive reinforcement and conditioned responses which play an important role in survival, for example, in food acquisition (Boileau et al., 2003). Also, alcohol has been shown to cause the release of norepinephrine (McDougle, Kresche, Goodman, & Naylor, 1995). Norepinephrine acts as both a stress hormone and a neurotransmitter. As a neurotransmitter, it is synthesised from dopamine and promotes restlessness and arousal (Carlson, 2004). LeMarquand, Pihl & Benkelfat (1994) have also found increased levels of serotonin in urine and blood during intoxication. Together, dopamine, norepinephrine, and serotonin induce positive emotions which are experienced during intoxication and may contribute to alcohol dependence through positive reinforcement (Loving, 1993). A rebound or 'dopamine hangover' effect occurs when alcohol leaves the body and feelings of depression and anxiety (when BAC returns to zero) can partly be attributed to a dip in dopamine, norepinephrine and serotonin levels (Weiss et al., 1981). Furthermore, sympathetic hyperactivity and low blood sugar (described above) can also cause depression and anxiety during a hangover (Schuckit, 1996).

1.1.1.7 Cognition

The psychopharmacological effects of a hangover on cognition are not well understood. It is possible that imbalanced chemicals in the brain, such as the inhibition of N-methyl-D-aspartate (NMDA) in the hippocampus, may contribute to cognitive deficits experienced during a hangover (Min, Lee & Kim, 2010). Also, Prat, Adan & Sanchez-Turet (2009) propose that photo and audio sensitivity may result in decreased alertness during a hangover. However, it is probably a combination of many chemical interactions in the brain that impair performance during a hangover. For example, sleep disturbances and dehydration also contribute to cognitive impairment (Adan, 2012; Alhola & Kantola, 2007). Moreover, an accurate measurement of distinct processes of cognition must first be investigated before a chemical explanation for impaired cognition can be reached.

1.2.5 The Role of the Hangover Cure

Hangovers have existed since alcohol was first produced almost 9,000 years ago (Meyer and Quenzer, 2005). Despite a limited understanding of the hangover, attention has often been focussed on creating a hangover cure with 1,160,000 google hits⁵ pertaining to a 'hangover cure'. This suggests that hangovers are important to those who experience them and that a cure is desirable. The earliest evidence of this comes from Ancient Egypt where a cure for a 'drunken headache' was thought to be achieved by wearing the leaves of an Alexandrian Laurel plant around the neck (Komeh-Nkrumah, 2014).

⁵ Search Google.co.uk 7th August 2018 using term "hangover cure"

The origins of 'the hair of the dog' is thought to come from the ancient Greek physician, Hippocrates. Historically, the phrase refers to an event where one has been bitten by a rabid dog and by using the hair of another, the likelihood of contracting rabies would be decreased (Cresswell, 2010). Hippocrates, believed that the 'hair of the dog' could be applied to the consumption of wine and the hangover. Indeed, his theory was described in a third B.C. play by Antiphanes which contains the phrase 'to drive out wine with wine' (Luschnig & Mitchell, 2007).

Today, 'hair of the dog' remains a popular solution to alcohol hangover symptoms, however, imbibing more alcohol to relieve a hangover and regain intoxication only serves to delay the effects of a hangover and may result in the development of an Alcohol Use Disorder (Verster, 2009; Piasecki, Robertson & Elper, 2010). As alcohol has a range of health and other effects; it is not a practical cure for the alcohol hangover.

Researchers continue to create antidotes for the alcohol hangover. For example, Iversen developed a formula which stabilises the release of prostaglandins and histamines while also controlling cytokine levels (Merlo et al., 2017). No empirical evidence of the effectiveness of this treatment are available at this time. However, other researchers argue that preventing an alcohol hangover may not be desirable as it may be serving as an alcohol deterrent (Smith, Bookner & Dreher, 1988). Indeed, Rohesnow et al. (2012) demonstrated participants that experience higher hangover severity have less risk of developing an Alcohol Use Disorder in the following 1-4 years. In this way, it can be argued that the alcohol hangover may act as protection against the development of alcohol problems. Mackus, Schrojenstein Lantman, van de Loo and Verster (2017) have suggested that if this is the case, then experiencing less hangover symptoms should result in more alcohol consumption. They administered a survey to

Dutch students (n=1837, 18-30 years) via Survey Monkey and found that most respondents (69.9%) reported that they would use a hangover treatment if it was made available.

Interestingly, when asked if drinkers would consume more alcohol if a treatment was available 13.4% responded 'yes' and 71.6% responded 'no' indicating that concerns relating to the development of alcohol use disorders if a cure becomes available may not be warranted. The results reflect self-reported projective behaviour and this may not reflect real life behaviours should an effective alcohol hangover cure become available. Of note, there is no current complete cure for a hangover other than to decrease the levels of consumption (Jayawardena, Thejani, Ranasinghe, Fernando & Verster, 2017; Kosem, van de Loo, Fernstrand, Garssen & Verster, 2015).

Hangover resistance, and hangover cures are not well understood. They depend on a better understanding of the puzzling phenomenon of a hangover in terms of definition and understanding, and the mechanisms involved in the production of an alcohol hangover. The next step towards gaining a better understanding of the alcohol hangover is to identify and understand the areas of performance that occur after a night's drinking.

1.3 Cognition and Human Performance

Cognition is the ultimate function of the brain (Robbins, 2011). It encompasses the study of the human mind and how it processes information and thus plays a fundamental role in everyday living (Levitan, 2002). After a night's drinking, our capacity to attend to stimuli is diminished and subsequently cognitive processes are impaired (Ling, Stephens & Heffernan,

2010). However, in the past decade research has yielded a series of inconsistent results which are likely due to methodological shortcomings described briefly later in this Chapter and the under-estimation of the complexity of the processes involved (Stephens, Ling, Heffernan, Heather & Jones, 2008). The full impact of the alcohol hangover on cognitive functioning is not well understood. The following sections consider specific cognitive systems and provide an overview of the cognitive processes explored in this thesis.

1.3.1 Attention

Attention is made up of a series of multicomponent processes (Pilcher, Band, Odle-Dusseau, Muth, 2007; Sarter, Givens & Bruno, 2001; Sturm & Willmes, 2001). James (1890) was the first researcher to state that attention was not a unitary process; he identified both voluntary and involuntary attention. Voluntary attention represents active attention driven by goals or expectations and involuntary attention is associated with passive processing e.g. an orienting reflex response (Eysenck & Keane, 2005). Sturm and Willmes (2001) propose a multicomponent structure of attention characterised by intensity and a selective type of attention. In this case intensity includes vigilance and sustained attention which is thought to represent more fundamental aspects of attention. The selective aspects of attention refer to more complex attentional processes and involve divided and focused attention (Sturm and Willmes, 2001). Posner and Peterson (1990) suggested three subsystems exist; target detection, orienting to a sensory event and the maintenance of a vigilant state. Target detection refers to executive functioning whereby in the moment that a target is detected, there is also interference that reduces one's ability to detect another target, otherwise known as focal attention (Duncan, 1980; Petersen & Posner, 2012). Orienting refers to one's ability to

focus attention on a particular sensory input or location. The maintenance of a vigilant state can also be referred to as alerting and involves the process of maintaining arousal. More recently Coulthard, Singh-Curry, Husain (2006) has proposed that attention can be divided into three categories; Selective attention, divided attention, and sustained attention. Here, selective attention refers to the way in which distractors are avoided and specific stimuli are attended to. Divided attention refers to one's ability to attend to more than one stimulus at a time, for example, holding a conversation while driving a car (Miller, 1982). Sustained attention is associated with one's ability to maintain alertness over a period of time (Perry & Hodges, 1999).

Hangover research has traditionally focussed on voluntary attention (Stephens, Ling, Heffernan, Heather & Jones, 2008). Although there is currently no universal agreement on the components that make up attention, the field of hangover research has mostly favoured Coulthard's explanation of attention by measuring selective, divided, and sustained attention using visual tasks (Stephens, Grange, Jones and Owen, 2014). This approach of investigating attention is broadly appropriate when first exploring the effects of an alcohol hangover on cognition; however, an approach which investigates more specific elements of attention and incorporates various theories of attention is now warranted in order to pinpoint the attentional mechanisms that are affected by an alcohol hangover.

To date, one study in recent years has addressed attention exclusively, however, others have assessed aspects of attention alongside other cognitive components. By investigating attention exclusively, discrete variations in performances in one sample of participants can be identified within a controlled and consistent environment and procedure. In this way, the number of confounding variables is lowered. McKinney, Coyle, Penning and Verster (2012)

investigated selective attention, Stroop performance, divided attention, and sustained attention using a naturalistic repeated measures design. Forty-eight participants were recruited from the Halls of Residence at Ulster University and were tested at 9am, 11am, and 1pm. This sample would most likely comprise of first year undergraduate students on a range of courses. The results revealed a significant effect of hangover state on Stroop performance, sustained, and selective attention but not on spatial or divided attention. According to Coulthard's theory (2006) this would suggest sustained and selective attention are affected by the hangover state but divided attention is not.

Other studies have assessed attention whilst exploring other areas of cognition. In support of the findings by McKinney et al., (2012), laboratory studies by Lemon, Chesher, Fox, Greeley & Nabke (64 male participants), Chait and Perry (1994, 10 male and 4 female participants) and Finnegan, Hammersley & Cooper (1998, 40 participants) found that divided attention was not impaired during a hangover state. In contrast, Roehrs, Yoon and Roth (1991) found significant decreases in divided attention. However, only five participants were recruited in Roehrs, Yoon and Roth's (1991) laboratory study.

McKinney and Coyle (2004) also found impaired selective attention after a night's drinking. Rohesnow et al. (2010) and Howland et al. (2010) in a laboratory setting using psychomotor vigilance and continuous performance tasks respectively revealed that sustained attention is impaired after a night's drinking. Finally, Anderson and Dawson (1999) using a naturalistic design and a paced auditory serial addition task found that sustained attention is impaired up to 16 hours after alcohol is consumed. These too support the conclusion of McKinney et al. (2012).

1.1.1.8 *Selective Attention*

Cherry (1953) was fascinated by the ‘cocktail party’ effect where one is able to focus in on one conversation when other conversations are taking place at the same time, in the same room. This spurred on a renewed interest by the scientific community in attention research (Lamers, Roelofs, & Rabeling-Keus, 2010). Using a form of experimental procedure called shadowing where two or more auditory sentences are presented to participants at the same time, Cherry (1953) was able to show that one can select a conversation to process while other unattended auditory samples are not processed. This experiment also highlighted that selective attention is a fundamental aspect of attention and it plays an important role in daily activities e.g. driving a car, grocery shopping, and performing work related tasks.

The Stroop (1935) is a commonly used measure for the dimensional aspect of selective attention. The Stroop effect or interference is calculated by subtracting compatible written colour words (e.g. **GREEN**) from incompatible written colour words (e.g. **BLUE**). The result represents the interference which occurs when the incompatible word distracts the participant from the focus of the task. To the author’s knowledge McKinney, Coyle, Penning and Verster (2012), McKinney, Coyle and Verster (2012) and McKinney and Coyle (2004) are the only studies which have explored the effects of Stroop performance during a hangover. Moreover, in Prat, Adan, Pérez-Pámies, and Sanchez- Turet (2008) review of the neurocognitive effects of a hangover, the authors conclude future studies on hangover performance should incorporate Stroop performance tasks as the frontal lobes have been shown to be sensitive to drug effects.

Eriksen's Flanker Task (1974) measures spatial aspects of selective attention which is thought to represent a separate entity to the dimensional elements of the Stroop task (Chajut & Algom, 2009). In Stephens, Grange, Jones and Owen's (2014) critical review of hangover methodology, a recommendation is made to replicate both Stroop (1935) and Eriksen's (1974) selective attention tasks as they reflect everyday activities and have also been shown to be sensitive to hangover effects. Thus, selective attention remains an important attentional system in the field of hangover research.

1.1.1.9 Divided Attention

The Rozelle Divided Attention Task involves a pursuit tracking task which requires the participants to follow a moving target using a joystick. The joystick controls a small rectangle that appears between two moving vertical lines. The speed at which the lines move increases throughout the task and the error rates corresponding to the speed are recorded, however, the speed levels are not specified (Lemon et al., 1993). In addition to this the participant is required to attend to circles that appear in the corners of the screen. When a circle contains a target diametrical line the participant must respond with an appropriate button press. The mean response times and errors are recorded for this task also. Together, the tracking and selective attention tasks require divided attention in order to attend to both of them at once. The performance is then computed into a standardised score and both components of the task are combined (Lemon et al., 1993). Using the Rozelle Divided Attention Task in a laboratory environment, Lemon et al. (1993) found no decrements in divided attention during an alcohol

hangover. The results showed that overall scores in the task did not differ twelve hours after alcohol consumption ceased.

Chait and Perry (1994) also found no deficits using a dual attention task. Again, Finnegan et al. (1998) used a primary tracking task along with a simple reaction time task to measure divided attention in a laboratory environment and found no deficits. Roehrs, Yoon and Roth (1991) and Roehrs and Roth (2001) used a dual attention task that involved a joystick tracking task and a simple reaction time task in a laboratory environment and found deficits in divided attention. To the authors' knowledge, these are the only studies that have found significant impairments on divided attention in the hangover state.

The divided attention task used by McKinney and Coyle (2004) has become established in the field of hangover and alcohol naturalistic research (McKinney, Coyle & Verster, 2012; McKinney, Coyle, Penning, Verster, 2012; Tedstone & Coyle, 2004). The task involves a vigilance task that requires participants to monitor the digits presented one at a time in the centre of the screen. Participants are asked to respond appropriately when three odd digits appear directly after one another. As well as this a simple reaction time task requires participants to attend to a blue box which appears randomly in one of four peripherals around the centre of the screen. Thus, both types of targets require the visual modality which ensures the attentional load relies less on the executive functioning which would otherwise involve higher levels of executive functioning. McKinney and Coyle (2004) found reaction times to the stimuli in the hangover compared to the control state approached significance ($F(1, 40) = 3.93, p < 0.054$) with slower responses in the hangover condition.

1.1.1.10 Sustained Attention

Sustained attention is also a fundamental part of daily life. For example, one's ability to concentrate on reading a newspaper article for long enough to complete the section requires sustained attention. Rohsenow et al. (2010), found decrements in two sustained attention tasks; a Continuous Performance Task and a Psychomotor Vigilance Task using a laboratory approach. Finnegan et al. (1998) accounted for order and found that performance was faster on the second testing occasion, however state did not significantly affect performance. Mean response time in the selective attention element of the task for the hangover condition was 454.17 (SD= 40.29) and for the no hangover condition was 455.24 (SD=50.3).

The Continuous Performance Task involves a series of stimuli (letters) appearing one at a time in the centre of the screen for 5 minutes at a rate of 1/1000ms. Participants are then required to respond appropriately when the number 5 appears (Baker, Chrzan, Park & Saunders, 1985). The Psychomotor Vigilance Task involves a series of infrequent stimuli presented in the centre of the screen for five minutes. As soon as the participants identifies the target they are required to respond as quickly and accurately as possible. Howland et al. (2010) also used a Psychomotor Vigilance Task to measures sustained attention in a laboratory environment and found that responses were significantly slower when hungover. Verster et al. (2003) and Lemon et al. (1993) both used the Mackworth Clock Test to measure sustained attention and found no deficits. Verster's (2003) laboratory study used a Mackworth Task that lasted one hour and required the participant to watch a target as it moves around a clock faced image. When the target makes a double move or jumps, the participant is required to respond

appropriately. Similarly, Lemon et al.'s (1993) version of the Mackworth Clock Task runs for 40 minutes. Finnegan, Hammersley and Cooper (1998) used a Continuous Performance Task in a laboratory environment and in contrast to Rohesnow et al.'s (2010) study found no effect. McKinney, Coyle & Verster (2012) also applied a Continuous Performance Task to measure sustained attention and found significant deficits in hangover participants using a naturalistic approach.

Despite the considerable duration of the Mackworth Clock Task it has not been shown to be sensitive to the alcohol hangover. The Continuous Performance Task and Psychomotor Vigilance Task (PVT) do appear to be sensitive to the hangover effects. Moreover, the PVT is particularly sensitive to sleep deprivation which is directly affected by a night's drinking (Roehrs & Roth, 2001). Furthermore, a sufficient number of studies have been carried out that report high levels of validity and reliability of the Psychomotor Vigilance Task (Lim & Dinges, 2008). In terms of validity, the PVT is sensitive to various types of sleep deprivation (e.g. chronic sleep restriction, simulated night shift work, jet lag and overnight flight simulation in pilot) across clinical, occupational and experimental approaches (Atzram et al., 2001; Dorian, Rogers & Dinges, 2005; Hughes et al., 2001; Price et al., 2003; Russo et al., 2004). The reliability of the task has been shown by Van Dongen, Maislin, Mullington, Dinges (2003). Here nine participants were tested over a five-day period. The participants were allowed an eight-hour sleep period each night and performance was measured throughout the day. Interclass correlation coefficients showed high reliability for lapses which represent responses that are over 500ms ($ICC=.89, p<0.0001$) and median response times ($.83, p<0.0001$).

1.1.1.11 Temporal Aspects of Attention

When a sequence of stimuli are presented in rapid succession in the centre of a screen there is a period of time called an Attentional Blink where stimuli are missed as a result of focussed attention on a target item previously presented (Martins & Wyble, 2010). The attentional capacity theory suggests that the first target fills ones' attentional capacity and as a result further targets presented within the Attentional Blink are unidentified (Chun & Potter, 1995). To the authors' knowledge, no hangover researchers have investigated the effects of a night's drinking on Attentional Blink.

1.1.1.12 Attentional Set Shifting

Attentional set shifting refers to the flexibility of one's attention as well as reasoning and working memory. Thus, it is associated with frontal lobe functioning (Sullivan et al., 1993). The set shifting paradigm was first described by Jersild (1927) and is most commonly measured using the Wisconsin Card Sorting task (Grant & Berg, 1948). Deficits have been found in task performance during intoxication (Lyvers & Maltzman, 1991). Impairment in set shifting has also been found in alcoholic participants (Sullivan, Rosenbloom, & Pfefferbaum, 1993). However, the residual effects of intoxication on attentional set shifting have not been explored.

1.3.2 Memory

Memory is a complex aspect of cognitive functioning that involves the encoding, storage, and retrieval of information (Atkinson & Shiffrin, 1968). Sensory, short-term and long-term memory play an important role in how we recall episodes in the past. Short term memory is used throughout day to day living. For example, temporarily recalling a hotel address for long enough to type into Google Maps. Baddeley and Hitch's (1974) model of working memory is the most prominent theory of short-term memory. It involves the phonological loop, which involves the recall of auditory information and the visuospatial sketch pad which processes visual and spatial information. The use of both the phonological loop and the visuospatial sketchpad are coordinated by the central executive (Baddeley, 2012). In contrast, an adaption of the short-term store, now called 'the standard model' (Shiffrin, 1999; Nairne, 2002) suggests that activated information from long-term memory moves into short-term memory and the decay of that information results in the removal of information from the short-term memory. This can be prevented through rehearsal (Eysenck & Keane, 2005). However, this theory has many limitations. Nairne, Whiteman and Kelley (1999) have shown that rehearsal is not required to prevent word decay. It also suggests that forgetting or decaying rates are fixed, however, these rates vary (Eysenck & Keane, 2005; Nairne, 2002). As a result, Baddeley's working memory approach is often favoured and will be used in the investigations of the alcohol hangover in this thesis.

1.1.1.13 Spatial Working Memory

Deficits in Visuospatial sketchpad may pose particular dangers to daily functioning. For example, while driving a car, the visuospatial sketchpad is likely to keep us informed on where

we are in relation to other cars (Baddeley, 1997). Spatial working memory has been shown to be sensitive to the effects of alcohol intoxication (White, Matthews & Best, 2000). However, Rohsenow et al. (2010) recruited 40 participants and did not find decrements in spatial working memory in the hangover condition using mean response latency for correct items. Using the same task Howland et al. (2010) recruited 193 university students and found spatial working memory deficits in the hangover condition. Both Rohsenow et al. (2010) and Howland et al. (2010) applied a laboratory approach. With this considered, further investigations into spatial working memory performance the morning after a night's drinking are required in order to address these inconsistencies.

1.1.1.14 Free Recall

Free recall often involves the active memorization of a list of words and the recall of them either immediately or after a specific time (delayed). It is a common method of measuring memory and several studies have been carried out which use free recall to measure memory in hangover research. McKinney & Coyle, (2004) found deficits in both immediate and delay recall tasks in their laboratory/naturalistic study of 48 students. Verster et al. (2003) found no impairment in immediate recall but significant impairments in delayed recall during an alcohol hangover in a laboratory environment. Also, Chait and Perry (1994) and Finnegan et al. (1998) did not find that free recall was significantly less in the hangover condition than in the no hangover condition.

There are two ways in which items are stored in a free recall task. The serial position effect describes the way in which information from the beginning and end of a word list is

recalled (Murdock, 1962). The serial position of the words recalled from a free recall task gives information about the way in which items are processed by the individual during the task. For example, words recalled from the beginning of a list (primacy) involves active rehearsal type learning and is associated with the transfer of information into the long-term memory whereas the recall of words from the end of a word list (recency) reflects passive learning that involves short-term memory (Glanzer & Cunitz, 1966). Although research on intoxication has revealed sensitivities in the serial position effect (Fox, Michie, Coltheart & Solowij, 1995), the phenomenon has not been explored in hangover research.

1.3.3 Psychomotor Performance

Psychomotor performance involves an innate capacity to react to external stimuli. These reactions develop through experience and can range from instantaneous reflexes to complex movements such as climbing stairs (Hindmarch, 2010). A popular way in which psychomotor performance is measured is through reaction time tasks or driving simulators. Finnegan et al. (1998, 2005) used reaction time tasks to measure psychomotor performance and found significantly slower responses in hungover participants in both laboratory and naturalistic environments. Chait and Perry (1993) however, also used a simple reaction time task but found no decrease in performance. Kruisselbrink, Martin, Megeney, Fowles & Murphy (2006) using a four serial choice reaction time task on 12 females and Rohesnow et al. (2006) using a ship engine simulator on 61 navy cadets in a naturalistic environment found no deficits in psychomotor performance. In contrast, McKinney and Coyle (2004) found significant decrements in simple and five serial choice reaction time tasks using a naturalistic approach.

In terms of performance on driving tasks, results have yielded equally inconclusive findings. Laurell and Törnös (1983) found deficits in one's ability to operate an automobile around cones using a naturalistic approach. However, using a simulator task Törnös and Laurell (1991) failed to find a difference in psychomotor performance. The effect of the alcohol hangover on psychomotor performance is likely to be complex. A simple or two choice reaction time task measures both alertness and motor speed, the four and 5 Choice Serial Reaction Time Task also measure alertness, and impulse control, and driving may reflect a combination of simple and complex psychomotor and attention functions (Liguori, Gatto & Robinson, 1998). As a result of the diversity of psychomotor tasks Prat, Adan, Pérez-Pàmies & Sánchez-Turet (2008) have called for further studies to clarify the effects of a hangover on psychomotor performance.

1.3.4 Energy Expenditure and Sleep

Tiredness is the most commonly reported symptom of an alcohol hangover. It is therefore of interest to explore the relationship of energy expenditure and sleep in hangover participants. The body responds to alcohol as a toxin and as our bodies flush toxins out of our system we also lose nutrients. For example, Ylikahri, Huttunen, Eriksson and Hikkilä (1974) found that during intoxication blood sugar (glucose) levels rise and then become lower than average after the alcohol leaves the system. Loss of blood sugars as a result of previous alcohol consumption causes feelings of fatigue and weakness (Swift & Davidson, 1998). Lack of energy and lowered energy expenditure can affect day to day experiences at home and at work, and

cognitive performance, therefore, it is of interest to explore the degree to which an alcohol hangover affects energy expenditure.

As well as this, alcohol's complex effects on sleep (as described in 1.2.4.3) is likely to contribute to the frequent reports of tiredness during an alcohol hangover (Prat, Adan, Sanchez-Tuert, 2009). Sleep disturbances can affect next day alertness (Roehrs t & Roth, 2000) and furthermore, alcohol induced sleep disturbances have been shown to reduce alertness the day after alcohol consumption (Roerhrs, Yoon & Roth, 1991). Despite this, most studies which investigate an alcohol hangover employ subjective reports of sleep (Rohesnow, Howland, Minsky & Arnedt, 2006; Verster, van Duin, Volkerts, Schreuder & Verbaten, 2003), for example, Rohesnow, Howland, Alvarez, Nelson, Langlois, Verster, Sherrard and Arnedt (2014) examined the role of caffeinated alcoholic beverages and subjective sleep quality, latency and time asleep and sleepiness in a sample of university students. The results of the laboratory study showed caffeine improved perceived sleep quality, however, reports of time taken to fall asleep and time spent sleeping were not affected by caffeine. However, a control (no hangover) group was not employed in this study. In a naturalistic study, McKinney and Coyle (2005) investigated affect while collecting data pertaining to sleep quantity and quality. The results showed time taken to fall asleep was significantly less in the hangover group than the no hangover group and significantly less hours of sleep were reported by hungover participants. Self-report measures of sleep quality revealed less satisfying and less refreshing sleep after alcohol consumption. Arnedt, Wilde, Munt and Maclean (2000) investigated prolonged wakefulness and alcohol consumption with self-reported sleepiness and simulated driving performance. The results revealed impairment after prolonged wakefulness (16 hours and 20 hours) and alcohol

consumption. The combination of wakefulness and alcohol consumption however was not significantly worse than when wakefulness or alcohol consumption occurred separately. Of note, there was only a modest association between perceived and actual impairment after wakefulness or alcohol consumption. This indicates that participants may not be accurate at judging performance after alcohol consumption or prolonged wakefulness. Although, actual sleep and perceived sleep were not examined, it is possible that one is less capable of rating sleep performance after a night's drinking also.

1.3.5 Methodological Shortcomings in Hangover Research

There are several methodological shortcomings that may result in inconsistencies relating to cognitive performance during a hangover. Firstly, differences in naturalistic and laboratory designs may result in different hangover experiences and therefore impact performance on cognitive tasks. For example, a set amount of alcohol depending on gender and weight is typically administered to participants in a laboratory study. In this setting, alcohol may be administered as vodka and orange juice in one drink and a placebo group drinks orange juice only (Stephens, Grange, Jones & Owen, 2014). As a result, the amount of alcohol administered is often considerably less than that consumed in a naturalistic environment where participants are free to consume any volume of alcohol, and the type of alcohol of their own preference (Finnegan, Hammersley & Cooper, 1998). As a result, the variation in alcohol consumption across laboratory and naturalistic approaches may contribute to inconsistencies found in hangover research.

The sample of participants recruited in hangover studies is often university students (Anderson & Dawson, 1999; Collins et al., 1971; Laurell and Tornros, 1983; McKinney & Coyle, 2004) or an all-male sample (Finnegan et al., 1998; Lemon et al., 1993; Roehrs et al., 1991; Streufert et al., 1995). Moreover, a number of studies also employ a small number of participants (Anderson & Dawson, 1999; Collins & Chile, 1980; Roehrs et al., 1991) which may limit the validity and reliability of the research and may also contribute to inconsistencies in the findings.

Finally, an idiosyncratic set of cognitive tasks is often used in hangover research. As such, a direct comparison of results cannot be carried out between the few studies in the hangover field, and differences in results may reflect task variation rather than differences in the elements of cognition being measured. Together, the study design, sample used and tasks administered are likely to contribute to the contrasting results found in cognitive performance the morning after a night's drinking (Ling, Stephens & Heffernan, 2010; Stephens, Ling, Heffernan, Heather & Jones, 2008).

1.4 Summary

This Chapter discussed alcohol consumption, the importance of studying an alcohol hangover, problems relating to a definition, and the symptoms involved. This Chapter also highlighted the mechanisms involved in the symptomology of a hangover. Although the body's response to the breakdown of alcohol from ethanol to acetaldehyde and then to acetate is complex, many of the symptoms can be described in terms of pain, gastrointestinal irritation,

sleep disturbance, sensory system imbalance, sympathetic hyperactivity, mood disruption and cognitive impairment (Swift & Davidson, 1998).

In particular, the chemical imbalances that occur in the brain which produce cognitive impairment after a night's drinking are not well understood. Further research is required in order to gain a better understanding of the cognitive processes affected by an alcohol hangover. Selective and sustained attention have been shown to be impaired after a night's drinking, however, divided and spatial attention remain relatively unaffected (McKinney, Coyle, Penning & Verster, 2012). However, contrasting evidence suggests that methodological shortcomings exist in the investigations of these processes (Chait & Perry, 1994; Lemon et al., 1993; Roehrs & Roth, 2001). Moreover, the impact on temporal and attentional set shifting processes during a hangover remain unexplored.

In terms of memory, spatial working memory, and immediate and delayed recall have been explored. However, the impact of a hangover on memory remains inconclusive as much of the results appear inconsistent (McKinney & Coyle; Verster et al., 2003; Chait & Perry, 1994; Finnegan et al., 1998). So too, there are methodological issues which affect this such as variations between laboratory and naturalistic designs, samples used and tasks administered.

The diversity of psychomotor tasks employed in hangover research makes it difficult to compare the findings (Stephens, Grange, Jones & Owen, 2014). For example, simple reaction time and simulated driving task encapsulate different aspects of psychomotor which cannot be directly compared. Thus, methodological limitations have likely contaminated research on attention, memory and psychomotor processes.

Laboratory and naturalistic designs represent the main methodological approaches in hangover research. The laboratory approach benefits from a controlled environment, whereas the naturalistic approach benefits from ecological validity. With this considered, this thesis employs a naturalistic approach and, also collects subjective information on variables that would otherwise be controlled in a laboratory approach (Cellini, Goodbourn, McDevitt, Martini, Holcombe & Mednick, 2015; Heffernan, 2008; Lim & Dinges, 2008). This involves going beyond the standard attention tasks employed in hangover research, to explore signal detection, temporal aspects of attention, Emotional Stroop performance and incorporate smartphone technologies to measure energy expenditure and sleep on a day after a night's drinking.

1.5 Aims

The overarching aim of this thesis is to gain a better understanding of the effects of a normal night's drinking on cognition and human performance while addressing methodological shortcomings of research to date. This will expand our understanding of cognition and the alcohol hangover beyond what is already known. The objectives for each Chapter to realise this aim are:

- Chapter 2: To introduce and discuss the methodology employed in this thesis. This includes the design, research approach, methods of data collection and analysis, sample selection and ethical considerations.
- Chapter 3: To understand the role of expectancy on cognitive performance the day after a nights' drinking. This Chapter also aims to introduce a standard test battery and

explore performance on tasks that have and have not already shown sensitivities to an alcohol hangover.

- Chapter 4: To measure performance on cognitive tasks in non-student social drinkers the day after alcohol consumption in a naturalistic approach (participants are tested in an office above the public house where recruitment and alcohol consumption takes place).
- Chapter 5: To investigate aspects of attention that are sensitive to sleep disturbances to understand consistencies in attention and alcohol hangover research (Cellini, Goodbourn, McDevitt, Martini, Holcombe & Mednick, 2015; Lim & Dinges, 2008; Stephens, Ling & Heffernan, 2008). This involves going beyond the standard attention tasks employed in hangover research, to explore signal detection, temporal aspects of attention, and Emotional Stroop performance.
- Chapter 6: To explore the role of the alcohol hangover on sleep and physical activity using smart phone and wearable technologies.

2. Methodology

The purpose of this Chapter is to introduce the methodological approaches used in this thesis. Chapter 1 has described key issues around alcohol consumption, hangover, and introduced the role of cognition and sleep in the hangover state. Here, a rationale for the chosen research design, recruitment procedures, and detail of the instrumentation and data analysis applied will link the methodology with the research questions in this thesis. Each Chapter will be considered in turn and the methodological rationale explained.

2.1 Methodological Approaches And Their Key Challenges In Alcohol Hangover Research

2.1.1 The Setting of Alcohol Hangover Research

There are two main data collection settings used in hangover research, the laboratory and naturalistic approach. In the laboratory approach, participants often drink alcohol in one sitting before returning home to bed at night. At lower doses, participants are often given 15-30 minutes to drink beverages. However, the specification of lower doses are not defined by Verster et al., (2010) or Howland et al., (2009). At high doses (alcohol administered to reach a peak BAC .11/.12%) beverages are consumed up to a level that are thought to induce a hangover. This often results in up to 1 hour for beverage consumption (Verster et al., 2010; Howland et al., 2009). Dosage can vary but is typically in the region of 1-1.2g of alcohol per kilogram of body weight per drinking occasion depending on weight, gender, age, amount of time allowed for drinking, dilution of the beverage, and time since last meal. This amount is the equivalent of around 7 units of alcohol (Rohsenow et al., 2007, Verster et al., 2010). A formula by Watson, Watson and Batt (1981; Verster et al., 2010) can be used to calculate the volume of alcohol needed to reach the peak BAC permitted during testing.

However, a study by Finnegan, Hammersley and Cooper (1998) has revealed that in a natural environment, 80% of participants consume more than 7 units of alcohol per occasion which is typically administered in a laboratory setting. Moreover, a naturalistic study by Finnigan, Schulze, Smallwood and Anderson (2005) revealed that participants report drinking a mean of 13.67 units on an average drinking session and consumed a mean of 15.5 units the night before testing. Furthermore, a study by McKinney, Coyle & Verster (2012) found that respondents reported consuming a mean of 11.84 units the night before testing. The location of alcohol consumption in Finnigan, Schulze, Smallwood and Anderson (2005) and McKinney, Coyle & Verster (2012) is not specified.

The number of units consumed can vary depending on location and may be influenced by the nature of the night/event. For example, McClatchley, Shorter and Chalmers (2014) found that more alcohol was consumed per person on a licensed premises in the Midlands than on a licensed premises in London, UK. Around 3 more units were consumed by participants during a standard night (16 units) in the Midlands than on a promotional drinks' night (12.9 units). However, younger participants were more likely to attend drinks promotional nights and on standard nights alcohol consumption was more likely to be spread across venues and a larger prevalence of participants engaged in preloading visiting a licensed premises (McClatchley, Shorter & Chalmers, 2014). Although this evidence suggests alcohol consumption is likely to vary due to demographic characteristics, much evidence suggests that less alcohol is administered in a laboratory environment than is consumed on a normal night's drinking. Of note, public houses are legally required to adhere to the Weights and Measures (1985) act when pouring alcohol beverages. However, caution should be taken when interpreting self-

reported measures of alcoholic spirit and liqueur consumption in the home as alcohol measurements may be subject to variation.

In the morning before laboratory testing, participants are often required to refrain from drinking coffee and are given breakfast before testing begins. Controlling for variables such as food and caffeine intake can prevent confounding variables from impacting results in a laboratory environment (Stephens et al., 2008) as these factors might impact on the outcomes of a laboratory experiment such as tiredness or cognition; nutrient consumption can directly affect cognitive performance (Gómez & Pimilla, 2008). However, eating behaviours are subject to change during and after alcohol consumption (Polivy & Herman, 1976). For example, observational and self-report measures show alcohol increases appetite (Lloyd-Richardson, Lucero, DiBello, Jacobson & Wing, 2008; Yeoman, 2010). Also, late night eating is more likely to occur after drinking and may involve larger portions and unhealthy food choices (Lloyd-Richardson, Lucero, DiBello, Jacobson & Wing, 2008).

Caffeinated alcohol beverages and soda drink mixers containing caffeine are popular among young drinkers (Mintel International Group, 2007). Such drinks increase feelings of stimulation during intoxication which in turn can impact activity during the drinking occasion (Peacock, Bruno, Martin & Carr, 2013). Thus, controlling food and caffeine intake may undermine the real life applicability of the research but, if adhered to, allows for the isolation of the effects of interest whilst controlling for other confounding effects.

The time of going to bed, evening activities, and sleep may be different on an evening where alcohol is consumed. For example, clubbing or dancing is a popular activity to do while

drinking (Long & Mongan, 2013). Nightclubs and late night bars are often open until 2.30am and later which means that drinking activities may reduce sleep time, disturb diurnal rhythms ,and/or shift the usual daily sleep routine. Differences in bed times and activity are not typically accounted for in laboratory experiments. Therefore, an advantage of the naturalistic approach is its ability to measure performance in participants who have undergone a night's sleep which is typical in characteristics to a normal night following alcohol consumption.

In a naturalistic environment, participants consume alcohol in their usual manner over a period of time suited to them. As a result, overall control is sacrificed for external validity. This approach does not use a placebo condition, instead the control condition in a naturalistic study typically involves a drink free evening. Consequently, the naturalistic approach is often criticised by its limited blinding abilities and some authors suggest this is problematic (Stephens, Ling, Heffernan, Heather & Jones, 2008; Ling, Stephens & Heffernan, 2010; Verster et al. 2010; Stephens, Grange, Jones & Owen, 2014). For example, Stephens, Ling, Heffernan, Heather and Jones (2008) argue naturalistic studies should not be used as definitive evidence for hangover effects as limited blinding abilities likely cause expectancy effects (e.g. anticipating poor behaviour the morning after alcohol consumption) which may contaminate the results. However, no speculation is made by Stephens, Ling, Heffernan, Heather and Jones (2008) as to how potential expectancy effects might affect performance during a hangover. Verster et al. (2010) and Stephens, Grange, Jones, and Owen (2014) suggest addressing blinding limitations, the nature of the study should be withheld and testing should take place the morning after a popular student night. In order to investigate changes in cognitive or human performance which might occur as a result of limited blinding abilities, subjective measures of task related

motivation have been applied before and after each task which relates to anticipated performance. From this, it can be determined if participants anticipate poorer performance on individual tasks after a night's drinking than after an alcohol free evening.

To improve control, subjective information (e.g. caffeine consumption, sleep, food intake) have been collected the morning after alcohol consumption. However, caffeine, sleep and food intake is not controlled directly by the investigators. Instead participants consume food and drink as they normally would and go to bed at a time convenient to them (Stephens, Grange, Jones & Owen, 2014). Food, drink, and sleep can be accounted for during data analysis. The subjective control measures will be discussed further in subsequent sections of this thesis (Section 2.3.6).

In a naturalistic study, drinking occurs according to the preferences of the drinker, usually gradual, one drink at a time, and often occurring with other drinkers (Rehm et al., 2003). However, participants may also drink alone or engage in activities such as drinking games. During and after alcohol consumption, social behaviour and mood can change; and the desire to communicate often increases (Collins, Parks & Marlatt, 1985). Mc Kinney and Coyle (2005) revealed in a naturalistic study, mood was lowered during a hangover. In contrast, Smith, Whitney, Thomas, Brockman and Perry (1995) found no effect on mood after a night's drinking using the laboratory approach. It is possible changes in mood the morning after a night's drinking may be related to the social interactions and the participants' behaviour the previous night. Such 'moral' and 'social' mood symptoms are not typically represented in laboratory settings, due to the limited social interactions. The alternate 'middle' ground between internal and external validity of bar laboratories (a bar environment created within a research

laboratory) attempt to overcome this by allowing for social interaction, whilst controlling the environment characteristics (Bot, Engels, Knibbe & Meeus, 2007)). However, these are still unnatural, created environments in which individuals know they are being watched. They are not typically used in hangover research, potentially due to the same ethical restrictions which limit the traditional laboratory investigations e.g. limited alcohol administration. Verster et al. (2010) suggests negative feelings or regrets about behaviour may be part of the overall hangover syndrome therefore the naturalistic approach may be more useful to provide a more comprehensive account of hangover symptomatology. Given the links between drinking, social interaction and mood, it is important to measure mood in hangover research.

The type of alcohol consumed is typically not controlled in a naturalistic environment (Prat, Adan, Pérez-Pàmies, Sánchez-Turet, 2008). This limits the study by overlooking potential effects that different chemicals within alcohol beverages may have on the body. For example, congeners are chemicals in alcoholic beverages that are often created during fermentation (Rohesnow & Howland, 2010). They are substances such as amides, acetones, acetaldehydes, polyphenols, methanol, histamines, fusel oil, esters, furfural, amines, and tannins, and they are typically found in darker drinks (Nathan, Zare & Ferneau, 1970). Drinks contain different levels of congeners, for example, bourbon has 37 times more congeners than vodka (Snell, 1958). Congeners are thought to impact on hangover severity (Rohesnow & Howland, 2010). In a laboratory study by Chapman (1970) participants reported more severe hangover symptoms after consuming bourbon than after consuming vodka. Rohesnow, Howland, and Arnedt (2010) also found higher levels of fatigue in participants who consumed bourbon than those who drank vodka. In hangover research, it is important to control not just the number of units, but

also account for the type of drinks consumed. Finally, the pace at which alcohol is consumed may also contribute to hangover severity and duration (Swift & Davidson, 1998). This is not traditionally controlled for in naturalistically designed studies, however, it is an important factor to consider, with alcohol consumed faster more likely to result in a hangover which is longer, and more severe.

In summation, the benefit of the laboratory approach is the controlled environment in which it is set, however it is disadvantaged by its limited ecological validity. In this thesis, the experimental design and naturalistic approach has been adopted to address the research questions. However, with consideration to the advantages of a controlled environment observed in a laboratory environment, this thesis subjectively accounts for potential confounding variables such as food intake, caffeine and food consumption, sleep, time of going to bed, mood, and alcohol consumption and context. The main criticism of the naturalistic approach is the potential expectancy effects due to the participant's awareness of alcohol consumption. To decrease these potential effects, task related motivation scales are administered before and after each task throughout this thesis and Chapter 3 follows a design which investigates potential expectancy effects.

2.1.2 Between or Within Experimental Designs

Both between (Lemon et al, 1993; Collins et al., 1971; Verster et al., 2010; Finnegan et al., 2005) and within (Laurell & Tornros, 1983; Tornros & Laurell, 1991; McKinney & Coyle, 2004; Collins & Chiles, 1980; Chait & Perry, 1994; Finnegan et al., 1998; Zink, Bensmann, Beste & Stock, 2018; Grange, Stephens, Jones & Owen, 2016) factor designs have been used in studies which investigate cognitive performance and alcohol hangovers. However, recent reviews on

the alcohol hangover have not discussed the benefits or drawbacks of each of these experimental design types (Stephens, Ling, Heffernan, Heather & Jones, 2008; Ling, Stephens & Heffernan, 2010). For example, Verster et al., (2010) suggests researchers should carefully consider the most appropriate design for the hangover study but does not discuss the appropriateness of these designs by their context. The following paragraphs address this gap.

A between factors design is conservative as there is no risk that one condition will contaminate the other condition (Elmes, Kantowitz & Roediger, 2003). This occurs with the caveat, that participants adhere to guidelines for their own condition, and that no contamination of Conditions occurs. For example, in a trial of an online brief intervention to reduce alcohol use, Cunningham and colleagues (2017) asked participants about other sources of online alcohol brief intervention help to determine if those allocated to one Condition, found any of the other interventions which were freely available online in the other Condition. The authors could not conclude that the participants assigned to Conditions did not access other interventions that were available online which highlighted the importance of reducing contamination across Conditions and the importance of ensuring that guidelines are adhered to?? However, the between measures design also has the potential to be confounded by groups with differing abilities (Verster et al., 2010). To reduce the likelihood of group differences, random allocations or block randomisation based on characteristic matching and then randomising can be carried out to control for known and unknown confounders (Elmes, Kantowitz & Rogers, 2003; Verster et al., 2012).

An advantage of a within factors design is that variation in group abilities do not occur as each individual acts as their own control (Verster et al., 2010). Rather, the performance of

each participant is compared across the experimental Conditions (Elmes, Kantowitz & Rogers, 2003). However, the within factors design is limited by the potential of order affects (Goodwin & Goodwin, 2016). This may be important when interventions are used, as their effects may carry over from one Condition to another. To minimise the likelihood of residual hangover or practice effects, it is important to understand how long the effects of testing might last, and account for this in the design of the study. As the duration of the alcohol hangover may be subject to individual differences, testing sessions took place 5-10 days apart. In addition, the next section discusses the role of Order in experimental design of drug studies.

2.1.3 Order Effects in Alcohol Hangover Research

In good experimental practice, a variable that is present in an experimental design should also be included in the analysis (Fisher & Fraser, 1981). Order can serve as a means of counterbalancing but it should also be considered as a variable in its own right when there is a possibility of asymmetrical transfer. This refers to an effect that occurs in repeated measures whereby the reverse order of testing sessions results in a different pattern of results to the initial order of testing sessions (Poulton & Freeman, 1966).

Drug research by Millar (1983) demonstrates an asymmetrical transfer between Order whereby the order of drug administration diminishes or exaggerates the effects of the treatment. Finnegan (1992) also cites asymmetrical transfer described by Millar (1983) as a potential issue in alcohol and human performance research. For example, Millar (1983) cites Potamianos and Kellett (1982) who conducted a study with one treatment (benzhexol-treatment for Parkinson's disease) and one placebo Condition, the study involved a series of

cognitive tasks (digit span, word list and story recall, word association learning) administered to 13 participants. At Order 1, the placebo was administered followed by drug administration, and at order 2 the drug was administered first and was then followed by placebo administration. The results by Millar (1983) demonstrate the asymmetrical transference which occurred across results. Order was not examined in the original analysis by Potamianos & Kellett (1982) and as a result, the interpretation of the results may have been misleading as they may have reflected the effect of one Order rather than two. For example, a main effect of drug was found for story recall, however, for Order 1, the drug had relatively no effect but from Order 2, a considerable increase in recall was observed. When pooled together, the analysis found an overall main effect of the drug, however, this is misleading as it occurs only at Order 2.

Therefore, it is arguable that the transfer between hangover and no hangover Conditions may not be asymmetrical and thus, counterbalancing for Order effects is not sufficient for hangover research and thus, Order should be included in all repeated measures analysis of this nature.

In addition, to facilitate comparisons between similar studies it is helpful to use similar experimental designs to previous studies carried out in the relevant area if the method used was appropriate to the research question. For example, the use of standardised tasks within hangover research facilitates replication which in turn provides insight into the variance of findings in the field. Therefore, studies that wish to explore the effects of an alcohol hangover on Selective Attention should use standardised tests such as Eriksen's Flanker Task or Stroop (Stephen's et al., 2014). With the same consideration, comparable studies carried out by McKinney and Coyle (2004; 2005); McKinney, Coyle, Penning and Verster (2012) also account

for order effects by investigating a between factors Order variable .Thus, it is considered best practice to maintain a consideration of this variable throughout repeated measures experiment designs within this thesis.

2.1.4 Characteristics of Participants in Hangover Research

Stephens et al.'s (2008) review which aimed to critically review the literature pertaining to performance during a hangover highlighted eight laboratory and three naturalistic studies identified through the use of database searches (e.g. Web of Knowledge, PSYCH info) and searching the reference sections of included papers for any other published works. The review aimed to find all studies investigating cognitive performance during a hangover, however, had quite stringent inclusion and exclusion criteria. This resulted in 21 studies which were excluded as they did not have inferential statistics, control or placebo Conditions, or did not collect Blood Alcohol Concentrations (Stephens et al., 2008). Those without inferential statistics may have been pilot studies assessing cognitive phenomena related to hangover; under-powered studies should not use inferential statistics (Lee et al., 2014). Those without control or placebo Conditions could be an experimental design where all groups are active or may be an observational study. These may add to the literature on hangover but are limited in their ability to compare Conditions. The criteria of BAC collection is warranted as without confirmation of BAC approaching zero, acute intoxication effects may be measured instead of an alcohol hangover.

Of the 11 studies that met inclusion criteria, five used an undergraduate student population (Collins et al., 1971; Anderson & Dawson, 1999; Laurell & Tornros, 1983; McKinney & Coyle, 2004; Finnegan et al., 2005). In addition, of the 9 studies that provided the mean age of participants, 8 were 25 years old or less (Stephen's et al., 2008). A report by Higher Education Statistics Agency (2014) suggests that 79.3% of full-time undergraduate students in the UK are 20 years or under. This represents a population of drinkers whom by law have been drinking for around two years or less. However, social drinking and alcohol hangovers occur in age groups beyond the scope of the student population. The 'Adult Drinking Patterns Survey Report 2013' for Northern Ireland showed between 1999 -2013 the largest increase in alcohol consumption occurred in the 60-75 age group (Health, Social Services and Public Safety, 2013). People aged between 30-44 years are twice as likely as those between 18-29 years to drink daily. Furthermore, 16% of adults aged between 60-75 years drink each day whereas on average just 1.5% of adults aged 18-29 years drink daily. The recruitment of predominantly student participants may limit the applicability of results, given the variation in consumption both between and within age groups. As such it is recommended that age of participants be reported and discussed in hangover research.

Age may also relate through tolerance. Evidence of Acute Tolerance Phenomenon suggests that prior alcohol experience increases alcohol tolerance (Hiltunen, 1996) and furthermore impacts on cognitive performance when in an intoxicated state (Hiltunen, 1997). Those who are younger have typically shorter experience and exposure to alcohol. Hangover severity and cognitive impairment after a night's drinking may also vary as a result of differing tolerances among experienced and non-experienced drinkers. However, so far evidence of

tolerance impacting hangover severity has been inconclusive (Hess & Tutenges, 2010; Howland et al. 2008) However, it may be recommended to consider tolerance in contemporary hangover research.

Four of the studies in Stephens et al (2008) review were conducted on non-student volunteers but all participants were male (Roehrs et al., 1991; Lemon et al., 1993; Streufert et al., 1995, Finnegan et al., 1998). This limits the ability to generalise the findings to all drinkers, both male and female. Gender differences in alcohol effects have been well documented (Wilsnack, Vogeltanz, Wilsnack & Harris, 2000; Dawson & Archer, 1992; Ely, Hardy, Longford & Wadsworth, 1999). Females typically have more body fat and less water than men of the same body weight (Frezza et al., 1990). Alcohol is water soluble therefore women typically reach higher BAC levels than men despite consuming an identical number of units (Taylor et al., 1996). The metabolism of alcohol per hour rate (β_0) also differs by gender. Mumenthaler, Taylor, O'Hara & Yesavage (1999) in a review which aimed to do review evidence of gender differences in alcohol metabolism and related performance. Out of 13 studies reviewed, nine suggested women have higher β_0 s than men and thus eliminate alcohol within the body faster than men. It was speculated that this could be due to higher BAC levels reached the night before which might accelerate metabolism. However, research carried out whereby both males and females reach the same BAC levels before testing showed faster metabolism in females than males (Taylor et al., 1996). Therefore, this is unlikely to be the case. This review also suggested alcohol consumption impaired cognitive functioning in women to a greater degree than in men (Mumenthaler, Taylor, O'Hara & Yesavage, 1999). For example, Jones and Jones (1976) who showed delayed recall performance was significantly worse in females than in

males after moderate doses of alcohol (BAC 0.072 in females, 0.063 in males). Furthermore, in decision making tasks response times are slower for intoxicated females than males (Haut et al., 1989). Taking into consideration the different ways in which alcohol is processed by males and females, and women's apparent susceptibility to alcohol effects on cognitive performance while intoxicated, the studies within this thesis have recruited samples of both male and female participants.

In the Stephens et al (2008) review, the following studies had small sample sizes, Collins and Chiles (1980), Roehrs et al., (1994), and Chait and Perry (1994), ranging between 5-14 participants which again limits the ability to generalise the findings. For example, Roehrs et al (1991) recruited just five participants for their study on Divided Attention performance during a hangover. Whilst this study was included (as it had inferential statistics), it is unlikely that it was appropriately powered to detect differences. With one of the criteria for exclusion the lack of inferential statistics, perhaps this should also have been excluded due to the limited ability to generalise beyond these five individuals.

Small studies are also affected by potential individual differences which may impact on the effects of a hangover. For example, Jackson, Rohsenow, Piasecki, Howland, and Richardson (2013), carried out a study that investigated the relationship between smoking, mood and, hangover incidence and severity on 113 American students. The study required participants to complete a 26 item survey pertaining to hangover symptoms, alcohol consumption, and cigarette smoking each day for 8 weeks. The results of the study revealed that the number of cigarettes consumed on a day of heavy drinking positively predicts both number and severity of hangover symptom (positive correlation). Smoking may be another factor worth consideration

in contemporary alcohol hangover research, so too, factors such as Body Mass Index, food intake, and duration of drinking episode also impact on BAC levels which may further impact hangover severity (Rohsenow, 1981).

Appropriateness of Instrumentation

Alcohol hangover research is also limited by the idiosyncrasy of cognitive tasks employed by researchers investigating cognition and human performance. The variability of tasks creates difficulty in synthesising research in reviews and/or comparing findings in empirical work (Gunn, Mackus, Griffin, Munafo & Adams, 2018). For example, in Chait and Perry's (1994) hangover study a Free Recall task as well as a Divided Attention, backwards digit span, digit symbol substitution and logical reasoning task were administered to participants in order to measure performance. In contrast, McKinney and Coyle (2004) administered Free Recall, delayed recognition, selective, divided, and sustained attention, Stroop, simple and choice reaction time tasks to measure cognitive performance. Here only two tasks are directly comparable (Free Recall and Divided Attention). So, whilst these two papers may both be measuring cognitive performance, they do so using different tasks which makes it difficult to compare and understand the effects of a hangover on cognitive performance. To address this, researchers should select tasks which have shown sensitivities to describe change within the field of hangover research (e.g. Eriksen's Flanker Task; McKinney & Coyle, 2004) and that are also applicable to everyday activities.

2.2 Methodology Of The Empirical Chapters

The design of the empirical Chapters has been created through accounting for the methodological limitations in the alcohol hangover field highlighted in section 2.1. It is acknowledged this may not be an exhaustive list of the methodological challenges in the alcohol hangover field, but these are highly relevant to experimental designs. Each Chapter will be considered below with reference to these challenges in experimental design, setting, between/within designs, order effects, participant characteristics, and range of cognitive tasks. This will be followed by a more general discussion of the methodological approach in this thesis.

In the interest of clarity, the first letters of the independent in Chapters 3, 4, 5, and 6 will be capitalised e.g. State and Order. Three experimental studies were carried out in order to collect the data for this thesis. Their corresponding Chapters are shown in Figure 2.1.

Figure 2.1 Correspondence of studies and Chapters within this thesis

Study 1	Chapter 3
Study 2	Chapter 4
Study 3	Chapter 5 & 6

2.2.1 *Chapter 3: The effects of expectancy on cognitive performance after a night's drinking*

Chapter 3 aimed to investigate the effects of expectancy on cognitive performance after a night's drinking. As discussed in section 2.1, Verster et al. (2010) noted revealing the purpose

of the study can affect the cognitive performance outcomes in alcohol hangover research. Verster et al. (2010) suggests the purpose of the study should be withheld until testing is complete. A between factors approach to investigating the effect of expectancy was chosen to satisfy ethical requirements of the field (British Psychological Society [BPS], 2014). Deception is a problem because it may cause distress, discomfort or harm to the participants and we accounted for this by using a between factors design in order to reduce the time in which the true purpose of the study was withheld. In this study, the independent variables were expectancy/no expectancy and hangover/no hangover. Participants in the expectancy group were informed that the purpose of the study was to investigate the effects of a night's drinking on cognitive performance and participants in the 'no expectancy' group were informed that the study aimed to examine the effects of time of day on cognitive functioning. The dependent variables were the cognitive tasks and the subjective questionnaires on mood and hangover severity. At the end of the study participants in both groups were told the true purpose of the study and a debriefing form was provided.

Predictability of student drinking enabled relatively well balanced hangover and no hangover group cells (20, 20, 20, 14). Participants were recruited on the morning of testing and testing took place on site which meant that participants were not encouraged to consume alcohol and travel was not required. Participants in the hangover group were often recruited on Wednesday and Friday mornings as Tuesday and Thursday nights were popular student nights at the time. Participants were assigned to expectancy/no expectancy Conditions using a pre-calculated randomisation formula on Microsoft Excel (RANDBETWEEN). Participants were

numbered in order of recruitment and the Microsoft Excel function provided a corresponding Condition for each participant number.

2.2.2 Chapter 4: The next day effects of a night's drinking on social drinkers in a natural environment.

Chapter 4 aimed to explore the effects of a night's drinking on a non-student sample. The design for this Chapter applied a repeated measures variable of hangover/no hangover with order of testing (hangover test 1st/hangover test 2nd). A within measures design was applied to eliminate the threat of ill matched group characteristics. For example, age matching would have been difficult in a between factors design as the age range in this study was anticipated to be larger than in student samples. In addition, a small community of individuals frequented the public house where recruitment took place, therefore a within factors design was implemented as fewer participants were required. As discussed in section 1.1.3, order was examined to identify asymmetric transfer and ensure consistency. All cognitive tests were measured in this way and participants were tested approximately 5-10 days apart. Non-proportional quota sampling was applied until a minimum of six participants were recruited for each experimental cell.

2.2.3 Chapter 5: The alcohol hangover and attention

Study 3 aims to investigate the effects of a night's drinking on attention using undergraduate and postgraduate students. Subjective and Objective measures were applied to investigate hangover/no hangover Conditions with between factors measures of Order (Order

1/Order 2). The analysis formed a 2x2 mixed factorial design. This design was chosen to reduce the likelihood of individual differences relating to performance which may occur in a between factors design. Recruitment continued until a minimum of 6 participants were recruited for each group by using non-proportional quota sampling.

2.2.4 Chapter 6: Smartphone and wearable technologies in an alcohol hangover study

Chapter 6 was carried out in unison with Chapter 5's data collection. The same sample and design was therefore applied. Chapter 6 aimed to investigate the impact of an alcohol hangover on sleep, and physical activity and energy expenditure. Chapter 6 also aimed to introduce the use of smartphone and wearable technologies to hangover research. Energy expenditure was measured on free living leisure days in both hangover and no hangover sessions. A free-living day is characterised by a day in which daily activities occur (Skarpsno, Mork, Nilsen & Holtermann, 2017). A leisure day refers to one where there are no study or work commitments (Skarpsno, Mork, Nilsen & Holtermann, 2017). In this way, activity did not vary according to work or study activity requirements.

2.3 Other Methodological Issues

2.3.1 Ethical Approval

Ethical approval was granted for all studies by the Psychology Filter Committee at Ulster University and participants were treated in accordance with the "Code of Ethics and Conduct"

(British Psychological Society, 2009) throughout. This involved the provision of information sheets tailored to each individual study. For Chapter 3 which involved deception, the true nature of the experiment was revealed at the earliest opportunity. Participants provided informed consent for each study in accordance with the Declaration of Helsinki.

2.3.2 Inclusion And Exclusion Criteria

Throughout this thesis, all participants were screened and excluded for head injury, medical treatment, pregnancy and previous treatment for alcohol or drug abuse. Also, volunteers with scores greater than three on the Short Michigan Alcohol Screening Test were excluded from all studies (Selzer et al., 1975). In order to maintain a quiet and constant environment, participants were tested one at a time throughout.

The Short Michigan Alcohol Screening Task (SMAST; Selzer et al., 1975)) was administered to all participants to exclude those with a potential drinking problem. The SMAST (Selzer et al. 1975) is a 13-item screening task that is suitable for a wide range of reading levels to detect probable alcohol use disorders. All questions have a Yes/No response with a maximum score of 13. A yes response earns one point on all questions apart from 1, 4 and 5 which are reverse scored (e.g. No=1 point). Participants scoring three or above on the questionnaire are excluded as this indicates a probable alcohol problem and the aim of the current research is to investigate social drinkers.

This screening task was chosen as it has high levels of internal reliability of between .76 to .93 (Selzer et al. 1975) and has been widely applied in both clinical and research contexts (Welfel & Ingersoll, 2001) as well as in similar research areas (Kim et al., 2003).

In Chapters 5 and 6, participants were screened online in order to avoid an unnecessary waste of volunteers' time. A recruitment email that highlighted four eligibility criteria, no head injury, no pregnancy, over 18 and no medical treatment for heart problems or treatments for alcohol or drug abuse was circulated around students at Ulster University. Potential participants that met the criteria were then encouraged to follow a Survey Planet link where they would be further screened.

2.3.3 Sample Size

In order to ensure that analyses were adequately powered in this thesis, the alpha, beta and the effect size needed to be considered. Alpha represents the probability of making a Type I error. A Type 1 error is an error that occurs when a true null hypothesis is incorrectly rejected (Lane, 2018). Beta is the probability of making a Type II error which refers to when a significance test incorrectly fails to reject a null hypothesis (Lane, 2018). It is important to minimise both of these values. The effect size refers to the magnitude of difference between variables. Cohen (1988) stipulated a small effect size as .10, a medium effect size as .25 and a large effect size of Cohen's f as .40. An examination of hangover research literature suggests that Cohen's f varies from medium to large in the area of cognitive performance during a hangover (Grange, Stephens, Jones & Owen, 2016; Rohsenow, Howland, Minsky & Arnedt, 2006).

G-power 30.0 is a statistical software package that calculates the required sample size with specific values of alpha, beta, and power according to the statistical design chosen (Buchner et al., 1997). To make a conservative assessment of power for the studies in this

thesis, we set large effect sizes (.40 and .45), alpha at 0.05, and power at .95 (beta=0.05).

Chapter 3 followed a between group design. For a three-way analysis of variance with four measurements (Hangover with Expectancy, No Hangover with Expectancy, Hangover without Expectancy, No Hangover without Expectancy) the total sample size required was 89. However, accounting for attrition/non-completion 10% was added to the proposed sample. As such the target for recruitment was 98. Chapter 4 followed a mixed measures design. For an ANOVA with 4 groups (Hangover Order 1, Hangover Order 2, No Hangover Order 1, No Hangover Order 2) and two testing sessions (Hangover and No Hangover), total sample size was 32. Again 10% attrition was accounted for and the sample size was 35. Chapter 5 and 6 followed a mixed measures design. Gpower provided as estimate of 28 participants required for an adequate sample size. For an alpha level of .45 and four groups (Hangover Order 1, Hangover Order 2, No Hangover Order 1, No Hangover Order 2).

2.3.4 The Robustness Of The Analysis Of Variance

If underlying assumptions of a test can be violated without considerably affecting the ratio of Type 1 and Type 2 errors, then a test is said to be robust. The assumptions of the Analysis of Variance concern normality, homogeneity of variance, sample size and independent observations. Moreover, the most frequently employed dependent variable throughout this thesis is response time. This variable meets assumptions regarding scale of measurement (having equal intervals) and independence, and therefore Analysis of Variance is an acceptable technique. In terms of sample size, cell sizes of more than 3 were employed in accordance with Winer (1962).

2.3.5 Appropriateness Of Instrumentation

Subjective, objective and physiological measures were carefully selected in accordance with the aims of each empirical Chapter. Each measure is described in detail in the following sections along with a justification for choosing each measure. Table 2.1 summarises the measures used in each Chapter.

Table 2.1: The Subjective, Objective, and Physiological Measures administered across empirical Chapters in this thesis

	Chapter 3	Chapter 4	Chapters 5 & 6
<i>Subjective Measures</i>			
Previous night drinking	X	X	X
Demographic information and alcohol consumption	X	X	X
Mood	X	X	X
Guilt			X
Task Related Motivation	X	X	X
Acute Hangover Scale	X	X	X
Hangover Duration			X
Sleep	X	X	X
Sleep quality			X
Short Michigan Alcohol Screening Task	X	X	X
Pre-Recruitment Screening	X	X	X
Alcohol Consumption App			X
<i>Physiological Measures</i>			
Accelerometer			X
Blood Pressure Monitor ⁶		X	X
Breathalyser	X	X	X
<i>Objective Measures</i>			
Flanker Task	X		
Stroop	X		
Divided Attention	X		
Free Recall	X		
Attentional Blink			X
Psychomotor Vigilance			X
Emotional Stroop			X
5 Choice Serial Reaction Time Task			X
Spatial Working Memory	X	X	
Intra/Extra Dimensional	X	X	
Choice Reaction Time Task		X	

⁶ Blood pressure (BP) was collected from some participants in chapters 4, 5 and 6. However, its use was discontinued as a) it did not relate directly to the research questions of this thesis, although theoretically of interest; b) individuals felt it was uncomfortable (it was an automatic device); c) some individuals were on heart medication, and cardiac risks of BP collection. Contemplations relating to the risks of continuing to collect BP data balanced with the lack of benefit to the thesis led to a decision to stop collecting BP.

2.3.6 Subjective Measures

2.3.6.1.1 Previous Night Drinking

Using a visual guide provided by the National Health Service (NHS, 2018), information regarding the type of alcohol consumption, the number of drinks and the total units consumed the previous night were gathered (see questionnaire in Appendix 1). Questions pertaining to the time that drinking began and ceased, and food and caffeine consumption were incorporated into all studies in this thesis as it is important to measure a range of factors which impact the peak BAC level reached and by consequence the hangover State (Simpson & Kapur, 1987).

2.3.6.1.2 Demographic Information and Alcohol Consumption

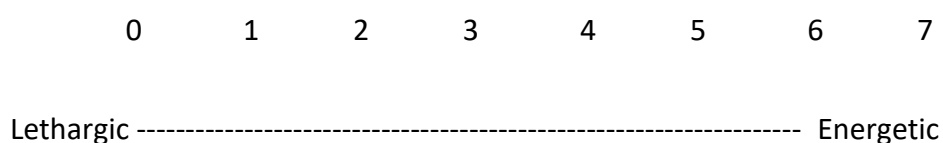
In total, there were 19 questions (Appendix 1). This allowed us to characterise the sample in each of the Chapters and understand the degree to which it may be similar or different to the existing literature (Verster et al., 2010). As mentioned in the introduction, measures of consumption are useful to understand the general level of consumption, and individual differences in participant drinking, particularly important as some researchers consider tolerance a factor in alcohol hangover (Hiltunen, 1997).

2.3.6.1.3 Mood

Mood was measured using an 18 item bipolar visual analogue scale developed by Bond and Lader (1974) and adapted by Herbert et al (1976). The scale was administered immediately before objective measures were carried out in order to gain an accurate record of mood at the time of testing. The questionnaire contained the following items presented at opposite ends of

an 8cm line: Alert-Drowsy, Contented-Discontented, Calm-Excited, Troubled-Tranquil, Strong-Feeble, Mentally Slow-Quick witted, Muzzy-Clear headed, Tense-Relaxed, Incompetent-Proficient, Happy-Sad, Antagonistic-Friendly, Interested-Bored, Withdrawn-Sociable, Depressed-Elated, Self-Centred-Outward going, Well Coordinated-Clumsy, and Lethargic-Energetic. Participants were required to mark on the line at a position which indicated how they were currently feeling. The raw scores for each line of bipolar items were then derived from the distance of the mark from the item on the left (0-7), an example of which is in Figure 2.1 below. As described in Chapter 1, alcohol elevates positive mood and a rebound or 'dopamine hangover' occurs when alcohol leaves the blood (Weiss et al., 1981). It has been demonstrated in a natural environment, lower mood is typical in the morning after a night's drinking (Collins & Chile, 1980; McKinney & Coyle, 2005). However, Smith, Whitney, Thomas, Perry and Brockman (1995) found no evidence of changes in mood during a hangover using the same Herbert et al (1976) scale as used in this thesis and used by McKinney and Coyle (2005).

Figure 2.2 An example item from the *Bipolar mood scale*



Items from Herbert et al.'s (1976) mood scale were computed into two factors as implemented by Herbert, John's and Dore (1976). The alertness factor consisted of items such as Quick-witted/mentally slow, Alert/Drowsy, Attentive/Dreamy, Energetic/Lethargic and Interested/Bored. Tranquillity was the second factor. It contained x items, including those

measured on a Likert scale from 1-10 representing two opposite characteristics such as tranquil/troubled, calm/excited, contented/discontented and relaxed/tense items. Scores range from 1-100 with higher scores relating to highest level of the characteristic.

2.3.6.1.4 Guilt

Participants were asked if they were currently experiencing feelings of guilt and if they had consumed more alcohol than they intended the night before testing. Participants were required to indicate their answers by ticking the relevant Yes/No box. Moral hangover symptoms such as guilt and shame have been overlooked in previous research and may play a role in the 'hangover effect' (Verster et al., 2010). Research suggests that when participants consume more than intended they are more likely to report feelings of guilt (Muraven et al., 2005). Guilt is included in some hangover scales as a symptom, and the cause of the guilt may be a function of either the alcohol consumption or actions taken as a result of the consumption. These questions were added in order to explore the prominence of this reaction after a night's drinking, its linkage to consuming more than intended and the potential impact that guilt may have on cognitive performance.

2.3.6.1.5 Task-Related Motivation

Before and after each task, visual analogue scales were administered to measure task related motivation. The pre-task scale included three questions; how difficult do you think the task will be? How much effort will you put into doing this task? How well do you think you will do on this task? Participants were required to respond using an eight cm bipolar line below each question. The post task scale consisted of the same assessment structure with reference to perceived task performance. The scales were previously used in hangover and cognitive

performance research by McKinney (2003) and the assessment provides a record of task motivation that compliments the objective measures of cognitive performance. Measure of perceived effort, performance and task difficulty before and after each task also provide information that may identify variation in performance as a result of expectancies.

2.3.6.1.6 The Acute Hangover Scale

The Acute Hangover Scale (Rohsenow et al. 2007) measures the severity of individual hangover symptoms and is acknowledged as adequately measuring important descriptive information in hangover research as measured close to the drinking event (Verster et al. 2010). The 9 item Likert scale requires participants to rate out of 7 the degree to which they feel a particular hangover symptom. There are four anchors above the scale, none (0), mild (1), Moderate (4), Incapacitating (7) and the hangover symptoms are hangover, thirsty, tired, headache, dizziness/faintness, loss of appetite, stomach ache, nausea, heart racing (Appendix 1).

2.3.6.1.7 Hangover Duration

Ylikahri, Huttunen, Eriksson & Nikkilä (1974) suggest hangover duration measurements are rarely collected. Verster et al. (2010) also noted information on hangover duration will provide information on the burden of the hangover on daily activities and therefore it is important to understand and measure this concept in future studies. Two additional items were added to the hangover section of the questionnaire. They are 'How long do your hangovers usually last?' and 'How long do you anticipate this hangover to last?' in order to address this. The latter is only included in the hangover Conditions. Participants could respond in minutes, hours, or days. At the time of developing the experimental design, this was the first study to the

author's knowledge to measure this, the question was left deliberately broad to allow participants to estimate the time they felt appropriate.

2.3.6.1.8 Sleep

Alcohol's complex effects on sleep gives rise to the assumption tiredness is the most frequently experienced hangover symptom (Prat, Adan, Sanchez-Tuert, 2009). Sleep disturbances can affect next day alertness (Roehrs, Carskadon, Dement & Roth, 2000) and further alcohol induced sleep disturbances have been shown to reduce alertness the day after alcohol consumption (Roehrs, Yoon & Roth, 1991). With this in mind, the duration and quality of sleep prior to testing sessions was measured. The following questions were included:

1. At what time did you go to bed?
2. At what time did you wake up this morning?
3. How long did it take you to fall asleep?
4. How many hours of sleep did you get last night?

2.3.6.1.9 Sleep Quality

A five item bipolar Likert scale was added to measure sleep quality. This scale has previously been implemented in hangover research and provides a measure of perceived sleep experience (McKinney, 2003). The previous use of this scale allows the results to be directly compared to the other naturalistic examination of alcohol hangover to date (McKinney, 2003). In this questionnaire, participants were asked to select a number (1=extremely, 2= quite, 3= slightly, 4=neither, 5=slightly, 6=quite and 7=extremely) on the scale which best reflected the

of 3mg will be set for the subsequent study. The accelerometer's sensitivity to movement is reflected in Phan, Bonnet, Guillemaud, Castelli & Thi's (2008) investigation of respiration which revealed that the vibrations from a body's heart beat alone equates to an amplitude of 80mg.

The acceleration means and sum vector magnitudes can be calculated at epochs of 1, 5, 10, 15, 30 and 60 seconds. Of note, vectors have both magnitude and directional qualities. The magnitude refers to the length of the vector and the sum magnitude can be calculated by adding the magnitude of two or more vectors. The mean level of activity and the overall time spent at the activity can be provided for each epoch. The sampling frequency can be set at up to 1kHz. However, sample rates at high frequencies use more energy and storage space, and this must be considered when selecting sample frequency. For this study sampling frequency was set at 60Hz as used by White, Westgate, Wareham and Brage (2016). In cases where participants are unable to return the watch before it has reached capacity, the frequency will be lowered in order to ensure that all relevant data is collected.

Using post processing software, data from the GENEActiv watches are converted into Signal Vector Magnitudes (SVM) expressed in 1 second epochs (Karatonis, Narayanan, Mathie, Lovell & Celler, 2006), using the formula:

$$SVMgs = \sqrt{x^2 + y^2 + z^2} - g$$

Where x, y and z represent the triaxial accelerations and g represents gravity. A calibration of activity thresholds of the GENEActiv accelerometer was carried out by Elsiger (2011). Firstly, a measurement of breath by breath VO_2 was filtered to one minute averaging using K4b2 apparatus (portable metabolic gas analyser). In this way, the GENEActiv

accelerometers could be synchronised to the VO^2 measurements. The participants were then given 15 activities to perform e.g. shelf stacking, slow run, brisk walk. A combined dataset of minute by minute accelerometer and VO^2 data was then devised for each activity. Finally, the VO^2 data was converted into METs using the standard conversion rate of $1 \text{ MET} = 3.5 \text{ mLkg}^{-1}\text{min}^{-1}$ and the equivalent SVMs could then be compared using the accelerometer data. The outcome intensity categories included sedentary ($<1.5\text{METs}$), light ($1.5\text{-}3.99 \text{ METs}$), moderate ($4.00\text{-}6.99$) and vigorous ($7+ \text{ METs}$) activity and from this the corresponding cut off points were set at 386 (sedentary to light), 542 (light to moderate) and 1811 SVMs (moderate to vigorous). In addition, the SVM cut offs were adapted to the frequency of recorded data by multiplying the cut off by the recorded frequency and dividing by the raw frequency measurement of 80Hz (frequency at calibration).

Furthermore, Elsiger (2011) measured the validity and reliability of the GENEActiv accelerometer using a multi axis shaking table (MAST). The results revealed the validity of the watch vs MAST was high ($r=.97$, $p<0.0001$). The instrument and inter-instrument reliability was 1.8% and 2.4% respectively indicating it is of sufficient quality for hangover research (Elsiger, 2011). The temperature gauge on the GENEActiv is a linear active thermistor with a range of 0-60 degrees with an accuracy of ± 1 degree. This is useful as temperature fluctuates during sleep and is also altered by alcohol consumption Kleitman (1939). As a result, addition information relating to the environment can also be collected.

2.3.7.1.2 Breathalyser

An alcohol hangover begins as blood alcohol concentration (BAC) approaches zero. To ensure participants are no longer intoxicated and have reached a hangover State, a Lion Alcometer SD-400 was used to calculate Breath Alcohol Concentrations (BrAC) before testing. This model of breathalyser is police grade and has been approved by the Home Office, Great Britain for Police use in the UK (Breathalyser Direct, 2018). In Chapters 3, 4, 5 and 6, BrAC was calculated on arrival to all testing sessions and was immediately converted into BAC. Participants with a BAC over 0.0001% were excluded from the study.

2.3.8 Objective Measures

2.3.8.1.1 Selective Attention (Eriksen's Flanker Task)

This test was developed by Eriksen and Eriksen (1974) and was administered in previous alcohol studies by McKinney, Coyle and Verster (2012) and Tedstone and Coyle (2004). This task was chosen as it is the standard test in hangover research for Selective Attention (Stephens, Grange, Jones & Owen, 2014). The targets and distracters consist of the letters A and B. Distracters are presented at either side of the target and appear either near (0.6° , 1cm) or far (1.9° , 3.4cm) from the target. As well as this, distracters are either compatible (AAA) or incompatible with the target (BAB). Participants are required to respond to the target letters by pressing an appropriate key as quickly and accurately as possible (Z for the target A, M for the target B). The attentional spotlight theory suggests that when incompatible distractors are presented within the visual field (within 1° of visual angle of the target) reaction times will be slower than when compatible distractors are presented within the visual field. Furthermore,

distractors outside of the visual field do not affect RTs (Posner, Snyder & Davidson, 1980; Eriksen and Yeh, 1985).

Once instructions are read, participants were required to complete a practice block and eight testing blocks with eight trials in each. Letters were presented for 1000ms and cues for 500ms. The cues were three asterisk symbols proportionately spaced across the centre of the screen. Dependent variables are compatible near, compatible far, incompatible near, incompatible far, and total errors.

2.3.8.1.2 Selective Attention (Stroop)

The Stroop task has been widely used in experimental research as it is sensitive to subtle changes in attention (MacLeod, 1992). Unlike Eriksen's Flanker Task that involves spatial aspects of Selective Attention, the Stroop measures intra-dimensional elements of Selective Attention (Chajut & Algom, 2009). In this task, participants are informed words will be presented on the screen one at a time. Ignoring the text-meaning of the words, participants are required to respond to the font colour only by using the corresponding buttons on the keyboard provided. Coloured stickers are placed on the buttons (z, x, c, v, b) representing each response. Participants are asked to hover both right and left hands over the appropriate keys. Words are presented in Blue, Green, Red, Purple and Brown as used in the original task (Stroop, 1935). When the meaning of the word corresponds to the font colour they are categorised as congruent items e.g. 'Blue' is written in blue font; and when they do not correspond to the word meaning they are known as incongruent items e.g. 'Blue' is written in red font. The word remains on the screen until the participants make a response, after that a cue is presented for 500ms (+) before the next item appears.

This task has been created on Superlab 4.5. and it contains one practice block and 5 testing blocks, each containing 10 trials. Congruent items are presented on 1/3 of the trials and incongruent items are presented in 2/3 of the randomised trials. Mean Reaction Times (RTs) for congruent items, incongruent items, and total errors are the output measures used. Stroop interference is calculated by subtracting the mean congruent RTs from the mean incongruent RTs.

A review by Prat, Adan, Perez-Pamies and Sanchez-Turet (2008) highlights the need for exploration of tasks sensitive to drug effects in hangover research and specifies the need for future hangover studies to investigate the Stroop effect. In addition, in the interest of replication further investigations of the Stroop effect are recommended by Stephens, Grange, Jones and Owens (2014) critical analysis of alcohol hangover methodology.

2.3.8.1.3 Simple Reaction Time Task

One choice response time measurements examine sustained and intensity aspects of attention. Responses are measured using a visual reaction time task run on Superlab 50.0. In this thesis the type of response time measurement applied is the PVT which has longer interstimuli intervals than standard one choice response time tasks (Ratcliff & Van Dongen, 2011). Here, the stimuli are presented at intervals between 2000-10000 milliseconds. The visual stimulus presented is a red 'X' in size 60, Times New Romans font in the centre of the screen. The test follows Dinges and Powell's (1985) original design, however, the test runs for five minutes as validated by Roach, Dawson and Lamond (2006). Psychomotor Vigilance is implemented in all areas of cognition and it is globally accepted that vigilance is the area of cognition most sensitive to sleep deprivation and furthermore is sensitive to homeostatic sleep

drive and circadian effects (Lim & Dinges, 2008). Alcohol affects sleep initiation, maintenance and proportion of sleep stages (Roerhs & Roth, 2001; Williams & Salamy, 1972) and it is therefore of interest to investigate Psychomotor Vigilance after a night's drinking. The test consists of one practice block and 10 testing blocks. Each block contains 10 trials of randomised intervals. Output variables are response times at intervals of 1000ms. (1000ms, 2000ms, 3000ms, 4000ms, 5000ms, 6000ms, 7000ms, 8000ms, 9000ms, 10000ms).

2.3.8.1.4 Divided Attention

The Divided Attention task was developed by (Tedstone & Coyle 2004) to investigate cognitive performance in sober alcoholics. It was also used in McKinney, Coyle and Verster's (2012) hangover study. A series of single digits appear in the centre of a computer screen at a rate of one per second. When three consecutive odd numbers appear (e.g. 5, 3, 7) participants are required to respond using a keyboard. In addition to this a blue box appears eight centimetres left, right, below or above the centre of the screen. Participants are also required to respond to when a blue box appears. The boxes are synchronised to appear while a number is also present on the screen. This task contains a practice block and 5 testing blocks.

Dependent variables include Divided Attention Central (RT), Divided Attention Peripheral (RT) and Divided Attention Error

2.3.8.1.5 Free Recall

The Free Recall task consisted of twenty words presented in uppercase letters at a rate of one word every two seconds. The words were selected from the handbook of Semantic Word Norms (Toglia & Battig, 1978) and have been used previously in hangover research by

McKinney, Coyle and Verster (2012). The test is presented on a computer screen and participants are required to write down as many words as they can remember. Two word lists were used in the thesis (Appendix 1). This task was chosen as to the author's knowledge no investigations have been carried out relating to serial position of Free Recall word tasks and analysis of serial position will provide a comprehensive understanding of working memory functioning during an alcohol hangover.

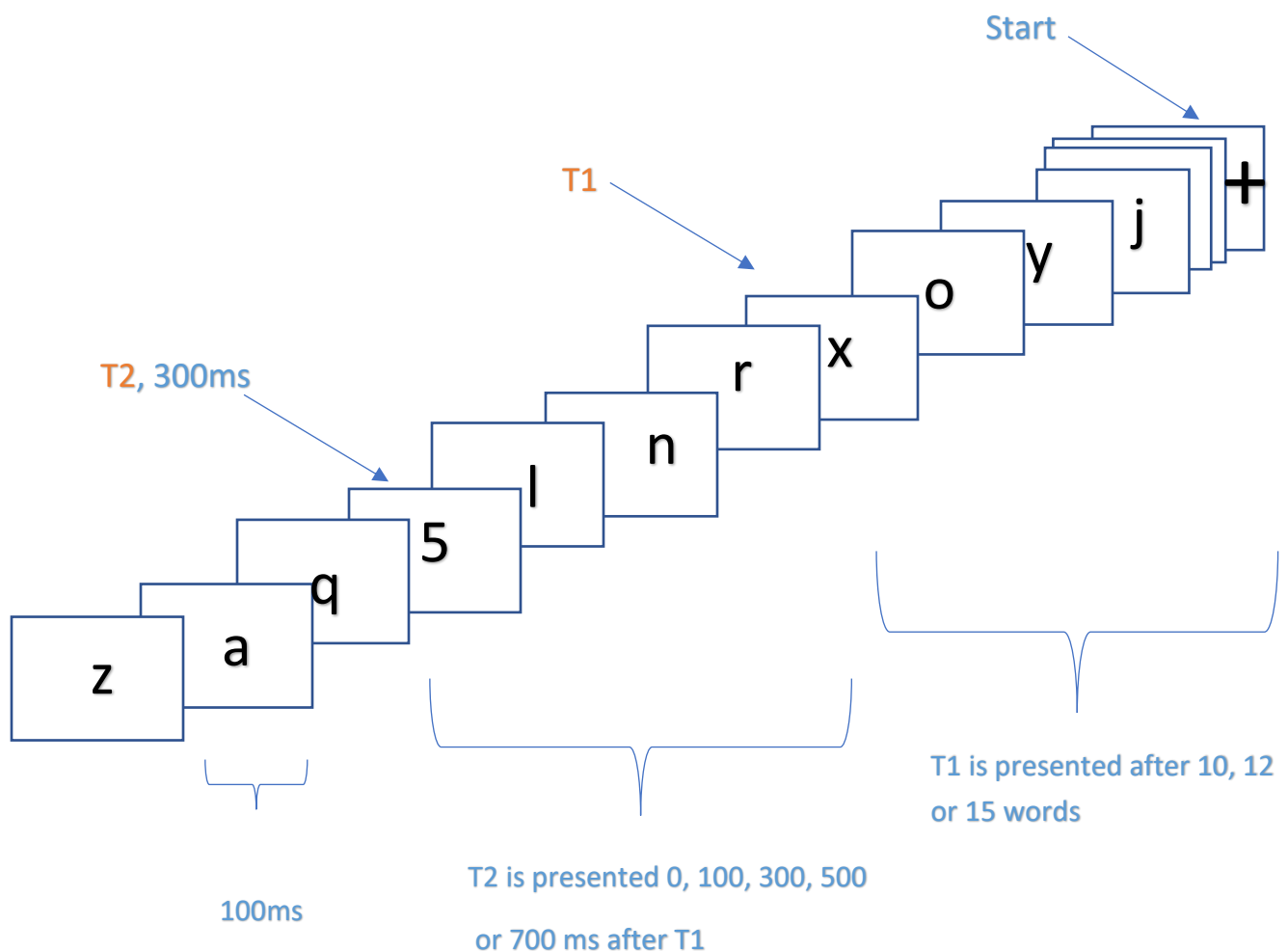
2.3.8.1.6 Attentional Blink

According to the controlled attention model, simple attention tasks are more affected than complex tasks during periods of interference (Pilcher, 2007). In this way, such tasks require greater levels of attention in order to overlook distractions. Attentional Blink is a selective and sustained attention task that applies Rapid Serial Visual Presentation from which participants must identify targets among rapidly changing distractors. This task was chosen as temporal aspects of attention are not traditionally investigated in hangover research despite evidence suggesting that response times are sensitive to the alcohol hangover (McKinney, Coyle & Verster, 2012). Differences in performance after a night's drinking are often evident from response times rather than error times (Finnegan et al., 1998; Roehrs, Yoon & Roth, 1991; Roehrs & Roth, 2001; McKinney & Coyle, 2004; McKinney, Coyle & Verster, 2012). For this reason, investigations into the temporal aspects of attention were sought to help determine whether slowed responses occur due to a speed accuracy trade off or a reduced ability to encode information quickly when hungover.

The task was designed on Superlab 50.0 and follows the procedure of Raymond, Shapiro and Arnell (1992). There were ten blocks, each containing six trials. Each trial consists of a list

of 26 items that are presented for 15ms with intervals of 75ms. Items are presented in size 36 Times New Roman font at the centre of a white screen. All stimuli are letters presented in black font apart from Target 2 (T2) which is the number 5. Participants are required to identify whether an 'X' appears in the presentation (T1) and if the number 5 is observed (T2; Figure 2.4). T1 is present in all trials and is located after either 10, 12 or 15 items proportionately. T2, is present in half of the trials and is presented either, 0ms, 100ms, 300ms, 500ms or 700ms after T1. Of note, T2 scores represent the number of correct responses to T2 when T1 is correct as described by Dux and Marois (2009).

Figure 2.4 Demonstration of Attentional Blink Task Trial.



2.3.8.1.7 Signal Detection In The Attentional Blink Task

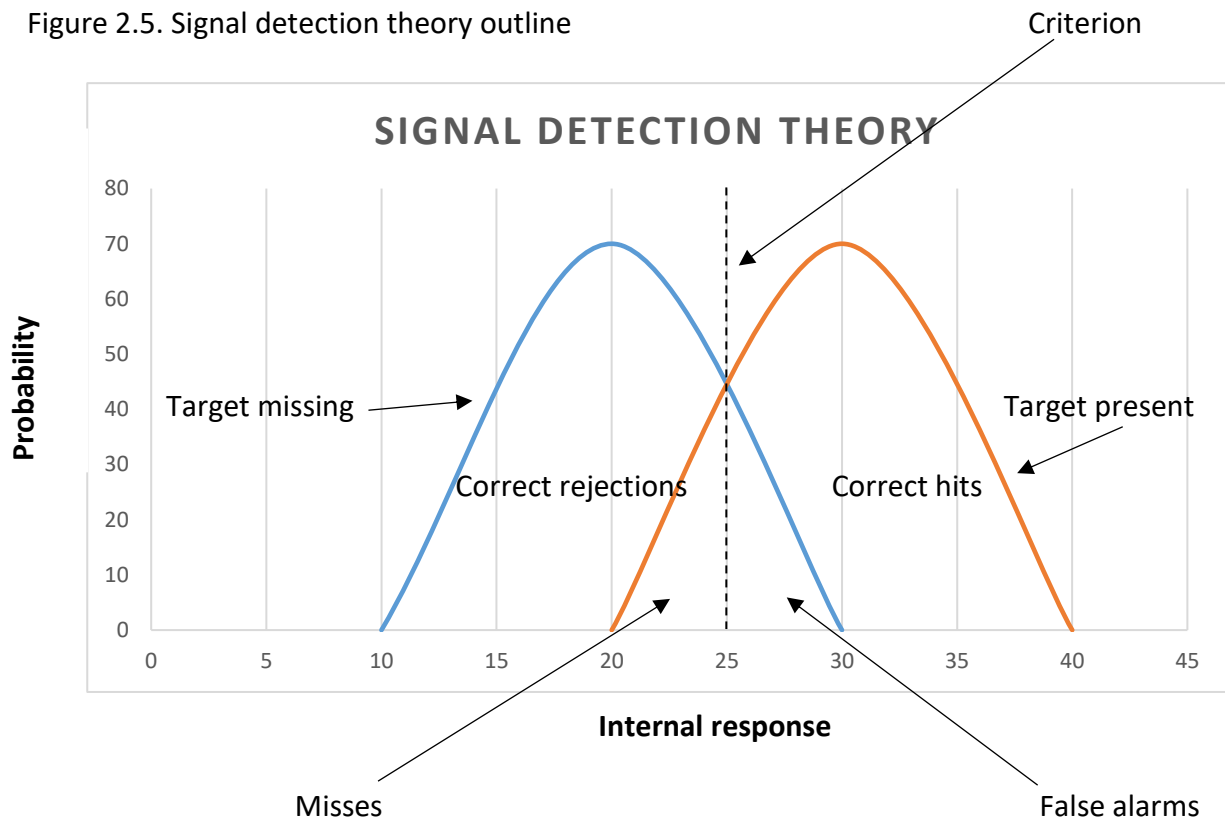
The Signal Detection Theory (SDT) is used to analyse the way in which decision making occurs in the presence of ambiguous stimuli (Abdi, 2007). In this thesis signal detection is applied to an Attentional Blink task (T2) in Chapter 5. As described above, this task requires participants to identify a target (signal) amongst distractors (noise). In figure 2.4, the blue curve represents the noise only trials and the orange curve represents the noise plus signal trials. There are four possible responses to this task: Hits (percentage of correct detections of the target), False Alarms (percentage of times the target is reported to be present when the target is not present), Correct Rejections (percentage of times the participant correctly reported that the target is absent) and Misses (percentage of times the target is present but not identified by the participant).

The participant's criterion will predict the number of hits, false alarms, correct rejections and misses. The sensitivity statistic refers to the distance between the two peaks in the graph and the spread of the curves, this is indicative of the difficulty in identifying the correct response. For example, when the peaks are far apart then it is easier to correctly respond to the stimuli than when they are close together. Brophy's (1986) algorithm is used to calculate a sensitivity statistic, d' and criterion, C .

Grange, Stephens, Jones and Owen's (2016) applied diffusion modelling to investigate response times on choice reaction time tasks in hungover participants. The results provided evidence to suggest response efficiency decreases and response caution increases during such

tasks. The study highlighted the importance of investigating beyond central tendencies in order to gain a better understanding of the attentional systems affected by a hangover. Thus, in order to extend our knowledge of the decision making processes involved in attentional task responses, the signal detection theory has been applied to the Attentional Blink task.

Figure 2.5. Signal detection theory outline



2.3.8.1.8 Emotional Stroop

Heavy drinking tends to lower mood and increase anxiety (Maddin, 1993). So too, Stroop performance is likely to be impaired after a night's drinking and when the individual is experiencing a hangover (McKinney & Coyle, 2005; Stetter et al., 1994; Alford, Hamilton-Morris & Verster, 2012; McKinney, Coyle & Verster, 2012; Marinkovic, Rickenbacher, Azma & Artsy,

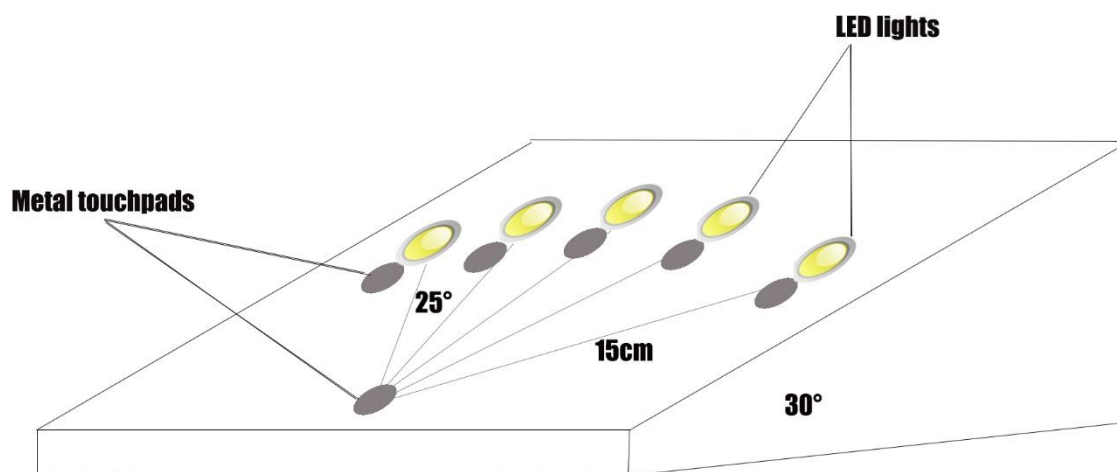
2012). However, to date and to the author's knowledge, the Emotional Stroop has not been administered to participants in a hangover investigation. This Emotional Stroop task (Mathew & MacLeod, 1985) was chosen as it investigates response times with both physical and social stress words included. The moral effects as highlighted by Verster et al. (2010) which are feelings of guilt and shame can be explored. In addition, the role of affect has been explored through subjective measures only, it is therefore of interest to carry out an investigation which will measure mood objectively (McKinney, 2005). This test was created using Superlab 50.0. Mathews and MacLeod's (1985) Emotional Stroop was adapted to be presented on a computer screen. The test consists of 12 physical threat words (e.g. disease, cancer, coffin), 12 social threat words (e.g. pathetic, foolish, inferior) and 24 non-threat words (e.g. playful, holiday, confident) as used by Beck, Laude and Bohnert (1974) and Hibbert (1984). Each block contains four threat words and four non-threat words and each stimuli is presented in 1 of 5 colours (red, blue, green, brown and purple) leading to 40 stimuli in each block. Participants were asked to ignore the words and respond appropriately to the font colour of the words only. Items remained on the screen until a response was made

2.3.8.1.9 5 Choice Serial Reaction Time Task (5CSRTT)

The 5CSRTT measures visuospatial attention, motor impulsivity, and response times (Robbins, 2002). It is most popularly known for its implementation in animal research but it has also been applied in human studies (Leonard, 1959). Hit rates and accuracy in this task are particularly sensitive to sleep disturbances in humans (Enkhuizen et al., 2013) and it was chosen to explore sleep discrepancies which may arise after a night's drinking.

Five LED lights are located on an arc shape within a wooden panel (see Figure 2.5). Directly below each light is a metal touch sensitive keypad. A 'home' keypad is located at the bottom centre of the display. It is 15 cms from each LED light and each light is at an angle of 25 degrees from the centre position. The lights and keypads are located on a black display tilted at an angle of 30 degrees. Using a metal pen attached to the board participants must touch the keypad matched to the light that is turned on before returning to the home keypad as quickly and accurately as possible (Figure 2.6).

Figure 2.6. Illustration of the five choice serial reaction time display board.



2.3.8.1.10 Cambridge Neuropsychological Test Automated Battery (CANTAB)

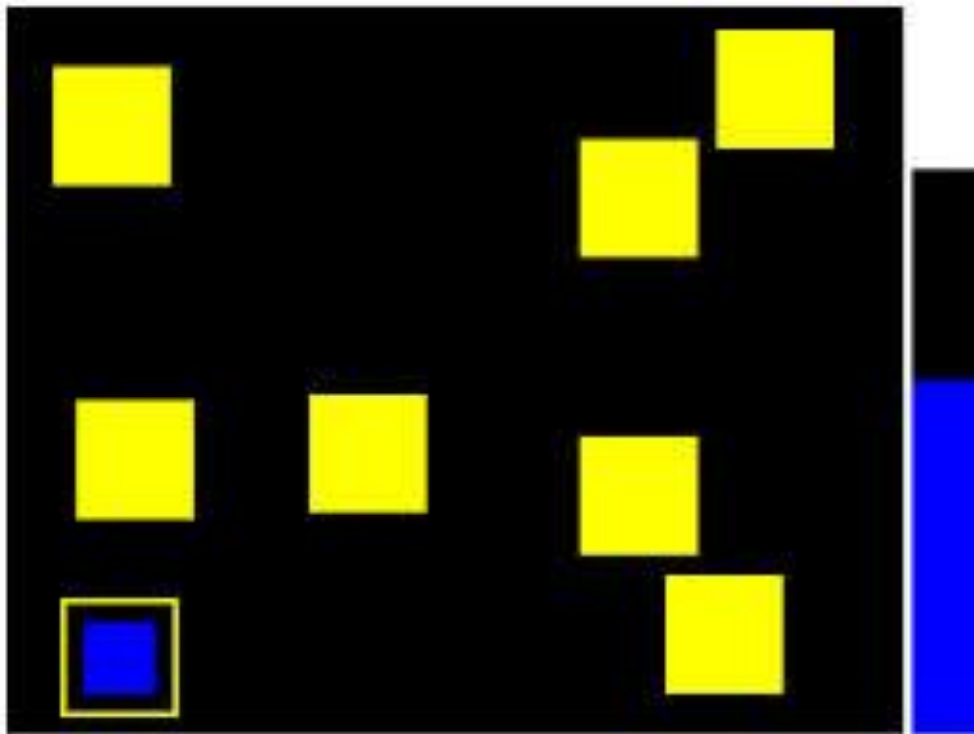
The CANTAB is comprised of a series of interrelated computerised tests used to assess the efficiency of memory, attention, information processing, visuospatial co-ordination, and executive function. The tests are administered using a touch sensitive screen, and a response key used for recording reaction times. The CANTAB is the most validated cognitive assessment

tool (Cambridge Cognition, 2018) and it has been used in this thesis to introduce a standard test battery for hangover research. Using a task battery such as the CANTAB provides a foundation from which future studies can be compared, not only in relation to hangover effects but comparisons can be made between alcohol hangovers and a variety of misused substances effects. Three tasks were used in this research, spatial working memory tasks, Intra-Extra Dimensional Set-shifting and Choice Reaction Time tasks.

2.3.8.1.11 The Spatial Working Memory Task (SWM) from the CANTAB suite:

The spatial working memory task measures the participant's ability to retain spatial information and to manipulate remembered items in working memory. It was chosen as it applies the measures of online processing, manipulation and storage which would help to build a more thorough understanding of a hangover's effects on working memory. The participant must touch the coloured squares in order to find a blue token.

Figure 2.7 Illustration of the final stage of the CANTAB's SWM

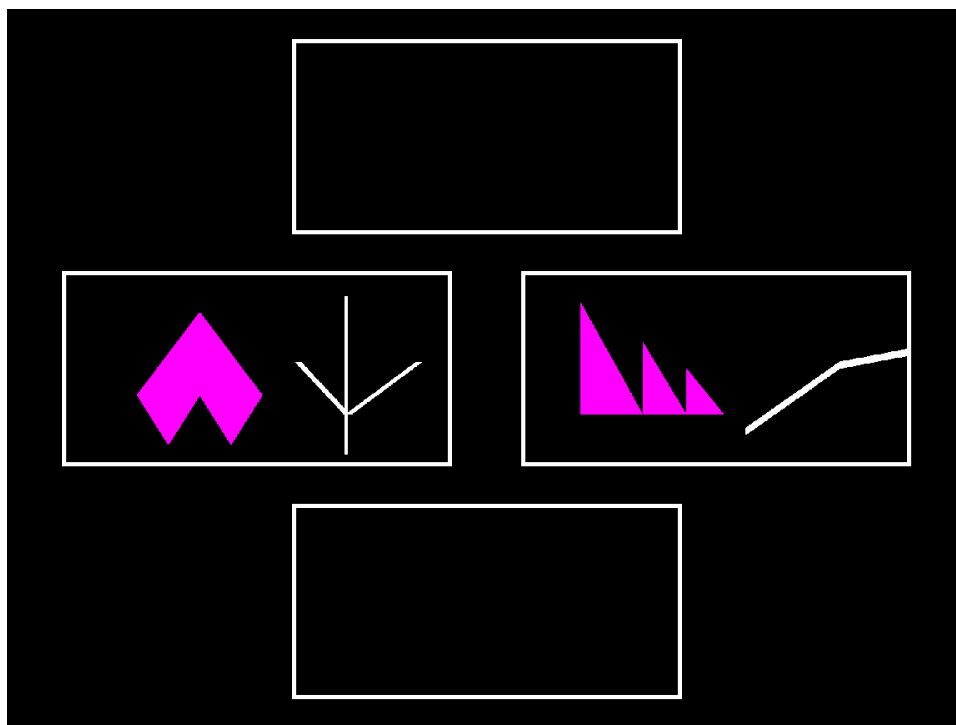


As demonstrated in Figure 2.7 a series of yellow boxes are presented on the screen and participants are required to tap on each yellow box to locate the blue token which is present in one of the on screen boxes (bottom left of Figure 2.7). Once a token is found it must be stored in the black column at the right of the screen. And once the column is filled with blue tokens a new block begins. The blue token only presents itself inside a particular box *once*. Touching a box in which a blue token has already been found is an error. Difficulty increases as the number of boxes increase from 3 – 8. In order to discourage the use of practice strategies the colour and position of the boxes change from trial to trial. Dependent measures include latency (mean, median, maximum and minimum), correct responses (total, percentage), commissions (button press too soon; total, percentage), and omissions (total, percentage).

2.3.8.1.12 Intra/Extra dimensional set shifting (CANTAB)

This test features visual discrimination and attentional set formation maintenance, shifting, and flexibility of attention. It also provides insight into rule acquisition and reversal. It is a computerised analogue of the Wisconsin Card Sorting test and involves categorisation of stimuli into sets (Cambridge Cognition, 2018). This task increases in difficulty as the test progresses.

Figure 2.8. Screenshot of Intra/extra dimensional set shifting task



Throughout, participants must select a pattern out of two possibilities and from this the computer gives feedback (*correct*, *wrong*). Pink colour-filled shapes and white lines are the synthetic dimensions used (see Figure 2.8). One correct and one incorrect stimulus are displayed at a time, initially two of only one dimension (pink shapes or white lines) corresponding to intra dimensional shifts in rules are presented. Then each of both dimensions

(pink shapes alongside white lines; Figure 2.8) corresponding to extra dimensional rules are presented. A rule must be learned to proceed to the next level. The rules are changed after six correct responses. There are eight blocks within this task and it takes approximately seven minutes to administer.

The blocks proceeded as follows:

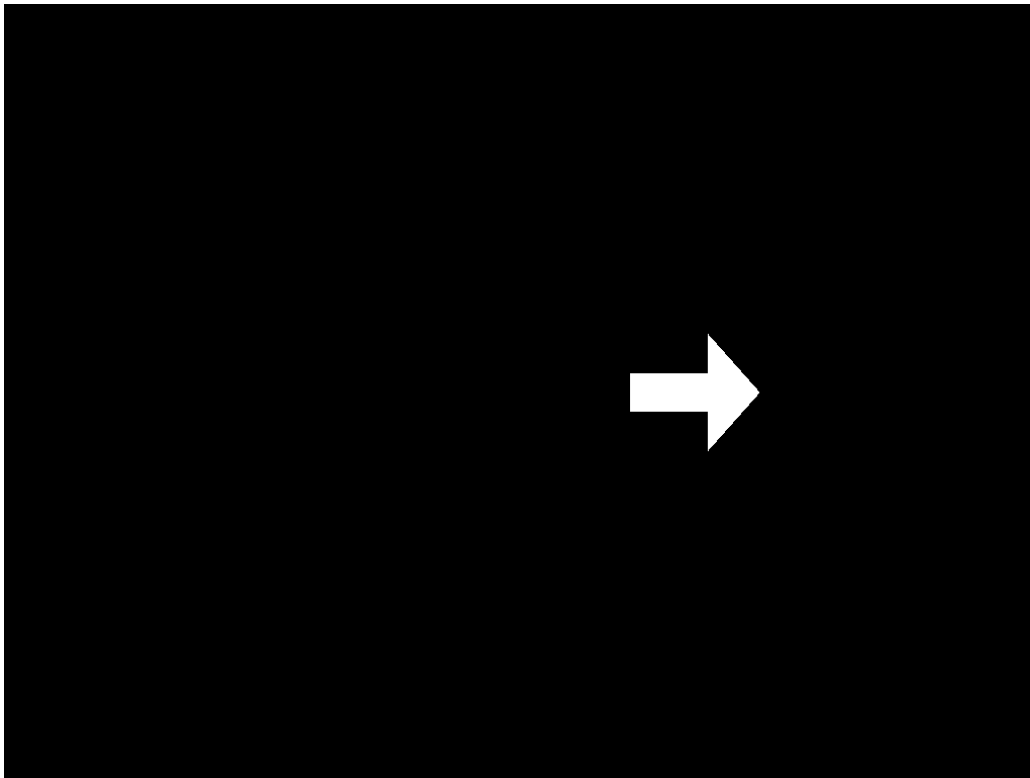
1. Pink shapes only
2. Pink shapes reversed. The correct stimulus becomes incorrect.
3. White lines are added but the correct dimensions from the previous block remain.
4. As in block two, the rules are then reversed.
5. New stimuli are presented however participants must continue to attend to pink shapes (intra-dimensional).
6. Rules are reversed again. The correct stimulus becomes incorrect (intra- dimensional).
7. New stimuli are presented and white lines becoming determinants of correct and incorrect responses (extra- dimensional).
8. Rule reversal.

It measures the participant's ability to attend to the specific features of compound stimuli and to shift attention when necessary. To date, rule learning has not been implemented in hangover research; however, a better understanding of the interaction of attention, rule learning, and hangover research will improve what we know of the attentional systems affected by an alcohol hangover.

2.3.8.1.13 Choice Reaction Time Task

The choice reaction time task measures alertness and psychomotor skills (Cambridge Cognition, 2016). Speed and accuracy on this task reflect the rates of information processing. This task was chosen because the mechanisms used to attend to stimuli in this task may also be comparable to those used when driving a car. This is important as driving a car is common activity that may be impaired after a night's drinking (Verster et al., 2014), moreover, this task has been shown to be more sensitive to the effects of ethanol than simple reaction time tasks (Barceloux & Palmer, 2012).

Figure 2.9 Right directed stimulus in choice reaction task from the CANTAB.



This CANTAB task requires participants to respond to two possible stimuli using a touchpad. The stimuli are an arrow facing right and an arrow facing left (Figure 2.8). Participants are asked to respond accordingly using the right and left buzzers. After a response,

participants were notified if their responses were correct/incorrect. The task takes approximately seven minutes to complete and outcome variables can be categorised in terms of latency (mean, median, maximum, minimum and standard deviation of), correct (total and percentage), incorrect (total and percentage), commissions (total and percentage), and omissions (button press too late; total and percentage).

2.3.8.1.14 DroidSurvey/iSurvey

Two platforms were used to collect data and determine eligibility. The first of these was Survey Planet is a free online survey that enables you to create surveys and administer them to participants through email link. As mentioned in section 2.3.2 above, survey planet was used to easily screen for probable alcohol use disorders. When the link to the questionnaire opened, the survey planet platform contained the SMAST questionnaire. An email address was also required in order to proceed to the start screen. Responses were checked daily and participants that completed the questionnaire were emailed with confirmation regarding the eligibility outcome.

The second platform was Harvest Your Data; this is a software package used to collect real time self-report information on alcohol consumption through the use of smartphone technologies. This is an application that runs in conjunction with both Android and Apple devices. A questionnaire was designed online, and a unique code was used to sync the questionnaire to the participant's phone through the DroidSurvey or iSurvey application. Participants were identified through coded usernames and responses were recorded and synced to the researcher's account online. When offline, the application stores data until the

device becomes online. The results can be exported in CSV. or SPSS format. The questionnaire required touch screen responses to four short questions pertaining to the number of drinks consumed, the type of drinks consumed, water consumption and the degree of intoxication experienced. This program was chosen as it offered offline data collection on both android and apple devices and implemented an easy to use interface that retained participant anonymity and allowed for single selection, multiple selection and scale responses.

3. The effects of expectancy on cognitive performance after a night's drinking

3.1 Introduction

Expectancy Theory was developed by Vroom (1964) while investigating motivation and decision making in a workplace environment. He described it as a “belief concerning the likelihood that a particular act will be followed by a particular outcome” (Vroom, 1964, p.17). This theory suggests that one’s perception of the relationship between effort and performance predicts their expectancies. Moreover, Vroom (1964) suggests that motivation is governed by choices made to maximise pleasure and minimise pain and are driven by valence (value) of the outcome and instrumentality (performance-reward relationship).

Expectancy theory can play a significant role in experimental research and has received considerable attention in placebo and nocebo experiments including those which explore the impact of expectancy on cognition (Barsky, Saintfort, Rogers, & Borus, 2002; Schwarz & Buchel, 2015). Expectancy effects have been found in cognitive experimental investigations (Oken, Flegal, Zajdel, Kishiyama, Hass & Peters, 2008). For example, in a study by Oken et al. (2008), 21 elderly participants (aged 65-85) were tested on three occasions and told that when they received a pill (placebo) before participation, cognitive performance would be enhanced although it was chemically inert, and another 19 elderly participants were not given a pill (nocebo). In addition, a placebo was administered following the final testing session so that everyone received a pill at some stage of the investigation. The researchers administered a series of cognitive tasks and found significantly better performance in participants who received the placebo pill on delayed and immediate Free Recall, Stroop, and choice reaction time tasks. This indicated that the anticipation of improved performance resulted in improved performance. The authors argued the results were not indicative of a speed accuracy trade off

as accuracy did not decrease with decreased reaction times. A regression analysis was carried out to identify predictors of the placebo (expectancy) effect using questionnaires pertaining to subjective measures such as task related motivation, stress, mood as well as heart rate, EEG and salivatory cortisol. The analysis revealed those with high levels of perceived stress benefited more from the placebo pill than those with low levels of perceived stress. This suggests stress impacts expectancy, but there was no effect of expectancy on placebo pill taking or self-efficacy. Of note, Vroom's theory of expectancy does not consider one's emotional state or past experiences which can be seen as a limitation since past experiences and mood were later shown to impact on expectancy effects of alcohol consumption and expectancies in both adult and adolescent participants (Goldman, Brown & Christiansen, 1987).

Regarding alcohol consumption, expectancies such as increased sociability as a function of alcohol use are formed in long term memory through direct or indirect past experiences. As a result, they govern future alcohol consumption (Jones, Corbin & Fromm, 2001; Montes et al., 2017). There are two models surrounding alcohol expectancies and cognitive performance that will be discussed in this Chapter, the Compensatory Model and the Motivational Model. The Compensation Model proposes that expecting to consume alcohol gives one the time to psychologically prepare for impairment so that performance deficits are avoided (Newlin, 1986; Shapiro & Nathan, 1986). In contrast, the Motivation Model proposes responses to expectancies are governed by motivation (Hockey, 2014).

The compensatory theory is associated with tolerance acquisition through classical Conditioning (Shapiro & Nathan, 1986). Here, if one is repeatedly administered alcohol in a particular environment then classical Condition occurs and the environment becomes paired

with alcohol. In a study by Shapiro and Nathan (1986), participants in Group 1 were administered alcohol in a 'distinct' environment and tonic water in a 'home' environment. Participants in Group 2 were administered alcohol in a 'home' environment and tonic in a 'distinct' environment. In the final testing session, all participants were administered tonic water in the 'distinct' environment. Participants that had never received tonic in the 'distinct' environment expected to receive alcohol and as a result showed a compensatory response in which performance as measured by a choice vigilance task was significantly increased relative to those who had received tonic in the 'distinct' environment (Group 2).

In a study by Peterson et al., (1990) 100mg/100ml of alcohol (high dose, .10% Blood Alcohol Concentration), 66mg/100ml (medium dose) or 13mg/100ml (low dose) of alcohol was administered to 72 participants. There were six groups of participants, which included those that were told they would receive high dose, received high dose; told high dose, received low dose; told low dose received low dose; told low dose, received high dose; told low dose, received moderate dose; told high dose, received moderate dose. A series of 20 cognitive tests were administered to all participants. Out of the 20 tasks only 2 showed expectancy effects. Those that were told that they were receiving high doses of alcohol performed significantly better in a digit symbol substitution task and a Free Recall task irrespective of the dose received. Neither of these tasks were affected by the actual alcohol dose received. The results suggest that expectancies effects may not be as prominent as suggested by Shapiro and Nathan (1986). A symposium paper by Testa, Fillmore, Norris et al., (2006) highlighted the role of the placebo on alcohol research and suggested that the effects of expectancies are often weak. However, when expectancies do occur, they often do so in a compensatory manner and these

responses are subject to variability as expectancies will have been learned through previous experiences. In summary, the role of compensatory expectancy effects of alcohol consumption are not well understood which may be a result of individual differences as a result of varying alcohol experiences.

The results from Shapiro and Nathan (1986) and Peterson et al., (1990) support Hockey's (2014) motivational control theory which argues that when performance is threatened (e.g. increased strain, fatigue), there is a trade-off whereby one can decide to exert more effort in order to protect performance or exert the same effort or less and accept lower performance. The results on the digit span and memory tasks from Peterson et al.'s (1990) study appears to demonstrate a situation where performance is (falsely) perceived as threatened (high dose intoxication) and as a result, participants opt to increase effort in order to protect performance.

As described in Chapters 1 and 2, expectancy in hangover research refers to a participant's knowledge that the purpose of an experiment is to investigate a hangover and the subsequent effects on task performance. Much of the work to date has been conducted in controlled experimental Conditions. As literature reviews have highlighted, there are concerns that those studies conducted outside controlled experimental Conditions i.e. naturalistic studies are particularly likely to be influenced by expectancy effects as a placebo group is not possible (Stephens, Ling, Heathers, Heffernan and Jones, 2008; Ling, Stephens and Heffernan, 2010). To date, investigations of expectancy have not been carried out on participants who are experiencing a hangover in the naturalistic setting and it is therefore unknown whether

expectancy plays a role in cognitive impairment, and if so which aspects of cognitive impairment after a night's drinking.

No model or theory of how expectancy might affect the hangover has been proposed (Stephen's et al., 2008; Rohesnow et al., 2010). Concerns regarding expectancy have developed from inconsistency of results found in laboratory and naturalistic studies (Scholey et al., 2012; Verster et al., 2010). For example, a laboratory study has failed to find hangover effects on Selective Attention (Lemon et al. 1993). However, Selective Attention has been shown to be impaired in naturalistic designed studies (McKinney & Coyle, 2004). In a laboratory, Chait and Perry (1994) found no changes in a dual performance task during a hangover, in contrast Roehrs and Roth (2001) using a similar dual task, found significant impairment on dual performance in a naturalistic environment. In order to account for these inconsistencies, investigators have considered the limitations of laboratory and naturalistic approaches (Stephens et al., 2008; Ling et al., 2010). In naturalistic studies, as the behaviour is controlled by the participant, it is difficult to blind participants to a hangover Condition and as such expectancy effects may occur. Thus, it has been proposed expectancy causes differences in results between the approaches but no explanations have been offered.

The role of expectancy in studies relating to hangover and performance may be overestimated. If one considers the contrasting levels of alcohol consumed in a laboratory versus naturalistic environment, it is plausible that the volume of alcohol consumed in a naturalistic environment may contribute to the significant levels of impairment found in the naturalistic environment. For example, in McKinney, Coyle and Verster's (2012) study, participants reported consuming 11.84 units the night before testing, whereas in Stephens,

Grange, Jones and Owen' (2012) critical review of hangover research, the authors note that a typical laboratory dose of alcohol is the equivalent of five 350ml bottle of 5% alcohol by volume of beer, this equates to around 8-9 units of alcohol (DrinkAware, 2017). The amount of alcohol in the experimental setting is limited by what is ethically appropriate to give to a participant given the knowledge that alcohol can cause a range of harms. In recent years, some researchers have moved away from a unitary amount of alcohol and adopted an approach that involves dosing participants to reach a particular level of intoxication (Gunn et al., 2018). For example, Rohsenow et al. (2013) administered beer to attain a BrAC of .12g%. This approach diminishes the differences in intoxication between participants of varying weight and gender. However, the amount of alcohol administered remains less than that consumed in a naturalistic environment, and it varies as a function of the time between drinking and measurement using a breathalyser (Finnegan et al., 1998; Rohsenow et al., 2007; Verster et al., 2010).

In summary, it is important to investigate expectancy in hangover research for several reasons. Firstly, if expectancy plays a significant role in cognitive performance tasks in participants experiencing a hangover, then naturalistic methodologies may need to be adapted in order to reduce the effects of expectancy on the outcomes of interest. For example, the purpose of the study may need to be withheld from participants in future studies, and particularly since expectancy effects may improve and reduce performance depending on the person's expectation and effort on the task. Secondly, if expectancy does not play a role in performance after a night's drinking then previous research may need to be re-examined with a different view of the naturalistic approach. Thus, it is possible that the discrepancies between

results in the naturalistic and laboratory settings may be more likely to be attributable to the differences in the amount of alcohol consumed than expectancy.

Considering the possible role of expectancy in a naturalistic setting, this Chapter aims to investigate the role of expectancy on cognitive performance in drinkers who are experiencing a hangover. In order to investigate if expectancy effects were present, four groups of participants involving two Conditions (expectancy, no expectancy) and two States (hangover, no hangover) were administered a series of cognitive tasks and questionnaires. As recommended by Verster et al., (2010) advantage was taken of the predictability of student drinking and in addition to this, task related motivation was measured before and after each task in order to gain insight into subjective expectancies and changes in reported effort.

3.2 Method

3.2.1 Participants

As discussed in the methodology Chapter, seventy-four volunteers participated in the present study. This included 39 male and 35 female participants. The mean age of participants was 24.49 (SD=70.07) and the mean age of first drink was 15.68 years (SD=4.42).

3.2.2 Design

This study followed a between participants design. The independent variables were expectancy/no expectancy and hangover/no hangover and the dependent variables were the cognitive tasks and the mood and hangover severity questionnaires. In order to allocate

participants to hangover and no hangover States, advantage was taken of the predictability of student drinking. For example, Tuesdays and Thursdays were popular student nights at the time of recruitment, therefore, Wednesday and Friday mornings were used to collect data for hangover Conditions. Participants were recruited for no hangover testing days on all other mornings. Recruitment took place on the morning of testing in the Halls of Residence at Ulster University. In this way, participants were not required to travel for testing and the true purpose of the study was withheld for a short amount (duration of testing) of time only. Participants were assigned to Expectancy/No Expectancy Conditions using a pre-calculated randomisation formula on Microsoft Excel (RANDBETWEEN) and this was based on the participant number assigned at recruitment.

3.2.3 Procedure And Stimuli

After participants confirmed compliance with pre-test requirements and read and signed the consent form (see Chapter 2 and appendices), the purpose of the study was disclosed in the following ways:

1. **Expectancy Condition**

Participants were informed that the study aimed to investigate the effects of a night's drinking on cognitive performance.

2. **No expectancy Condition**

Those in the no expectancy Condition were informed that the purpose of the study was to investigate the effects of time of day on cognitive performance.

Participants then completed a series of questionnaires on hangover severity (hungover participants only), demographic information, sleep, usual alcohol consumption, previous night's alcohol consumption and mood. Details about the questionnaires are found in Chapter 2 of this thesis and a copy of the questionnaire can be found in Appendix 1. Eriksen's Flanker Task, Divided Attention, Stroop, Intra-Extra Dimensional Set Shifting, Spatial Working Memory and Free Recall tasks were administered in a randomised order. The tasks are described in detail in Chapter 2 and a brief description of the tasks are presented below:

3.2.3.1 Eriksen's Flanker Task

In this Selective Attention task, the targets and distracters consist of the letters A and B (Eriksen & Eriksen, 1974). Distracters are presented at either side of the target and appear either near (1cm) or far (3.4cm) from the target. Distracters were either compatible (AAA) or incompatible with the target (BAB). Participants were required to respond to the target letter by pressing an appropriate key as quickly and accurately as possible. Dependent variables included 'total errors', 'distance' and 'compatibility' response times. DistanceDif was calculated by subtracting response times (RTs) to far items from near items, and CompatibilityDif was computed by subtracting compatible items from incompatible items.

3.2.3.2 Stroop

In this task, words were presented on the screen one at a time in Blue, Green, Red, Purple and Brown as used in the original task (Chajut, Schupak & Algom, 2009; Stroop, 1935). Ignoring the text-meaning of the words, participants were required to respond to the font colour only by using the corresponding buttons on the keyboard provided. Dependent variables

included the number of Errors and Stroop Interference. Stroop Interference represented the difference between RTs for Congruent (e.g. red presented in red font) and Incongruent items (e.g. red presented in green font).

3.2.3.3 Divided Attention Test

In this test (Tedstone & Coyle, 2004; McKinney, Coyle & Verster, 2012), a series of single digits appeared in the centre of a computer screen at a rate of one per second. When three consecutive odd numbers appeared in the centre of the screen participants were required to respond appropriately using the keyboard in front of them (central, 'Z'). Simultaneously, a blue box appeared left, right, below or above the centre of the screen (peripheral). Participants were required to respond when a blue box appeared on the screen as quickly and accurately as possible by pressing 'M' on the keyboard. Dependent measures included Total Errors, Central RTs and Peripheral RTs.

3.2.3.4 Free Recall

The Free Recall task consisted of twenty words that were presented on the computer screen one at a time (1/2000ms rate). In the minute directly following presentation participants were required to write down as many words as they can remember. The dependent measure was the number of correctly recalled words in this task.

3.2.3.5 Spatial Working Memory

The CANTAB spatial working memory task required retention and manipulation of visuospatial information (Cambridge cognition, 2018). The participants needed to touch the coloured squares (screen) in order to find a blue token. A number of coloured boxes were

shown on the screen, and the participants were required to find one ‘token’ (smaller box) in each of a number of boxes and use them to fill up an empty column on the right-hand side of the screen (Cambridge Cognition, 2018). Task difficulty varied as the number of boxes was gradually increased. Colour and position of the boxes changed from trial to trial to prevent predictability. The most efficient strategy was to choose an order to press the boxes and start over in the same order each time a token was found. Dependent measures included number of Errors for 4, 6 and 8 boxes (selecting boxes that have already been visited), Total Errors and Strategy. Of note, higher strategy scores indicated poorer use of the best strategy.

3.2.3.6 Intra-Extra Dimensional Set Shifting

This test was a computerized analogue of the Wisconsin card sorting task which featured visual discrimination and attentional set formation maintenance, shifting and flexibility of attention (Cambridge Cognition, 2018). In this task, participants were required to use feedback to work out the rule that determined which stimulus was correct. After six correct responses, the stimuli and/or rule changed. Starting with simple stimuli (individually shown white lines/ pink shapes) corresponding to intra-dimensional shifts in rules. Gradually, the task became more complex (e.g., white lines overlaid on the pink shapes) also requiring extra-dimensional rule shifting. Dependent variables included Stages Complete, Total Errors, Total Errors Adjusted, Completed Stage Errors, Total Trials, Total Trial Adjusted, Extradimensional Errors and Intradimensional Errors

3.2.4 Statistical Analysis

Unless otherwise Stated cognitive tests were analysed in a two-way Analysis of Variance (State x Condition). The between factor of State refers to the hangover and no hangover States and the between factor of Condition refers to the expectancy and no expectancy Conditions. A Pearson's product-moment correlation coefficient analysis was carried out to investigate the relationship between variables. In all instances Alpha was set at 0.05.

3.3 Results

3.3.1 Descriptive Statistics

A summary of the descriptive statistics from Study 1 is found in Table 3.1. As can be seen from the table Age and Age of First Drink are well matched across groups. Analysis of group differences are discussed in the subsequent sections.

Table 3.1. Background characteristics of participants split by Condition (n=74) Age and Age of first drink in sample of

	Hangover		No Hangover	
	Expectancy	No expectancy	Expectancy	No Expectancy
N	20	20	20	14
Gender (male/female)	8/12	13/7	10/10	8/6
Age	23.70 (7.91)	24.20 (70.08)	24.30 (6.54)	26.29 (6.999)
Units consumed	150.08 (110.04)	10.62 (8.56)	---	---
AHS total	14.55 (12.71)	10.35 (10.57)	---	---
Sleep (mins)	358.75 (129.67)	381.42 (10.93)	444.74 (124.20)	425.62 (129.53)
Age of First Drink M(SD)	16.55 (70.06)	15.40 (1.54)	15.83 (2.16)	14.64 (4.92)
Alertness	39.50 (110.00)	46.90 (12.63)	49.35 (15.77)	50.86 (10.54)
Tranquillity	33.30 (6.31)	34.40 (7.92)	34.35 (11.73)	35.14 (8.30)

3.3.1.1 Alcohol Consumption

The majority of participants (52%) reported consuming alcohol at a frequency of ‘once or twice a week’. Twenty-nine percent of participants reported consuming alcohol ‘less than once a week’, 16% reported consuming alcohol ‘3 to 5 times a week’ and 3% drank ‘6 times per week to every day.’ Most participants reported consuming a typical quantity of 3 to 5 drinks (39%) or 6 to 7 drinks (32%) in one sitting. Only one participant reported drinking less than 3

drinks in the average sitting. Thirty one percent of participants reported having drank a maximum of 11 to 13 drinks in one sitting, 26% of participants report consuming a maximum of 8 to 10 drinks and 24% have consumed 13 or more drinks in one sitting.

Thirty two percent of participants reported having consumed this volume (largest amount in one sitting) once or twice a year and 28% of volunteers reported drinking this volume less than once a year. Nineteen percent of participants consume this amount 3 to 6 times a year, 14% drink in this way once or twice a month and 4% more than once a month. Twenty nine percent of participants report drinking to reach a State of intoxication once or twice a month, 22% do so 3 to 6 times a year and 21% drink to reach intoxication every time they drink. Forty three percent of participants report usually consuming alcohol in a pub or bar, while 42% of participants drink at home or at the homes of their friends. Finally, 15% of participants report usually drinking alcohol in a nightclub.

3.3.1.2 Previous Night's Drinking

A mean number of 12.85 units (SD=10.01) were consumed by participants in the hangover Condition. A mean of 1.79 units (SD=3.37) of wine was consumed, 5.87 units (SD=7.29) of cider or beer, 1.32 (SD= 2.94) of alcopops and 3.88 units (SD=5.64) of spirits. Participants in the expectancy Condition drank a mean of 150.08 units (SD=110.04) and in the no Expectancy Condition a mean of 10.62 units (SD=110.04) were consumed. A t-test revealed that units consumed by expectancy and no expectancy Conditions did not differ significantly ($t(72)=-.57, p=.57$).

3.3.1.3 *Sleep*

Participants reported a mean of 6.66 hours (SD= 20.06) of sleep the night before testing. Participants in the hangover State reported getting 6.16 hours of sleep (SD=1.93) whereas those in the no hangover State reported a mean of 7.28 hours of sleep (SD=20.08). A one way analysis of variance revealed that participants in the hangover State slept significantly less than those in the no hangover State ($F(1,69) = 5.46, p=0.02$). In the hangover State, just 15% of participants were in bed before midnight. In contrast, 45% of participants in the no hangover State reported going to bed at or before 12am.

3.3.1.4 *Mood*

An Analysis of Variance (State x Condition) was run to assess the impact of Hangover State and Expectancy Condition on Alertness. The main effect of State was significant $F(1,70)=5.36, p=0.02$, such that alertness was lower in the hangover State ($M= 43.13$; $SD=12.30$) compared to the no Hangover State ($M= 49.97$; $SD=13.69$). There was no significant main effect of Alertness on Expectancy ($F(1,70)=2.26, p=0.14$), nor any significant interaction effect between State and Condition on Alertness ($F(1,70)=10.00, p=0.32$). Tranquillity did not differ significantly across States ($F(1, 70)=0.19, p=.67$) or Condition ($F(1, 70)=.21, p=.65$).

3.3.1.5 *Acute Hangover Scale*

The nine items in the Acute Hangover Scale were collapsed into one variable. The mean total hangover score was 12.45 (SD=11.73). The highest rated hangover symptom was tiredness (Mean=3.35, SD=2.42) and the lowest rated hangover symptom was a racing heart

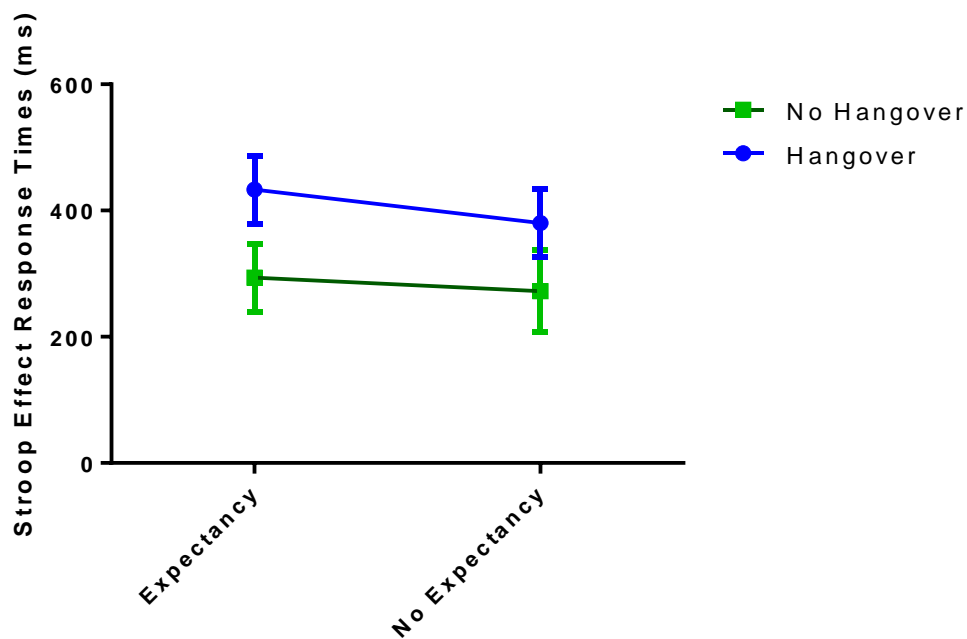
(Mean=.5750, SD=1.38). A t-test revealed no significant difference between expectancy and no expectancy Conditions ($t(72)=-.84$, $p=.41$).

3.3.2 Cognitive Performance

3.3.2.1 Stroop Performance

Stroop Interference represented the difference between RTs for congruent and incongruent items. Results from the Stroop task were submitted to a (2x2) ANOVA comprised of the between factors of State and Condition. As can be seen in Figure 5.1., Stroop Interference was larger in both Expectancy and No Expectancy Conditions for participants in the hangover State than in the no hangover State.

Figure 5.1 Stroop interference: the difference between incompatible and compatible items across State and Condition.



A significant main effect of State was found ($F(1,70)=4.79$, $P=0.03$). The hangover State's interference was significantly greater ($M=406.7$, $SD=242.96$) in the hangover State than those in the no hangover State ($M=284.82$, $SD=231.76$). However, there was no main effect of Condition ($F(1, 70)=.43$, $p=.51$) and no interaction of State by Condition ($F(1,70)=0.08$, $P=.78$).

Participants in the hangover State made more errors (Mean 5.5, $SD=1.91$) than the no hangover State (Mean 6.32, $SD=4.56$), however this result did not reach significance ($F(1, 70)=0.04$, $p=.84$).

Furthermore, subsequent analysis using congruent and incongruent dependent variables showed that participants in the hangover State took significantly longer to respond to incongruent items than those in the no hangover State ($F(1,70)=5.5$, $p<0.05$). The mean response time for incongruent items was 1648.94 ($SD=330.84$) in the hangover State and $M=1201.17$ ($SD=408.98$) in the no hangover State. However, differences in response times for congruent items did not reach significance ($F(1, 70)=1.7$, $p=.25$). There was no main effect of Condition (Expectancy/No Expectancy) for Stroop Errors, or congruent or incongruent response times ($F=.166$; $F=1.34$; $F=0.42$). Moreover, a first order interaction of State by Condition did not reach significance for task errors ($F(1, 70)=0.04$, $p=.84$), congruent ($F(1, 70)=.48$, $p=.49$) or incongruent items ($F(1, 70)=0.099$, $p=.75$). These results indicate that expectancy does not affect performance on the Stroop task.

3.3.2.2 Eriksen's Flanker Task

For this task, the response time data were submitted to a mixed measures Anova (2x2x2x2) in which the within factors of Distance (near and far) and Compatibility (compatible and incompatible) were combined with the between factors of State and Condition. Table 3.2 displays the means and standard deviations of response times across States and Conditions.

Table. 3.2 Response times (ms) for compatible near, compatible far, incompatible near and incompatible far items across groups and Conditions

		Hangover		No Hangover	
		Expectancy	No Expectancy	Expectancy	No Expectancy
<i>Compatible</i>	Near	565.70 (127.26)	527.92 (74.94)	494.90 (54.95)	498.86 (46.75)
	Far	582.99 (139.67)	553.50 (133.14)	492.27 (69.44)	483.87 (56.73)
<i>Incompatible</i>	Near	621.31 (164.79)	584.81 (90.78)	550.85 (71.67)	537.79 (53.34)
	Far	560.18 (133.34)	520.30 (94.85)	491.58 (57.37)	489.36 (36.65)

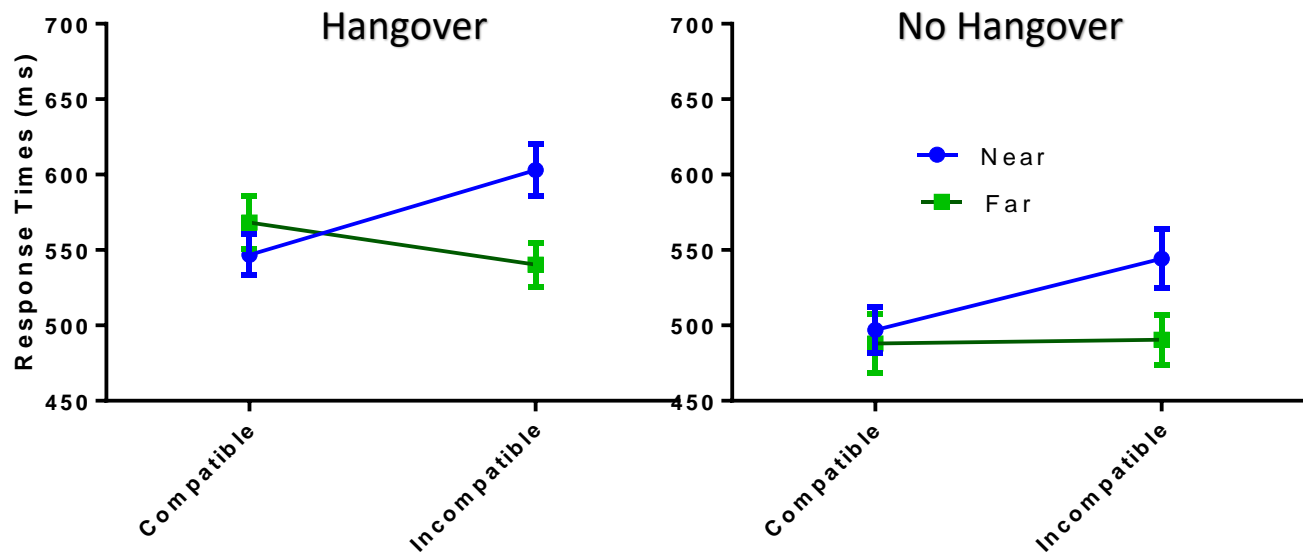
Note: Standard deviations are in parentheses

As expected, there was an overall main effect of compatibility ($F(1,69)=35.26, p<0.0001$) whereby compatible items were responded to faster than incompatible items; and a main effect of distance ($F(1,69)=16.92, p<0.0001$) whereby items that were placed far from the target were responded to faster than those placed near to the target. There was a main effect of State ($F(1,69)=7.22, p=0.01$) showing that overall slowed responses occurred during the hangover. However, there was no main effect of Condition ($F(1, 69)=.85, p=.36$).

The analyses revealed a first order interaction of distance with compatibility ($F(1, 69)=39.89, p<0.0001$) which supports previous studies using this task (Eriksen, 1995). This suggests that when items are incompatible with distractors and those distractors are within 1 degree from the target, the response time is slower than when distractors are either compatible with the target or far from the target. A second order interaction of compatibility, distance and State did not reach significance ($F(1, 69)=3.67, p=0.06$). This shows that the way in which compatibility and distance does not interact differently across States.

Further analysis where the output was split between groups revealed no main effect of compatibility in the hangover State ($F(1, 69)=3.35, p=0.08$), however, a main effect of compatibility was evident in the no hangover State ($F(1,69)=40.26, p<0.0001$) where compatible items were responded to faster than incompatible items. There was also a main effect of distance in both hangover ($F(1, 38)=9.43, p=0.004$) and no hangover ($F(1, 31)=39.42, p<0.0001$) States. Moreover, compatibility and distance interacted in both hangover ($F(1, 31)= 280.04, p<0.0001$) and no hangover ($F(1, 31)=15.87, p<0.0001$) States. The results of the split file analysis are demonstrated in Figure 3.2 showing a similar pattern of responses across States but with longer response times in the hangover State.

Figure 3.2. The interaction between Compatibility, Distance and State on Eriksen's Flanker task



Of note, there were no significant differences in errors made between States ($F(1, 69)=.87, p=.35$) or Conditions ($F(1, 69)=3.52, p=0.07$). In addition, State and Condition did not interact ($F(1, 69)=.97, p=.33$).

3.3.2.3 Divided Attention

A three factor ANOVA comprised of the combination of between factors of State and Condition, and a within factor of target location (central, peripheral) was used to investigate Divided Attention. Overall, it took participants significantly longer to respond to peripheral items ($M=7590.05, SD=1460.00$) than to central items ($M=669.26, SD=169.96$; $F(1,71)=21.43, p<0.001$). There were no main effects of State or Condition and no second or third order interactions from the analysis. Further analysis on task errors showed no significant differences across States and Conditions.

3.3.2.4 Free Recall

The mean score on the Free Recall task refers to the mean number of words recalled correctly by the participant.

Table 3.3. Mean number of words recalled during Free Recall task

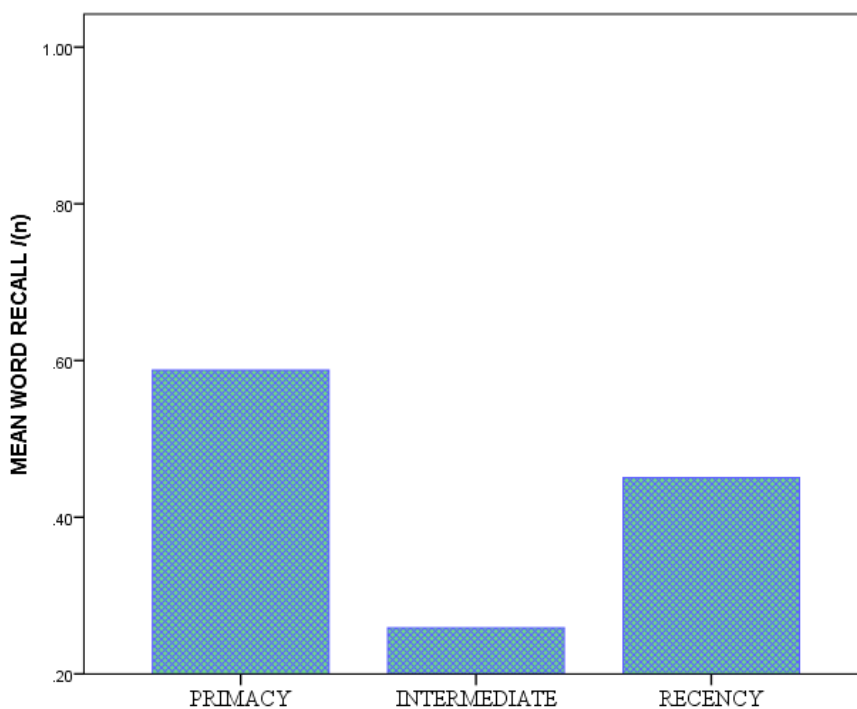
	Hangover			No Hangover		
	Mean	SD	<i>N</i>	Mean	SD	<i>N</i>
Expectancy	8.15	2.87	20	8.25	2.29	20
No Expectancy	6.90	2.49	20	9.29	2.79	14
Total	7.53	2.73	40	8.68	2.52	34

The results from a two factor ANOVA (State(2) x Condition(2)) showed a main effect of State ($F(1, 70) = 4.11$ $p = 0.046$) with more words recalled by participants that were not hungover ($M = 8.68$, $SD = 2.52$) than those that were hungover ($M = 7.53$, $SD = 2.73$) but no main effect of Condition ($F(1, 70) = 0.03$, $p = .86$) and no interaction between State and Condition ($F(1, 70) = 3.48$, $p = 0.07$). This shows that expectancy does not appear to affect overall word recall in a Free Recall task.

Further analyses were carried out on the serial positioning of words recalled. The mean scores on the first 6 items on the word list were collapsed into a Primacy variable and the mean scores on the last 6 words on the list were collapsed into a recency variable. The middle words were collapsed into an intermediate variable. It was not possible to divide the list into three

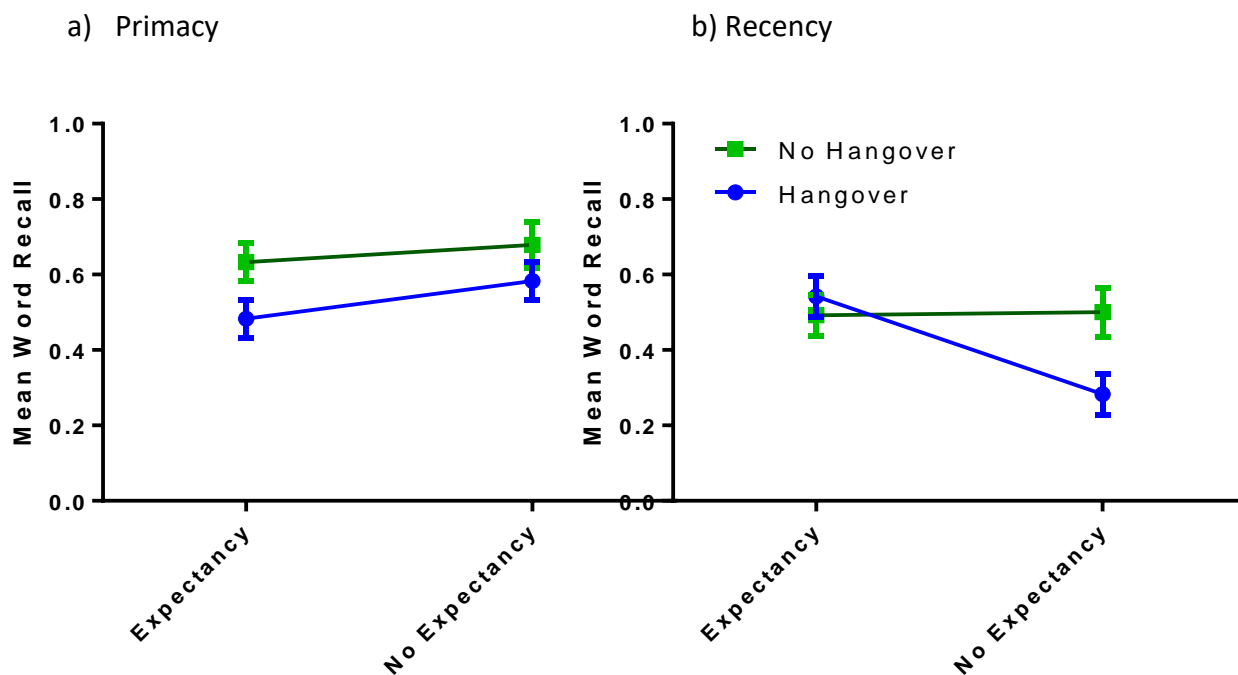
equal serial position variables so in order to create variables that were directly comparable, the mean score for each of the variables was then divided by the number of items within the variable. As can be seen from figure 3., more words were recalled from the beginning (M=58.78%, SD=22.95%) and end (M=450.05%, SD=25.99%) of the word list than words from the middle (M=25.87%, SD=19.88%) of the list as expected. Paired Samples t-tests revealed that significantly more words were recalled from the beginning of the list than the middle ($t(73)=10.12$, $p<0.0001$) and moreover, significantly more words were recalled at the end of the list than the middle ($t(73)=5.23$, $p<0.0001$). Also, significantly more words were recalled at the beginning of the list than at the end ($t(73)=3.62$, $p=0.001$).

Figure 3.3 Overall serial position of word recall demonstrating primacy and recency effects



A 3 factor ANOVA was carried out to measure State (2) x Condition (2) x Serial Position (3). The analyses reveal a main effect of serial position $F(2, 69)=51.80$, $p<0.0001$ and a main effect of State $F(1, 70)=60.01$, $p=0.02$. Condition did not interact with serial position $F(2, 69)=0.05$, $p=.83$. Moreover, State and Condition interacted $F(1, 70)=40.079$, $p=0.047$. Subsidiary analyses were performed separately on primacy and recency data.

Figure 3. 4. Results of analyses of State and Condition for words at the start of the word list (primacy) and at the end of the word list (recency)



There was a main effect of State for items at the beginning of the list $F(1, 70)=5.48$, $p=0.02$ with less words recalled in the hangover State ($M=.53$, $SD=.23$) than in the no hangover State ($M=.65$, $SD=.22$). However, Condition did not reach significance ($F(1, 70)=1.92$, $p=.17$) and there was no first order interaction of State and Condition ($F(1, 70)=.27$, $p=.60$) which shows that expectancy does not affect primacy words differently across States. For words at the end

of the list there was a main effect of Condition ($F(1, 70)=4.78, p=0.03$) and a first order interaction of Condition and State was revealed ($F(1, 70)=5.44, p=0.02$). Indeed, significantly more words were recalled in the expectancy Condition than in the no expectancy Condition of hangover participants ($F(1, 38)=11.71, p<0.0001$). Condition did not influence recency word recall of non hangover participants ($F(1, 32)= 0.009, p=.92$). Condition only affects word recall in hangover participants for items at the end of the word list.

3.3.2.5 *Intra Extra Dimensional Set Shifting (IED)*

Table 3.4. Shows the means and standard deviations for the output variables of a self-paced IED task. A two factor ANOVA revealed no main effect of State or Condition for any of the variables and furthermore, no first or second order interactions were observed. The results are demonstrated in Table 3.5.

Table 3.4. Results of State and Conditon analysis on IED task output variables

	IED Variable	N	F	p-value
Condition	Stages complete	72	1.442	.234
	Total errors	72	.638	.427
	Total errors adjusted	72	1.353	.249
	Completed stage errors	72	.427	.516
	Total trials	72	.277	.600
	Total trials Adjusted	72	1.251	.267
	Extradimentional errors	72	30.097	0.083
	Intradimentional errors	72	0.049	.826
State	Stages complete	72	.357	.552
	Total errors	72	.529	.469
	Total errors adjusted	72	.675	.414
	Completed stage errors	72	.674	.414
	Total trials	72	.435	.512
	Total trials adjusted	72	.291	.591
	Extradimentional errors	72	1.269	.264
	Intradimentional errors	72	3.512	0.065
Condition x State	Stages complete	72	0.081	.777
	Total errors	72	.672	.415
	Total errors adjusted	72	0.080	.778
	Completed stage errors	72	0.014	.906
	Total trials	72	.731	.396
	Total trials adjusted	72	.543	.464
	Extradimentional errors	72	.543	.464
	Intradimentional errors	72	.146	.704

Of note, total errors adjusted= 25 errors added to total errors to account for stages not completed, total trials adjusted= 50 trials added for stages not complete.

Table. 3.5. Means and Standard Deviations of output variables for State and Condition on Intra-Extra dimensional Set shifting Task

Intra-Extra Dimensional Set Shifting Task (CANTAB)	Hangover M (SD)			No Hangover M (SD)		
	Expectancy N=20	No Expectancy N=20	Total N=40	Expectancy N=19	No Expectancy N=13	Total N=32
IED Stages Complete	8.30 (.98)	8.50 (.89)	8.40 (.93)	8.37 (.96)	8.69 (.75)	8.50 (.88)
IED Total Errors	20.25 (90.05)	20.30 (11.70)	20.28 (10.33)	20.47 (10.57)	16.54 (8.32)	18.88 (9.78)
Total Errors Adjusted	310.00 (21.20)	26.70 (20.84)	28.85 (20.87)	28.37 (21.26)	21.31 (16.63)	25.5 (19.54)
Completed Stage Errors	13.6 (11.63)	15.30 (9.43)	14.45 (10.48)	120.05 (7.47)	13.23 (6.37)	12.53 (6.96)
Total Trials	85.95 (14.85)	87.45 (26.97)	86.70 (21.51)	86.84 (16.33)	80.54 (12.41)	84.28 (14.98)
Total Trials adjusted	103.45 (37.35)	99.95 (44.77)	101.70 (40.73)	105.26 (380.05)	88.23 (27.65)	98.34 (34.77)
Extra-dimensional Errors	13.90 (10.32)	11.40 (9.60)	12.65 (9.92)	12.95 (11.37)	6.85 (90.04)	10.47 (10.76)
Intra-dimensional Errors	6.60 (2.54)	5.95 (4.29)	6.27 (3.49)	8.21 (6.53)	8.38 (3.43)	8.28 (5.41)

3.3.2.6 *Spatial Working Memory (SWM)*

Table 3.6. shows the mean number of errors made at four boxes, six boxes and eight boxes. In addition to between factor variables State and Condition, a within factor variable Difficulty (6 box and 8 box errors) was added. Four box error scores were not included in this as this task block resulted in a floor effect of 0-1 errors (see Table 3.6.) which may contaminate the results (Wang, Zhang, McArdle & Salthouse, 2009). The results revealed a main effect of difficulty ($F(1, 65)=63.55, p<0.0001$) but no effect of State ($F(1, 65)=.27, p=.61$) or Condition ($F(1, 64)=2.23, p=.14$).

Separate between factors analysis of variance on variable types revealed a main effect of State on strategy with participants in the hangover State demonstrating higher levels of strategy than those in the no hangover State ($F(1, 69)=4.29, p=0.04; 3.7$). State did not interact with any other variables however a first order interaction of State by Condition was revealed for 6 box errors ($F(1, 65)=6.67, p=0.01$). The interaction is shown in Table 3.7 and Figure 3.5.

Table 3.6. Mean errors and Strategy outputs for SWM task organised between State and Condition

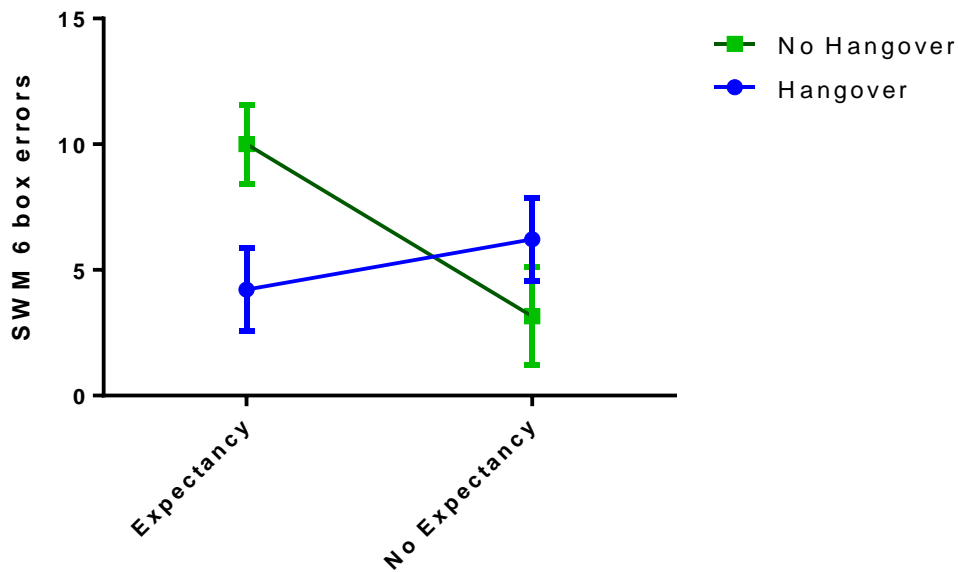
	Hangover M (<i>SD</i>)			No Hangover M (<i>SD</i>)		
	Expectancy <i>N</i> =18	No Expectancy <i>N</i> =17	Total <i>N</i> =35	Expectancy <i>N</i> =20	No Expectancy <i>N</i> =13	Total <i>N</i> =33
Spatial Working Memory (CANTAB)						
Total Errors (4 boxes)	0.61 (1.29)	0.28 (0.67)	0.44 (10.03)	.70 (1.53)	0.23 (.60)	0.51 (1.25)
Total Errors (6 boxes)	4.22 (4.71)	6.22 (7.99)	5.22 (6.54)	10.00 (9.20)	3.15 (.28)	7.26 (7.89)
Total Errors (8 boxes)	16.78 (15.22)	160.00 (11.44)	16.39 (13.28)	21.25 (15.23)	13.46 (10.65)	18.18 (13.97)
Overall Errors	21.61 (19.23)	22.50 (170.00)	220.06 (17.89)	31.95 (22.39)	16.85 (13.46)	260.00 (20.54)
Strategy	30.33 (5.82)	28.33 (9.58)	29.33 (7.88)	30.60 (5.58)	34.77 (3.32)	32.24 (5.18)

Table 3.7 Analysis of variance results for SWM variables with Condition and State interactions.

	SWM variable	N	F	p-value
Condition	4 box errors	69	20.084	.15
	6 box errors	69	20.003	.16
	8 box errors	69	1.679	.20
	Total Errors	69	5.654	0.02*
	Strategy	69	.449	.51
State	4 box errors	69	0.006	.94
	6 box errors	69	.626	.43
	8 box errors	69	0.086	.77
	Total Errors	69	2.617	.11
	Strategy	69	4.291	0.04*
Condition x State	4 box errors	69	0.060	.81
	6 box errors	69	6.674	0.01*
	8 box errors	69	1.125	.29
	Total Errors	69	4.347	0.04
	Strategy	69	3.635	0.06

Of note, strategy refers to the number of times a participant starts with a new box for 6 and 8 box trials

Figure 3.5. Spatial Working Memory, 6 box errors interaction with State and Condition interaction



Further analyse using the split output command revealed a significant difference in 6 box errors made between Conditions in the no hangover State $F(1, 31)=6.58$, $p=0.015$ but no effect of Condition in the hangover State ($F(1, 34)=.84$, $p=.37$). This indicates that expectancy does not impact performance when hungover but more errors are made when the purpose of the study is disclosed and participants are not hungover.

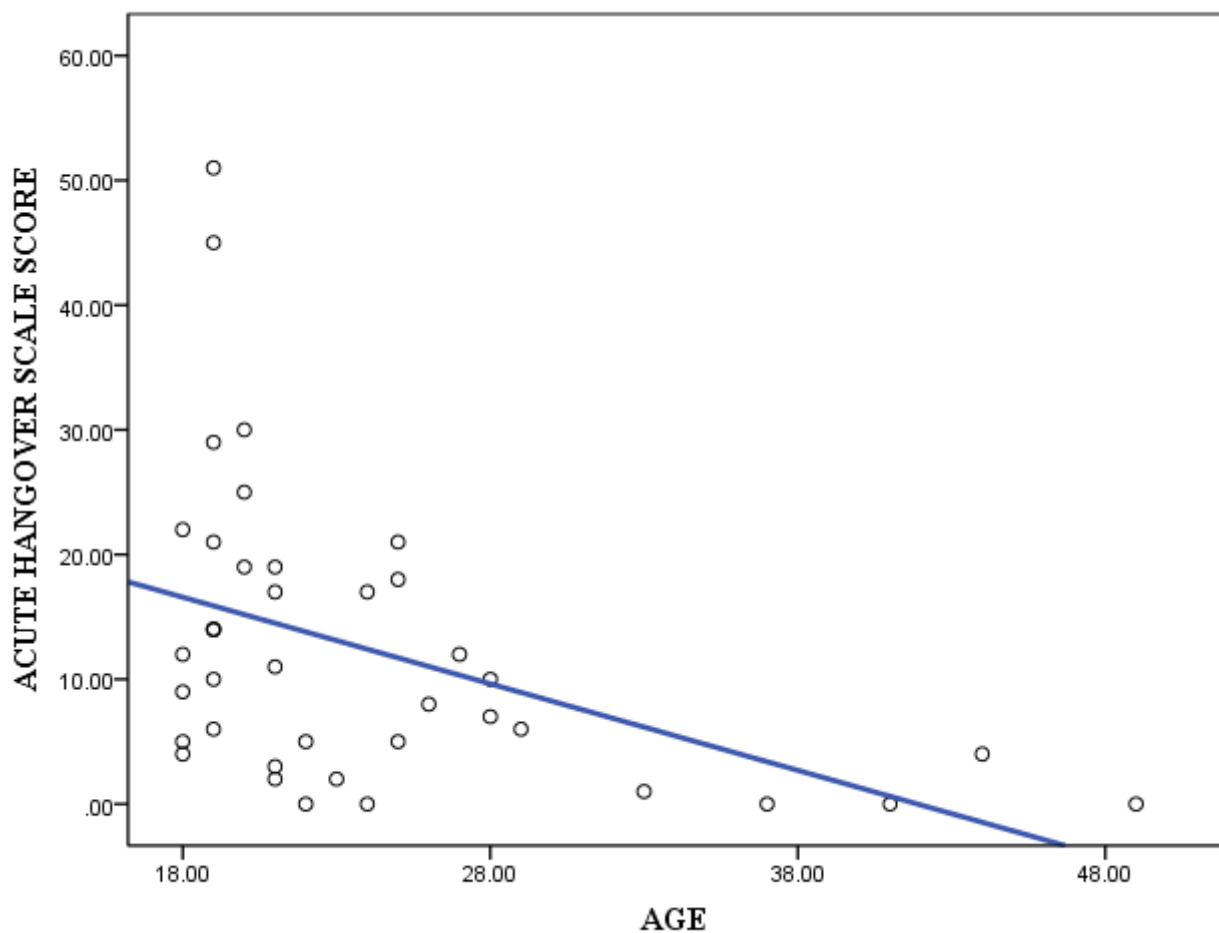
3.3.2.7 Correlation

A Pearson's product-moment correlation was carried to investigate the relationship between age, sleep, hangover symptoms, units consumed, performance and mood (See Appendix 2). The results revealed a large positive correlation between units consumed and AHS score ($r=.74$, $p<0.0001$). This was expected as more hangover symptoms are likely to be reported by people who have consumed large amounts of alcohol the night before than those that have consumed small amounts (Mackus et al., 2017). There was also a large negative correlation between AHS and alertness scores ($r=-.64$, $p<0.0001$, $n=40$). Of note, sleep interacted with only one (SA incompatible Far; $r=-.27$, $p=.04$, $n=74$) performance output. This suggests that total hours of sleep are not significantly related to hangover symptoms or performance variables in this study.

In terms of attention, Eriksen's Flanker and Stroop Errors were positively correlated ($r=.64$, $p<0.0001$, $n=74$). The Stroop task involves dimensional aspects of Selective Attention; therefore, it is not surprising that the results revealed a correlation between errors on these tasks. Moreover, items in the Eriksen's Flanker Incompatible Near variable produced a large correlation with Incompatible Far variable ($r=.86$, $p<0.0001$, $n=74$). These variables come from the same task and represent participants mean reaction times for items that are Incompatible and, Near or Far from the target. Fast reaction times on Incongruent Far items are related to fast responses for incongruent near items and slow responses for Incongruent Far items are also associated with slow responses to Incongruent Near items.

A medium negative correlation between age and total AHS score was observed ($r=-.44$, $p=0.01$, $n=40$). This suggests that the older the participant the less the severity of hangover symptoms are reported. The results from this study indicate that reported hangover severity decreases with age and are shown in scatter plot (Figure. 7). There were also medium positive correlations between AHS scores and Incongruent Near ($r=.43$, $p=0.01$, $n=40$) and Far ($r=.43$, $p=0.01$, $n=40$) items from the Selective Attention task as well as negative correlations for Divided Attention Errors ($r=-.34$, $p=0.02$, $n=74$) and Tranquillity ($r=-.36$, $p=0.04$, $n=74$).

Figure 3.6. Scatter plot of relationship between age and acute hangover scale score variables



In terms of units consumed, there were two medium sized correlations. Divided Attention ($r=.37$, $p=0.02$, $n=40$) and intra-extra dimensional ($r=.33$, $p=0.02$, $n=40$) errors positively correlated with total units consumed the night before. Moreover, there was a negative correlation between alertness and units consumed ($r=-.49$, $p<0.0001$, $n=40$). Of interest, there were positive correlations between task error variables (e.g. divided and Selective Attention errors, $r=.39$, $p=0.02$; spatial working memory and Selective Attention errors, $r=.28$, $p=0.02$; intra-extra dimensional and spatial working memory errors, $r=.38$, $p<0.0001$, $n=40$) which suggest that accuracy may be similar across tasks.

3.3.3 Task Related Motivation

3.3.3.1 *Stroop Performance*

A mixed measures analysis (Time x State x Condition) was carried out to investigate task related motivation before and after each task. Time as a within factor represented the pre and post measures. The scale measured difficulty, effort and perceived performance. The results of the ANOVA revealed a main effect of time $F(1, 69)=19.60$, $p<0.0001$ with perceived difficulty lower after the task was completed. Analyses on effort revealed no significant differences. Perceived effort was significantly lower before the task than after $F(1, 69)=220.06$, $p<0.0001$, however it did not interact with State $F(1, 69)=2.3$, $p=.13$) or Condition ($F(1, 69)=.48$, $p=.49$).

3.3.3.2 Eriksen's Flanker Task

The 2 x 2x 2 analysis using the same factor structure as Stated above revealed a main effect of time for task difficulty ($F(1, 70)=18.88, p<0.0001$) with lower perceived difficulty after ($M=20.01, SD=1.94$) task completion than before ($M=3.28, SD=2.25$). As shown in Table 3.8, there were no significant effects of State or Condition on effort and no second or third order interactions were shown for any of the task's task related motivation.

Table 3.8. Task related motivation ratings for difficulty, effort and perceived performance on Eriksen's Selective Attention Task

Selective Attention	N	F	p value.
Difficulty			
Time (Pre vs Post)	70	18.88	0.00*
Condition	70	30.08	0.08
State	70	1.28	.26
State* Condition	70	.89	.35
Time* Condition	70	0.02	.89
Time* State	70	.14	.71
Time* Condition* State	70	0.00	.96
Effort			
Time (Pre vs Post)	70	.39	.54
Condition	70	0.01	.95
State	70	1.73	.19
State* Condition	70	0.00	.99
Time* Condition	70	0.06	.81
Time* State	70	10.01	.32
Time* Condition* State	70	.16	.69
Perceived performance			
Time (Pre vs Post)	70	3.383	0.070
Condition	70	4.697	0.03*
State	70	.990	.323
State* Condition	70	0.056	.814
Time* Condition	70	.101	.752
Time* State	70	0.040	.842
Time* Condition * State	70	.101	.752

3.3.3.3 Divided Attention

There was a significant main effect of time for Divided Attention ($F(1, 9)=16.37$, $p=0.0001$) with lower scores for difficulty after task completion. There was also a main effect for Condition ($F(1, 69)=5.22$, $p=0.03$) with higher levels of perceived difficulty in participants in the expectancy Condition. However, State did not interact with task related motivation. There was a main effect of time for effort ($F(1, 69)=4.99$, $p=0.03$) which revealed lower levels of effort after the task than before. However, the analyses on perceived task performance failed to reveal any significant differences between State and/or Condition (see Table 3.9, $p>0.05$).

Table 3.9 Perceived performance on Divided Attention task

	<i>N</i>	<i>F</i>	<i>p value</i>
Perceived performance	73	1.58	.21
Perceived performance	73	20.01	.16
* State			
Perceived performance	73	1.40	.24
* Condition			
Perceived performance	73	.80	.37
* State * Condition			

3.3.3.4 Free Recall

The 3 factor analyses of variance revealed no effect for task difficulty ($F(1,70)=.74$, $p=.39$) or effort ($F(1, 70)=10.06$, $p=.31$). However, a State with Condition interaction was revealed for perceived performance ($F(1, 70)=5.39$, $p=0.02$). As can be seen from Table 3.10, when in the hangover State participants in the no expectancy Condition report lower levels of perceived performance than participants in the expectancy Condition. Moreover, when

participants are not hungover, perceived performance is lower in the expectancy State than in the no expectancy State. This indicates that knowing that the purpose of the study is to investigate a hangover may increase perceived performance when hungover but decrease perceived performance when no hungover.

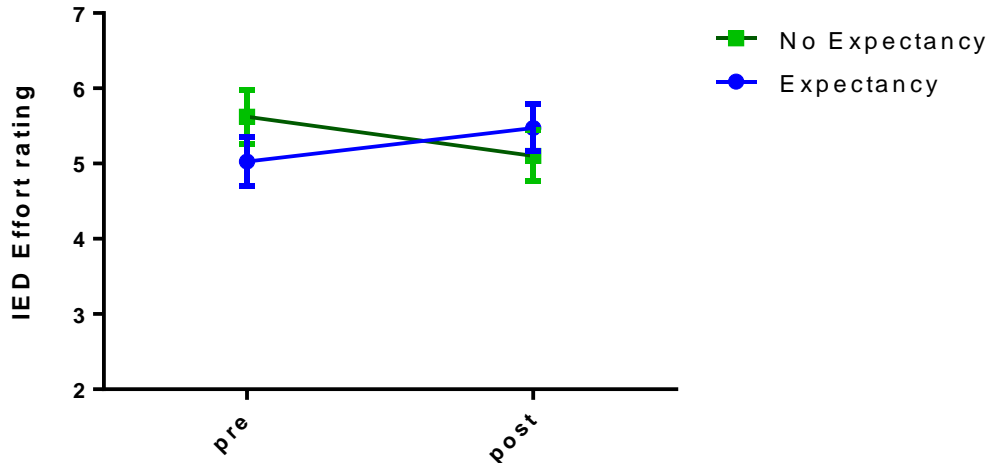
Table 3.10. Time, Condition and State perceived performance rating for word recall

Perceived Effort (Free Recall)					
Time	Condition	State	Mean	SD	N
Pre-Task	expectancy	hangover	2.15	1.87	20
		no hangover	2.25	2.22	20
	no expectancy	hangover	1.95	1.70	20
		no hangover	3.14	2.18	14
Post Task	expectancy	hangover	2.95	2.33	20
		no hangover	1.95	2.16	20
	no expectancy	hangover	1.65	1.46	20
		no hangover	30.07	2.20	14

3.3.3.5 Intra Extra Dimensional Set Shifting

Analyses on task related difficulty did not reach significance ($p > 0.05$). However, a first order interaction of Condition and time on task related effort was revealed ($F(1, 70) = 40.09$, $p = 0.047$). From Figure 3.7., it can be seen, that less effort is perceived before task completion in participants in the expectancy Condition ($M = 3.55$, $SD = 2.15$) than those in the no expectancy Condition ($M = 2.97$, $SD = 2.37$). However, after task completion, task related effort is higher for participants in the expectancy Condition ($M = 2.33$, $SD = 20.03$) than in the no expectancy Condition ($M = 1.64$, $SD = 1.79$).

Figure 3.7 Time and Condition interaction for perceived effort on IED task



In relation to perceived task performance, a main effect of time was revealed ($F(1, 70)=5.97, p=0.017$) with lower levels of perceived performance after task completion indicating that participants anticipated doing better on the task before the task was started.

Spatial Working Memory

From Table 3.11. It can be seen that analyses on task related difficulty and effort revealed no main effects or interactions. However, there was a main effect of State for perceived performance $F(1, 70)=4.71, p<0.001$ indicating that participants in the hangover State reported lower levels of task performance than those in the no hangover State.

Table 3.11. Mixed measures analysis on task related motivation of Spatial working memory task.

	<i>N</i>	<i>F</i>	<i>p-value</i>
<i>Difficulty</i>			
Time	70	0.039	.844
Condition	70	1.161	.285
State	70	.890	.349
Condition*State	70	.443	.508
Time* Condition	70	.488	.487
Time* State	70	2.353	.130
Time*Condition*State	70	0.039	.844
<i>Effort</i>			
Time	70	1.614	.208
Condition	70	0.082	.775
State	70	.557	.458
Condition*State	70	.318	.574
Time* Condition	70	0.006	.938
Time* State	70	.519	.474
Time* Condition*State	70	.659	.419
<i>Perceived Performance</i>			
Time	70	0.002	.963
Condition	70	3.226	0.077
State	70	4.71	0.033
Condition*State	70	0.006	.937
Time* Condition	70	.478	.492
Time* State	70	20.041	.158
Time* Condition*State	70	1.124	.293

3.4 Discussion

3.4.1 Summary

This study indicates that a hangover causes detriments to cognitive performance. Response times on Eriksen's Flanker Task and the Stroop Task were significantly longer in hungover participants. Participants recalled significantly less words from a Recall Task after a night's drinking. Expectancy does not significantly affect performance on overall task scores after a nights drinking. Of interest, this is the first study to explore the serial position effect and expectancy in a hangover context. The results indicate that expectancy may play a role that is not evident in mean task scores but may be present at discreet levels. For example, overall word recall was not affected by expectancy, however, when serial positioning was explored an effect was observed. Further research should look beyond central tendencies to investigate underlying effects of expectancy.

3.4.2 Performance Measures

3.4.2.1 *Stroop*

Performance on the Stroop Task revealed significantly longer Stroop interference in hungover participants. However, the number of errors between States did not reach significance. This suggest that one's Selective Attention is slowed when in the hangover State. In support of this McKinney, Coyle, Penning and Verster (2012) also found impairments in Stroop performance after a night's drinking. Condition did not interact with Stroop interference which suggests that knowledge of the study's purpose did not interfere with performance on this task. Incongruent items are more difficult to attend to than congruent items; they require one to focus on the target (word colour) and ignore the distractor (word meaning). There was a

significant difference in response times for such items with hungover participants taking longer to respond to the target than non-hungover participants. However, this effect was not observed for congruent items. This suggests that reaction times to Stroop items without distractions are not affected by previous night's alcohol consumption, however, one's encoding of contrasting stimuli such as incongruent words and colours, are significantly slowed after a night's drinking. This may occur as a written word can be read quicker than font colour can be named (Dyer, 1973). Morton and Chambers (1973) suggest that this is also a result of response competition between word and font colour. For example, if one has several stimuli responses available e.g. written word and font colour, then these responses will compete. Another theory that may explain the slower responses for incongruent items is the automaticity theory. It is theorised that reading written words has become automatic and therefore the word is processed first before attending to the font colour (Posner & Snyder (1975). It could be postulated that hungover participants may no longer have automatic responses to written words, they may not be able to juggle several responses in competition, or processing speed may be slowed as a result of alcohol's effects on the prefrontal cortex (Abernathy, 2010). The prefrontal cortex plays a major role in the ability to process incoming information. Prefrontal Cortex neuron activity is dependent on GABA and glutamate synaptic inputs (Tu et al., 2007). As described in Chapter 1., alcohol consumption affects the GABA and glutamate cycle, thus, it is possible that attentional impairment may be attributable to the chemical imbalance in the prefrontal cortex.

In terms of task related motivation, participants perceived task difficulty to be higher before task completion than after and effort ratings were lower before completion than after.

This suggests that participants put in more effort than they planned to and that the task may have required less effort than they expected. Nonetheless, State did not interact with task related motivation.

3.4.2.2 Eriksen's Flanker task

The results from Eriksen's Flanker task revealed an interaction between compatibility and distance. This was expected as Eriksen's spotlight theory indicates that stimuli that are present within the visual field (spotlight; within 1 degree angle of target) will distract participants from the target (Eriksen, 1986). When stimuli are presented outside of the 'spotlight', the stimuli no longer act as distractors. Similar to Stroop interference, competition may be the cause of slower response times when distractors are incompatible. Furthermore, there was a main effect of State on Eriksen's Flanker task and an interaction between State, distance and compatibility approached significance. These results suggest that State influences the interaction between compatibility and distance differently. There was an interaction of compatibility and distance in both States, however, there was no main effect of compatibility in the hangover State. Thus, it is plausible that in the hangover State participants may struggle to attend to targets with both compatible and incompatible distractors. Task related motivation revealed a main effect of time with participants reporting that the task was not as difficult after task completion. No effects of State reached significance for related motivation of this task.

3.4.2.3 Divided Attention

As expected there was a main effect of target location with faster response times for central items than peripheral items. This was demonstrated by McKinney and Coyle (2004) and

it is suggested that as the central items require continuous monitoring and as a result, participants may interpret central items as being more important (Middlebrooks, Kerr & Castel2017). However, State and Condition did not interact with performance. This suggests that Divided Attention is not impacted by the hangover State. The results from the task related motivation visual analogue scale showed no significant differences of State or State with Condition.

3.4.2.4 Free Recall

The mean number of words recalled in the no hangover State was higher than in the hangover State indicating that Free Recall is impaired the morning after a night's drinking. Further analyses on serial positioning indicated that more words were recalled from the beginning and end of the list than from the middle. This U-shape of word recall represents two memory systems (Glanzer & Cunitz, 1966). The recall of words from the beginning of a list is otherwise known as a primacy effect (Murdoch, 1962). It is associated with the transfer of information into long term memory and requires active learning through repetition. In contrast, recency refers to recall of items at the end of a word list, it requires short term memory banking and it often occurs through passive learning (Greene, Prepisci & Levy, 2000). To the author's knowledge, serial positioning has not been investigated in hangover research to date. The results from the analyses of serial positioning in this study revealed that less words were recalled from the beginning of the list in the hangover State than in the no hangover State. For items at the end of the list, there was a main effect of Condition, and a Condition by State interaction was also observed. Here, hungover participants recalled more items from the end of

the list if they knew that the purpose of the study was to examine the effects of a night's drinking rather than time of day.

From these results it is not possible to attribute the cause of the serial position interactions. It is possible that, one's ability to systematically bank items from the beginning of a word list as well as remember words from the end of a word list is somewhat limited after a night's drinking. Therefore, it is possible that one strategically sacrifices the rehearsal of words from the beginning of the list in order to recall words from the end of the list when hungover. Moreover, recall of words from the end of the list increased when participants knew the purpose of the study. Speculatively, it is possible that one's knowledge of the purpose of the study resulted in participants in the expectancy Condition perceiving the task differently to those in the no expectancy Condition. For example, time of day (no expectancy) may be perceived as a Condition that is out of one's control, therefore, subconsciously participants may not exert as much effort as those in the expectancy Condition as a hangover may be perceived as something that one can control. Thus, when more effort was made by hungover participants in the expectancy Condition, more words may have been recalled from the end of the list as this may have been a simpler strategy.

Indeed, task related motivation measurements of perceived performance revealed that hungover participants in the expectancy Condition reported doing better in the task than those in the no expectancy Condition. In contrast, participants that were not hungover reported doing better in the no expectancy Condition than in the expectancy Condition.

3.4.2.5 *Intra-Extra dimensional Set Shifting*

Results from the intra-extra dimensional set shifting task revealed that less intra dimensional errors were made by participants in the hangover State than those in the no hangover State. Intra-dimensional set shifting is thought to be less difficult than extradimensional set shifting as it does not involve a change in target dimensions (LBow & Tritt, 1971). However, this task was not timed and one possible reason for the outcome is that hungover participants may have sacrificed time in order to improve response accuracy whereas non-hungover participants may have felt more confidence in the intra-dimensional trials and subsequently made more mistakes. Indeed, the speed-accuracy trade off may have resulted in more response caution in hungover participants (Rabbitt, 1979). Subjective measures of task related motivation revealed no effects of State. However, participants that knew the purpose of the study reported less effort before the task than after and those in the no expectancy Condition reported more effort before the task than after. This suggests that more effort was required from those that knew that the study was aimed at investigating a night's drinking than was previously anticipated. In contrast, those that believed that the study was about time of day exerted less effort than they intended, possibly because less effort was required to reach a satisfactory level of performance.

3.4.2.6 *Spatial Working Memory*

The results from the SWM task indicated that hungover participants exerted higher levels of strategy than those in the no hangover State. One might deduce that it is possible that an overconfidence effect may have resulted in participants in the no hangover State adhering to a less strict strategy than those in the hangover State. Alternatively, participants in the

hangover State may have developed strategies to locate the blue token as they were aware of their limited memory capacities in the hangover State. Moreover, those in the no hangover State made more 6 box errors when the purpose of the study was disclosed. These results also support the idea that an overconfidence effect may have occurred and as a result participants that were not hungover but knew that the study was about a hangover made more mistakes. Subjective measures of task related motivation showed no interaction or main effects suggesting that difficulty, effort and perceived performance did not vary across States and Conditions.

3.4.3 Demographic Information

The mean age of participants in this study was 24.49 years. This corresponds to the mean age in Finnegan et al.'s (1998) study on cognitive performance during a hangover where the mean age was 25.60 years. And, McKinney and Coyle's (2004) study on the effects of a night's drinking recruited participants with a mean age of 23.38 years. Age did not differ significantly across State and Condition (see Appendix 2). The mean age of first drink was 15.68 years. Although there is no agreed upon estimate of average age of first drink in the UK, a statistical report by Health and Social Care Information Centre (2015) revealed that by the age of 15 years, 72% of children have consumed alcohol. A study by Morean, Kong, Deepa, Camenga, Cavallo, Connell and Krishnan-Sarin et al. (2014) found that among their participants, age of first alcoholic drink was 16.16 (SD=2.14) years. In America, the most common age of drink initiation is 15-17 years old (Substance Abuse and Medical Help Services Administration; SAMHSA, 2014). This demonstrates that the age of first drink in the sample recruited in this study is similar to age of first drink across other research samples.

Most drinking took place in a bar or pub (43%) or at home (42%). These results are similar to those found by Clapp (2000) as his results revealed that 42% of university students report drinking in pubs or restaurants and 43% consumed alcohol drank in their homes. Also, these results support the findings of Lewis et al. (2011) which also demonstrated high levels of alcohol consumption among college students at home and in a pub environment. Moreover, 12.85 units were consumed the night before testing. In a study by Finnigan, Schulze, Smallwood and Anderson (2005), participants drank an average of 15.5 units the night before test and in a another more recent study by McKinney, Coyle and Verster (2012), participants consumed drank a mean of 11.84 units. This indicates that the present study is closely matched to the number of units consumed in other studies that focus on hangover effects.

3.4.4 Subjective Measures

In terms of sleep, the mean number of hours of sleep was 6.66 hours (6:40mins) and matches recent research by The Royal Society of Public Health (RSPH; 2016) which indicates that UK residents get an average of 6 hours and 48 minutes of sleep each night. From the analyses in this Chapter, it can be seen that an alcohol hangover affects perceived sleep duration, with those in the hangover State sleeping less than those not hungover. Although alcohol's effects on sleep have been noted for many years, less hours of sleep after alcohol consumption was not predicted as alcohol can cause one to wake up early but also decreases time of sleep onset (Kleitman, 1939; Feige et al, 2006; Roehrs & Roth, 2001). However, in support of these results, a similar study by McKinney and Coyle (2006) showed that hungover participants reported significantly less hours sleep than participants that were not hungover.

Sleep duration in the hangover State may be explained by a change in bed time. For example, almost half of participants in the no hangover State reported going to bed before 12am, however, just 15% in the hangover State were in bed before midnight. This suggests that one is more likely to stay awake for longer if one consumes alcohol. Nonetheless sleep did not correlate with units consumed or the Acute Hangover Scale and failed to interact with all but one performance variables.

As expected, subjective reports of alertness were lower after a night's drinking. Using the same mood scale by Herbert (1976), McKinney and Coyle (2006) also found lower levels of alertness after a night's drinking. In a study by Penning, McKinney and Verster (2012) it was shown that 79% of participants reported reduced alertness.

In terms of hangover symptoms, the overall AHS score in this study was 12.45. Similarly, Rohsenow et al. (2007), found a total AHS score of 129.60 which suggests that hangover symptoms in this study are in keeping with previous hangover research. In support of Verster, van Herwijnen, Olivier and Kahler's (2009) research, tiredness also scored the highest on the AHS questionnaire in this study. There are many possibilities for the increased levels of tiredness reported, for example, as discussed earlier, hungover participants report less hours of sleep, alcohol also effects sleep quality through disturbances in one's sleep wake cycle; and loss of nutrients such as blood sugars and beverage ingredients like congeners can also contribute to feelings of tiredness (Rohsenow et al., 2010; Ylikahri, Huttunen, Eriksson & Hikkila 1974; Schrojenstein Lantman, Roth & Roehrs, 2017).

3.4.5 Limitation

In this Chapter participants with a positive BAC reading were excluded from participation (N=9). At the time of designing and conducting the study this was best practice as it was argued that a positive BAC could produce additional (acute) effects on performance (Verster et al., 2010). However, a recent definition of the alcohol hangover put forward by the AHRG States that alcohol hangovers occur when “BAC approaches zero” (Schrojenstein Lantman et al., 2016, p.153). On reflection, it would have been beneficial to include participants with a positive BAC reading in the study as there may be variations in expectancy effects when alcohol is still in the body.

3.4.6 Conclusion

The findings from this study support the need for measures to be taken around safety critical environments e.g. oil and gas rigs, railways, nuclear plants. Human errors are responsible for 70% of accidents on oil and gas rigs that can cost up to around £2 billion per accident (Health and Safety Executive, 1999). Alcohol consumption is forbidden during working hours on oil and gas rigs but there are no regulations in place to reduce the risk of alcohol related cognitive impairment that may increase the potential for human error (International Association of Oil and Gas Producers, 2016). Such considerations may be beneficial to a wide of organisations who wish to reduce human error related accidents in the workplace.

The next day effects of a night's drinking should be considered when carrying out day to day activities that require attention, psychomotor performance or memory, such as operating machinery or driving a car. An alcohol hangover affects speed of reaction in systems of

attention differently. Moreover, the role of expectancy on next day performance does not appear to significantly affect overall mean response times or total errors, however some evidence in this study suggests that expectancy may influence some aspects of performance as a result of over confidence or speed-accuracy trade off.

4. The next day effects of a night's drinking on social drinkers in a natural environment.

4.1 Introduction

The samples of participants used in hangover research studies often do not reflect the diversity of social drinkers. For example, Stephens et al.'s (2008) review highlights eight laboratory and three naturalistic studies that were deemed good enough to warrant consideration in their review. A considerable number of these studies employed student populations (Collins et al., 1971; Anderson & Dawson, 1999; Laurell and Tornros, 1983; McKinney & Coyle, 2004). Those investigations carried out on non-student volunteers have often recruited all male populations (Roehrs et al., 1991; Lemon et al., 1993; Streufert et al., 1995; Finnegan et al., 1998). In an updated review, Ling, Stephens and Heffernan (2010) highlighted four hangover studies that were published after Stephens et al.'s (2008) review; of which, three studies applied a sample of university students and the other recruited maritime academy cadets. Moreover, two of the studies recruited participants with an age range from early to mid-twenties (Howland et al., 2010; Rohesnow et al., 2006), another recruited a sample with a mean age of 22.2 (McKinney & Coyle, 2007) and a final study tested participants within a range of 21-33 years (Rohesnow et al., 2010).

A variation in drinking behaviours across ages has been demonstrated by Britton, Shlomo, Benzeval, Kuh and Bell (2015) who conducted a study using several cohorts containing longitudinal data in order to explore drinking patterns across a lifetime. The results showed that alcohol consumption is common from adolescence to 90+ years of age. In adolescents, drinking begins at under 10 units per week and increases in males to 20 units per week at the age of 25 (Britton, Shlomo, Benzeval, Kuh & Bell, 2015). Alcohol consumption then declines and stabilises during middle age. Britton et al., (2015) report a similar trajectory for female respondents

however, a considerably lower peak of 7 to 8 units were reported. Of note, Britton's study population ranged from those born from 1939 to 1973 and female alcohol consumption in the UK has been reported to have increased considerably in the 21st century (Tyrell, Orton & Tata, 2016; National Institute on Alcohol Abuse and Alcoholism, 2017). Britton et al. (2015), also highlights that irregular consumption of large volumes of alcohol occur in the early stages of adult life and as age increases the volume of alcohol consumed decreases, however drinking occasions become more frequent.

A report by Alcohol Research UK (2016) using qualitative and quantitative methods divided drinking occasions into three categories; low risk (less than 6 units for women, less than 8 for men), increasing (6-12 units for women, 8-16 for men) and high-risk drinking (more than 12 units for women, 16 or more units for men). The results showed that older participants (35 years or over) with high socioeconomic statuses (measured using Mosaic categorisations; Experian, 2016) were more likely to engage in high risk drinking occasions and were more likely to drink frequently than their younger counterparts. The results from Britton et al.'s (2015) and Alcohol Research UK's (2016) investigations suggest that drinking behaviours of student samples are likely to differ to those of non-students aged samples.

The public house has been a focal point in western communities for many years (Cunningham, 2013). Indeed in 1838, there were 21,000 public houses in Ireland (Competition Authority, 1998) and approximately 91,000 in the UK (Kneale, 1999). The number of public houses in the UK peaked at 115,000 in 1870 (Kneale, 1999). However, in the 20th century, the British government introduced laws in the UK that included shorter opening times, higher duties on alcohol and reductions in strength and production of beer (Kneale, 1999) and a

similar Licensing law 1874 was enforced in Ireland (Irish Statute Book, 2007). Concerns surrounding the negative effects of alcohol abuse resulted in increased interest in the health and social impact of alcohol (Cunningham, 2013) and by the 21st century, the number of public houses had declined to a total of 60, 800 in the UK (Statista, 2017) and 11,000 Ireland (Molloy, 2002).

Today, there are over 50,000 public houses in the UK (Statista, 2017) and 7,193 in Ireland (Foley, 2017). Moreover, it is estimated that over 15 million people visit public houses in the UK each week (Hastings, 2008). There are no weekly figures available for Ireland, however, it can be posited that public houses are visited at a considerable frequency as figures show that consumer spending on alcoholic beverages within the Republic of Ireland is €954 million and in Northern Ireland €390 million. Moreover, 27% of Dublin pubs have an annual turnover of €1.25million or more (Foley, 2013). The number of public houses today appears modest in comparison to the 19th century, however, the frequency of visits as well as pub revenue and spending suggest that the public house remains a popular place to consume alcohol in both the UK and Ireland. The popularity of the public house is not constrained to a demographical characteristic or society, Watson (2002) suggesting that public houses have been the centrepiece of social, political and economic exchange in almost every type of society. Indeed, among working men and women, alcohol is the most commonly used psychoactive drug (Frone, 2004). With this considered, it is beneficial to include the public house in investigations into real life effects of a night's drinking.

Undergraduate students that attend university after finishing school are likely to have limited experience of alcohol consumption in comparison to seasoned non-student drinkers.

Alcohol tolerance refers to a reduction in the effects of alcohol after repeated consumption (Chen, 1972). In terms of functionality, there is sufficient evidence to suggest that heavy drinkers perform better at cognitive tasks during intoxication than light due to increased tolerance (Goodwin et al., 1971, Mello & Mendelson, 1978). For example, using repeated administration sessions, Pohorecky, Brick and Carpenter (1986) showed that the BAC does not change significantly with increased drinking sessions, however, motor coordination is improved after 17 dosing days of ethanol. Of note, not all areas of cognition improved with drinking experience. Pohorecky, Brick and Carpenter (1986) found that tolerance for startle responses does not improve with increased dosing sessions.

Metabolic tolerance has been described as the change in absorption, distribution, degradation or excretion of alcohol (Tabakoff, Cornell & Hoffman, 1986). Dyr and Taracha (2012) demonstrated increased metabolic tolerance after repeated exposure in a study using 16 Warsaw High Preferring rats. The results showed ethanol elimination rates increased after increased exposure to ethanol over a twelve week period. Cederbaum (2012) suggests that metabolic tolerance may be explained through the hypermetabolic State theory (Israel et al, 1975). Hypermetabolic State theorists argue that thyroid hormone levels increase with increased ethanol exposure (Israel et al., 1975) and as a result NADH (nicotinamide adenine dinucleotide and hydrogen) reoxidation is increased which is a product of the break-down of acetaldehyde to acetate and plays an important role in the metabolism of ethanol (Thurman et al, 1989; Wendell & Thurman, 1979; Zakhari, 2006). Of note, NAD and NADH are electron carriers that facilitate oxidative metabolism by increasing levels of the principle enzyme involved in the breakdown of ethanol and acetaldehyde (alcohol dehydrogenase; ADH; Zakhari,

2006). However, there is conflicting evidence relating to the role of the thyroid hormone in alcohol metabolism (Begleiter & Kissin, 1996) as both decreases in thyroid hormone levels as well as evidence of no alteration during intoxication have been reported (Balhara & Deb, 2013). Moreover, to the authors knowledge there is no evidence of increased metabolic tolerance with repeated exposure in human studies. For more details on alcohol metabolism see Chapter 1. Section 1.2.4.

If the rate at which alcohol is eliminated from the body is mediated by tolerance then it may also impact hangover duration and severity. Thus, it is advantageous to note the drinking experience of participants in hangover research. Moreover, evidence suggests that very young animals display a slower rate of alcohol elimination than middle aged animals; and older animals are likely to show slower metabolic rates as a result of smaller liver mass and water content (Cederbaum, 2012). It is therefore predicted that cognitive performance may be impaired during a hangover in a non-student sample. However, the effects of a night's drinking will differ from previous studies that have recruited student samples.

In addition, differing test batteries have been used to measure cognition in hangover studies. The proposed study will make use of a standard test battery; Cambridge Neuropsychological Automated Task Battery (CANTAB) in combination with previous tests used by McKinney, Coyle and Verster (2012) to investigate cognitive performance. In the previous study (Chapter 3) a between participants variable of State (hangover/no hangover) was included in the design. In contrast the current study follows a rather more sensitive within participants design. Verster et al. (2010) suggests that hangover severity and symptoms are prone to individual differences and as a result a within participants variable of State is to be

preferred. However, Verster et al. (2010) also argue that a within factor design is limited because blinding may be ineffective as participants in laboratory studies can deduce at which testing sessions a placebo and alcohol drink is administered; and in a naturalistic design as the researcher must arrange a hangover testing session thus blinding is not possible. As the results from Chapter 3 indicate that expectancy does not appear to affect performance, blinding is not applied and a within factor of State is favoured.

Furthermore, a naturalistic design will be applied. As discussed in Chapter 1, a naturalistic design is the preferred approach to capturing the real-life effects of a hangover. This study provides a fresh approach to the naturalistic design by maintaining control through subjective measures while also recruiting social drinkers from their local public house. In this way a broader sample of social drinkers can be recruited that will represent the variability in drinking behaviour and experience of social drinkers.

4.2 Method

4.2.1 Participants

The study included 25 male and 20 female participants. The mean age was 32.73 years (SD=10.94; Order 1 M= 35.73, SD=11.49, Order 2 M=26.21, SD=7.35). The mean age of first drink was 15 (SD= 2.46) and this was well matched across Order (Order 1 M=150.04, SD=2.88; Order 2 M=14.95, SD=1.81). Recruitment took place in a licensed premises in a small town with a population of 6,839 (Census, 2011).

4.2.2 Design

The study followed a mixed measures design in which the within participants variable of State (hangover /no hangover) was combined with the between participants variable of Order (Order 1= Hangover/No Hangover; Order 2= No Hangover/Hangover). There were 12 males and 14 females in Order 1 and 13 males and 6 females in Order 2. Testing sessions were conducted between 5-10 days apart. The dependent variables were derived from the measures of cognitive performance and the responses to the subjective questionnaires.

As a result of the quasi experimental recruitment approach participants were allocated to Order depending on alcohol consumption on the day of recruitment. In this way, participants were not encouraged to consume alcohol by the researcher. However, the frequency of attendance by patrons on both drinking and non-drinking days enabled hangover and non-hangover data (both testing sessions) to be gathered within a 5-10 day timeframe.

4.2.3 Procedure

Participants first confirmed compliance with the pretesting requirements and a consent form was read and signed (see Chapter 2 and Appendix 1). Next, participants were breathalysed and a series of questionnaires pertaining to mood, sleep drinking behaviour and demographic information were administered (described in Chapter 2 and found in Appendix 1). Afterwards, a series of cognitive tasks were administered including Eriksen's Flanker Task, Free Recall, Spatial Working Memory, Intra-extra dimensional set shifting and a Choice reaction time task. Again, tasks were administered in a randomised order as in Study 1 (Chapter 3). The second testing session included an almost identical procedure, however, questionnaires on

demographic information, usual alcohol consumption and Short Michigan Alcohol Screen Task were not administered. In the interest of replication, detailed descriptions of the subjective and objective (cognitive) measures are found in Chapter 2, and a brief description of the cognitive tasks are presented below.

4.2.3.1 *Eriksen's Flanker Task*

The Selective Attention task involved the use of targets and distracters (letters A and B; Eriksen & Eriksen, 1974). Distracters were presented at either side of the target and were either compatible (AAA) or incompatible with the target (BAB), and near or far from the target. Participants were required to respond to the target letter by pressing a key on the computer keyboard. Outcome variables included 'Total Errors', 'Distance' and 'Compatibility' response times. DistanceDif was calculated by subtracting response times (RTs) to far items from near items, and CompatibilityDif was computed difference between compatible and incompatible items.

4.2.3.2 *Stroop*

In this task, participants were required to attend to the font colour of a word while ignoring the word meaning. Words were presented on the screen one at a time in Blue, Green, Red, Purple and Brown as used in the original task (Chajut, Schupak & Algom, 2009; Stroop, 1935). Dependent variables included the number of Errors and Stroop Interference. Stroop Interference represented the difference between RTs for Congruent (e.g. red presented in red font) and Incongruent items (e.g. red presented in green font).

4.2.3.3 *Free Recall*

The Free Recall task consisted of two set of twenty words from the Handbook of Semantic Word Norms (Toglia & Battig, 1978; Appendix 1) that are presented on the computer screen one at a time. After the words were presented, participants were required to write down as many words as possible from the list using the pen and paper provided. The order of words recalled on paper was irrelevant. The dependent measure was the number of correctly recalled words.

4.2.3.4 *Spatial Working Memory*

This task was presented on a touch screen CANTAB device. Coloured boxes appeared on a black screen and participants were required to touch the coloured boxes to find a token (smaller box). Once found, participants were required to use them to fill up an empty column on the right-hand side of the screen (Cambridge Cognition, 2018). Task difficulty varied as the number of boxes gradually increased. Dependent measures included 4 box, 6 box, and 8 box errors (selecting boxes that have already been visited), Total Errors (4+6+8 box errors) and Strategy. Higher strategy scores indicate poorer use of the best strategy.

4.2.3.5 *Intra-Extra Dimensional Set Sifting*

In this task, participants were required to use feedback (correct, wrong) to equate a rule that determined which stimulus was correct. After six correct responses, the stimuli and/or rule changed. The task starts with simple stimuli (individually shown white lines and pink shapes) corresponding to intra-dimensional shifts in rules and then becomes more difficult as the

participant progresses (e.g., white lines and pink shapes) and also requires extra-dimensional rule shifting.

4.2.3.6 Choice Reaction Time Task

This task required participants to respond to arrows presented on the screen (one at a time) as quickly and accurately as possible. The arrows were presented on the screen until the participant made a response and there were two possible responses. A right button press was required when the arrow pointed right, and left, when the arrow pointed left. Dependent variables include latency (correct Maximum, Minimum & Mean), percentage correct trials and omission, and total correct and incorrect trials.

4.2.4 Statistical Analysis

Unless otherwise Stated the data was subjected to an ANOVA comprised of the within factor of State and between factor of Order. State refers to Hangover and No Hangover testing sessions and Order refers to the Order in which testing took place. In Order 1, participants completed a Hangover testing session followed by a No Hangover testing session. In Order 2, a No Hangover testing session was followed by a Hangover testing session. A Pearson's correlation coefficient was used to investigate the relationships between variables. In all instances Alpha was set at 0.05.

4.3 Results

4.3.1 Descriptive Statistics

A summary of demographic Information regarding the sample of participants recruited is demonstrated in Table 4.1. As the study followed a repeated measures design which included Hangover and No Hangover testing sessions, variables: Age, Gender, and Age of First drink were only measured in one testing session. Units consumed and AHS total were measured in Hangover sessions only as alcohol was not consumed the night before the No Hangover testing sessions. Of note, 5 participants in the hangover testing session reported no hangover symptoms. However, this does not indicate immunity to cognitive symptoms of a hangover, therefore they were included in the analysis.

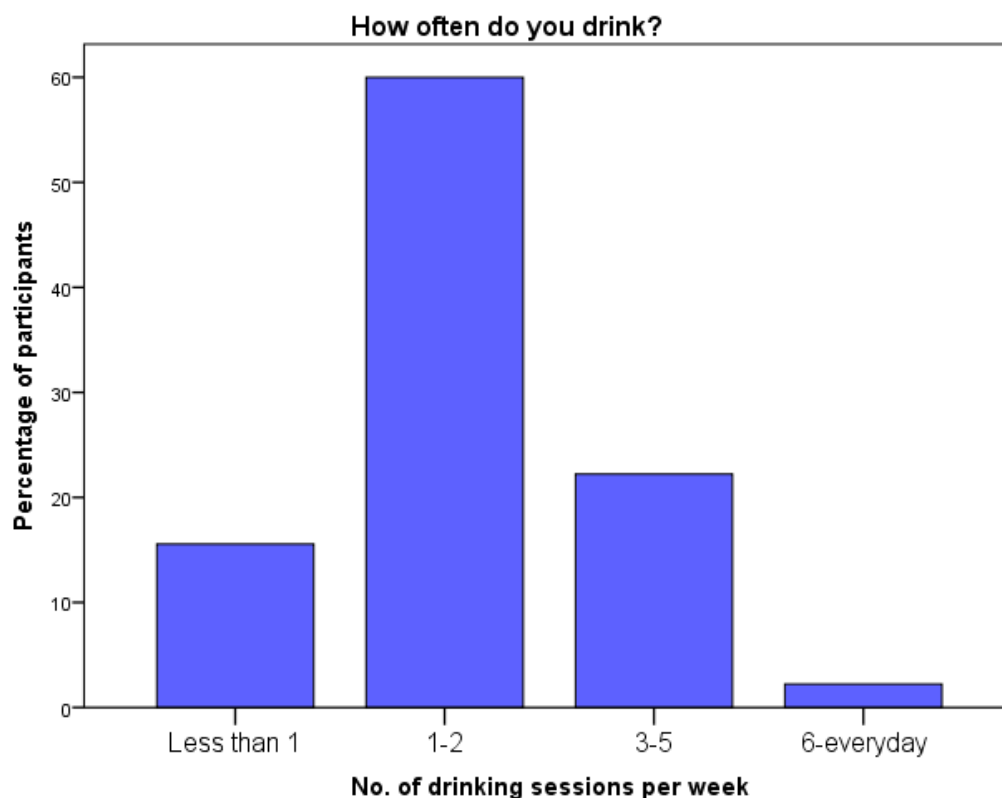
Table 4.1. Summary of demographic, mood and alcohol information pertaining to the sample investigated.

	Hangover Session		No Hangover Session	
	Order 1 (H/NH)	Order 2 (NH/H)	Order 1 (H/NH)	Order 2 (NH/H)
N	26	19	--	--
Gender (male/female)	12/14	13/6	--	--
Age	35.73 (11.49)	26.21 (7.35)	--	--
Units consumed	13.71 (7.44)	16.77 (11.57)	--	--
AHS total	12.62 (80.04)	16.79 (12.41)	--	--
Sleep (hrs)	7.45 (1.39)	70.09 (1.98)	7.37 (1.49)	7.71 (2.33)
Age of First Drink M(SD)	150.04 (2.88)	14.95 (1.81)	--	--
Alertness	43.96 (13.49)	350.05 (11.39)	52.88 (120.04)	49.11 (80.03)
Tranquillity	33.85 (10.88)	32.22 (6.87)	38.12 (90.08)	42.89 (15.99)

4.3.1.1 Alcohol Consumption

As can be seen from Figure 4.1, sixty percent of respondents reported consuming alcohol once or twice a week and 22% reported drinking 3-5 times a week. 15.6% of participants consumed alcohol less than once a week and 2% consumed alcoholic beverages 6 times to everyday.

Figure 4.1 Frequency of alcohol consumption among participants.



The number of drinks consumed on a normal drinking occasion were mostly between 3 and 5 (31%) or 6 and 7 (31%). However, almost $\frac{1}{4}$ of participants reported consuming 8 or more drinks on an average drinking session and more than half of participants have been consuming alcohol in this way for five years or more. Moreover, 53% of participants reported having consumed a maximum of '13 drinks or more' in one sitting. When asked 'how often have you drank this amount of alcohol at any one sitting?', 76% reported drinking in this way less than 6 times a year. However almost $\frac{1}{4}$ reported drinking in this way at least once a month. Similarly, almost $\frac{1}{4}$ participants reported drinking to reach intoxication at least once a month. In terms of drinking location, most participants (71%) reported consuming alcohol in a bar or pub.

In terms of drinking experience, the mean number of years reported drinking in this way was 60.04 years (SD=4.49). The minimum time drinking in this way was 6 months and the maximum time drinking in this way was 20 years (Range=19.50 years)

4.3.1.2 *Tobacco and Drugs*

Twenty-seven participants reported that they smoke regularly. The average length of time that participants had been smoking was 10.26 years (SD= 8.65). Twenty-two participants (48.9%) reported that they smoked cannabis, of which, the mean number of years they had been consuming cannabis was 9.61 (SD=8.38). When asked 'Do you take any other drugs?' Thirteen participants (28.9%) responded 'Yes'. In terms of stimulants, six participants reported taking cocaine, one reported taking MDMA, five reported taking Ecstasy and one reported taking both Ecstasy and Cocaine. Excluding cannabis, one other depressant was reported by a participant that reported consuming tranquilizers but did not specify the type.

In total, 23 participants (51.1%) reported that they consume illegal drugs (of any type). A univariate analysis of variance was carried on total Acute Hangover Scale scores with Drugs (No/Yes) as an independent variable. The results showed no significant differences in hangover symptoms or severity in drug consumers ($F(1, 43)=.314$, $p=.58$).

4.3.1.3 *Previous Night's Alcohol and Drug Consumption*

On the night before testing, 15.32 (SD=9.25) drinks were consumed on average. The most popularly type of alcohol consumed fell under 'Lager or Cider' with a mean of 10.01 units (SD=10.57) consumed overall. Moreover, 68.9% of participants reported consuming Lager or Cider the night before testing, with a mean of 14.53 units of Lager or Cider consumed.

Furthermore, 46.7% of participants reported consuming spirits the night before testing and of those who consumed spirits a mean 5.79 units of spirits were consumed per person (overall $M=2.70$, $SD=4.83$). Forty percent of participants reported consuming wine the night before testing with an average of 5.78 units of wine consumed by wine drinkers (overall $M=2.31$, $SD=4.36$). Participants consumed alcohol for an average of almost 5 hours ($M= 4.96$, $SD= 20.08$). However, the range of time spent consuming alcohol differed considerably between participants (Range=8.7 hours). Five participants reported consuming illegal drugs the night before the hangover testing session of which two consumed depressants only (e.g. Cannabis), one consumed a stimulant only (e.g. ecstasy) and two consumed both stimulants and depressants. Finally, two participants reported consuming depressants the night before the no hangover testing session.

4.3.1.4 4.3.1.6 Sleep

On average, participants reported sleeping 7.55 hours ($SD=1.76$) the night before testing. Hungover participants reported a mean of 7.30 hours ($SD=1.65$) of sleep the evening before testing, whereas when participants were not hungover they reported a mean of 7.51 hours ($SD=1.87$). There was a considerable range in both Hangover and no hangover testing sessions with one participant reporting just one hour of sleep before testing when hungover and another participant reporting just 30 minutes (e.g. .50) of sleep the night before the no hangover testing session. Maximum hours slept were 12 hours in the no hangover session and 10.3 hours in the hangover session.

An analysis of variance (State x Order) on hours of sleep revealed no main effects of State ($F(1, 43)=.47$, $p=.50$), Order ($F(1, 43)=0.00$, $p=.99$) or State or Order interaction ($F(1, 43)=.83$, $p=.37$) indicating that cells were well balanced for sleep. Frequency calculations have revealed 11% of participants went to bed at or before midnight after consuming alcohol during the hangover testing session. In contrast, 43.1% of participants when in the no hangover State went to bed at or before midnight.

4.3.1.5 4.3.1.7 Caffeine

51.1% of participants consumed caffeine the morning before the hangover testing sessions and 53.3% of participants consumed caffeine before the no hangover testing sessions. In this way, both sessions are balanced with an almost equal number of participants having consumed alcohol before testing. Furthermore, a univariate analysis of variance was carried out on caffeine consumption in the hangover State and Total Acute Hangover Scale (AHS) scores in order to investigate potential effects of caffeine on hangover symptoms and severity. The results showed no significant effect of caffeine consumption on AHS ($F(1, 43)=2.26$, $p=.14$).

4.3.1.6 4.3.8 Mood

Items within Herbert et al.'s (1976) mood scale were collapsed into two variables; Alertness and Tranquillity. For the hangover testing sessions, the mean Alertness score was 40.39 (SD=13.37) out of a possible score of 77. When participants were not hungover, the mean score for perceived Alertness was 51.25 (SD=10.56). Furthermore, an analysis of variance indicated a significant State difference between testing sessions ($F(1, 42)=34.39$, $p<0.0001$) and moreover, there was a main effect of Order ($F(1, 42)=4.89$, $p=0.03$) with higher levels of

alertness reported by participants at Order 1 (48.66, SD=11.21) than at order 2 (420.08, SD=7.48). However, State and Order did not interact with Alertness ($F(1, 42)=2.14$, $p=0.15$). Tranquillity was rated at 33.12 (SD=9.49) in the hangover session out of a possible score of 49 and was scored at 40.07 (SD=12.73) in the no hangover session. An analysis of variance revealed a significant main effect of State ($F(1, 41)=11.82$, $p=0.00$). Order did not reach significance ($F(1, 41)=.33$, $p=.57$) and there was no interaction of Order and State ($F(1, 41)=20.04$, $p=.16$).

4.3.1.7 4.3.9 Acute Hangover Scale

As in Chapter 3, the nine item Acute Hangover Scale was collapsed into one variable. A univariate analysis of variance revealed no significant difference between Orders ($F(1, 43)=1.88$, $p=.18$). The mean total hangover score was 14.38 (SD=10.20). The highest rated hangover symptoms were Tiredness ($M=3.42$ SD=20.04), Thirstiness ($M=30.00$, SD=1.85) and Hungoverness ($M=2.58$, SD=1.5). One-way analysis of variance on AHS with between groups measure of Order are presented in Table 4.2.

Table 4.2. Analysis of variance F and significance values for individual items in the Acute Hangover Scale

	N	F	P value
Hangover	45	1.95	.17
Thirsty	45	1.74	.19
Tired	45	.54	.47
Headache	45	0.02	.89
Dizziness/Faintness	45	1.57	.22
Loss of Appetite	45	.33	.57
Stomach Ache	45	0.06	.81
Nausea	45	10.09	.30
Heart Racing	45	3.58	0.07

4.4 Performance

4.4.1 Stroop performance

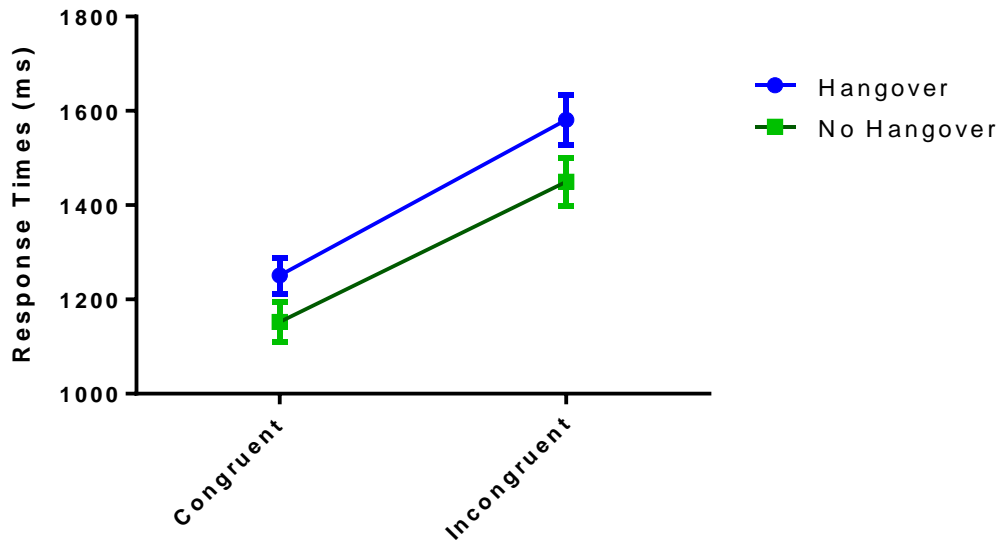
A 2x2x2 analysis of variable was carried out in order to investigate State, Order and congruency (congruent, incongruent). A summary of response times and error rates across testing sessions and between Condition are presented in Table 4.3. Mean response times for congruent items in the hangover testing sessions were 1249.46 ms (SD=252.62) and 1144.18 ms (SD=280.97) in the No Hangover testing sessions. Mean response times to incongruent items were 1586.53 ms (SD=346.44) and 1438.52 (SD=345.79) in the Hangover and No Hangover testing sessions respectively. Table 4.3 demonstrates the means of response times and errors made in this task.

Table 4.3 Mean Congruent and Incongruent response times as well as mean number of Errors on Stroop performance

	Order 1 (N=26)		Order 2 (N=19)	
	Hangover	No Hangover	Hangover	No Hangover
<i>Congruent</i>	1242.56 (239.82)	1101.32 (2710.04)	1258.91 (275.58)	1202.84 (290.96)
<i>Incongruent</i>	1616.61 (361.65)	1378.43 (316.31)	1545.36 (329.59)	1520.76 (375.46)
<i>Stroop Errors</i>	5.19 (1.55)	5.15 (1.67)	5.58 (20.06)	5.84 (1.86)

The analysis revealed a main effect of congruency ($F(1, 43)=188.51, p<0.0001$) with longer response times for incongruent items; and a main effect of State ($F(1, 43)=5.25, p=0.03$) with longer response times during the Hangover testing session ($M=1415.86, SD=299.53$) than in the No Hangover testing session ($M=130.84, SD=313.48$). However, congruency and State did not interact ($F(1, 43)=10.01, p=.32$). Moreover, there was no effect of Congruency by State by Order was not significant ($F(1, 43)=3.89, p=0.055$). Order and Congruency did not interact ($F(1, 43)=.26, p=.61$). Errors made during the Stroop task did not differ across State ($F(1, 43)=0.08, p=.77$) or Order ($F(1, 43)=20.03, p=.16$). A first order interaction between State and order did not reach significance ($F(1, 43)=.16, p=.69$).

Figure 4.2 Congruency and State response times for Stroop task



4.4.2 Eriksen's Flanker Task

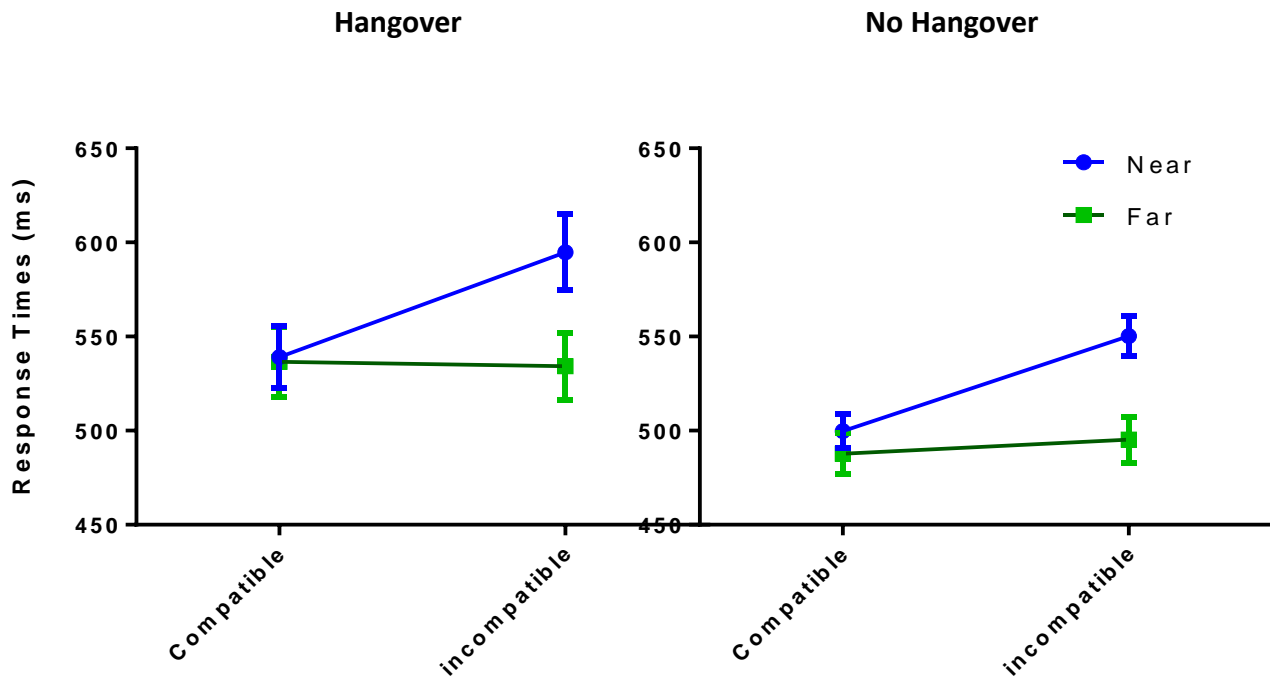
A 2x2x2x2 mixed measures Anova was carried out on State, Condition, Compatibility (compatible, incompatible) and Distance (near, far) to investigate performance on Eriksen's Flank Task. Table 4.4 shows the means and standard deviations of the 5 output variables of Eriksen's Flanker Task between Orders 1 and 2, and within State Conditions. Mean response times for compatible near items were 537.41 (SD=108.54) during a hangover and 501.84 (SD=61.88) without a hangover. Incompatible near items were responded to in 594.92 ms (SD=61.88) without a hangover. Incompatible near items were responded to in 594.92 ms (SD=131.68) in the Hangover testing sessions and 551.69 ms (SD=70.75) in the No Hangover sessions. Compatible far items were responded to in 537.45 ms (SD=1220.00) and 4890.02 (SD=710.00) in Hangover and No Hangover States respectively. Finally, incompatible far items were responded to in 533.98 ms (SD=1170.00) during a hangover and 496.36 (80.66) without a hangover.

Table 4.4 Means and standard deviations of response times on Near Compatible, Near Incompatible, Far Compatible, Far Incompatible and Error variables from Eriksen's Flanker Task.

	Order 1 (N=26)		Order 2 (N=19)	
	Hangover	No Hangover	Hangover	No Hangover
<i>Near Compatible</i>	528.29 (760.00)	512.94 (67.45)	549.90 (143.16)	486.66 (51.20)
<i>Near Incompatible</i>	595.49 (92.24)	559.27 (75.20)	594.14 (174.84)	541.32 (64.69)
<i>Far Compatible</i>	542.23 (1060.07)	495.51 (80.81)	530.91 (143.80)	480.13 (57.39)
<i>Far Incompatible</i>	532.85 (94.85)	502.69 (93.52)	535.52 (144.79)	487.70 (60.17)
<i>Errors</i>	1.96 (1.37)	2.81 (2.59)	30.00 (2.38)	2.16 (1.83)

The results from the mixed measures analysis of variance showed a main effect of State ($F(1, 43) = 4.77, p = 0.03$; Figure 4.3) with overall slower response times during the hangover testing sessions (see Figure 4.3). As expected there was a main effect of distance ($F(1, 43) = 72.39, p < 0.0001$) and a main effect for compatibility ($F(1, 43) = 39.74, p < 0.0001$). Furthermore, there was an interaction between compatibility and distance $F(1, 43) = 52.18, p < 0.0001$. This interaction was expected however, it was not moderated by the variable of State ($F(1, 43) = .97, p = .33$).

Figure 4.3 Response Times for Compatible Near, Compatible Far, Incompatible Near and Incompatible Far items across State.



4.4.3 Free Recall

The means and standard deviations of the number of words recalled are displayed in Table 4.5. The mean words recalled in the hangover State was 7.40 (SD=30.05) and in the no hangover State the mean number of words recalled were 9.31 (SD=2.50). Moreover, an analysis of variance revealed a main effect of State ($F(1, 43)= 13.89, p=0.001$), however, Order did not reach significance ($F(1, 43)=1.50, p=0.227$). Moreover, State and Order did not interact ($F(1, 43)=.16, p=.69$)

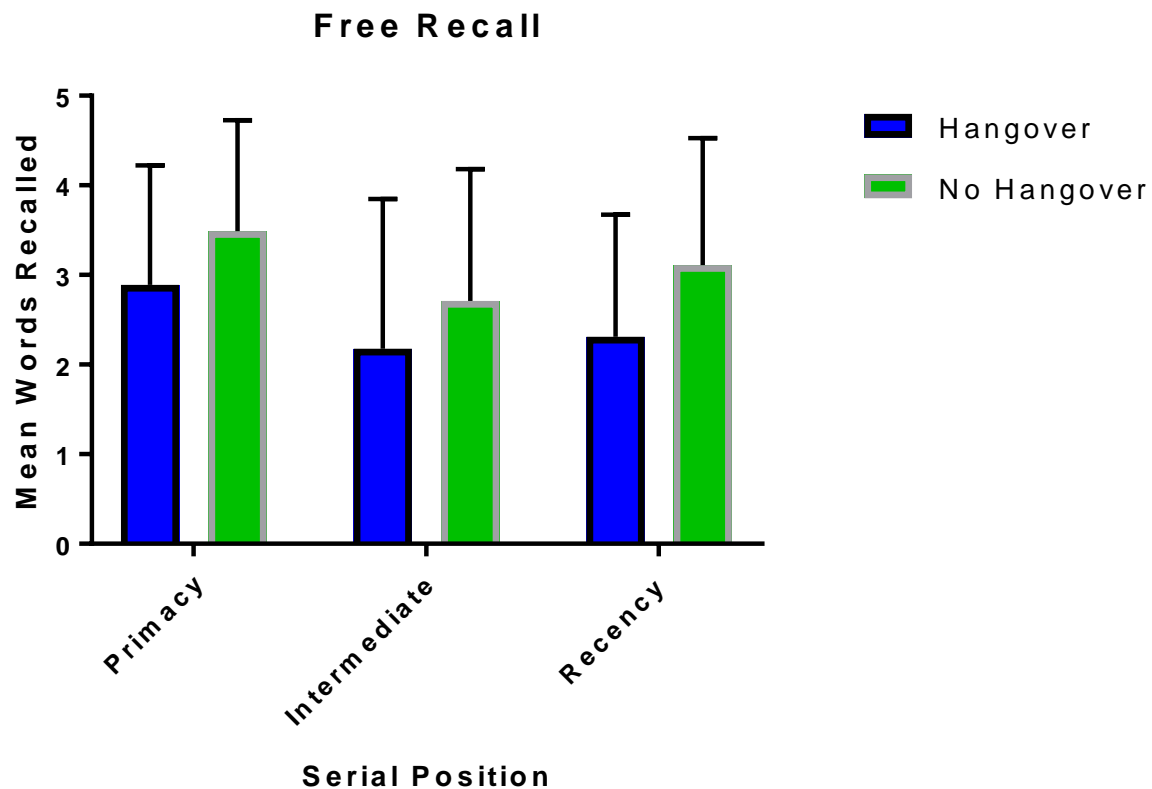
Table 4.5 Mean number of words recalled at Order 1 and Order 2 in both Hangover and No Hangover States

	Order 1 (N=26)		Order 2 (N=19)	
	Hangover	No Hangover	Hangover	No Hangover
<i>Free Recall</i>	7.92 (3.12)	9.58 (2.79)	6.68 (2.87)	8.95 (20.07)

4.4.4 Serial Positioning

A mixed measures analysis of variance was carried out on State, Order and Serial Position (Primacy/Intermediate/Recency). As serial position variables contained unequal numbers of items, serial position variables were divided by the number of items collapsed into the variable. The primacy variable (first six items in word list) was divided by six, intermediate (middle eight items) was divided by eight and Recency (last six items) was divided by six. As expected, the results showed a main effect of State ($F(1, 43)=14.52$, $p<0.0001$; Figure 4.4). There was no effect of Order ($F(1, 43)=.137$, $p=.16$). However, there was a main effect of serial positioning ($F(1, 43)=34.55$, $P<0.0001$). The first order interactions position and Order ($F(1, 43)=.57$, $p=.57$), State and Order ($F(1, 43)=.38$, $p=.54$), State and Position ($F(1, 43)=.49$, $p=.62$) did not reach significance. In addition, a second order interaction of Position, State and Order did not reach significance ($F(1, 43)=0.05$, $p=.77$).

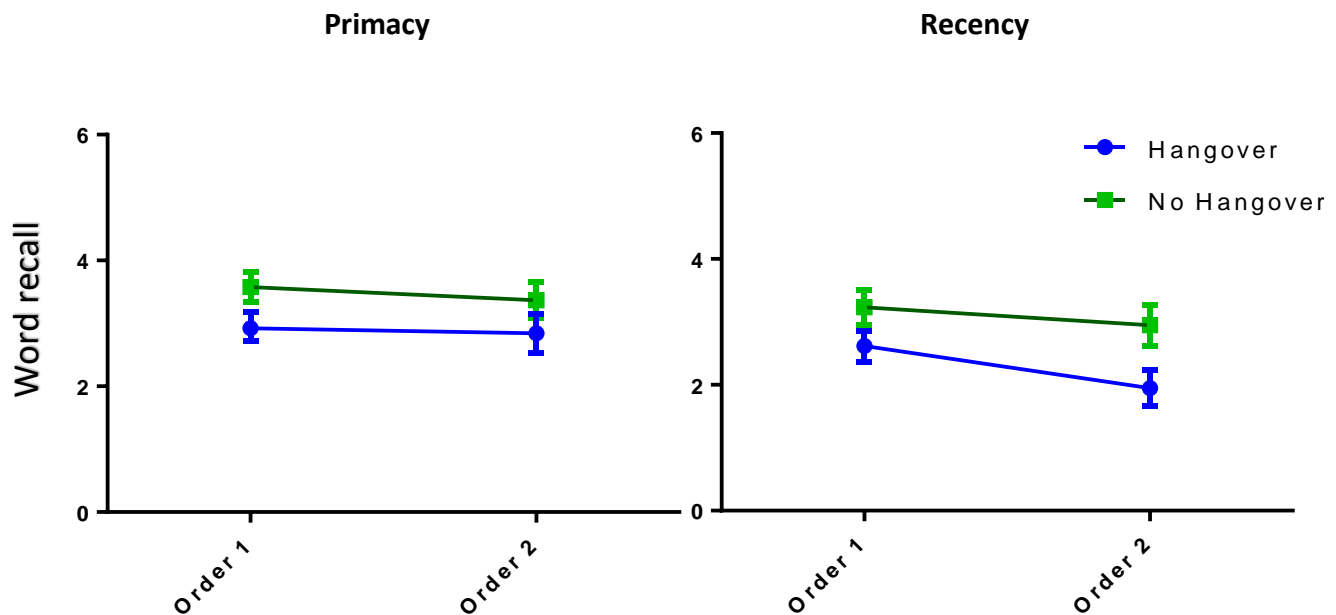
Figure 4.4. Serial positioning of words recalled across Hangover and No Hangover States.



Subsequent analyses using paired samples T-tests showed that the difference between hangover ($M=2.89$, $SD=1.34$) and no hangover ($M=3.49$, $SD=.24$) States for primacy items was not significant ($t(44)=-20.00$, $p=0.052$; see Figure 4.5). There was a significant difference between scores in hangover and no hangover sessions for words in the recency variable ($t(44)=-2.95$, $p=0.01$; see figure 4.5). However, State did not reach significance for items in the middle of the list ($t(44)=-1.66$, $p=.105$). In the hangover sessions, the average word score was higher at the beginning of the word list than the end ($t(44)=2.16$, $p=0.036$) as well as in the middle ($t(44)=5.73$, $p<0.0001$). Also, more words were recalled from the end of the list than the middle in the hangover State ($t(44)=2.92$, $p=0.01$). T-test analysis on No Hangover serial positioning

showed that the average word recall at the beginning and end of the list did not differ ($t(44)=1.53$, $p=.13$). However, primacy and intermediate words differed significant in the no hangover sessions ($t(44)=5.47$, $p<0.0001$) and more words were recalled from the end of the list than the middle in the hangover State ($t(44)=3.99$, $p<0.0001$).

Figure 4.6 Mean word recall and standard error of primacy and recency items across State and between Order



4.4.6 Intra Extra Dimensional Set Shifting Task

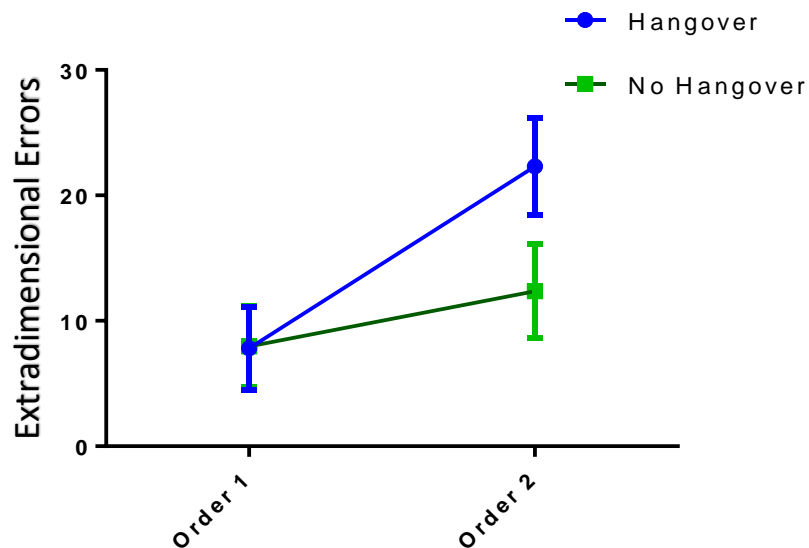
A two factor repeated measures multivariate analysis of variance did not show a significant difference across States ($F(1, 43)=.184$, $p=.31$) or between Orders for stages complete ($F(1, 43)=2.48$, $p=.123$). The Total Trials variable represents the total trials completed on all attempted stages. Significantly more trials were completed in the hangover State

($M=80.38$, $SD=14.19$) than in the no hangover State ($M=73.89$, $SD=13.62$; $F(1, 43)=7.79$, $p=0.008$). Of note, six consecutive correct responses (trials) must be completed in order to move to the next stage of the test and a participant must complete 50 trials to fail a stage.

A large main effect of State was found when total trials were adjusted for stages that were not completed ($F(1, 43)=17.15$, $p=0.0001$) with more trials in the hangover State than in the no hangover State. 'Total Trials Adjusted' did not interact with Order of testing session ($F(1, 43)=2.7$, $P=.11$). Significantly fewer extradimensional errors were made by participants during the no hangover session than the hangover session ($F(1, 43)=4.47$, $p=0.04$) and fewer errors were also made between Order 1 (H/NH) and Order 2 (H/NH) groups ($F(1, 43)=4.57$, $P=0.04$). Moreover, a first order interaction of State by Order reached significance ($F(1, 43)=4.76$, $p=0.04$).

Figure 4.6 shows that more errors were made in the Hangover State when participants were hungover in the second testing session than in the first. Moreover, extradimensional errors did not differ significantly within hangover and no hangover sessions at Order 1 (see Figure 4.6; $t(25)=-0.08$, $p=.93$). In contrast, intradimensional errors did not differ significantly across States ($F(1, 43)=1.2$, $p=.27$) or Order ($F(1, 43)=.1$, $p=.76$).

Figure 4.6. Mean number of Extradimensional Errors made in CANTAB's Set Shifting Task between Orders and across States



4.4.5 Spatial Working Memory

A three way mixed measures ANOVA comprised of the factors of State, Order and Task Difficulty (6 and 8 Box Errors; Table 4.6) was performed on these data. Four box errors were removed as descriptive statistics revealed a ceiling effect of 0 to 1 errors from this block (Hangover $M=0.80$, $SD=20.02$; No Hangover $M=.44$, $SD=1.4$). The analysis revealed a main effect of State ($F(1, 42)=6.26$, $p=0.02$) with fewer errors made in the no hangover State ($M=7.30$, $SD=6.27$) than in the hangover State ($M=10.22$, $SD=8.24$). As expected, a large main effect of task difficulty ($F(1, 42)=93.63$, $p<0.0001$) with fewer errors made in the 6 box Error block ($M=3.67$, $SD=4.34$) than in the 8 Box Error block ($M=13.90$, $SD=9.25$). However, State did not interact with difficulty ($F(1, 42)=2.18$, $p=.15$).

Table 4.6. N, F and p values from a mixed measures analysis on Spatial Working Memory Difficulty with State and Order

Variables	N	F	P value
Difficulty	43	93.626	0.000
Order	43	.677	.409
Difficulty * Order	43	.119	.732
State	43	6.258	0.016
State * Order	43	0.005	.942
Difficulty * State	43	2.183	.147
Difficulty * State * Order	43	.696	.409

A separate analysis was carried out to investigate Strategy on the spatial working memory task. Strategy refers to the number of times a participant starts a new trial with a different box. Significantly lower scores were found for strategy in the no hangover testing session ($M=27.71$, $SD=6.69$) than the hangover testing session ($M=30.04$, $SD=6.78$) indicating that a better strategy was applied when participants were not hungover ($F(1, 42)=4.31$, $p=0.04$). the results are displayed in Table 4.6.

Table 4.7. State and Order analysis on Strategy variable from Spatial Working Memory Task

Variable	N	F	Sig.
State	43	4.310	0.04
Order	43	1.323	.26
State* Order	43	.927	.34

4.4.6 Choice Reaction Time Task

The analyses on the mean response latency output (correct responses only) from the choice reaction time task revealed faster responses when participants were not hungover ($M=303.57$, $SD=30.17$) than when they were hungover ($F(1, 43)=16.50$, $p<0.0001$). Order did not interact with response time latency ($F(1, 43)=.87$, $p=.36$). The maximum correct latency was significantly larger during the hangover sessions than the no hangover sessions ($F(1, 43)=4.21$, $p=0.046$) and again, Order did not significantly impact the results ($F(1, 43)=2.60$, $p=.11$). Also, Order and State did not interact on the maximum latency on this task ($F(1, 43)=0.0$, $p=.82$). Similarly, the minimum correct latency was largest during hangover testing sessions ($F(1, 43)=6.32$, $p=0.02$) with a minimum response time of 221.62ms ($SD=310.06$) during a hangover and 209.36 ($SD=25.18$) during the no hangover sessions. This indicates that the slowest reactions to stimuli were made when participants were hungover and the fastest response times were made when participants were not hungover irrespective of the Order that testing took place. Order did not reach significance ($F(1, 43)=0.098$, $p=.76$) and

State and Order did not interact ($F(1, 43)=.139$, $p=.71$). From table 4.7, it can be seen that a ceiling effect occurred for the Correct Trials variable and floor effects can be seen in the omissions and errors variables, therefore repeated measures analyses were not carried out on these variables. Omissions referred to instances where participants responded to a stimuli too late. The low levels of omissions and errors were expected as the cognitive demand on this task was relatively low.

Table 4.8 Choice Reaction Time output variables pertaining to latency, trials and omissions across hangover and no hangover testing sessions and between Order 1 and Order 2.

	Hangover			No Hangover		
	Order 1	Order 2	Total	Order 1	Order 2	Total
	<i>N</i> =26	<i>N</i> =19	<i>N</i> =45	<i>N</i> =26	<i>N</i> =19	<i>N</i> =45
Mean Latency	325.29 (45.29)	322.80 (40.12)	324.24 (42.72)	301.73 (30.6)	3060.08 (30.21)	303.57 (30.17)
Max Latency	715.31 (255.65)	658.16 (234.11)	691.18 (245.71)	621.96 (230.08)	541.89 (112.56)	588.16 (191.99)
Min Latency	221.42 (34.20)	221.89 (270.09)	221.62 (310.06)	207.65 (24.51)	211.68 (26.56)	209.36 (25.18)
% Correct Trials	99.42 (.81)	99.63 (.60)	99.51 (.73)	96.69 (9.67)	99.58 (.96)	97.91 (7.46)
% Omissions	0.00	0.00	0.00	2.62 (9.24)	0.00	1.51 (70.09)
Total incorrect Trials	.50 (.65)	.37 (.60)	.44 (.62)	.58 (.86)	.42 (.96)	.51 (.90)

Definitions: Max=Maximum, Min=Minimum

4.5 Correlations

A Pearson's product-moment correlation was performed on the data to investigate the relationship between age, sleep, hangover symptoms, units consumed, performance and mood (See table 4.5). Of note, the difference between hangover and no hangover scores were

calculated for performance, sleep and mood variables by subtracting hangover from no hangover scores. The results revealed a positive correlation between units consumed and AHS score ($r=.39$, $p<0.0001$, $n=45$). This was expected as more hangover symptoms are likely to be reported by people who have consumed large amounts of alcohol the night before than those that have consumed small amounts. However, Intra dimensional errors and units consumed were the only other variables that correlated ($r=-.34$, $p=0.02$, $n=45$; Appendix 3).

4.6 Task Related Motivation

Unless otherwise Stated, a mixed measures analysis of Time by State by Order was run for each Task in order to examine task related motivation. Time represented task related motivation before and after each task (pre, post). The scale measured perceived Difficulty, Effort and Performance. A copy of the task related motivation questionnaire is presented in Appendix 1.

4.6.1 Stroop

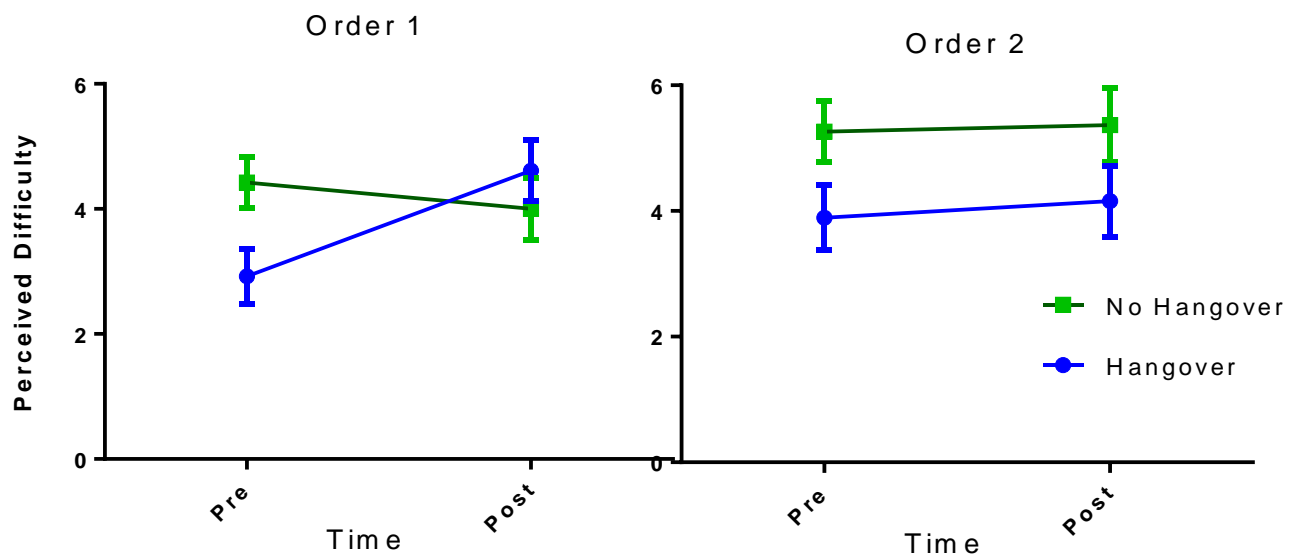
The results from the analysis of variance revealed a main effect of Time with lower levels of perceived Difficulty after task completion ($F(1, 43)=18.57$, $p<0.0001$). Moreover, there was a main effect of State with higher levels of task difficulty reported in the hangover sessions ($M=3.70$) than in the no hangover sessions ($M=2.88$; $F(1, 43)=4.66$, $p=0.04$). In terms of Effort made, the results did not differ significantly across Time ($F(1, 43)=2.89$, $p=.10$), State ($F(1, 43)=.79$, $p=.38$) or Order ($F(1, 43)=.45$, $p=.50$). Finally, analysis on perceived Performance revealed participants reported performing better on the task after task completion than before

task completion ($F(1, 43)=32.92, p<0.0001$). As well as this, participants' perceived task performance scores were significantly higher in the no hangover sessions than in the hangover sessions ($F(1, 43)=90.00, p=0.00$). However, time and State did not interact with perceived performance ($F(1, 43)=70.02, p=.11$).

4.6.2 Selective Attention

From the analysis on task Difficulty, a main effect of State was revealed with lower levels of task Difficulty reported in the no hangover testing sessions ($F(1, 43)=6.75, p=0.01$). Time did not interact with this variable ($F(1, 43)=2.57, p=.12$). However, a first order interaction of State and Time was revealed ($F(1, 43)=6.27, p=0.02$) and a second order interaction of Time by State by Order was revealed ($F(1, 43)=4.65, p=0.04$; see Figure 4.7).

Figure 4.7 The interaction between Time, State and Order for perceived task difficulty on Selective Attention task.

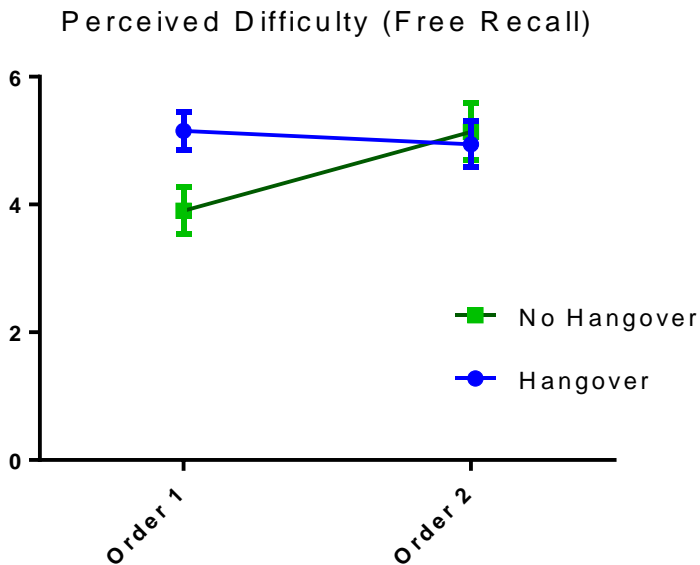


Perceived Effort on the task did not interact with State ($F(1, 43)=7.27, p=.26$), Order ($F(1, 43)=1.98, p=.17$) or Time ($F(1, 43)=1.65, p=.21$). However, a main effect of State on perceived task performance ($F(1, 43)=10.14, p<0.00$) demonstrated that perceived task performance was higher in the no hangover testing sessions than in the hangover testing sessions. However, Time did not interact with perceived performance ($F(1, 43)=.58, p=.45$). Also, perceived error did not differ across Orders ($F(1, 43)=0.06, p=.81$).

4.6.3 Free Recall

The analysis of variance that was carried out on task Difficulty did not reveal any main effects (Table 4.8). However, a first order interaction of State and Order was revealed ($F(1, 42)=5.14, p=0.03$). Figure 4.8 demonstrates the way in which Order interacts with Difficulty across States. From Figure 4.8. It can be seen at Order 2 Hangover ($M=5.15, SD=1.52$) and No Hangover ($M=4.94, SD=1.38$) ratings have similar values. In contrast, at Order 1, participants rated the task more difficult ($M=5.15, SD=1.62$) when hungover, than when not hungover ($M=3.90, SD=1.99$).

Figure 4.8. Perceived difficulty of Free Recall task at Order 1, Order 2, and Hangover and No Hangover sessions.



The analysis carried out on perceived Effort did not show any significant interactions indicating that effort did not change across Time ($F(1, 42)=1.47, p=.23$), State ($F(1, 42)=1.87, p=.18$) or Order ($F(1, 42)=.77, p=.39$). However, there was a main effect of State on perceived task performance with participants reporting better performance in the No Hangover sessions than the Hangover testing sessions ($F(1, 43)=6.55, p=0.01$). Here the mean rating for task related perceived performance was 5.44 (SD=1.85) during a hangover and 5.74 (SD=1.73) when not hungover.

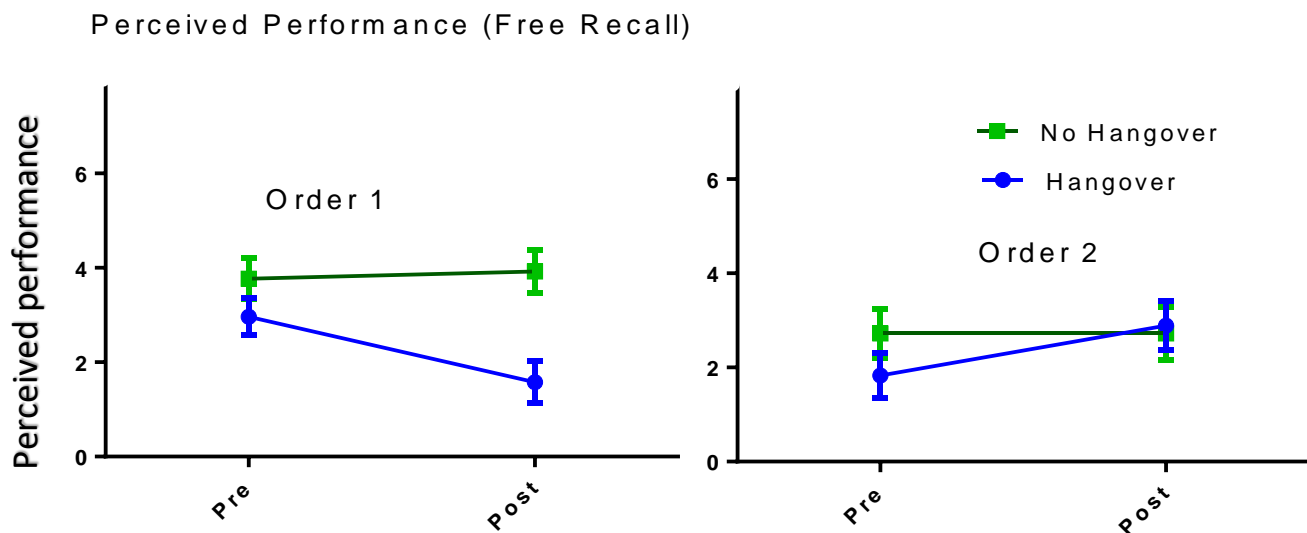
Table 4.9. Summary of interactions between Time, Order and State on Task Related Motivation scale questions pertaining to Performance, Effort and Difficulty

<i>Difficulty</i>	<i>N</i>	<i>F</i>	<i>P value</i>
Order	44	1.48	.23
Time	44	.52	.47
Time * Order	44	2.43	.13
State	44	2.75	.10
State * Order	44	5.14	0.03*
Time* State	44	0.01	.93
Time * State* Order	44	40.08	0.05
<i>Effort</i>			
Order	44	.77	.39
Time	44	1.47	.23
Time * Order	44	2.84	.10
State	44	1.87	.18
State * order	44	.29	.59
Time* State	44	.34	.56
Time * State* Order	44	0.01	.93
<i>Perceived Performance</i>			
Order	44	1.45	.24
Time	44	6.55	.85
Time * Order	44	2.58	0.01*
State	44	0.04	.12
State * order	44	6.60	0.01*
Time* State	44	.18	.67
Time * State* Order	44	5.22	0.03*

A three way interaction of Time by State by Order was also revealed ($F(1, 43)=5.22$, $p=0.03$). This indicates that when participants were not hungover at Order 1, participants

perceived their performance as better both pre ($M=3.77$, $SD=2.12$) and post ($M=3.92$, $SD=2.44$) than when hungover pre ($M=2.96$, $SD=2.14$) and post ($M=1.58$, $SD=20.08$) task. Moreover, at Order 1, performance was scored higher before task completion than after for hungover participants. In contrast, at Order 2 ratings remained the same pre ($M=2.72$, $SD=2.37$) and post ($M=2.72$, $SD=2.19$) task in the no hangover testing sessions. However, perceived performance was lower before the test was administered during the hangover testing sessions ($M=1.83$, $SD=1.79$) than after test completion ($M=2.89$, $SD=2.42$). The three way interaction is demonstrated in Figure 4.8.

Figure 4.8 Perceived Performance on Free Recall Task across Time and State and between Orders



4.6.4 Choice Reaction Time

The analysis carried out on Task Related Motivation of the Choice Reaction Time task revealed a main effect of Time ($F(1, 43)=4.86$, $p=0.03$) with task Difficulty reported to be higher

before task completion than after. However, State ($F(1, 43)=.96, p=.33$) and Order ($F(1, 43)=3.85, p=0.06$) did not interact with perceived Difficulty. The three factor analysis on effort revealed no main effects or interactions of perceived Effort on the Choice Reaction Time task (See Table 4.9) Moreover, there were no main effects or first order interactions displayed in the analysis on perceived task Performance as demonstrated in Table 4.10. However, Order, State and Time interacted with perceived performance ($F(1, 43)=4.67, p=0.04$)

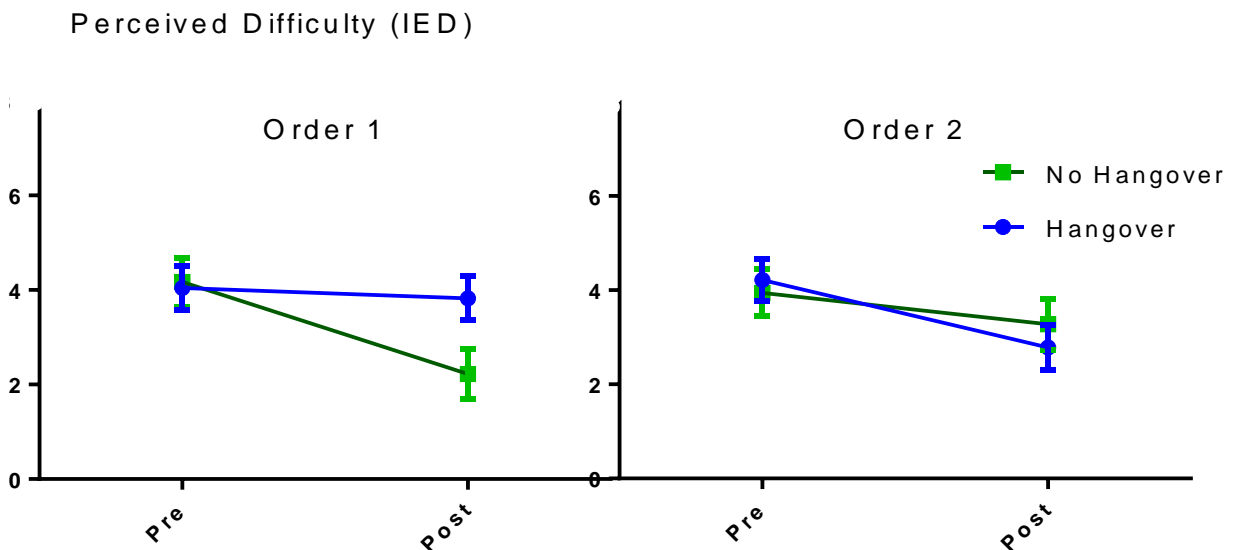
Table 4.10. Analysis of Task Related Motivation (Choice Reaction Time) across Time, State and Order variables.

<i>Difficulty</i>	<i>N</i>	<i>F</i>	<i>P value</i>
Order	45	3.85	0.06
Time	45	.96	.33
Time * Order	45	.74	.39
State	45	4.86	0.03
State * Order	45	1.60	.21
Time* State	45	.50	.48
Time * State* Order	45	1.25	.27
<i>Effort</i>			
Order	45	1.53	.22
Time	45	0.07	.79
Time * Order	45	.46	.50
State	45	0.03	.87
State * order	45	1.50	.23
Time* State	45	.15	.70
Time * State* Order	45	.53	.47
<i>Perceived Performance</i>			
Order	45	.23	.64
Time	45	0.00	.96
Time * Order	45	2.24	.14
State	45	.18	.67
State * Order	45	.30	.59
State * Order * Time	45	4.67	0.04
Time* State	45	.11	.74
Time * State* Order	45	4.67	0.04

4.6.5 Intra-Extra Dimensional Set shifting

A mixed measures analysis on task Difficulty revealed a main effect of Time with decreased task Difficulty after task completion ($F(1, 43)=12.48, p<0.05$) with higher levels of task difficulty reported before completing the task. State did not interaction with perceived difficulty ($F(1, 39)=0.00, p=.98$) and Order did not reach significance ($F(1, 39)=.55, p=.47$). However, a three way interaction of Time by State by Order reached significance indicating that State and Order interacted differently before and after the IED task ($F(1, 43)=4.48, p=0.04$). The interaction is demonstrated in Figure 4.8.

Figure 4.8 Perceived Difficulty on Attentional Set Shifting Task across Time, State and Order



The analysis on perceived effort revealed a main effect of Time only with higher perceived difficulty before the task than after ($F(1, 43)=10.45, p=0.00$). State did not affect

perceived effort in this task ($F(1, 43)=0.001, p=.98$) and Time did not interact with perceived effort ($F(1, 39)=0.01, p=.94$). Finally, investigations into perceived performance in the Choice Reaction Task revealed no main effects, indicating that neither Time ($F(1, 39)=.14, p=.71$), State ($F(1, 39)=0.04, p=.84$) nor Order ($F(1, 39)=.29, p=.60$) impacted on perceived performance.

4.6.6 Spatial Working Memory

Analysis on task difficulty for Spatial Working Memory did not reach significance for Time ($F(1, 42)=.20, p=.66$) and State ($F(1, 42)=.34, p=.56$) variables. However, a main effect of Order was revealed ($F(1, 42)=4.75, p=0.04$), showing that participants in Order 1 ($M=3.21, SD=1.11$) reported higher levels of task difficulty than those in Order 2 ($M=2.41, SD=1.26$). This interaction was not repeated for perceived effort ($F(1, 43)=0.001, p=.98$). The analysis on Effort in this task revealed no main effects or interactions (Table 4.11). Moreover, perceived performance did not interact with Time, State or Order variables ($p>0.05$; Table 4.11).

Table 4.11. Perceived Difficulty, Effort and Performance (SWM) on Order, Time and State.

<i>Difficulty</i>	<i>N</i>	<i>F</i>	<i>P value</i>
Order	44	4.75	0.04*
Time	44	.20	.66
Time * Order	44	.40	.53
State	44	.34	.56
State * Order	44	.77	.39
Time* State	44	.12	.73
Time * State* Order	44	1.87	.18
<i>Effort</i>			
Order	44	0.00	.98
Time	44	10.04	.31
Time * Order	44	1.92	.17
State	44	.22	.64
State * order	44	.78	.38
Time* State	44	.83	.37
Time * State* Order	44	0.07	.79
<i>Perceived Performance</i>			
Order	44	.23	.64
Time	44	.87	.36
Time * Order	44	.50	.49
State	44	1.10	.30
State * order	44	.66	.42
Time * State	44	0.08	.78
State * Order * Time	44	1.50	.23

4.7 Discussion

4.7.1 Summary

The present study demonstrates Hangover effects on Stroop performance, Selective Attention, Free Recall, Intra-Extra Dimensional Set Shifting, Spatial Working Memory and Choice Reaction Time tasks. Stroop interference and Selective Attention responses times were slower in the Hangover testing sessions than in the No Hangover testing sessions. Significantly more words were recalled in the Free Recall task during the No Hangover testing sessions than in the Hangover testing sessions. In relation to Intra-Extra Dimensional Set Shifting, more extradimensional errors were made when participants were hungover than when they were not hungover, however, State did not influence intra dimensional errors. Similarly, in the spatial working memory task, more errors were made by participants during the Hangover sessions than during the No Hangover sessions. Finally, an analysis on the Choice Reaction Time task revealed that response times were longer during a Hangover than when the participants were not hungover. The results indicate that a non-student sample in a natural environment display cognitive impairment during a hangover. Moreover, the results suggest that task errors are significantly increased in non-time restricted tasks with high difficulty levels. For example, task errors are not significantly different across States in Selective Attention and Stroop performance tasks, however the intra-extra dimensional set shifting task revealed that more errors are made in more difficult blocks within their tasks (extra-dimensional errors).

4.7.2 Performance Measures

4.7.2.1 *Stroop*

As expected, there was a main effect of congruency. This supports the theory surrounding the Stroop Effect which argues that congruent stimuli take less time to respond to than incongruent stimuli due to response competition between the cognitive mechanisms mediating word and colour content (MacLeod, 2015). There was a main effect of State with slower response times in Hangover testing sessions than No Hangover testing sessions. These results corroborate the findings of Study 1 of this thesis and another study by McKinney, Coyle, Penning and Verster (2012). Both of these studies which have explored Stroop performance during a Hangover have employed student samples. The following results demonstrate Stroop impairment in a non-student sample. Thus, it can be concluded that despite differences in drinking experience, Stroop detriments are similar across samples as well as within and between factor designs.

The findings from the Stroop task are corroborated by the results from the Task Related Motivation questionnaire as participants reported higher levels of task difficulty when hungover. Perceived effort did not differ across testing sessions, however perceived performance scores were higher during the No Hangover testing sessions than the Hangover testing sessions. This suggests that although a similar amount of effort was solicited, the task was more demanding during a Hangover and thus performance was impaired.

4.7.2.2 *Eriksen's Flanker Task*

As expected, there was an overall main effect of distance and compatibility, and an interaction between compatibility and distance which supports Eriksen's Spotlight Theory (Eriksen, 1986). The theory suggests that when incongruent flankers are presented within a 1 degree angle of the target (visual field) then response times are slowed, however, when incompatible flankers are presented outside of the visual field then they do not distract the participant from attending to the target and thus, responses are not slowed (Eriksen, 1986). As shown in previous Hangover research (McKinney & Coyle, 2004), response times were slower across compatible near, compatible far, incompatible near and incompatible far variables in the Hangover sessions. These results suggest that a spotlight effect occurs in the Hangover and No Hangover State, however, responses to all targets are slowed in the Hangover State. Moreover, the blanket effect of slowed responses is also evident in Study 1 and McKinney, Coyle, Penning and Verster's (2012) study. This suggests that a Hangover impacts Selective Attention similarly in both student and non-student samples as well as across between and within factor designs.

The task related motivation questionnaire revealed that perceived task difficulty was higher during a Hangover than during No Hangover testing sessions. Moreover, there was an interaction of Time, State and Order. The interaction indicates that the way in which Time (pre, post) and State interact differs between Order 1 and Order 2 groups. At Order 1, before task completion perceived difficulty was considerably higher during a Hangover than during No Hangover sessions. It is possible that this may reflect a lowered self-efficacy in the Hangover State as confidence has been shown to be lowered in a Hangover State (McKinney, 2003). After task completion, perceived difficulty was much lower indicating that the task was perceived as

less difficult than first anticipated. In contrast, at Order 1, during the No Hangover testing sessions participants reported a lower pre-testing difficulty rating than the Hangover sessions and this increased after the task was completed. Indeed, post-test, perceived difficulty was lower in the Hangover sessions than in the No Hangover sessions. These finding may contribute to the Hangover effects on task performance as according to Maynard and Hake (1997), decreased levels of perceived task difficulty increase task performance.

At Order 2, pre-test perceived Difficulty in Hangover and No Hangover sessions were higher than post-test perceived difficulty. However, there were overall higher perceived Difficulty scores during the Hangover testing session. At the first testing session, participants perceived the task with low levels of Difficulty both before and after task completion. However, on the second testing session participants perceived the task as considerably more difficult as they were hungover. Participants reported higher levels of task Performance while in the No Hangover sessions than in the Hangover sessions and effort did not differ across variables. This suggests that variance in Performance cannot be accounted for by changes in Effort. However, further research on task related motivation is needed in order to account for State and Order differences reported for this task.

4.7.2.3 Free Recall

The results from the Free Recall task showed a main effect of State with less words recalled when participants were hungover. This corroborates the results from McKinney and Coyle's (2004) and Howland et al.'s (2010) research as well as the findings from the previous Chapter indicating that Free Recall is impaired across samples of participants with varying

drinking experience and this effect has been found in both between and within factor designs. In terms of task related motivation participants appeared to report higher levels of task performance when not hungover. Moreover, the way in which State and Time interacted differed at Order 1 and Order 2.

At Order 1, participants reported high levels of task Performance both before and after task completion during the No Hangover testing sessions. However, when hungover, participant perceived task Performance lowered considerably from pre task to post task. At Order 2, a medium level of perceived task Performance was reported both pre and post task completion by participants in the No Hangover session. However, when participants were hungover perceived task Performance was low before task completion and increased to medium post task completion. It is note that the Free Recall tasks differs from other tasks administered as participants are able to gauge their performance post task as all words recalled can be counted before submission.

The results from the Serial Positioning analysis revealed that more words were recalled at the beginning and end of the word list as expected. More words at the beginning of the word list were recalled by participants that were not hungover than when the participants were hungover; and State approached significance. However, the only significant effect of State was found in items at the end of the word list. As items from the end of a word list are associated with passive, short term recall it may be posited that recency effects are more prominent when participants are hungover. And long term memory associated with the rehearsal process of words from the beginning of the list is not impaired. Contrary to the conclusions of Stephens, Grange, Jones and Owen (2014) that suggest that episodic long term memory is impaired after

a night's drinking but short term memory is not, these results provide evidence that short term memory is impaired to a larger degree than longer term memory. Nonetheless, the evidence from Study 1 supports the evidence provided by Stephens, Grange, Jones and Owen (2014). As a result, the contrasting results from the serial positioning analysis may be accounted for by the experimental design or the sample of participants of which were older than the samples referenced by Stephens, Grange, Jones and Owen (2014).

4.7.2.4 Choice Reaction Time Task

As expected, the Choice Reaction Time Task revealed a main effect of State with participants responding slower in the Hangover testing sessions than in the No Hangover testing sessions. These results support the conclusions made from the Selective Attention analysis as they indicated slowed responses to time constricted yet low level cognitive demands. Moreover, these results support the findings that decision making and motor skills are impaired the morning after a night's drinking (Grange, Stephens, Jones & Owen, 2016; McKinney & Coyle, 2004). In terms of task related motivation there were no effects of State or Order.

4.7.2.5 Intra-Extra Dimensional Set Shifting

The results indicated that the number of stages completed did not differ across States. However, more extradimensional errors were made in the Hangover testing session than in the No Hangover sessions and intradimensional errors did not differ across States. These results suggest that although rule acquisition (stages) did not differ across States, impairment in Hangover testing sessions occurred when task demands became more complex (after set shift).

Thus, Hangover effects only occurred as task difficulty increased. Of note, differences in errors made across States have not been shown in time restricted attention tasks (Roehrs et al., 1991; Rohsenow et al., 2010; McKinney et al., 2012) indicating that a speed-accuracy trade off results in increased response caution in hungover participants (Rabbitt, 1979). The results from this task demonstrate decrements in complex learning capabilities after a night's drinking.

An interaction between State and Order of extradimensional errors showed that Hangover and No Hangover errors did not differ at Order 1. However, considerably more errors were made in the Hangover sessions than in the No Hangover sessions at Order 2. Although, a conclusion cannot be made using the results from this analysis, it is possible that increased caution may have occurred on the first testing session at Order 1 which may have decreased the errors made in the hungover State. According to Dutilh (2012), practice results in a decrease in response caution in attention task. Thus, this may explain high levels of extradimensional errors in the Hangover sessions at Order 2. It is possible that this effect may not be evident at Order 1 as the participants were hungover on their first testing session which may have hindered their ability to recall the task on the 2nd testing session. Moreover, as participants were aware of their Hangover State at Order 1, a further increase in caution may have occurred however, caution may have not been pronounced during the Hangover session at Order 2 as participants were already familiar with the task.

Task Related Motivation analyses revealed no main effects of State or Order for perceived Difficulty, Effort or Performance. However, a three way interaction of Time, State and Order was revealed for perceived difficulty. It can be seen that at Order 1 there is a slight decrease in difficulty ratings from pre to post task during the Hangover sessions; and at Order 2

there is a slight decrease in difficulty from pre to post task in No Hangover sessions. Similarly, a steep decline in perceived difficulty occurred at Order 1 in the No Hangover testing session across time and a similar decline is evident in the Hangover session at Order 2. These contrasting results appear to represent an order effect where perceived pre task difficulty is rated higher in the 2nd testing session and decreases considerably after task completion.

4.7.2.6 *Spatial Working Memory*

The findings of the Spatial Working Memory task showed that more errors were made in the Hangover testing sessions than in the No Hangover testing sessions. As expected there was a main effect of task difficulty. In contrast to the finding from the intra-extra dimensional set shifting task, State do not have a differential effect on levels of task difficulty. Furthermore, a better strategy was applied in the No Hangover testing sessions than in the Hangover testing sessions. Strategy represents the number of times that a participant begins a new trial with a different box. This task tests executive functioning, as well as one's ability to manipulate remembered items (Cambridge Cognition, 2018). As a result, this task represents a novel approach to memory measurements as previous research on memory during a Hangover have applied immediate and delayed recall tasks (Taylor et al., 1996; McKinney & Coyle, 2007). There were no noteworthy results from the task related motivation questionnaire.

4.7.3 Demographic information

The mean age of participants was 32.73 years with a 19-60 year range. This does not correspond to previous Hangover research that has been carried out on student samples as

they are often of a younger age (Finnegan et al, 1998; McKinney & Coyle, 2004; Howland et al, 2010).

The mean age of first drink was 15 years, this supports the finding of previous studies by Morean et al. (2014), SAMHSA (2014) and Health and Social Care Information Centre (2015). Most participants reported consuming alcohol once or twice a week. However, during alcohol consumption more than half of participants report consuming more than 6 alcoholic beverages. According to NHS (2017), 6 or more units constitutes a binge drinking episode which equates to 2-3 standard glasses of (13%) wine or 2-3 pints of 4% lager indicating that the sample recruited in this study were binge drinkers.

Furthermore, 71% of participants reported consuming alcohol in a pub or bar. Moreover, this finding gives support to the argument that the public house remains an important part of society (Cunningham, 2013). The evidence supports the findings by McKinney (2003) that showed that 68.6% of respondents in a survey reported consuming alcohol in a pub. Nonetheless, the prevalence of pub drinking found in this study is higher than that found in studies carried out on student samples. For example, Clapp, Segars and Shillington (2000) using a sample of 401 participants found that 42% of student drinkers reported consuming alcohol most often in a pub, this is also corroborated in Chapter 3 of this thesis as 43% of participants reported consuming alcohol most often in a pub. However, as recruitment took place in a public house, the preference of public house drinking was expected and is reflected in the findings. The 'Lager or Cider' category was the most popular alcohol type of choice, with a mean of 14.53 units consumed. Moreover, of those that consumed 'Lager or Cider' a mean of 14.53 units

of such were consumed. This indicates that people who consume 'Lager or Cider' are more likely to consume higher volumes of alcohol than any other type of alcohol consumers tested.

On the night before the Hangover testing sessions participants consumed an average of 15.32 units. This is comparable to other naturalistic hangover studies (15.5 units; Finnigan, Schulze, Smallwood & Anderson, 2005). However, more alcohol was consumed by the non-student sample in this study than the student sample used in the previous study (12.85 units). More than half of the participants recruited in this study reported consuming drugs; and cannabis was the most popularly consumed drug. These findings are higher than the national average in Ireland (27% in lifetime, 7% in past year; National Advisory Commission on Drugs, 2011) and the UK (34.7% in lifetime, 8.4% past year; Home Office Statistics Unit, 2015; Home Office Statistics Unit, 2016). However, the high levels of drug use may be linked to the prevalence of binge drinking in this sample. According to a survey by Wechsler, Dowdall, Davenport, and DeJong (1995) using 484 respondents, frequent binge drinkers are almost three times more likely to smoke cigarettes; four times more likely to use cannabis; five times more likely to use amphetamines and LSD; and six times more likely to use hallucinogens compared to non-binge drinkers (in the past year). Moreover, the authors found that more than half of frequent binge drinkers used cannabis and cigarettes in the past year, compared to 13% and 22% of non-binge drinkers.

Furthermore, evidence also suggests that illegal drug use is increasing. The National Centre on Addiction and Substance Abuse (CASA, 2007) found that student illegal drug use in America rose from 30.6% to 36.6% between 1993 and 2005. Research carried out in Ireland showed that between 2002/03 and 2014/15 the percentage of people age 15-64 years having

tried cannabis rose from 18.5% to 30.7% (National Advisory Committee on Drugs and Alcohol, 2016). In the UK, 35% of adults aged 16-59 have tried illegal drugs with 8.4% having consumed illegal drugs in the past year (Lader, 2016).

In terms of sleep, there was no significant difference in hours of sleep between Hangover and No Hangover sessions. Of note, evidence suggests that alcohol decreases sleep onset time and causes one to wake up earlier than usual (Kleitman, 1939; Feige et al, 2006; Roehrs & Roth, 2001). As a result, differences in hours of sleep were not expected. However, these results do not support the findings of the previous study (Chapter 3). It was speculated that differences in sleep may be explained through later bedtimes in Study 1. Interestingly, the previous study was carried out on university students on week days and the current study was carried out on participant during non-working days. Thus, although participants went to bed later after alcohol consumption they also got up later as there were not work obligations the following day.

As in the previous study, subjective Alertness was higher in No Hangover testing sessions than in Hangover testing sessions. Furthermore, participants reported higher levels of Tranquillity during No Hangover testing sessions than Hangover testing sessions. These results support the findings of McKinney and Coyle (2006) and Penning, McKinney and Verster (2012). In terms of Acute Hangover Scale, the total mean score was 14.38. As expected, Tiredness scored highest in the scale which supports the findings from Verster, van Herijnen, Olivier and Kahler (2009).

4.7.4 Limitations

This study may be limited by the variation in testing times as participation took place from the opening of the premises (between 10.30 a.m. and 12.30.p.m) until 3p.m. in accordance with public house legal opening hours (Vintners Federation of Ireland, 2018). Diurnal effects have been found in cognitive performance. E.g. short term memory is superior early in the morning and deteriorates over the day (Baddeley, 1970). Therefore, it is possible that the time of testing may have affected performance on the tasks administered in this study. Future studies should implement time of day analysis investigation if diurnal effects confound performance while in a hungover State.

4.7.5 Conclusion

In summation, this novel approach to the naturalistic design of hangover research provides a foundation from which future studies can build a more real life measurement of the alcohol hangover. Stroop, Selective Attention and Free Recall appear to be comparable across samples and designs. However, serial positioning analyses revealed differing effects of primacy and recency from Study 1. Further replication of Free Recall, Spatial Working Memory and serial positioning analyses are required in order to investigate if the results can be accounted for by design or sample differences. The results from the Stroop, Selective Attention and Choice Reaction Time task support the argument that hungover participants responses to stimuli are slowed irrespective of task difficulty. However, the results from the Attentional Set Shifting task indicate that an increased number of errors are made by hungover participants when the task becomes more complex. Further research on attention in both time and non-time restricted tasks is required to gain a more comprehensive understanding of the attentional processes

impacted by a hangover. In particular, future research should look towards a hangover's impact on decision making, planning and executive functioning.

5. The Alcohol hangover and attention

5.1 Introduction

Attention is made up of a series multicomponent processes (Pilcher, Band, Odle-Dusseau, Muth, 2007; Sarter, Givens & Bruno, 2001; Sturm & Willmes, 2001) which have been under-represented in hangover research. To date, one study in recent years has addressed attention exclusively. McKinney, Coyle, Penning and Verster (2012) investigated Selective Attention, Stroop Performance, Divided Attention, Spatial Attention and Sustained Attention. The results revealed a significant effect of the hangover State on Stroop Performance, Sustained and Selective Attention but not on Spatial or Divided Attention. However, the authors of the study acknowledge that the study was carried out prior to a consensus on best practice in hangover research (Verster et al., 2010) and that proposed methodological adjustments would improve the accuracy of the results. This includes incorporating measurements of intoxication to hangover studies as well as applying a standardised set of tasks. In addition to applying the standardised attention tests applied in hangover research (Selective Attention, Psychomotor Vigilance and 5 Choice Serial Reaction Time Tasks) an Attentional Blink and Emotional Stroop task were also employed. No publications to date have carried out hangover testing sessions using these tasks (Google Scholar, 2018; ScienceDirect, 2018; ResearchGate, 2018; Psych info, 2018).

5.1.1 Attentional Blink

The Attentional Blink phenomenon was first described by Raymond, Shapiro and Arnell (1992). In the first 18 years since it was described Google Scholar recorded over 450 publications with the phrase “Attentional Blink” (Martins & Wyble, 2010). Today, Google Scholar (2018) has recorded 11, 800 journal articles relating to “Attentional Blink”. The

popularity of the Attentional Blink may stem from its focus on temporal aspects of attention which provided insight into how long a stimulus may occupy attentional capacity (Martins & Wyble, 2010). In hangover research most, attention tasks that have been implemented apply analysis to response time data (Collins & Chiles, 1980; Howland et al., 2010; Lemon, Chesher, Fox, Greeley & Nabke, 1993; McKinney & Coyle, 2004; McKinney, Coyle & Verster, 2012; Roehrs et al., 1991; Rohesnow et al., 2010; Verster et al., 2003). This task explores attention beyond the scope of response time tasks.

Several findings relating to the Attentional Blink paradigm which are noteworthy include findings by Olivers and Nieuwenhuis (2005) which showed if one's focus on target identification is reduced then the Attentional Blink magnitude is attenuated. To show this, Olivers and Nieuwenhuis (2005) recruited 66 participants, of which, 17 were assigned to a control Condition and free association (each), and 16 participants in music listening and reward Conditions (each). In the free association Condition, investigators asked participants to think about irrelevant topics or listen to unrelated music while an Attentional Blink task was administered. In the free association task participants were told to think about either their most recent holiday or their shopping requirements for an imaginary dinner with friends. In the music listening group, an unspecified rhythmic tune was played. In the reward Condition, participants were paid for their participation, however, the amount was not specified. A reward Condition was included because an explanation of improved performance may be due to increased motivation, by including this Condition, investigators were able to address this potential confounding variable.

The results showed that T2 accuracy increased in the free association group. The reward group did not show any improvement on performance. In addition, in the listening to

music group, performance was higher than any other Condition. The authors conclude that if the focus of participants differs then a change in Attentional Blink magnitude is likely to occur. It is worth noting that the free association Condition required participants to concentrate on positive activities (holiday, dinner with friends) and positive mood may be induced by thinking of these topics which in turn is likely to influence performance. For example, Vermeulen (2010) has shown that positive affect increases one's ability to report T2 in an Attentional Blink task. The type of music used in this study was not specified. However, Ho, Mason and Spence (2006) have demonstrated improved identification of T2 on Attentional Blink performance therefore one can postulate that the effect of mood and music may contribute to the finding by Olivers and Nieuwenhuis (2005).

5.1.2 Bottleneck Theory

Many theoretical explanations of the Attentional Blink phenomenon have been developed but an agreement among researchers has not been reached (Dux & Marois, 2009). One of the most notable models is the bottleneck model (Jolicoeur et al., 2001). Chun and Potter (1995) implemented categorical and perceptual targets in an Attentional Blink task in order to demonstrate a limitation of information processing. Here they presented black letter targets among black digit distractors (category) and red targets among black distractors (perceptual). The results showed that even when the features of targets and distractors differ categorically and perceptually, an Attentional Blink still occurs. Chun and Potter (1995) proposed a two-stage bottleneck model where at stage 1 stimuli are identified and at stage 2 information is encoded and moved to working memory. Thus, Stage 2 is capacity limited. If limitations in capacity result in Attentional Blink then working memory is likely to be involved

(Crebolder, Jolicoeur, & McIlwaine, 2002; Visser, 2012). However, increased working memory capacity does not appear to reduce the magnitude of Attentional Blink (Akyurek & Hommel, 2005). Therefore, the limited resources described in the bottleneck theory remain unclear and unsupported.

5.1.3 Gating Theory

Another theory of Attentional Blink is the gating theory (Raymond et al., 1992), here, it is proposed that post target stimuli are suppressed in order to prevent featural confusion. Thus, when target one (T1) is detected an attentional episode is triggered. This has been described as a hypothetical gate opening. To increase the probability of a correct response of T1, the post target stimuli are suppressed, in other words, the hypothetical gate is closed and remains this way until the identification of target one is completed. In this way, it is hypothesised that the Lag 1 sparing occurs as both T1 and T2 stimuli are presented directly after one another and therefore both stimuli are permitted through the gate. However, this theory does not explain the phenomenon whereby multiple targets are identified when presented in succession without distractors e.g. T1, T2, T3, T4 (Di Lollo et al., 2005; Kawahara, Kumada, & DiLollo, 2006; Lagroix, Spalek, Wyble, Jannati & DiLollo, 2012; Nieuwenstein & Potter, 2006; Olivers & Meeter, 2008; Olivers et al., 2007; Potter, Nieuwenstein, & Strohminger, 2008).

5.1.4 Interference Model

Finally, the interference model was created after the results of a study by Shapiro, Raymond, and Arnell (1994) revealed that the identification of T1 was not required for Attentional Blink to occur, rather, detection was all that was needed. In their study, Shapiro,

Raymond and Arnell (1994) carried out an experiment where participants were required to identify T1 (computer generated; B, G or S in white font, grey background) as well as T2 (X in black font, grey background). As expected an Attentional Blink occurred. In a subsequent experiment, participants were required to detect if a T1 was present or absent (a white letter) and to identify T2. Here, the participants were repeatedly told that the T1 letter was unimportant. Nonetheless, an Attentional Blink was also revealed through detection of T1 in this experiment indicating that Attentional Blink occurs through target one detection and identification. Thus, the results challenged the conclusions of the gating theory of the Attentional Blink paradigm which specifies the need for target identification to occur (Raymond et al., 1992). As a result, Shapiro, Raymond and Arnell (1994) proposed the interference model which suggests initial perception representations are created for each stimulus in the stream. Then using a template created when the task instructions are presented at the beginning of the task, participants are able to select the items which most closely matches the template, those items are then transferred into the visual working memory store. Once in visual working memory, the targets (T1 and T2) as well as their direct successors interfere with one another. Items are also ranked based on available space and similarity to the templates. As a result of limited space, T2 is thought to have a low-ranking position and thus, susceptible to interference from other items. Shapiro et al (1994) suggests that Attentional Blink is limited to around 500ms because visual short-term memory is flushed after this period of time. However, it can be argued that this is not the case as the identification T1 and T2 are often required after all the stimuli are presented (Morley, Howard & Henges, 2018). Shapiro also argues that lag 1 sparing

occurs because only three items enter the store e.g. T1, T2 and T2 successor). However, an explanation around why this occurs has not been offered.

None of the proposed models of the Attentional Blink can be fully supported by findings (Dux & Marois, 2009). However, it is probable that working memory, attentional selection, enhancement and engagement, distractor inhibition, episodic registration and response selection are all implicated in the Attentional Blink phenomenon. Of note, if distractors are not presented between T1 and T2 then Attentional Blink is not present. This phenomenon is referred to as 'spreading the lag-1 sparing effect' (DiLollo et al., 2005). The lag-1 sparing effect is anticipated to occur in both hangover and no hangover testing sessions.

In addition, it is predicted that Attentional Blink will not differ across orders 1 and 2 (provided both groups have equal attentional abilities) as Attentional Blink does not change with experience (Taatzgen et al., 2009). For example, Braun (1998) carried out a study using three groups of participants: novices (that had never completed an AB task before), trained observers (that had practiced 1000s of AB trials) and experts (with extensive experience of tachistoscopic tasks but no practice). The results showed the same pattern of Attentional Blink across all participants. The magnitude of Attentional Blink has shown large individual differences (Martens & Johnston, 2008) and as a result an exact universal agreement of Attentional Blink duration has not arisen. However, it is estimated that attention blink occurs around 200ms and 500ms after T1 (Nieuwenstein, Potter & Theeuwes, 2009). It is unclear whether this will change during a hangover as the mechanism involved in the Attentional Blink phenomenon are not well understood.

5.1.5 Signal Detection

As Stated in Chapter 2, signal detection is used to provide insight into the process of decision making and identification of a target among ambiguous items (Abdi, 2007). To date, only one other study has looked beyond central tendencies in performance during a hangover (Grange, Stephens, Jones & Owen, 2016). Here, a diffusion model was applied to a choice reaction time task that identified three outcome variables; drift rate, which indicates the efficiency of information processing and boundary separation which identifies response caution. Finally, non-decision time reflects the time taken to execute a motor response. The results showed that drift rate decreased but did not reach significance, boundary separation increased and reached significance, and non-decision-time decreased (approached significance). Indicating that during a hangover, efficiency of information processing increases, however, more caution is exerted during responses and more time is needed to exert motor functioning (e.g. button press). Although the application of the signal detection theory to cognitive performance during a hangover is exploratory in nature, the findings of Grange et al., (2016) give rise to the idea that efficiency is decreased therefore, it is anticipated that the discrimination index is likely to be lower during a hangover. However, the impact of a hangover on the criterion cannot be predicted as decision processes have not been examined.

5.1.6 Emotional Stroop

The Emotional Stroop is often used to assess emotional valence through information processing (Williams, Mathews, & MacLeod, 1996). It is considered a measure of information processing as the response latencies during the presentation of emotional words are thought to

be a function of the processing of items in the task (Smith, 2009). As in the traditional Stroop task (Stroop, 1935), participants are required to respond to the font colour and ignore the meaning of the words presented on screen. Rather than colour words such as Green or Blue words in an Emotional Stroop task are emotionally charged, i.e. they are either socially (hated) or physically (mutilated) threatening, or neutral (holiday). The Emotional Stroop effect occurs when social or physical threat words cause slowed responses to word fonts.

The theory behind the Emotional Stroop effect argues that the interference in information-processing caused by the emotional content reflects the participant's implicit attitudes, emotions, and motivations (Dagleish, 2005). With this considered, the Emotional Stroop was chosen to provide information on the current mood of participants during an alcohol hangover. Moreover, as the classical Stroop has already been established in hangover research (Stephens, Ling and Heffernan, 2008; Gunn et al., 2018), the Emotional Stroop will also provide further information on Selective Attention performance while investigating attentional bias during a hangover. Adaptions of the traditional Stroop have been used in previous alcohol related research to examine attentional bias (Bruce & Jones, 2004; Field, Christiansen, Cole & Goudie, 2007; Roy-Charland et al., 2017). Bruce and Jones (2004) tested 30 participants using a pictorial Stroop task in heavy (heaviest drinking day previous week, 9.2 ± 1.9 , 6-12 units) and light social drinkers (heaviest drinking day the previous week, 3.1 ± 20.0 , 0-6 units). The participants were presented with two types of content (alcohol related e.g. glass of wine and neutral e.g. can of beans) and two variations of complexity which included a single object (e.g. glass of beer or cooker) on a white background and a scene (e.g. off license shelves or kitchen

units). The results showed that distraction times for alcohol related images were longer in heavy drinkers than in lighter drinkers which indicated an attentional bias in heavy drinkers.

Investigators have studied mood and affect the day after a night's drinking (Collins & Chiles, 1980; Griffin Freeman, Adams & Smith, 2018; McKinney & Coyle, 2005; Penning et al., 2012; van Schroyen Lantman, Mackus, van de Loo & Verster, 2017). The results have shown elevated mood ratings during a hangover (McKinney & Coyle, 2005; Penning et al. 2012, van Schroyen Lantman et al. 2017; Griffin et al., 2018). In terms of anxiety, McKinney & Coyle (2005) found significantly higher levels of anxiety in participants during a hangover than in the control Condition (no hangover), as well as a main effect of order where those in the no hangover/hangover order reported higher levels of anxiety than those in the hangover/no hangover Condition. It was postulated at testing session 2 (hangover) this occurred due to participants remembering the previous testing session (when not hungover) and anxiety increases due to the compromised (hangover State) that they are in. However, such expectancies would need further investigation in order to gain a comprehensive understanding of the role of hangover, testing order and anxiety. The term 'hangxiety' has been coined in social media (10,600 google hits; Google, 2018) to describe feelings of anxiety experienced during a hangover, however, little scientific attention has been given to the human relationship between the hangover and anxiety (Bogin et al., 1986; Smith & Barnes, 1983). Studies using rodents have demonstrated anxiety like behaviour during a hangover (Karadayian, Busso, Feleder & Cutrera, 2013; Prediger, da Silva, Batista, Bittencourt & Takahashi, 2006), however, the translatability of mood behaviours in rodents to humans is unclear (Hanell & Marklund, 2014; Slatery, 2014). In addition, rodent behavioural studies are subject to variability as animal-

experimenter interactions, behaviour interpretations and animal motivations may interfere with performance (Hanell & Marklund, 2014).

With this considered, further explorations into the effects of an alcohol hangover on mood and anxiety is warranted. No researchers to date have reported the use of an emotion based cognitive task in hangover research. The Emotional Stroop task will provide a unique perspective on changes in mood during a hangover. In addition, expectancies relating to negative mood or 'hangxiety' the morning after alcohol consumption may confound subjective measures e.g. 'Monday blues' (Croft & Walker, 2006). Through the use of an emotion based cognitive task in this Chapter, the potential for such confounds is reduced.

With consideration of the evidence discussed above, it is predicted that Attentional Blink and Emotional Stroop along with selective and sustained attention will be impaired in the hangover testing sessions.

Methods

5.1.7 Participants

Twenty-five participants took part in the following study. Order 1 included 6 male and 8 female participants with a mean age of 27.64 (SD=80.04). At Order 2 there were 6 male and 5 female participants with a mean age of 23.18 (SD=4.69). The documentation of sleep and physical activity collected using a wrist-worn accelerometer was offered to participants as an incentive.

5.1.8 Design

This study followed a similar design to Chapter 4, a within participants variable of State performance was applied to a between groups variable of Order. As in Study 2, testing session 2 was carried out within a window of 5-10 days following testing session 1.

5.1.9 Procedure

After compliance was confirmed and a consent form was signed, participants were assigned a GENEActiv watch to be worn on the night before and on the day of testing. On the day before hangover testing, a meeting was scheduled with each participant in order to install the Droidsurvey/iSurvey app. As well as this an hourly alarm was set on each participants phone to remind them to complete the survey each hour during drinking. On the day of hangover and no hangover testing sessions, participants were breathalysed and then questionnaires were administered. In addition to questionnaires pertaining to mood (Herbert, Johns & Dorés, 1986), sleep quantity, demographic information and alcohol consumption, the following questions were included:

1. How long do your hangovers usually last?
2. How long do you anticipate this hangover to last?
3. Did you consume more units than you intended?
4. Are you currently experiencing feelings of guilt?

Furthermore, a sleep rating scale requiring a rating of how good, satisfying, restful, refreshing and deep the sleep was also added to the questionnaire (Appendix 1). Questions not

pertaining to current mood, previous night's alcohol consumption or hangover symptoms were removed from the session 2 questionnaire as they were already collected in session 1.

Next, a series of 5 cognitive tests were administered. They included an Emotional Stroop, Eriksen's Flanker, Psychomotor Vigilance, 5 Choice Serial Reaction Time and Attentional Blink Tasks. A detailed description of each task is presented in Chapter 2. The tasks are also briefly described below.

5.1.9.1 Emotional Stroop

This test consisted of social and physical threat words as well as neutral words. The words were presented in blue, green, red, yellow or purple font. Participants were required to ignore the word meaning and respond to the font colour only. Words remained on the screen until a response was made. Coloured stickers indicate the appropriate keyboard responses. The task consisted of one practice block and 6 test blocks with 10 trials in each.

5.1.9.2 Eriksen's Flanker Task

This task required participants to attend to the central stimuli only and ignore distractors presented at either side. Distractors were either near or far, congruent (AAA) or incongruent (BAB) from the target. Items remained on the screen until participants responded. If responses were not made within 2 seconds, the next trial is presented. Each trial was separated by a one second presentation of 3 asterisks placed in the location of the targets and distractors. The task contained one practice block and six testing blocks within which there are 9 trials.

5.1.9.3 *Psychomotor Vigilance Task*

This one choice response time task measured sustained attention. Participants were required to press 'B' when a red 'X' (size 60 Times New Romans) appears on the screen. Stimuli intervals were marked with a '+' on the centre of the screen and vary in duration from 1000-10000 milliseconds. The task lasts approximately 5 minutes and contains 5 blocks of 10 trials. Each block contains an equal duration of inter-stimuli delays.

5.1.9.4 *5 Choice Serial Reaction Time Task (5CSRTT)*

A wooden panel containing 5 LED lights with corresponding touch sensitive pads were presented in an arc shape with a home pad in the centre of the arch. When a light turned on, participants were required to move a stylus to the corresponding pad and return the stylus to the home pad as quickly as possible. This task lasts approximated 7 minutes.

5.1.9.5 *Attentional Blink*

A rapid serial visual presentation of letters were presented in the centre of a white screen at a speed of 1 per 100 milliseconds. Participants were asked to detect whether T1 (letter X) and/or T2 are present (number 5) in the sequence. T1 was presented after 10, 12 or 15 letters and T2 is present 0, 100ms, 300ms, 500ms or 700ms (0, 1, 3, 5 or 7 items) after T1. The task contains 1 practice block and 10 testing blocks. The task took a maximum of 10 minutes to complete and all trials were presented randomly and in equal numbers in each test.

5.1.10 *Analysis*

Unless otherwise Stated, the data in this Chapter was subjected to a mixed measures analysis of variance comprised of the within groups factor of State and between groups factor

of Order. A Pearson's product moment correlation analysis was carried out to investigate the relationship between variables. Bonferroni tests were selected for post hoc analysis. Data was analysed using SPSS 24 statistical package and, in all instances, Alpha was set at 0.05

5.2 Results

5.2.1 Descriptive statistics

A summary of descriptive statistics is presented in Table 5.1 . An Analysis of variance revealed no significance differences between age ($F(1, 24)=2.66, p=.12$) and gender ($F(1, 24)=.314, p=.58$) across Order 1 and 2 groups. Furthermore, units consumed, AHS total, age ($F(1, 24)=2.66, p=.12$), age of first drink ($F(1, 24)=0.05, p=.83$), sleep (Hangover sessions, $F(1, 24)=.13, p=.72$; No Hangover sessions, $F(1, 24)=.18, p=.67$), alertness (Hangover sessions, $F(1, 24)=.41, p=.53$; No Hangover sessions, $F(1, 24)=.38, p=.54$) and tranquillity (Hangover sessions, $F(1, 24)= 0.01, p=.91$; No Hangover sessions, $F(1, 24)=.43, p=.52$) did not differ at Order 1 and 2. Demographic information, units consumed and AHS were tested on one occasion only.

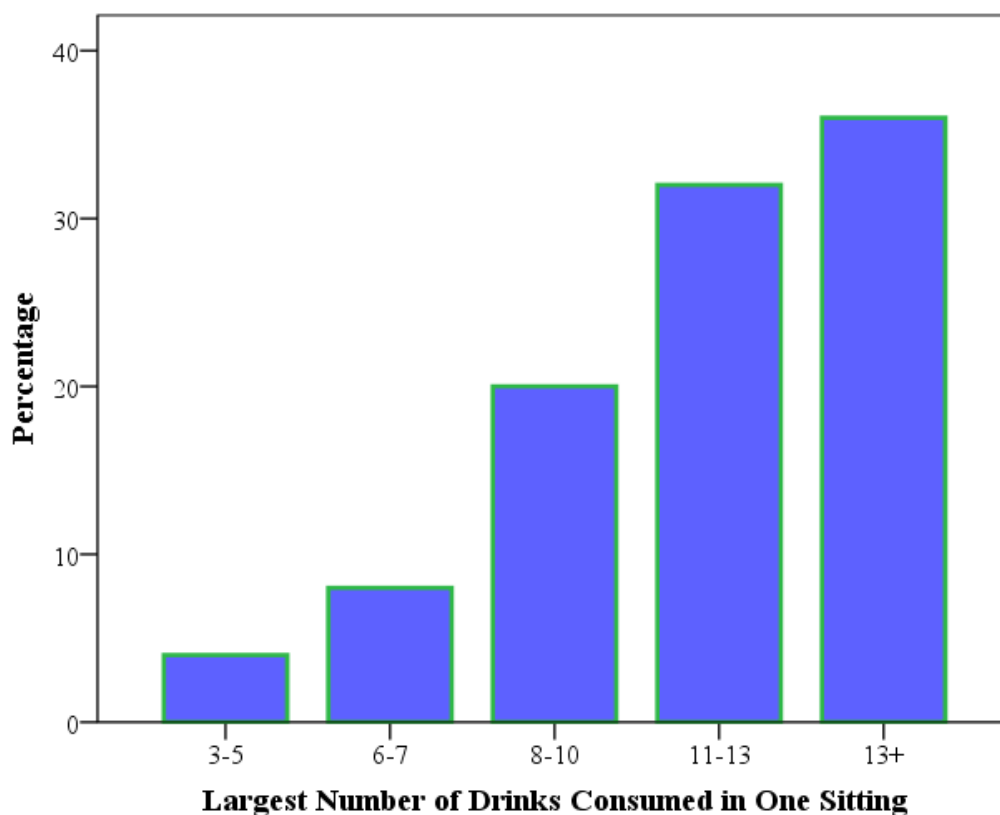
Table 5.1 A summary of descriptive statistics pertaining to the sample tested in this Chapter.

	Hangover Session		No Hangover Session	
	Order 1 (H/NH)	Order 2 (NH/H)	Order 1 (H/NH)	Order 2 (NH/H)
N	14	11	14	11
Gender (male/female)	6/8	6/5	6/8	6/5
Age	27.64 (80.04)	23.18 (4.69)	--	--
Units consumed	13.81 (5.66)	11.46 (3.70)	--	--
AHS total	21.79 (90.01)	17.91 (7.33)	--	--
Sleep (hrs)	6.47 (1.37)	6.74 (2.36)	6.79 (2.10)	70.09 (10.07)
Age of First Drink M(SD)	150.07 (1.69)	14.91 (1.97)	--	--
Alertness	250.07 (160.09)	21.82 (7.47)	410.07 (16.43)	37.36 (11.37)
Tranquillity	10.64 (6.83)	90.09 (4.30)	16.29 (10.31)	16.73 (9.40)

5.2.1.1 Alcohol Consumption

The mean age of first consumption of alcohol was 15 years (SD=1.78). Moreover, the most popular frequency of alcohol drinking sessions in a week were 1-2 (48%) with just 4% reporting consuming alcohol between six times per week and every day and 32% of participants consuming alcohol less than once a week. Moreover, 48% of participants reported consuming an average of 3-5 drinks in one sitting, with no reports of eight or more drinks and 32% of 6-7 alcohol beverages in one sitting. When asked how long they have been drinking in this way, the mean response was 5.43 years (SD=5.22). As can be seen from Figure 5.2, the largest proportion of participants reported 13 or more drinks as the largest number of drinks consumed in one sitting.

Figure 5.1 Percentage of largest number of drinks consumed in one sitting



Participants reported consuming this amount (largest amount they had ever consumed) of alcohol between once and twice a year (64%). Thirty two percent of participants reported consuming the maximum amount of alcohol in one sitting less than once a year and 4% reported consuming alcohol in this way 3-6 times a year. Despite this, 36% of participants reported drinking alcohol to reach a State of intoxication between once and twice a month and a further 8% reported doing so every time they drink. Fifty six percent of participants reported drinking to reach intoxication 6 or less times a year. Finally, the public house was reported as the most common place to consume alcohol (48%) closely followed by 'at home or at a friend's house' (40%). Interestingly, only 12% of respondents reported consuming alcohol most often in a club or nightclub.

5.2.1.2 *Smoking, Caffeine and Drugs*

Most respondents reported that they did not smoke cigarettes (64%). Moreover, 84% reported that they did not smoke cannabis and no other drugs were noted. No drugs were consumed on the night before testing. In relation to caffeine consumption, 60% of participants reported consuming caffeine before the no hangover testing sessions and 64% of participants reported consuming caffeine before the hangover testing sessions.

5.2.1.3 *Previous Night's Drinking*

Retrospective self-report measures revealed a mean of 12.78 (SD=4.95) units consumed. The minimum number of units consumed were six and the maximum units consumed were 30. The highest number of units were consumed in the form of lager/cider/beer (M=5.16, SD=70.00) followed by spirits (M=40.00, SD=3.86). The drink type with the least number of units were consumed was Alcopops (M=.60, SD=20.08). Ten participants reported consuming more alcohol than intended.

5.2.1.4 *Sleep*

In the no hangover testing sessions, 64% of participants reported going to bed at or after midnight. In contrast, 100% of participants went to bed after midnight on the night before the hangover testing sessions. In the hangover session, the mean time that people woke up was 9.37 (SD=1.57) hours and in the no hangover testing session this was 8.34 (SD=1.24) hours. Paired samples t-test analysis revealed that participants woke up significantly earlier when they were not hungover ($t(23)=2.88$, $p=0.01$). The mean number of hours slept before no hangover testing was 7 hours and 1 minutes (SD=1 hr 50mins) and 6 hours and 40 minutes (SD=1 hr 53

mins) when hungover. A repeated measures analysis of variance revealed no significant difference in the number of hours slept in hangover and no hangover sessions ($F(1, 23)=.58$, $p=.46$) and the between factors variable of Order ($F(1, 23)=.14$, $p=.99$) did not reach significance also indicating that the groups are well matched in terms of sleep.

Ratings of sleep quality revealed that subjective quality of sleep was significantly worse after consuming alcohol than when alcohol was not consumed ($t(24)=2.68$, $p=0.04$). In addition, sleep was rated as significantly less restful ($t(24)=3.22$, $p=0.00$) and less refreshing ($t(24)=2.94$, $p=0.00$) after alcohol consumption. Sleep was rated more satisfying when participants were not hungover ($M=40.04$, $SD=1.59$) than when participants were hungover ($M=3.36$, $SD=1.25$), however this did not reach significance ($t(24)=1.89$, $p=0.07$). Moreover, similar reports of deepness of sleep were revealed in both States (Hangover $M=50.00$, $SD=1.63$; No hangover $M=50.04$, $SD=1.7$) and this did not reach significance ($t(24)=.10$, $p=.92$).

5.2.1.5 *Mood*

As described in Chapter 2., items from the mood scale were collapsed into Alertness and Tranquillity variables. Repeated measures analysis revealed that participants reported higher levels of tranquillity when tested in the no hangover State ($F(1, 23)=13.74$, $p=0.00$) than in the hangover State. Furthermore, a large main effect of State on Alertness was also revealed ($F(1, 23)=25.72$, $p<0.0001$). Order did not interact with Tranquillity ($F(1, 23)=0.04$, $p=.84$) or Alertness ($F(1, 23)=.57$, $p=.47$). In the hangover session, the highest ranked moods were Antagonistic ($M=5.36$, $SD=1.32$) and Sadness ($M=5.32$, $SD=1.95$). In contrast, the highest rated mood in the no hangover testing session was Contentedness ($M=6.52$, $SD=.77$) and Interest

($M=6.56$, $SD=10.06$). In terms of feelings of guilt, over $\frac{1}{4}$ participants reported feelings of guilt the morning after drinking (28%), however, no participants reported guilt in the no hangover testing sessions. Moreover, 40% of participants reported consuming more alcohol than they intended. This may have contributed to ratings of guilt. Subsequent paired t-test analyses were carried out on individual mood items. The results are presented in Table 5.2.

Table 5.2 *individual mood rating items from Herbert et al.'s (1986) mood scale including mean, SDs, t tests and p values.*

N=25	Hangover (SD)	No Hangover (SD)	t	p value
Alert - drowsy	30.00 (20.04)	10.08 (1.26)	4.16	0.00*
Contented - discontented	2.60 (1.98)	.48 (.77)	5.13	0.00*
Calm - excited	1.72 (1.65)	10.08 (1.29)	2.37	0.03*
Troubled - tranquil	3.96 (1.90)	4.44 (1.71)	-10.03	.31
Strong - feeble	3.16 (1.68)	1.60(1.47)	4.32	0.00*
Mentally slow - quick witted	2.48 (1.81)	4.32 (1.22)	-5.95	0.00*
Muzzy - clear headed	2.68 (1.95)	4.76 (1.27)	-6.10	0.00*
Tense - relaxed	3.96 (1.97)	4.72 (1.46)	-1.88	0.07
Attentive- dreamy	3.80 (20.04)	2.28 (4.80)	1.46	.16
Incompetent - proficient	3.12 (1.94)	4.48 (1.45)	-2.90	0.01*
Happy - sad	1.68 (1.95)	.64 (0.91)	2.80	0.01*
Antagonistic - friendly	5.36 (1.32)	5.64 (0.64)	-.98	.34
Interested - bored	1.71 (1.85)	.54 (10.06)	2.81	0.01*
Withdrawn - sociable	4.24 (1.90)	5.24 (1.33)	-2.58	0.02*
Depressed - elated	3.76 (1.64)	4.80 (1.38)	-3.50	0.00*
Self-centered - outward going	3.72 (1.49)	4.36 (1.89)	-1.48	.15
Well-coordinated - clumsy	3.80 (2.31)	1.96 (20.01)	3.74	0.00*
Lethargic – energetic	2.32 (2.17)	4.44 (1.36)	-50.03	0.00*

Significant differences between the hangover and control day ($p < 0.05$) are indicated by *

5.2.1.6 *Severity and Duration*

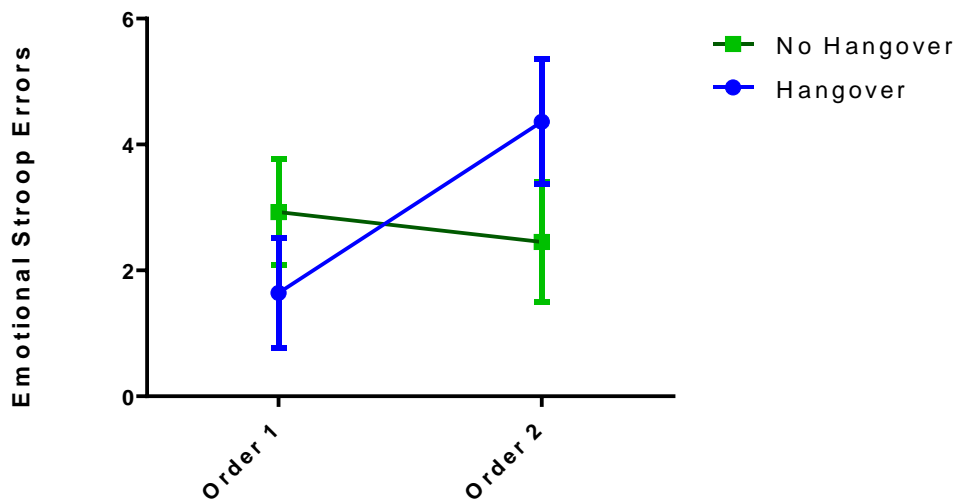
Participants were asked how long their hangover usually lasted, the mean number of hours reported was 11.62 (SD=7.71), while the mean number of hours that participants anticipated their hangover to last on the day of testing was 10.04 hours (SD=10.46) indicating that testing occurred shortly after hangover onset. The mean total score in the Acute Hangover Scale was 20.08 (SD=8.38) out of a maximum of 63 and a minimum of 0. The highest rated symptom was tiredness (M=4.4, SD=1.58) followed by thirst (M=40.04, SD=1.54) and hungover-ness (M=3.36, SD=1.54). The least common symptoms reported were a stomach ache (M=10.00, SD=1.12), heart racing (M=10.00, SD=1.73) followed by nausea (M=1.20, SD=1.61).

5.3 Performance

5.3.1 Emotional Stroop

A three-way mixed measures analysis of variance was carried out with State, Order and Word type (physical threat, social threat and neutral) variables. The results revealed a main effect of word type ($F(2, 22)=34.80, p<0.0001$), State ($F(1, 23)=51.11, p<0.0001$) but not Order ($F(1, 24)=1.62, p=.22$). State and Order did not interact ($F(1, 23)=3.26, p=0.06$, State, Order and Word Type did not interact ($F(2, 22)=.83, p=.45$) In addition Word Type and State did not interact ($F(2, 24)=10.01, p=.38$). Errors did not differ across States ($F(1, 23)=.79, p=.41$) or Orders ($F(1, 23)=.81, p=.38$). However, a first order interaction of State and Order was revealed ($F(1, 23)=18.60, p=0.0001$; Figure 5.2).

Figure 5.2. Errors (Means and Standard errors) made in Emotional Stroop task across States and between Orders 1 and 2



Paired T-test analyses were carried out to investigate differences in threat type (physical, social) and neutral response times. The results revealed significantly slower response times to control ($t(24)=3.90$, $p=0.00$), social ($t(24)=4.93$, $p<0.0001$) and physical ($t(24)=3.729$, $p=0.00$) threat words in the hangover State than in the no hangover State. From Table 5.3 it can be seen that control words are slower than physical threat words in both hangover and no hangover States. This reached significance at both hangover ($t(24)=30.03$, $p<0.0001$) and No Hangover ($t(24)=2.22$, $p=0.00$) States. Moreover, social threat words were significantly slower than controls in the no hangover testing sessions ($t(24)=3.373$, $p=0.03$) but not the hangover testing sessions ($t(24)=-0.77$, $p=.45$).

Table 5.3. *Mean response times to word subgroups in Emotional Stroop test at hangover and no hangover testing sessions.*

	Hangover (SD)	No Hangover (SD)
Control	1499.12 (290.65)	1255.35 (157.44)
Social	1545.19 (263.88)	1349.30 (236.52)
Physical	1291.47 (283.42)	11290.09 (236.23)

From the Table above, it can be seen that control words are slower than physical threat words in both hangover and no hangover States. This reached significance at both hangover ($t(24)=30.03$, $p=0.00$) and No Hangover ($t(24)=3.73$, $p=0.00$) States. Moreover, social threat words were significantly slower than controls in the no hangover testing sessions ($t(24)=3.73$, $p=0.00$) but not the hangover testing sessions ($t(24)=.77$, $p=.45$).

5.3.2 Selective Attention

A four-way mixed measures analysis of variance was carried out on State, Order, Compatibility (Compatible, Incompatible) and Distance (Near, Far). A summary of the mean and standard deviation values across States and between Orders is demonstrated in Table 5.4. As expected incompatible near items took the longest to respond to in both Hangover ($M=587.98$, $SD=91.11$) and No Hangover ($M=528.41$, $SD=53.50$).

Table 5.4 The mean and standard deviation response times and errors for Eriksen's Flanker task.

	Order 1 (N=26)		Order 2 (N=19)	
	Hangover	No Hangover	Hangover	No Hangover
<i>Near Compatible</i>	518.31 (57.49)	495.27 (61.77)	538.58 (112.69)	4760.07 (30.28)
<i>Near Incompatible</i>	577.65 (57.50)	531.42 (67.44)	601.14 (123.63)	524.58 (30.49)
<i>Far Compatible</i>	507.34 (81.33)	488.12 (52.87)	515.11 (133.58)	480.68 (370.02)
<i>Far Incompatible</i>	501.10 (59.77)	481.29 (66.40)	522.53 (107.29)	475.64 (43.60)
<i>Errors</i>	1.64 (1.39)	1.92 (1.38)	2.91 (2.17)	2.54 (1.44)

*The metric of measures is milliseconds in all dependent variables aside from errors.

The results of an analysis performed on Compatible Near, Compatible Far, Incompatible Near and Incompatible Far revealed a main effect of Compatibility with slower responses to items within the visual field than outside of it ($F(2, 23)=27.55$, $p<0.0001$) as well as a main effect of Distance with slower response on incompatible than compatible stimuli ($F(1, 23)=33.52$, $p<0.0001$). Moreover, the results revealed a main effect of State ($F(1, 23)=50.01$, $p=0.04$) but not for Order ($F(1, 23)=0.04$, $p=.84$). There was a first order interaction of Compatibility and Distance ($F(1, 23)=34.26$, $p<0.0001$) but no other first or second order interactions reached significance. These results replicate the findings of Chapters 3 and 4 and are demonstrated in Table 5.5.

Table 5.5. N, F and p value results from mixed measures analysis on Eriksen's Flanker Task, including State, order, distance and compatibility

	N	F	P value
State	25	50.01	0.04*
State * Order	25	.58	.45
Compatibility	25	27.55	0.00*
Compatibility * Order	25	.69	.41
Distance	25	33.52	0.00*
Distance * Order	25	0.00	.97
Order	25	0.04	.84
State* Compatibility	25	1.68	.21
State * Compatibility * Order	25	0.00	.94
State * Distance	25	3.77	0.06
State * Distance * Order	25	.37	.55
Compatibility * Distance	25	34.26	0.00*
Compatibility * Distance * Order	25	0.00	10.00
State * Compatibility * Distance	25	.78	.39
State * Compatibility * Distance * Order	25	.59	.45

5.3.3 Choice Serial Reaction Time Task

A repeated measures analysis was carried out on 5 Choice Serial Reaction Time Task (5CSRTT) interference scores. Interference was calculated by subtracting the move time (time taken to reach the target stimuli) from the return time (time taken to return from the stimuli to

the home keypad). The results did not reveal a significant difference across States ($F(1, 23)=.642, p=.43$). State and Order did not interact ($F(1, 23)=.39, p=.54$). Moreover, there was no main effect of Order ($F(1, 23)=10.04, p=.32$). However subsequent t-tests revealed that move time was significantly slower when participants were hungover than when they were not ($t(1, 24)=4.11, p<0.0001$). As well as this, return time differences reached significance with slower responses when participants were in the hangover State ($t(1, 24)=2.5, p=0.02$). The results indicate slowed psychomotor and decision-making responses in the hangover State.

Table 5.6. The mean response times for 5CSRTT including Move Time, Return Time and Interference in hangover and no hangover States.

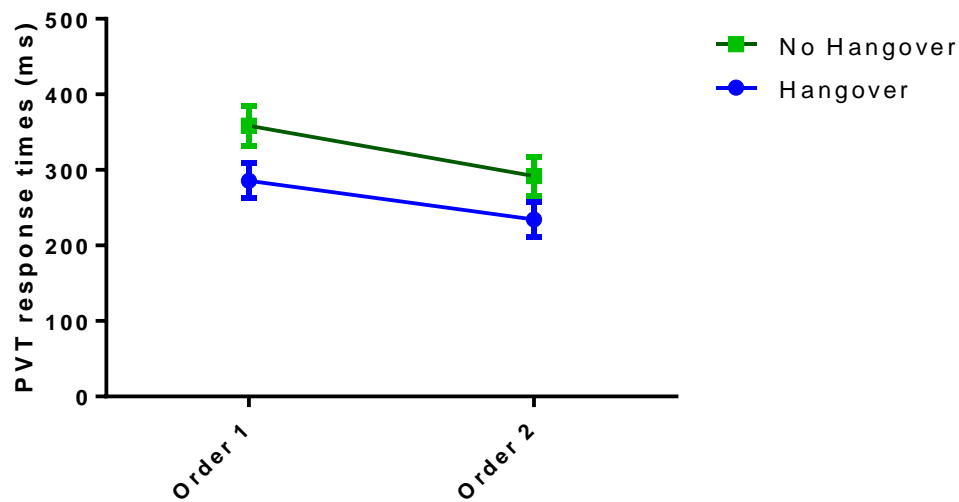
	Move Time	Return Time	Interference
	(SD)	(SD)	(SD)
Hangover	671.69 (72.83)	443.64 (85.22)	2280.05 (76.78)
No Hangover	614.35 (55.40)	40.19 (59.62)	214.16 (66.96)

5.3.4 Psychomotor Vigilance Task

Mean response time measures and the number of lapses were calculated for participant performance on the Psychomotor Vigilance Task (PVT). Responses were classed as lapses if they were longer than 500ms. For the response time analysis, cut off points of less than 100ms and more than 500ms were applied as implemented by Ratcliff and Van Dongen (2011). An analysis of variance on response times revealed a main effect of State with longer response times when participants were hungover ($M=317.62$ $SD=92.63$) than when they were not ($M=259.63$,

SD=890.0; $F(1, 23)=122.39$, $p=0.00$). Participants were also significantly slower at Order 2 than at Order 1 ($F(1, 23)=4.61$, $p=0.04$). However, State and Order did not interact ($F(1, 23)=.21$, $p=.65$; Figure 5.3).

Figure 5.3. Mean participant response times to Red 'X' stimuli in PVT task across State and between Orders

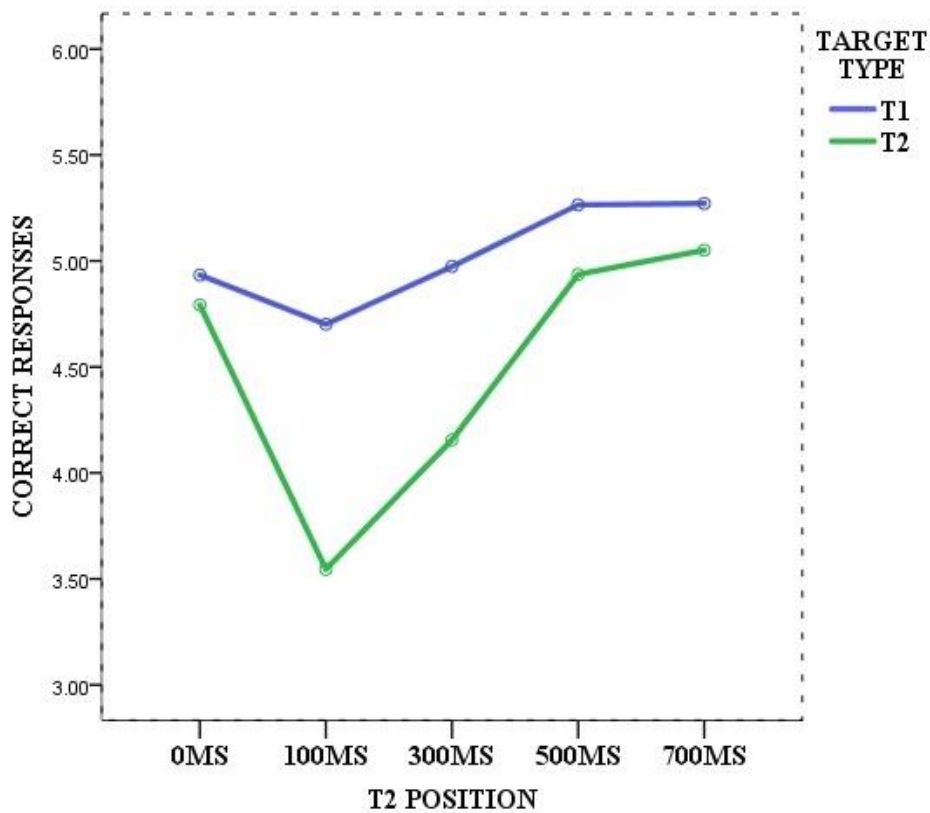


The number of lapses made during the PVT was higher in the hangover testing sessions ($M=11.88$, $SD=110.01$) than in the no hangover testing sessions ($M=8.75$, $SD=10.63$). However, an Analysis of variance did not reveal a significant effect of State ($F(1, 22)=.65$, $p=.43$). Moreover, Order did not reach significance ($F(1, 22)=.52$, $p=.48$) and State and Order did not interact ($F(1, 22)=.65$, $p=.43$).

5.3.5 Attentional Blink

In order to examine the Attentional Blink paradigm a four-way repeated measures analysis of variance was carried out that included, Position (0ms, 100ms, 300ms, 500ms and 700ms) x Target Type (T1, T2) x State x Order. The analysis revealed a main effect of target type ($F(1, 20)=22.25, p<0.0001$) and position ($F(1, 20)=13.65, p<0.0001$) as demonstrated below. There was no main effect of Order ($F(1, 20)=.708, p=.41$). State reached significance ($F(1, 21)=8.173, p=0.01$) with more errors in the hangover State ($M=10.02, SD=7.69$) than in the no hangover State ($M=7.31, SD= 6.70$). A first order interaction of Target Type x Position was also revealed ($F(4, 20)=3.22, p=0.03$) but no other first order interactions were revealed (Target type and Order, $F(1, 23)=.13, p=.73$; Position and Order, $F(1, 23)= 2.24, p=.10$; State and Target type, $F(1, 23)=1.87, p=.19$). Finally, State by Target x position did not reach significance ($F(1, 23)=.74, p=.58$) and State x Position x Order did not reach significance ($F(1, 23)=.59, p=.67$).

Figure 5.4. The relationship between target type and position of target 2, correct responses out of 6.

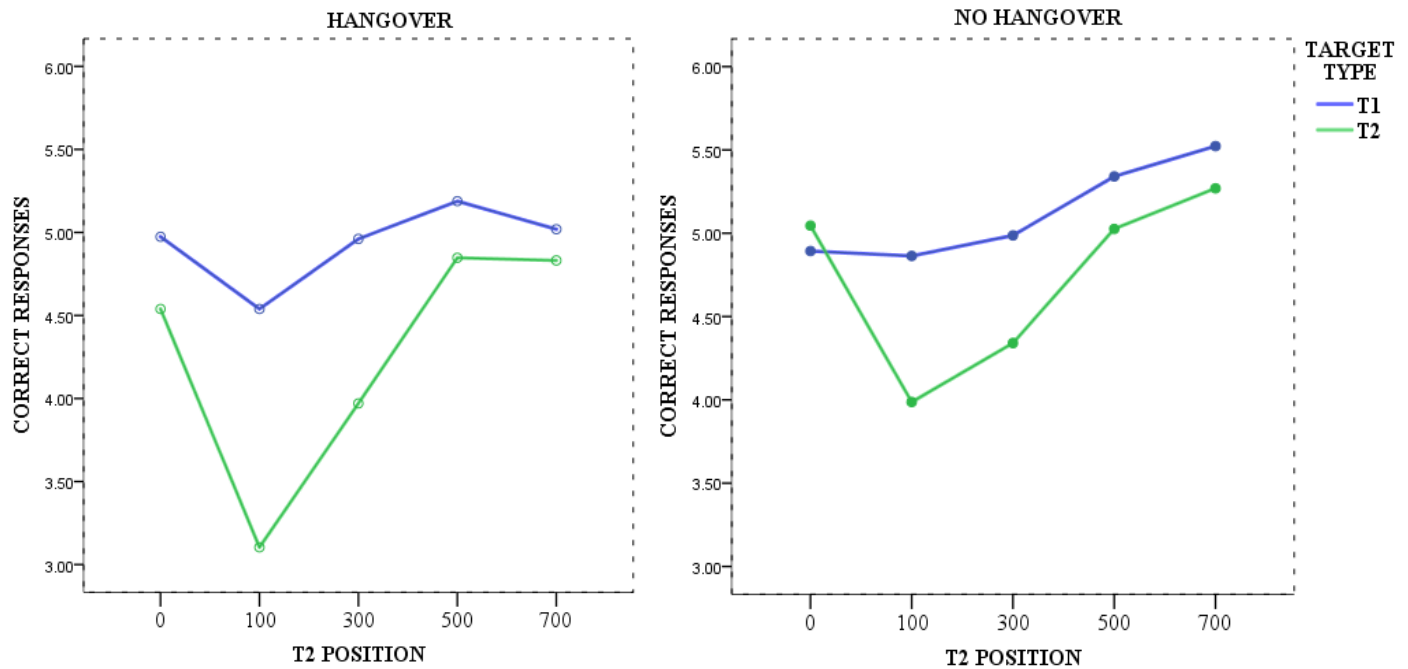


Post hoc analysis on Target 2 revealed a significant difference between State when T2 was at 100ms ($F(1, 24)=6.40, p=0.02$) indicating that Attentional Blink effect was more severe in the hangover State at 100ms, however magnitude of the Attentional Blink did not increase significantly in the hangover State as State did not differ at any other T2 positions. A summary of the results are demonstrated in Table 5.7.

Table 5.7. Summary of Bonferroni analysis on Hangover and No hangover responses for T2 items at 0, 100, 300, 500 and 700 milliseconds.

	Hangover (SD)		No Hangover (SD)		P value
0ms	4.56	(1.26)	50.04	(.79)	0.09
100ms	3.16	(1.82)	40.04	(1.54)	0.02*
300ms	40.00	(1.22)	4.36	(.99)	.19
500ms	4.84	(.90)	50.04	(.89)	.42
700ms	4.80	(1.26)	5.28	(.84)	10.00

Planned comparison analysis was carried out on hangover testing session results and revealed that T2 scores between positions 0ms and 100ms ($p=0.03$), 100ms and 500ms ($p=0.01$), 300ms and 500ms ($p=0.03$) and 100ms and 700ms ($p=0.01$) differed significantly. However, 100 and 500ms ($p=0.02$), 100 and 700 ($p=0.00$) and 300ms and 700ms ($p=0.01$) differed in the no hangover testing sessions. These results indicate a different pattern of lag -1 sparing and Attentional Blink recovery from 300ms to 700ms across States. Moreover, an overall (Hangover and No Hangover) within groups contrasts revealed a Target Type and Position interaction for Target Type x Position levels 2 vs 5 ($F(1, 23)=10.35.44$, $p=0.00$) and Target Type x Position levels 3 vs 5 ($F(1, 23)=5.43$, $p=0.03$). From Figure 5.4.4, a lag-1 sparing can be seen in both hangover and no hangover States with a mean of 4.56 (SD=1.26) T2 correct responses out of 6 in the hangover testing sessions and 4.92 (out of 6; SD=.64) T2 correct responses in the no hangover testing sessions. Moreover, an Attentional Blink can be seen in both hangover and no hangover testing sessions.

Figure 5.5 *Attentional Blink paradigm in hangover and no hangover States*

Furthermore, T1 and T2 responses in the hangover sessions differed only at 100ms ($F(1, 24)=15.47, p=0.00$), 300ms ($F(1, 24)=150.00, p=0.00$) and 500ms ($F(1, 24)=4.38, p=0.05$). Targets one and two did not differ at 700ms ($F(1, 24)=.71, p=.41$) or 0ms ($F(1, 24)=1.78, p=.20$) in the hangover State. In the no hangover testing sessions, T1 and T2 performance differed only at 100ms ($F(1, 24)=5.93, p=0.02$) and 300ms ($F(1, 24)=5.85, p=0.02$), in all instances of significant interactions, T2 performance was worse than T1. T1 and T2 at 500ms ($F(1, 24)=2.42, p=.13$), 0ms ($F(1, 24)=.35, p=.56$) and 700ms ($F(1, 24)=10.06, p=.31$) did not vary in the no hangover State. Paired T-test analyses were carried out in order to compare overall performance on T1 and T2 target types (when T2 was present) across States. The results revealed no main effect of State of T1 targets ($t(24)=-1.16, p=.26$) but T2 target performance was significantly better when participants were not hungover ($t(24)=3.440, p=0.03$).

5.3.6 Signal Detection Theory

As Order did not significantly affect errors on Attentional Blink Yes/No responses, it was removed from Signal Detection analysis. T-test analyses were carried out to compare hits, misses, correct rejections and false alarms across States. The results revealed significantly more false alarms and less hits in the hangover State ($t(24)=3.440$, $p=0.00$; $t(24)=-3.440$, $p=0.00$) as well as less correct rejections and more false alarms in the hangover State ($t(24)=-2.56$, $p=0.02$; $t(24)=-2.56$, $p=0.02$).

Figure 5.8 Signal Detection theory measures Hits, Misses, Correct Rejections and False alarms across States

	Hangover	No Hangover
Hits	21.36 (3.71)	23.76 (3.55)
Misses	8.24 (3.41)	6.24 (3.55)
Correct Rejections	26.28 (2.76)	27.68 (2.59)
False Alarms	3.72 (2.76)	2.32 (2.59)

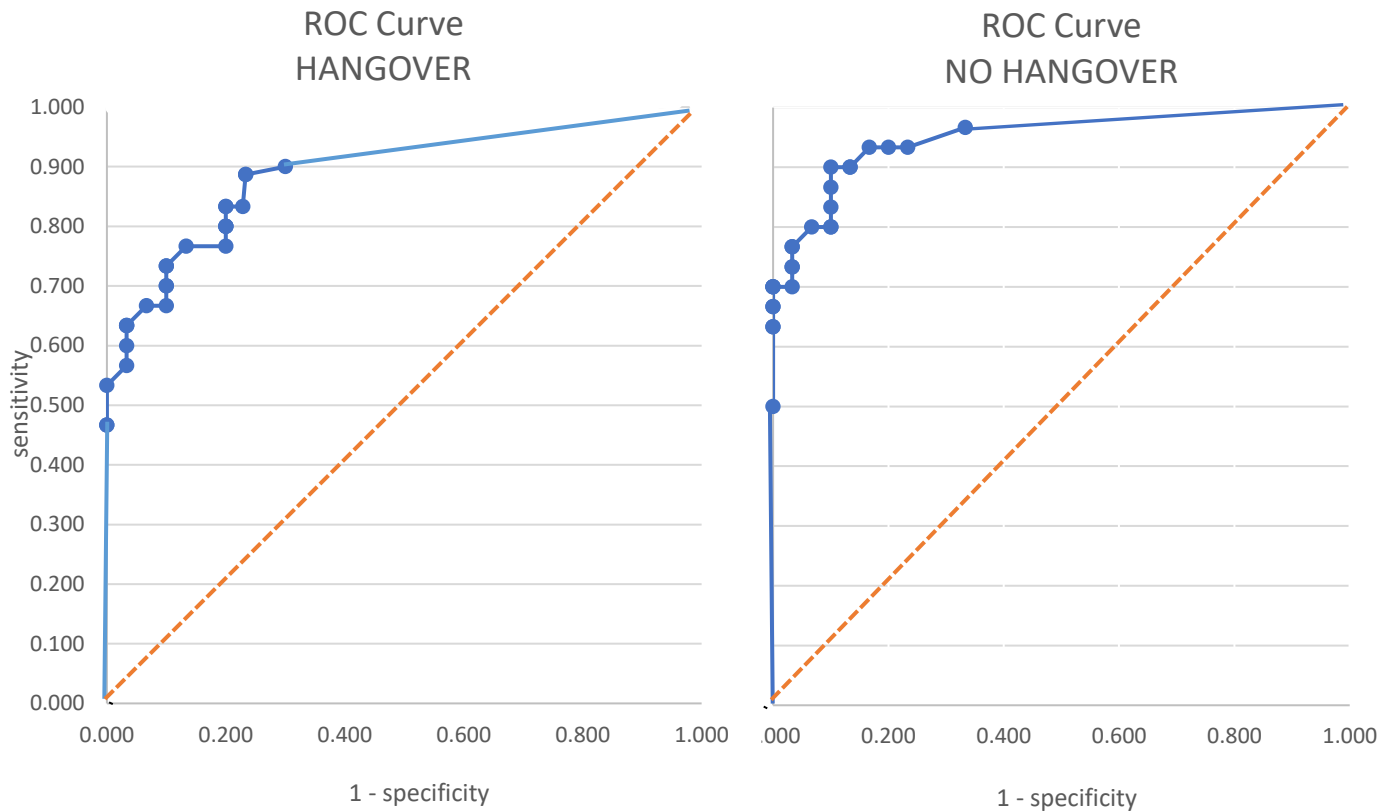
Subsequent signal detection theory analysis was calculated on Microsoft Excel (version 1808) using a macro developed by Gaetano (2014). As can be seen from table 5.8 below the criterion remains similar across States however, d' differs considerably indicating that participants were better able to distinguish between the signal and noise when they were not hungover than when they were hungover. In addition, the likelihood ratio differed considerably across States.

Table 5.9. Signal detection theory analysis results for the discrimination index, criterion and likelihood ratio across hangover and no hangover States.

	Hangover	No Hangover
d' (DISCRIMINATION INDEX)	1.93	2.40
C (CRITERION)	0.36	0.31
β (LIKELIHOOD RATIO)	3.56	6.13

Paired t-test analyses were carried out on Hit Rates, False Alarm rates, d' , c and β . The results showed a significant difference between hangover and no hangover Hit Rates ($t(24) = -3.33$, $p=0.00$) as well False Alarm rates ($t(24)=6.59$, $p<0.0001$). d' was significantly different across States ($t(24)=-2.291$, $p=0.03$) indicating that discrimination between signal and noise was better in the no hangover State than the hangover State. However, c did not differ ($t(24)=.2447$, $p=.447$) and β was not significant ($t(24)=-1.838$, $p=0.08$). Figure 5.6, demonstrates the Receiver Operator Curves (ROC) during hangover and no hangover testing sessions. Each point on the curves represent a sensitivity and specificity valued pair relating to a particular decision threshold. A curve that is closer to the top left corner indicates better levels of accuracy. Thus, the ROC curves suggest better accuracy in the No Hangover testing sessions than in the hangover testing sessions.

Figure 5.6 Receiver Operator Curve calculated for Hangover and No hangover responses to Attentional Blink T2 stimuli



5.4 Correlations

A Pearson's product-moment correlation was carried out on age, sleep, hangover symptoms, units consumed, performance and mood (See Appendix 4.). As in Study 2, the difference between hangover and no hangover scores were calculated for performance, sleep and mood variables by subtracting hangover from no hangover scores. The results revealed a correlation between alcohol consumption reported next day and in real time ($r=.57$, $p<0.0001$, $n=25$). Also, Age negatively correlated with 5CSRTT ($r=-.49$, $p=0.03$, $n=25$). Attentional Blink Target 2 errors correlated with total Acute Hangover Scale symptoms ($r=.42$, $p=0.03$, $n=25$) and

subjective measures of Alertness and Tranquillity also positively correlated ($r=.57$, $p<0.0001$, $n=25$).

5.5 Discussion

5.5.1 Summary

In this Chapter, next day effects of a night's drinking were found on Emotional Stroop, Eriksen's Flanker, 5 Choice Serial Reaction Time, Psychomotor Vigilance and Attentional Blink tasks. The Attentional Blink task is the first to demonstrate decrements in temporal aspects of attention during a hangover. The results indicate differences in the severity of the Attentional Blink but not the magnitude. Thus, the findings give rise to the argument that decrements in distractor inhibition occur during a hangover as well as changes in episodic registration, attentional and response selection. It is likely that temporal aspects of working memory are also implemented in the Attentional Blink task, however, further research is needed to pinpoint how a hangover may affect working memory in relation to the Attentional Blink. The application of the signal detection theory to the Attentional Blink task provided novel insight into the way in which decision making occurs during a hangover. The results showed that the criterion for which one decides on a yes or no response does not change during a hangover. However, as expected, one's ability to discriminate between signal and noise becomes significantly worse during a hangover. These results may help to explain why slower responses occur during a hangover and why more time is spent on accuracy in this State (Grange et al., 2016). The role of order did not appear significant in all but one analysis indicating that the groups were well matched and that experiencing a hangover on the first or second testing session did not affect performance.

5.5.2 Performance

5.5.2.1 *Emotional Stroop*

The results showed no main effect of State Word type and State. A closer look revealed that responses to social threat, physical threat and control words were significantly slower when in the hangover State. This supported the previous findings in attention research that suggest that attention is slowed during a hangover irrespective of task difficulty. Slower response times were expected in the hangover State and the slower responses to control words when hungover supports the findings of Mathews and MacLeod (1985) which imply that when experiencing anxiety participant response times to control items are slower. However, a significantly slower response to social threat words than control words was predicted but not found in the hangover State. Although the responses were slower they did not reach significance. In contrast, social threat words were significantly slower than controls in the no hangover testing session. These results suggest that although general anxiety is likely to increase during a hangover (McKinney & Coyle, 2006), test anxiety may be higher when participants are not hungover. There are several reasons why this may have occurred. Speculatively, the extended time taken to respond to control items in the hangover testing sessions may reduce the difference between social threat and control words. In support of this, social threat word response times were significantly slower during a hangover than when not hungover. However, further research is needed in order to further test this hypothesis.

In relation to physical threat words, the reduced response times in both hangover and no hangover Conditions suggest that physical threat anxiety does not occur during testing. Similarly, Bruce and Jones (2004) found that light drinkers were more distracted by neutral

words than alcohol related words. These results mirror that of Mathew and MacLeod who, using the same items found faster responses to physical words than control words. Mathew and MacLeod also found that this occurred in those that experienced anxiety but that did not have health concerns. With this considered, the results from this task may represent higher levels of social anxiety during a hangover, slowed responses to all items but low levels of physical health anxiety. As traditionally, 'hangxiety' is thought to centre around social behaviours the night before, it appears logical that social anxiety would be affected (Dean, 2017). In contrast, physical threats concerns are generally not considered a symptom of a hangover. Moreover, cognitive testing labs are unlikely to induce a feeling of physical unsafety.

5.5.2.2 Selective Attention

As expected the results from the Selective Attention task mirrored that of previous findings (McKinney & Coyle; Chapter 3 and 4 of this thesis). The slowed responses to incompatible near items demonstrated that the task adequately demonstrated Eriksen's Spotlight Theory (1974) which argues that objects incompatible with the target item and placed inside the visual field will take longer to respond to than compatible items or those placed outside of the visual field.

5.5.2.3 Choice Serial Reaction Time Task (5CSRTT)

The results revealed no main effects or interactions of State or order on interference. However, the slower responses to move and return times in the hangover Condition indicate that overall responses are slowed during a hangover which supports previous findings pertaining to reaction time data, for example., selection attention described above. The results

partially support the findings of McKinney (2003) which found slower move times when participants were hungover than when they were not. However, the study also investigated the effect of stress through the sound of white noise. The findings showed that move time was significantly slower in the no noise Condition, however for return moves e.g. no decision-making times the hangover had little effect. In contrast, the finding from the 5CSRTT in this study suggests that decision making as well as psychomotor performance is impaired after a night's drinking. In support of the effects of the effect of hangovers on motor skills, a study by Karadayan, et al., (2017) on 41 male Swiss mice, showed reduced motor skills 6 hours after a high ethanol dose.

5.5.2.4 *Psychomotor Vigilance Task (PVT)*

As expected the response times were significantly slower when participants were hungover than when they were not. Interestingly in a study by Howland et al., (2010) also found significantly slower response times in PVT tasks among college students. The amount of alcohol administered to participants in this study varied according to gender and weight. Alcohol was administered in the form of beer and non-alcoholic beer was administered as a control. Participants were given one hour to imbibe the drink, but the administration target was .12g% BrAC. Of note, this equates to just .12 % BAC level or 16090.07mLs of 4.8% beer for males (less than 3 UK pints; White Hat Ltd, 2018) and 11220.09 mls (2 UK pints; White Hat Ltd., 2018) for women. In contrast, participants in this study consumed a wide range of alcohol types of a longer period of time. The results support the findings within this thesis of slowed responses to stimuli during a hangover. It also demonstrates Psychomotor Vigilance impairment the day

after alcohol consumption using an alternative methodological approach to that used by Howland et al. (2010) as well as across a variety of alcohol types.

Of note, an Order effect revealed overall slower responses to stimuli among participants in Order 2 (NH/H) than in Order 1 (H/NH). These results suggest a benefit to testing in the hangover State first. However, it is not possible to speculate why this might be without further research. Furthermore, no other order has been revealed in this study therefore the Order effect here must be interpreted with caution. Moreover, more lapses (as defined by Ratcliff and Van Dongen, 2011) were found in the hangover State than in the no hangover State. To the authors knowledge no other studies have investigated PVT lapses during a hangover. These lapses suggest that one's ability to sustain attention may be somewhat dished during a hangover. In support of this a finding by McKinney, Coyle and Verster (2012) showed a significantly higher number of missed targets in a sustained attention task when participants were presented with 100 items per minute and the task required a response 'B' press when three odd numbers were presented in a row. In conclusion, the results from this study support the findings that response time accuracy is impaired after a night's drinking.

5.5.2.5 *Attentional Blink*

As expected the results showed a main effect of target position as also shown by Shapiro (1992). The relationship displayed between target type and position demonstrates an Attentional Blink effect within the data (as also described by Dux & Marois, 2009). On further inspection the results indicated these interactions were most pronounced between 100 and 700ms and 300 and 700ms. The residual effects of intoxication also negatively affected overall

performance on this task. This to date is the first study to demonstrate decrements in such temporal aspects of attention during a hangover.

Furthermore, the results from the post hoc analyses revealed that the size of the Attentional Blink did not appear to differ across States, however, the severity of the blink increased significantly at 100ms. With regards to the magnitude of the Attentional Blink, this study does not show that a simple increase in magnitude occurs during a hangover. The findings by Olivers and Nieuwenhuis (2005) found that an increase in Attentional Blink magnitude occurred when participants were more focused on the task than when they were distracted. With this in mind the results do not appear to demonstrate a difference in focus across States.

The results also suggest that the pattern of Attentional Blink differs with slower recovery times from 300 to 700ms. The lag-1 sparing refers to the phenomenon where T1 and T2 are reported accurately when presented in quick succession with no distractions placed in between. (DiLolli et al., 2005). However, the post hoc analysis indicates that there is a significant decrease in correct responses from 0ms to 100ms in the hangover testing session but it does not reach significance in the no hangover testing session. Moreover, although T1 and T2 scores do not differ significantly at 0ms in hangover or no hangover sessions, it can be seen that less correct responses to T2 items are displayed in the hangover testing sessions than in the no hangover testing sessions. These findings indicate that a different transition from lag-1 sparing to Attentional Blink may occur during a hangover. According to the two-stage bottleneck theory proposed by Chun and Potter, Lag-1 sparing occurs due to the slow temporal dynamics of the attentional system. If this is the case, then one might speculate that the change

in Attentional Blink onset in this study, reveals a faster temporal shift in the hangover State. However further research is needed to explore this theory. As expected there were no order effects shown in the Attentional Blink task. In sum, the results from the Attentional Blink task cannot determine detriments in working memory, attentional selection, enhancement and engagement, distractor inhibition, episodic registration and response selection in isolation. However, the results indicate a change in temporal functioning in relation to attention during a hangover.

The results from the signal detection theory analysis demonstrates that the criterion although, slightly more liberal during a hangover does not differ significantly across States. This indicates that the criteria required for a yes or no response does not differ when a person is hungover (Heeger, 2006). A significant difference between the discrimination index indicates a discrepancy in one's abilities to distinguish signals and noises across States. Indeed, the d' during a hangover was lower than in the no hangover Condition indicating that more overlap among internal responses and thus participants ability to distinguish noise from signal is diminished. Moreover, the beta likelihood ratio variable refers to a ratio where the target present and target missing responses meet the criterion (see Figure 2.4.) The results from this study show no significant differences in relation to the likelihood ratio. These finding support the findings by Grange, Stephens, Hones and Owen (2016) who applied diffusional modelling to look beyond central tendencies in a reaction time task during a hangover. Efficiency was reduced during a hangover and concluded that participants struggle to identify a target during a hangover. The study also found increased time taken to improve accuracy. Drawing on the findings by Grange et al. (2016) and the results from the signal detection analysis, one can

speculate that as it becomes more difficult to detect a target from noise when hungover, extra time is needed to ensure accurate responses to the stimuli thus accounting for slower response times to attention tasks when hungover. However, no firm accounts of this theory can be drawn from the data.

5.5.3 Demographic Information

The age of first drink was 15 years. This supports the findings in Chapters 3 and 4 as well as the research carried out by Morean et al. (2014), SAMHSA (2014) and Health and Social Care Information Centre (2015). As found in Chapters 3 and 4, the most popular place where drink is reported to be consumed is in a public house. However, in comparison to the non- student sample (71%) drinking in a public house was reported significantly less frequently (43%, 48%). The mean age was 25.68 and is similar to that of Chapter 3 (24.49) and McKinney and Coyle (23.38, 2004) who also tested students at Ulster University. Of note, age and gender was well matched across State and did not differ significantly. The frequency of which participants reported consuming alcohol to reach intoxication varied considerably indicating that rare, moderate and regular drinkers took part in this study.

The mean number of units retrospectively reported (12.78) was similar to that found in Study 3 (12.85) and McKinney, Coyle and Verster (2012). However, the number of units was considerably lower than that found in Chapter 4 (15.32) and Finnegan, Schulz, Smallwood and Anderson (2005). Although the mean age of participants in Finnegan et al.'s study (23.83) was similar to that of student samples mentioned above, however, the study did not require that they be university students. In relation to sleep, the results showed that participants woke up

earlier when they were not hungover. This contrasts with previous findings that suggest an early wake time when alcohol is consumed the night before (Roehrs & Roth, 2001). This may be due to study obligations or the later bed times reported after alcohol consumption.

Moreover, as shown in Study 3 and 4, participants were more likely to stay awake after midnight when alcohol was consumed. Participants subjectively reported sleeping 7 hrs and one minute in the no hangover Condition and 6hrs and 40 mins in the hangover Condition which are similar reports to those estimated by The Royal Society for Public Health (RSPH; 2016). Quality of sleep was rated worse, less restful and less refreshing after alcohol consumption. Similarly, Arnedt et al. (2011) found lower ratings of sleep quality the morning after a night's drinking as well as increased reports of sleepiness both before sleep and the morning after sleep alcohol had been consumed.

In terms of mood, alertness was rated lower after a night's drinking as has been shown in Chapters 3 and 4 as well as in studies by McKinney & Coyle (2006) and Penning, McKinney and Verster, (2012). Moreover, as in the study by McKinney and Coyle (2005) tranquillity was rated lower during a hangover. Interestingly, 28% of participants reported experiencing guilt during a hangover, however, no participants reported experiencing feelings of guilt when in the no hangover testing session. Gunn (1973) found that around half of both regular drinkers and alcoholics reported experiencing feelings of guilt after drinking. Similarly, Harburg et al., (1981) found a positive correlation between guilt and frequency of hangover symptoms. Moreover, 40% of participants reported consuming more than they intended which may have contributed to the feelings of guilt expressed during a hangover. Labhart, Anderson and Kuntsche (2017) also found that young people tend to consume more than they intended. The results showed

that men drank more than intended over 50% of the time and women drank more than intended just over 44% of the time. Although the reason for over consuming alcohol is not fully understood, it has been argued that volitional control as well as high self-efficacy are needed in order to stick to a pre-planned number of drinks to consume in a night (Ajzen, 1991; Ajzen and Madden, 1986).

Participants reported a hangover duration of almost twelve hours. Despite consuming a similar number of drinks, a study carried out by Schroyen Lantman, Mackus, Verster et al. (2017) reported that participants' hangover's lasted on average 18.4 hours. Despite this, there are many potential reasons for this and more information and analysis would be required to conclude why these reports differ. Of note, participants in Schroyen Lantman, Mackus, Verster's study were asked to report on their latest *heavy* drinking session whereas participants in this study were asked how long their hangovers *typically* last.

Furthermore, the number of drinks consumed did not correlate with hangover severity or duration. As in the previous Chapters, tiredness was the most highly rated symptom. The total mean rating of hangover (20.08) was considerably higher than that of the non-student sample in the previous Chapter (14.38). This may reflect the difference in drinking behaviours between student and non-student samples. Interestingly the mean number of drinks reported was lower in this study indicating potential differences in hangover severity among student and non-student drinkers.

5.5.3.1 *Limitations*

At the time of designing and conducting this study it was best practice to remove participant with a BAC of more than 0 as it was argued that a positive BAC could produce additional (acute) effects on performance. However, current consensus resulted in a definition of the alcohol hangover stating that hangovers occur when “BAC approaches zero” (van Schrojenstein Lantman et al., 2016). In retrospect, it would have been interesting to also include participants with a positive BAC reading in the study and determine to what extent this influences performance.

5.5.3.2 *Implications*

The applicability of Attentional Blink to daily adult activities is vast (e.g. caring for children, reading, driving). The results from this study indicate temporal attention is impaired during a hangover, thus, performance on daily tasks involving rapid sequences of visual input is likely to be impaired. For example, an impaired ability to respond to moving objects may pose a particular danger during a hangover. Thus, this study provides further support for the argument that operations of moving vehicles should be carried out with caution the day after a night's drinking.

The methodological implications of this study relate to the analysis and tasks carried out. Although, selective, divided, reaction time and Stroop attention tasks are standardised in hangover research, the use of alternative tasks and analyses provide additional information that help us to better understand the hangover. For example, variation in response times but not error rates in attention tasks may represent an increase in time needed to make an

accurate response as well as slowed motor responses. This knowledge applicable to standardised tasks is gained through exploration of alternative tasks and analyses.

5.5.3.3 Conclusion

This study highlights the complexity of the attentional systems and gives insight into areas of attention such as visual information processing and response inhibition. Moreover, the signal detection analysis provides novel insight into the decision-making mechanisms at play during a hangover and also provides information on why participants may take longer to respond to attention task when hungover. Future studies should apply attentional bias analyses and look beyond central tendencies (Bruce & Jones, 2004; Grange et al., 2016) in order to gain a more comprehensive analysis of the alcohol hangover.

6. Smartphone and wearable technologies in an alcohol hangover study

6.1 Introduction

The use of smartphone and wearable technologies has garnered much attention within the fields of behavioural and physiological research as they offer the possibility of additional real time information as well as more detailed and varied data collection than traditional self-report measures (Kerr, Aronoff & Messé, 2000). This study introduces the use of smartphone and wearable technologies to investigate real time sleep, physical activity and alcohol consumption after a night's drinking.

According to a definition compiled by the AHRG, the alcohol hangover refers to the combination of mental and physical symptoms, experienced the day after a single episode of heavy drinking, starting when blood alcohol concentration approaches zero (Van Schrojenstein Lantman, van de Loo, Mackus, & Verster, 2016). Many factors may aggravate hangover severity and corresponding performance impairment, one of which is the quality and duration of sleep after a heavy drinking session (Wolf, Perhats, Delao & Martinovich, 2017). Indeed, tiredness is the most commonly reported hangover symptom (Penning, McKinney & Verster, 2012). Both hangover and sleep disturbances have been shown to significantly impair one's ability to negate potentially dangerous daily activities such as driving a car (Jongen et al. 2014; Verster et al. 2014). It is therefore necessary to further examine the relationship between alcohol consumption, sleep, and the alcohol hangover.

Up to now, several studies have addressed this issue (Finnegan et al, 1998; Roehrs et al., 1999; Van Schrojenstein Lantman et al., 2017) and the collected scientific data comes from either self-report or biopsychological assessments such as polysomnography. However, self-report measures may not accurately reflect sleep efficiency, and in contrast polysomnography

studies may reduce the real-life applicability of data collection as they require participants to complete the study in a laboratory. In addition, although evidence suggests that an alcohol hangover impacts on one's energy expenditure, no real time data has been collected in order to investigate this prediction. The following sections will explore these issues.

6.1.1 Alcohol Consumption

Self-report measures are one of most widely used tools in psychological research (Haeffel & Howard, 2010). In the case of alcohol consumption this at the minimum involves using retrospective memory to recall the type and number of alcoholic beverages consumed (Baldwin, 1999) as well as applying one's ability to comprehend the question being asked, make decisions about the accuracy of the information recalled, and format an answer (Jobe & Herrmann, 1996). Although this approach is often used in hangover research (McKinney & Coyle, 2006; McKinney, Coyle, Penning and Verster, 2012; Finnegan, Schulze, Smallwood & Helander, 2005) it is also limited by response bias (Furnham & Henderson, 1983). For example, participants may be reluctant to disclose information about the number of drinks consumed the previous night. As well as response bias, diminished retrospective ability may prevent accurate recall as the environmental context of which drinking takes place is likely to differ to the experimental setting (Godden & Baddeley, 1975). Furthermore, it may not be possible to accurately report on alcohol consumption as according to White (2003), periods of memory loss while a person is intoxicated can begin after one or two drinks and McKinney and Coyle (2004), reported memory can be significantly impaired the morning after a night's drinking.

To date, Monk, Heim and Price (2015) are the only researchers to report applying smartphone technologies to investigate in vivo alcohol consumption. In their study, an application was designed to give hourly prompts to participants to select the context and number of drinks consumed. The results showed that participants significantly under-reported alcohol consumption when using self-report measures. A difference of almost four drinks was reported on alcohol consumption (8.45 in vivo, 4.17 retrospective). In consideration of this, real time measurements are desirable for increased accuracy on alcohol consumption measures. The following study applied smartphone technologies using Droid Survey and iSurvey apps designed by Harvest My data to collect real time data on alcohol and water consumption, as well as hourly ratings of intoxication. As described in Chapter 2, the implementation of this programme provides a real time measurement of alcohol consumption and ratings of intoxication that is traditionally reported retrospectively in hangover and alcohol research.

6.1.2 Sleep

Most evidence on the association between an alcohol hangover and sleep comes from self-report methods, either collected in clinical studies or via retrospective surveys (Finnegan et al., 1998; Hogewoning et al., 2016). These revealed that drinking time often results in later bed times (drinking at the expense of total sleep time) and that alcohol has a detrimental effect on sleep quality. For example, in a controlled study, Finnigan et al. (1998) observed that participants fell asleep faster after alcohol consumption and reported reduced next-day alertness. McKinney and Coyle (2004) also examined alcohol hangover effects and sleep in 48 social drinkers. Applying a naturalistic study design, the researchers did not interfere with drinking behaviour and no restrictions placed on the participants sleep behaviour. Similar to

Finnigan et al. (1998), McKinney and Coyle found that sleep was disrupted after alcohol consumption and next-day fatigue was significantly increased. After alcohol, sleep was qualified as less satisfying, refreshing, and restful. Further, after alcohol consumption participants went to bed significantly later when compared to the alcohol-free day, resulting in a significantly reduced TST. Moreover, if the amount of alcohol intake increased, sleep latency reduced accordingly. Similar findings were reported by Hogewoning et al. (2016) who's naturalistic study also revealed that drinking time goes at the expense of TST and that bed time is significantly delayed after alcohol consumption compared to an alcohol-free evening by more than 1.5 hours.

Rohsenow et al. (2006) examined power plant operations in 61 merchant marine cadets the day following an evening of alcohol administration to achieve a BAC of 0.11% compared to an alcohol-free control test day. After an 8h period of supervised sleep, participants reported significantly improved sleep quality in the alcohol Condition. The latter unexpected finding may be explained by the fact that after alcohol consumption participants reported significantly reduced sleep onset latency. Of note, power plant performance was not impaired in the hangover State. Nonetheless, as with retrospective reports of alcohol consumption, subjective measures of sleep may also be subject to limitations such as diminished retrospective ability and response bias as well as varied interpretations and estimations of quantity and quality of sleep. For example, Lewis (1969) compared subjective and objective measures of sleep and demonstrated that individuals often overestimate sleep onset latency, underestimate TST and overestimate time spent awake during the night. In addition, using actigraphy, Landry, Best, and Lui-Ambrose (2016) demonstrated that sleep quality ratings do not correlate with objective

measures in older adults (55+). Therefore, subjective measures of sleep should be interpreted with caution.

In terms of surveys, Van Schrojenstein Lantman et al. (2017) conducted a survey among 578 Dutch University students examining the impact of TST on the presence and severity of their latest alcohol hangover (past month). Participants who consumed more alcohol reported sleeping significantly longer. A positive association was also found between TST and the duration of the alcohol hangover State. However, at the same time prolonged TST was associated with significantly reduced overall hangover severity. Thus, reduced TST was associated with more severe hangover complaints. In a second survey by van Schrojenstein Lantman et al. (2017), 335 adults reported that sleep quality was significantly worse after their latest alcohol consumption session that resulted in an alcohol hangover, and that next-day sleepiness was significantly increased compared to the alcohol-free day. It is therefore of interest to explore the relationship between hangover symptoms and objective sleep measures in this Chapter. It is also predicted that the time in which participants fall asleep will be later after a night's drinking than during the no alcohol Condition.

In relation to real time data collection, Rohsenow et al. (2010) applied polysomnography to examine sleep in relation to alcohol hangover in N=95 social drinkers. In a double-blind study, sleep was assessed after alcohol administration to achieve a BAC of 0.11% and on an alcohol-free control day. The authors found that alcohol significantly reduced sleep efficiency and rapid eye movement sleep. And next day self-reported sleepiness was significantly increased during hangover. Significantly more severe hangovers were reported by participants

with reduced sleep efficiency and shorter TST. In addition, when hangover severity increased, less time was spent in rapid eye movement sleep.

Polysomnography studies with lower alcohol dosages revealed similar effects on sleep (Roehrs et al. 1991, Roehrs et al. 1999, Feige et al. 2006). Alcohol significantly reduced sleep latency and the time spent in REM sleep. In the first half of the night, alcohol consumption significantly increased the time spent in deep sleep (stage 3 and 4), while in the second half of the night, time spent in stage 1 sleep (drowsy light sleep) was significantly increased. The observations confirmed previous findings that after alcohol consumption individuals fall asleep quicker and spent less time in REM sleep in the first 4 hours of sleeping (e.g., Roehrs et al. 1991). In next 4 hours (the second half of the night), sleep is more disturbed and fragmented, and is often characterized by multiple awakenings and increased time spent in Stage 1 sleep (e.g., Roehrs and Roth 2001). Roehrs et al. (1991) also conducted a Multiple Sleep Latency Test (MSLT) the day following alcohol consumption (peak BAC 0.08%) or placebo. The assessments showed that throughout the hangover day participants fell asleep significantly faster when compared to the alcohol-free day. In conclusion, this study highlights the variation in sleep performance in the first and second half of the sleep period.

Wilkinson et al. (2018) applied actigraphy to a study with ten healthy participants without sleep disturbances. Participants continuously wore an actigraph starting three nights before the day of alcohol consumption up to 4 days thereafter. In the two days before the alcohol challenge, mean (SD) TST was 80.0 (10.0) and no naps were recorded. On the test day, alcohol (0.89 g/kg for men and 0.81 g/kg for women) was administered in a controlled laboratory setting. This was done in the morning at 9a.m., and a peak BAC of approximately

0.14% was reached. In the 24 hours thereafter, participants completed the Acute Hangover Scale (Rohsenow et al. 2007). After the morning of alcohol consumption, seven out of 10 participants took an unscheduled afternoon nap, on average 8.7h after drinking, which lasted 0.6h. The authors further analysed the data separately for those who had napped and those who had not after alcohol consumption. Given the small sample size of the study it may not be appropriate to compare a group of 3 non-napping participants with 7 napping participants. Also, a rationale for having these groups was not provided. Nonetheless, the analysis revealed that the groups did not differ significantly on TST or hangover severity. TST the night after alcohol consumption was 8.7h in nappers and 8.1h in not in non-nappers. Mean (SD) hangover severity of nappers was 1.1 (0.6) and 1.3 (1.8) for the non-napping group. A limitation of the study is that alcohol was administered at 9.a.m in the morning. Therefore, it is unclear to what extent this study mimics real-life drinking and the 'normal' alcohol hangover experience. With this considered, the following study sought to apply real time measures to a naturalistic setting with a larger sample of participants in order to investigate the relationship between sleep and hangover severity.

6.1.3 Physical Activity

Despite research that indicates energy is reduced during a hangover, no objective evidence is available to review this assumption. Lessened energy and a heightened feeling of tiredness were the most frequent alcohol related consequence reported by 800 Dutch (63%, Verster, van Herwijnen, Olivier & Kahler, 2009). The body responds to alcohol as a toxin and as our bodies flush toxins out of our system we also lose nutrients. For example, Ylikahri,

Huttunen, Eriksson and Hikkilä (1974) found that during intoxication blood sugar (glucose) levels rise and then become lower than average after the alcohol leaves the system. Loss of blood sugars as a result of previous alcohol consumption causes feelings of fatigue and weakness (Swift & Davidson, 1998).

Considering the literature presented above, it is predicted that alcohol consumption may not be accurately reported following a night of heavy drinking. It is also anticipated that sleep time will be later in evenings where alcohol is consumed. Finally, it is predicted that sleep efficiency and TST will be reduced during a hangover and participants will engage in less demanding physical activities during a hangover.

6.2 Method

6.2.1 Participants

For ease of exposition, data for this Chapter was collected in unison with that described in Chapter 5 and forms part of Study 3. The same sample of participants ($n=25$) were tested as in Chapter 5 and testing took place over the same time frame. In terms of incentive, participants were offered the opportunity to view a summary of their physical activity and sleep measures (in PDF) after participation.

6.2.2 Design

In this Chapter a within participants variable of State (Hangover/No Hangover) with a between groups variable of Order (1/2). As in Chapter 5, the study comprised of an evening of alcohol consumption (hangover) and an alcohol-free (no hangover) test day. Participants

consumed alcohol at a venue of their own choice, and type and quantity of alcohol and activities during the evening were not controlled by the researchers in order to closely mimic a real-life drinking occasions (Hogewoning et al. 2016). Next morning the participants came to the Institute for testing. Testing took place in private testing cubicles at the University's cognitive testing laboratory.

6.2.2.1 *GENEActiv accelerometer assessments*

Esliger et al., (2011) has validated and calibrated the GENEActiv accelerometer using Metabolic Equivalent of Tasks (METs) and Signal Vector Magnitudes (SVM, magnitude of watch movement). Of note, METs represent the energy costs of physical activity. One MET refers to an individual's resting metabolic rate and can be calculated by dividing the volume of oxygen (VO_2) used during the activity by 3.5 (1 MET= 3.5 ml O_2 /kg/min; Jetté, Sydney & Blumchen, 1990; Esliger et al., 2011). The outcome intensity levels categorised by Esliger (et al., 2011) and included in this study were: sedentary (<1.5, METs), light (1.5-3.99 METs), moderate (4.00-6.99 METs) and vigorous (7+ METs) activity. From this, the corresponding cut off points were set at 386 SVM (sedentary to light), 542 SVM (light to moderate) and 1811 SVM (moderate to vigorous). The SVM cut offs were adapted to the frequency of recorded data by multiplying the cut off by the recorded frequency and dividing by the raw frequency measurement of 80Hz (frequency at calibration) In addition, outcome measures also included the percentage of time spent in sedentary, light, moderate and vigorous activity from waking up to midnight, and total METs spent on the hangover and control day were calculated.

Continuous measurements of activity and inactivity allowed calculation of time of falling asleep, wake up time, total sleep time, sleep efficiency, and number and duration of nightly awakenings/activity. For further information on GENEActiv accelerometer see Chapter 2. An opensource sleep macro was used to convert the raw data from the GENEActiv devices to computed variables of overall sleep performance (ActivInsights, 2017). Sleep efficiency refers to the ratio of total sleep time (the number of epochs within the assumed sleep period as sleep multiplied by the epoch length) to assumed sleep time (time between sleep start and final wake time) multiplied by 100 (Lindert & Someren, 2013). As a result, the sleep efficiency variable is represented as a percentage.

6.2.3 Procedure

6.2.3.1 *Smartphone App*

A meeting was scheduled before a planned drinking session whereby participants were required to install and register the smartphone app Droidsurvey/iSurvey, as well as set an hourly alarm that would alert them during the time that alcohol consumption took place. Participants were instructed to complete a questionnaire on the app each time that the alarm signalled. The questionnaire required touch screen responses to four short questions pertaining to the number of drinks consumed, the type of drinks consumed, water consumption and the degree of intoxication experienced (Visual Analog Intoxication Scale). It takes approximately one minute to complete. See figure 6.1 below for questions.

Figure 6.1. Example of real time alcohol consumption data collection using smartphone technologies iSurvey and Droidsurvey

The figure displays six sequential screenshots of a smartphone survey application interface:

- Screen 1 (Welcome):** Titled "TEST MODE". It says "Welcome to the survey. Touch the Start button to continue" and features a large "Start" button and an image of a glass of red wine.
- Screen 2 (Alcoholic Drinks):** Asks "How many alcoholic drinks have you consumed in the past hour?". It provides radio button options: 0, 1, 2, 3, 4, and 5+.
- Screen 3 (Drink Types):** Asks "What kind of drinks have you consumed in the past hour?". It lists several drink types with checkboxes: Weak Beer/Cider (pint), Weak Beer/Cider (bottle, 330ml), Strong Beer/Cider (pint), Strong Beer/Cider (bottle, 330ml), Wine (small glass 125ml), Wine (large 250ml), spirit (shot with mixer), alcopop, and None. It is labeled "Multiple select".
- Screen 4 (Water Consumption):** Asks "Have you consumed water?". It provides radio button options: No, Yes, 1/2 pint, Yes, 1 pint, and Yes, more than 1 pint. It is labeled "Pick 1".
- Screen 5 (Intoxication Scale):** Asks "On a scale of 0-10, how intoxicated do you feel?". It features a horizontal slider with a purple bar and a circular handle, ranging from 0 to 10.
- Screen 6 (Thank You):** Says "Thank you for completing the survey" and features a large "Finish" button.

At the bottom right, there is a logo for **Ulster University** and a footer that reads "Powered by droidsURVEY - www.surveysoft.com".

6.2.3.2 Watches

On each test day, participants were asked to wear a GENEActiv accelerometer (GENEActiv, 2018) and were given the option to wear the watch between testing sessions also. As can be seen from Figure 6.2. participants were unable to view measurements on the watch and identification numbers were used to match participants and watches.

Figure 6.2. Illustration of GENEActiv watch.



6.2.4 Subjective Measures

Mood (Herbert, Johns & Dorés, 1976), sleep quantity and quality (McKinney, 2003), hangover severity (AHS; Rohsenow, 2007) and alcohol consumption questionnaires were administered the day after alcohol consumption. For more information see Chapter 2 and Appendix 1.

6.2.5 Analysis

A mixed measures analysis of variance was carried out to investigate State and Order differences across objective measures. Paired t-test analysis was applied to compare subjective and objective reports of sleep as well as light exposure. Pearson's product moment correlation analyses were used to investigate the relationship between measures. In all instances, alpha was set at 0.05.

6.3 Results

Three participants did not attend the testing sessions, as a result, 25 participants completed both testing sessions. Descriptive statistics pertaining to age, gender, alcohol and caffeine consumption, drinking duration and hangover severity are summarized in Table 6.1.

Table 6.1. Descriptive statistical analysis pertaining to sleep and alcohol consumption of participants.

	Mean (SD)
<i>N</i>	25
Male/Female	12/13
Age (years)	25.68 (70.02)
Age of first drink (years)	14.9 (1.68)
Total sleep time (min)	393 (115)
Caffeine Consumption Hangover (Yes/No)	16/9
Caffeine Consumption No Hangover (Yes/No)	15/10
Reported units of alcohol consumed	12.78 (4.95)
Start time drinking	20:48 (3:47)
Stop time drinking	01:17 (1:12)
Duration of alcohol consumption	04:53
Consumed more alcohol than planned (Yes/No)	10/15
Alcohol hangover severity	20.35 (8.7)

6.3.1 Smartphone Technologies

Results from the real time data collection of alcoholic drinks consumption revealed that a mean of 11.39 (SD= 3.83) beverages were consumed however participants reported a mean of 80.04 beverages (SD= 2.65) the following day. A paired samples T-test revealed a significant difference in real time and next day reports of alcohol consumption ($t(22)=-5.133$, $p<0.0001$).

Of note all participants reported consuming over the amount considered a binge in real time reports, however, one person revealed drinking less than 4 drinks the following day (HRB, 2013). Moreover, 14 participants reported consuming water during alcohol consumption of which 42.9% consumed a half pint glass and 21.4% consumed one pint glass and another 21.4% consumed one and one half pints of water. On the visual analogue intoxication scale, participants reported a mean peak intoxication of 62.47/100 (SD=20.25).

As expected a correlation analysis revealed a positive relationship between drinks consumed and ratings of intoxication ($r=.424$, $p=0.03$, $n=24$). Those that consumed water reported lower levels of intoxication ($M=58.5$, $SD=22.12$, $n=24$) than those that did not ($M=68.67$, $SD=16.16$). However, the difference did not reach significance ($F(1, 21)=1.41$, $p=.25$, $n=24$). For those that consumed beer or cider, the mean level of peak intoxication (highest rating per person) was 66.92 ($SD=15.93$). Wine consumers reported a mean peak intoxication of 53.89 ($SD=17.74$) and alcopop drinkers reported an intoxication rating of 56.43 ($SD=29.17$) and finally, those that consumed spirits reported the highest peak intoxication levels ($M=72$, $SD=9.95$). Out of the participants that completed the Droidsurvey/iSurvey (23/25), 65% reported mixing drink in real time. However, only 56% of participants reported mixing drinks the following day.

6.3.2 Accelerometer

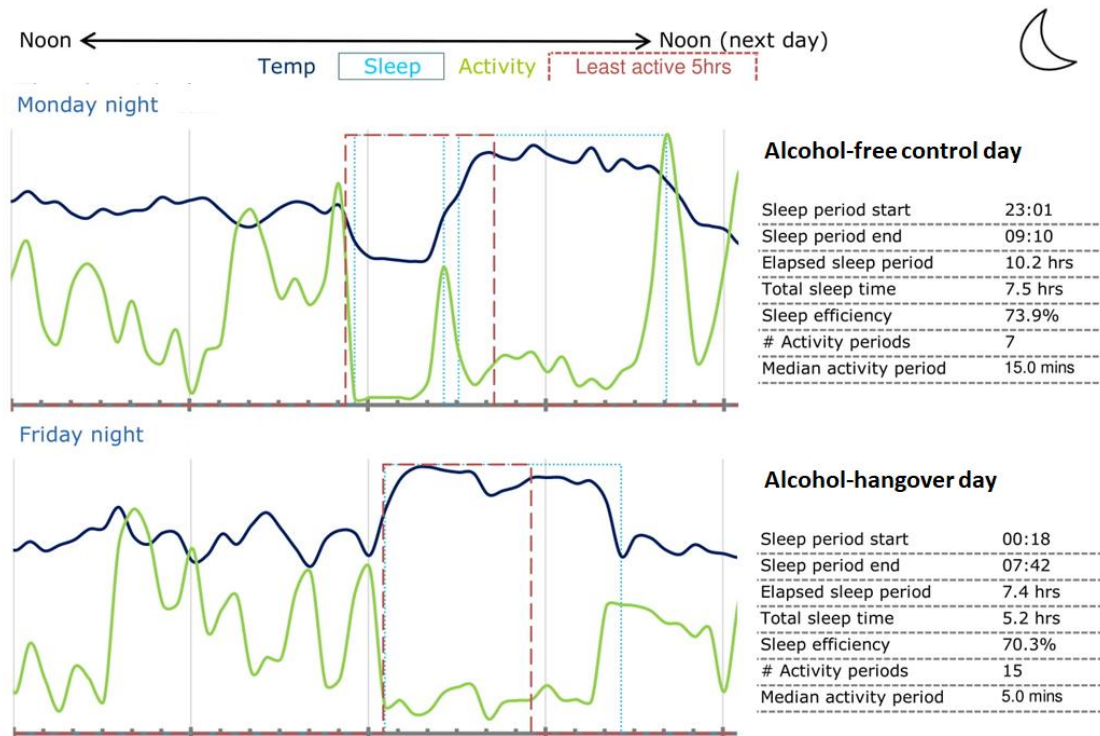
6.3.2.1 Sleep Analyses

An example of the output data pertaining to sleep is presented in Figure 6.3.

6.3.2.2 *GENEActiv sleep assessments*

It can be seen in Figure 6.3 that there is a phase delay in sleep time in the hangover Condition. The participant in this example went to bed 1h and 17 minutes later after alcohol consumption when compared to the alcohol-free night. Also, there are more activity periods during the night when the participant is hungover and Sleep Efficiency is lower when hungover also.

Figure 6.3 An example of the visual output and summary data



Mixed measures analyses of Sleep Efficiency revealed significantly better Sleep Efficiency in the no hangover State than in the hangover State ($F(1, 23)=4.92, p=0.04$). However, Order differences did not reach significance ($F(1, 23)=.33, p=.57$).

Moreover, the results revealed the time at which participants woke up in the morning differed across hangover ($M=9:46$, $SD(1:37)$) and no hangover ($M=8:56$ ($SD=1:53$), however it did not reach significance ($F(1, 23)=4.13$, $p=0.05$). Order was not significant also ($F(1, 23)=40.05$, $p=0.06$). In order to analyse the time that participants went to sleep a 'roll on' variable was computed whereby 01:00 hours (1.a.m.) was transformed into 25:00 hours. In this way, the TST variable was converted into a scale variable so that mean scores could be analysed.

Using this method, a mixed measures analysis was carried out on TST and as expected, the results revealed a main effect of State ($F(1, 23)=43.5$, $p<0.0001$) with earlier bed times in the no hangover testing sessions ($M=00:41\text{am}$, $SD=1\text{hr } 16\text{mins}$) than in the hangover testing sessions ($M=02:41\text{ am}$, $SD= 1\text{hr } 17\text{ mins}$). Although the TST (in minutes) was longer in the no hangover testing sessions ($M=479.24$, $SD=282.86$) than in the hangover testing sessions (394.4 , $SD=225.95$), the difference did not reach significance ($F(1, 23)=1.81$, $p=.19$). Interestingly, Elapsed Sleep Time was similar in both hangover ($M=644.64$, $SD=3580.01$) and no hangover ($M=640.64$, $SD=270.59$). More Activity Periods were recorded during the night after alcohol was consumed ($M=9.15$, $SD=5.38$) than when alcohol was not consumed ($M=80.00$, $SD=60.07$), however, State did not reach significance ($F(1, 23)=0.03$, $p=.87$). There were no Order interactions in any of the sleep variables analysed. A summary of objective sleep measures is presented in Table 6.2.

Table 6.2. Summary of GENEActiv Sleep variables

	Hangover	No Hangover	p-value
Start time sleeping	02:41 (1:17)	0.41 (1.16)	0.00*
Wake up time	9:46 (1:37)	8.56 (1:53)	0.06
Time in bed (h:mins)	9:27 (2:46)	9:22 (2:14)	0.85
Total sleep time (h:mins)	6:34 (3:45)	7:59 (4:42)	0.19
Sleep Efficiency (%)	690.0 (16.7)	80.0 (15.2)	0.04*
Number of nightly activity periods	8.4 (5.5)	80.0 (6.1)	0.87

6.3.2.2.1 Subjective verses physiological methods

A series of paired sample t-tests were carried out in order to compare the means of subjective and objective sleep and wake time variables. Mean scores and standard deviations are presented in the table 6.3 below. The analysis revealed no significant differences in subjective and objective reports of sleep and wake times in hangover and no hangover testing sessions (6.3).

Table 6.3. Subjective vs Objective hangover reports across hangover and no hangover testing sessions

	Hangover M(SD)			No hangover M(SD)		
	Subjective	Objective	p-value	Subjective	Objective	P value
Sleep Time	02:28 (1:14)	02:41(1:17)	.22	00:23 (1:11)	00:41 (1:16)	.17
Wake Time	9:00 (2:25)	9:46 (1:37)	.22	8:25 (1:14)	8:56 (1:53)	.16

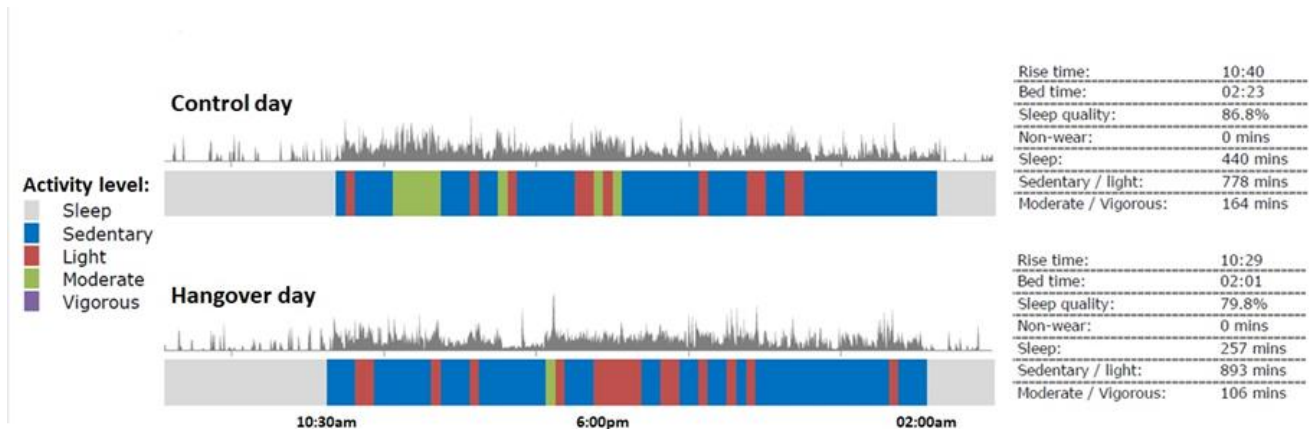
6.3.2.2.2 Correlation

A Pearson's correlation analysis of differences (hangover minus no hangover) in objective and subjective sleep measures revealed a significant positive relationship between subjective and objective bed times ($r=.46$, $p=0.02$, $n=24$) and a significant negative correlation between objective Sleep Efficiency and activity periods ($r=-.58$, $p=0.01$, $n=24$). Subjective and objective wake times did not correlate ($r=.22$, $p=.29$, $n=24$). In addition, objective Sleep Efficiency and subjective sleep quality ($r=.46$, $p=0.03$, $n=24$), and objective efficiency and subject sleep satisfaction positively correlated ($r=.43$, $p=0.04$, $n=24$). Objective TST and efficiency ($r=.45$, $p=0.03$) as well as objective TST and elapsed sleep time positive correlated ($r=.71$, $p=0.00$). Subjective bed time negatively correlated with sleep satisfaction ($r=-.53$, $p=0.01$, $n=24$), restfulness ($r=-.51$, $p=0.01$, $n=24$) and refreshing-ness of sleep ($r=-.54=0.01$, $n=24$) As expected, objective rise time and subjective TST negatively correlated ($r=-.42$, $p=0.04$, $n=24$). See Appendix 5 for more details.

6.3.2.3 Physical Activity

As with the sleep measures, physical activity percentage and METs measures were analysed using a mixed measures analysis. An example of the dependent physical activity measures is demonstrated in Figure 6.4. It is evident from Figure 6.5 that activity levels were reduced on the hangover day. Most time was spent in the sedentary activity mode. Whereas moderate activity levels were seen on the no hangover day which were absent on the hangover day. In this example, this may be associated with the large reduction in TST and poorer sleep quality the night before the hangover day.

Figure 6.4. Sample accelerometer output of hangover and no hangover day activity.

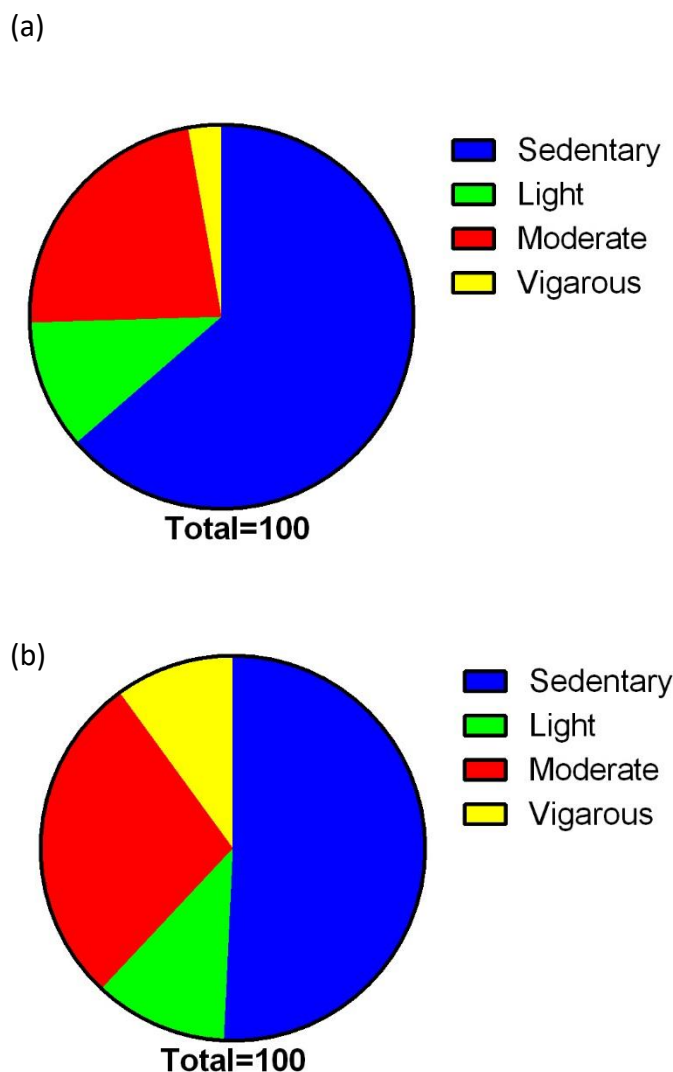


6.3.2.3.1 Percentage Activity Level Analysis

A mixed measures analysis revealed that a higher percentage of the participants day was spent in a sedentary manner when hungover ($M=63.63$, $SD=22.59$) than when not hungover ($M=50.75$, $SD=24.13$; $F(1, 23)=8.47$, $p=0.02$). The effect of Order did not reach

significance ($F(1, 23)=.65, p=.43$) and did not interact with State ($F(1, 23)=1.33, p=.26$). Analysis on light activity revealed similar levels of activity in hangover ($M=10.89, SD=7.31$) and no hangover ($11.23, SD=6.20$) testing sessions ($F(1,23)=0.001, p=.98$). As expected Order did not reach significance ($F(1, 23)=10.09, p=.31$). Furthermore, moderate activity did not differ across testing sessions ($F(1, 23)=2.63, p=.12$). However, the percentage of time spent engaged in vigorous activity was significantly less when participants were hungover ($M=2.81, SD= 5.34$) than when they were not ($M=10.02, SD=17.45; F(1, 23)=5.40, p=0.01$).

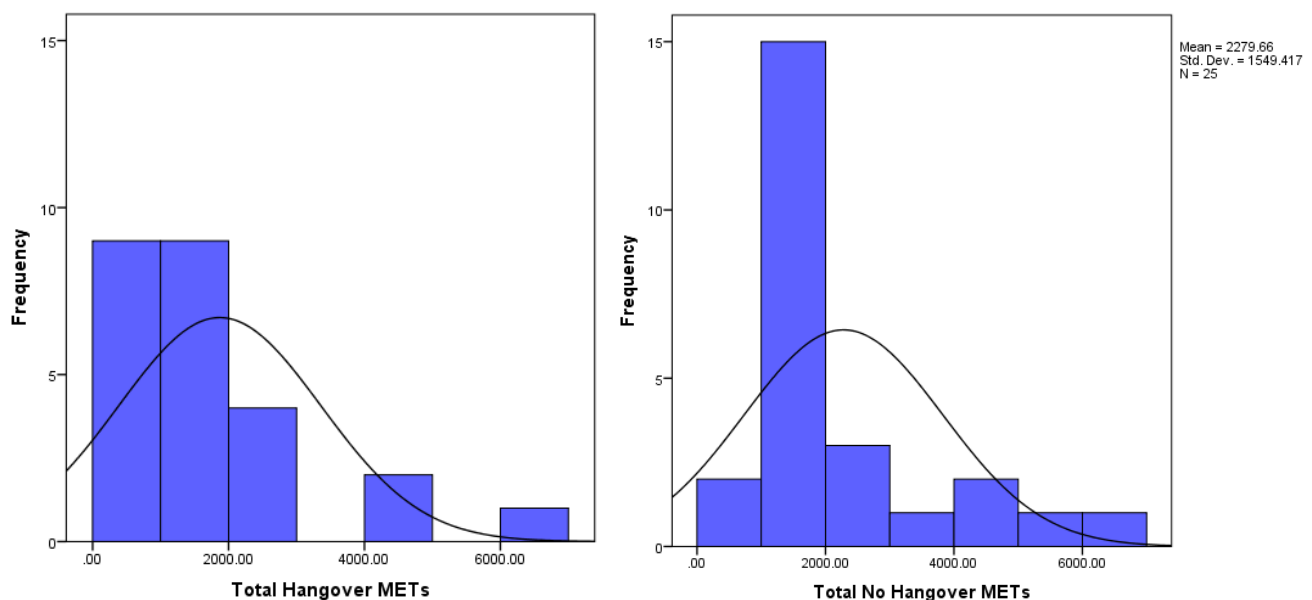
Figure 6.5. Percentage of day spent engaging in sedentary, light, moderate and vigorous activity (a) Hangover day (b) No Hangover day



6.3.2.3.2 METs

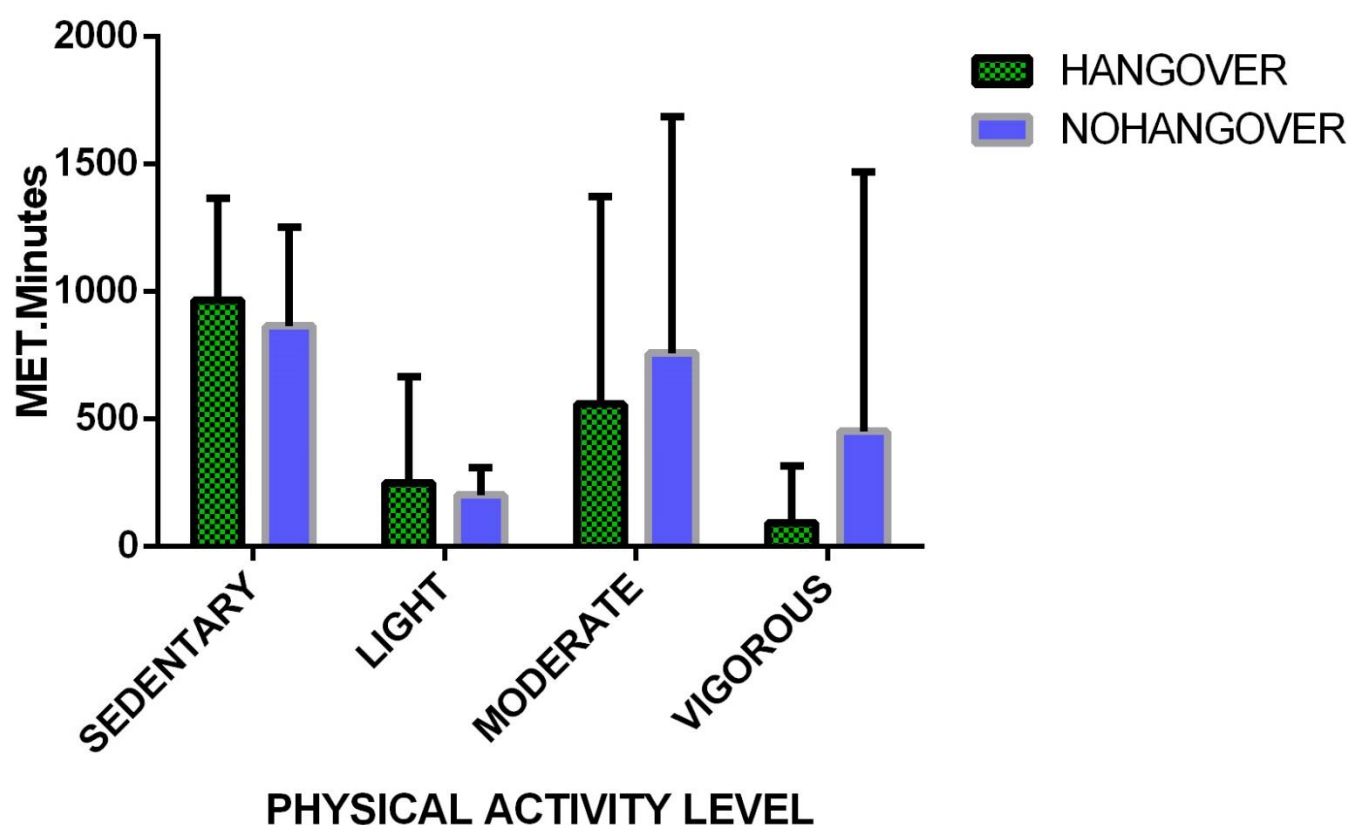
The total number of METs did not differ significantly across Hangover and No Hangover States ($F(1, 23)=2.13, =.16$). However, a total of 408.66 METs separated the Hangover (1870.99) and No Hangover (2279.66) testing sessions. A considerable spread of mean total METs was revealed in both Hangover ($SD=14870.02$) and No Hangover (1549.42) sessions (Figure 6.6). Despite this, skewness of total METs in hangover (20.02) and no hangover (1.68) days fall on the guidelines (value of ± 2) suggested by Trochim and Donnelly (2006); Field, (2000, 2009), and Gravetter and Wallnau, (2014).

Figure 6.6. Skewness of Hangover and No Hangover testing sessions (METs)



Sedentary activity did not differ significantly across States ($F(1, 23)=.56$, $p=.46$) and no interactions of Order were revealed ($F(1, 23)=.35$, $p=.56$). Similarly, no main effects of State or Order were revealed for light ($F(1, 23)=.49$, $p=.49$; $F(1, 23)=2.45$, $p=.13$) or moderate activity ($F(1, 23)=3.18$, $p=0.09$; $F(1, 23)=10.04$, $p=.32$). However, a main effect of State was revealed for vigorous activity with more METs in the No Hangover testing session than in the Hangover testing session ($F(1, 23)=4.51$, $p=0.045$).

Figure 6.7. Mean MET scores for each activity level across hangover and no hangover States



A paired t-test analysis was carried out on light exposure across hangover and no hangover testing sessions. Although light exposure was higher during no hangover testing ($M=682642.75$, $SD=731425.22$) than hangover testing ($M=446771.25$, $SD=604439.63$), the differences did not reach significance ($t(23)=1.49$, $p=.15$).

6.3.2.4 *Correlation*

A Pearson's product moment correlation was carried out on the percentage variables of activity levels, performance variables, age, units consumed, total acute hangover scale scores, intoxication ratings of alertness, tranquillity and sleep during a hangover. The results revealed a negative correlation of sedentary and vigorous activity ($r=-.47$, $p=0.02$, $n=25$). As well as this, sedentary activity positively correlated Stroop Control ($r=.41$, $p=0.045$, $n=25$) and Social word ($r=.43$, $p=0.03$, $n=25$) response times. Moderate activity positively correlated with Move Time (5CSRTT; $r=.43$, $p=0.03$, $n=25$), incompatible near (Selective Attention; $r=.40$, $p=0.047$, $n=25$) and physical threat words (Emotional Stroop; $r=.41$, $p=0.04$, $n=25$). Vigorous Activity positively correlated with Choice Return Time ($r=.40$, $p=0.047$, $n=25$) but no other variables correlated ($p>0.05$, see Appendix 6.)

6.4 Discussion

6.4.1 Summary

This study introduces a novel approach to collecting real time data during an alcohol hangover. The results revealed that participants reported consuming significantly more drinks in real time than retrospectively the following day. The results from the sleep data revealed that participants accurately reported sleep times. However, the quality of the sleep

experienced was lower during a hangover, with more disruptions and activity periods. Despite this, correlational data indicated that there is no relationship between Sleep Efficiency and performance during a hangover.

Energy expenditure after a night's drinking has not been previously explored. The findings show that more time is spent in sedentary activity after a night's drinking than when drink has not been consumed. Most interestingly, significantly more vigorous METs were expended in the no hangover Condition than in the hangover Condition. From these findings it may be speculated that during a hangover, activities are carried out at a slower and therefore less vigorous pace.

6.4.2 Smartphone Technologies

The results from the analysis on real time reports verses retrospective reports of alcohol revealed a difference of over 3 drinks. Indicating that the following day, participants under-reported the number of drinks consumed the night before testing. Indeed, according to the real time data collection, all participants consumed alcohol at a binge level on the night before the hangover testing session (HRB, 2013).

The results also indicate that lower reports of intoxication were associated with water consumption but did not reach significance. These results should be interpreted with caution as water consumption was not monitored before alcohol consumption on the drinking day. Body water differences have been documented across genders (Frezza et al., 1990) and ages (Schoeller, 1989), however this has not been controlled for. Future research should address this

by measuring body water levels and monitoring daytime food and water consumption prior to alcohol consumption.

The highest mean peak intoxication ratings were reported by those that consumed spirits even though the most alcohol consumed was done so by those that consumed cider or beer. In summation, real time data collection indicates that next day self-report measures alone may not be as accurate as previously thought. Future studies should incorporate smart phone technologies to hangover research to ensure that an accurate representation of alcohol consumption.

6.4.3 Sleep

The sleep analysis data indicates that Sleep Efficiency is better when not hungover. efficiency represents a ratio of total sleep time to assumed sleep, therefore, these results imply less disrupted sleep during a hangover. Similar values for elapsed sleep time across States were revealed but varying Sleep Efficiency indicate that the time spend in bed does not appear to differ across States, however the time spent asleep does. Reduced Sleep Efficiency found in this study is supported by the findings of Rohsenow et al. (2010). In addition to this, more activity was recorded during sleep when hungover which further support the argument that sleep is disrupted during a hangover. These finding support that of Salamy (1972) which showed that alcohol affects the proportions of sleep stages throughout the night. Interestingly, it has been argued that it does so by suppressing the REM stages of sleep however the analysis on REM sleep and State did not reach significance (Salamy, 1972). During REM sleep, more movement

occurs (Roethlis and Roth, 2001). Thus, the findings of increased activity during a hangover do not support the argument of reduced REM sleep during a hangover (1972).

The results from the comparisons between subjective and physiological measures of sleep suggest participants accurately reported sleep and wake time. However, subjective reports of sleep may overlook sleep disturbances that offer insight into the way in which intoxication affects sleep. Subjective ratings of sleep did not correlate with sleep at either hangover or no hangover Conditions indicating that the way in which a night's sleep is interpreted may not accurately reflect the true sleep experience and this should be considered in future studies. Similarly, Landry, Best and Liu-Ambrose (2015) have found discrepancies between subjective and objective reports of sleep irrespective of gender, age or cognitive status.

6.4.4 Physical Activity

The results from the physical activity data indicate that a higher proportion of the day is spent in a sedentary State during a hangover and significantly less time engaging in vigorous activity. Although light and moderate activity did not differ significantly across States. The results from the METs analysis indicate no significant difference in total METs across States. However, 408.66 more METs were expended during the no hangover testing session. A main effect of State was revealed for vigorous activity but not sedentary. These results indicate that although a larger percentage of the day is spent in sedentary activity, the energy expenditure difference occurs across States during vigorous activity. Speculatively this may mean that day to day vigorous activities such as rushing up a staircase to answer a phone, may not be engaged

during a hangover. Instead, activities may be carried out with less intensity which gives rise to the overall sluggish behaviour associated with a hangover.

Of note, METs analysis revealed considerable variance which among participants which may have reduced the likelihood of revealing a main effect of State. More METs can be acquired with less time during vigorous activity. Therefore, differences in energy expenditure during vigorous activity will be larger with much shorter periods of time.

6.4.5 Limitations

The smartphone application measured the number of drinks and type of drinks consumed. However, the number of units consumed could not be calculated as the number of each beverage type was not available e.g. five drinks consumed including wine and vodka drinks. On reflection, a norming experiment would have highlighted this issue before data was collected. However, due to the limited duration of testing times available within each academic semester, it was not possible to run both a norming experiment and the final experiment.

ActivInsights (2018) calculate Sleep Efficiency by dividing total sleep time by elapsed sleep time and multiplying by 100 over one. In this study, Sleep Efficiency does not represent an exact percentage of this ratio. It is also worth considering that the cut off threshold for sedentary and sleep States may be subject to inaccuracies. For example, Sleep is calculated by using the median of the sum of standard deviations of acceleration across the x, y and z axes (see Chapter 2 for more details on algorithm) in the last two hours. If more than half of the epochs in this period are less than one, the macro will conclude that the person is asleep. It will also do this during non-wear time. Therefore, if a participant removed the watch during the

night, non-wear time may not be detected. With this considered, one might posit that movement throughout the night e.g. sleepwalking, talking during sleep might trigger the macro to classify this time as wake time. Also, wake times may not reflect sleep ending but instead may represent initial move time after sleep ends.

6.4.6 Implications

The results from this study contribute to the growing body of research on the relationship between sleep and the alcohol hangover. Differences in objective Sleep Efficiency and bed times help to account for reports of tiredness after a night's drinking. This study offers a unique measurement of sleep in contrast to subjective and biopsychological measures. In addition, it provides a more accurate measurement of sleep than subjective measures and is also less expensive than biopsychological measures. The GENEActiv accelerometer allows for objective measures while the naturalistic environment remains intact, which is not possible with most biopsychological measure. As tiredness is the most popularly reported hangover symptom (Penning, Coyle & Verster, 2012), an increase in Sleep Efficiency will likely reduce the unpleasantness of the overall hangover experience. On a practical level, the presence of reduced Sleep Efficiency during a hangover has significant implications for those who wish to reduce symptoms of hangover related fatigue in order to fulfil their job requirements. For example, the British Army has acknowledged the potential for impairment during a hangover and this has been incorporated into education programmes for Commanders (Barker, 2004). Considering the evidence of reduced Sleep Efficiency and energy expenditure found in this study, organisations such as the British Army may wish to use energy supplements (e.g. Red Bull) in order to combat these symptoms. Therefore, future studies should explore the

effectiveness of products available that may restore energy levels and increase sleep efficiency after a night's drinking.

Real-time measures of alcohol consumption highlight implications for researchers in the field and as a result future studies should interpret retrospective reports of alcohol consumption with caution. The use of alcohol diary apps (e.g. Drink Less; University College London, 2018) in preventative treatments should also seek to apply real time measures of consumption. Nonetheless, during heavy drinking episodes it is possible that inebriation may prevent an individual from accurately completing an alcohol consumption questionnaire. It is therefore imperative that the design of smartphone apps enable an individual to complete the questionnaire through simple means e.g. button press only.

6.4.7 Conclusion

The results from this study provides evidence to support the use of real time data collection in hangover research. Future studies should apply smartphone technologies to collect accurate information pertaining to alcohol consumption. Sleep quality reports should be collected along with physiological measures as subjective measures do not appear to be accurate. Changes in sleep efficiency help to explain symptoms of fatigue that occur during a hangover. In relation to energy expenditure, it is possible that less vigorous activity is carried out during a hangover as participants prefer to expend less energy through slower movements when hungover. Future studies should combine subjective and physiological measures of physical activity and energy expenditure in order to explore the way in which activities are carried out during a hangover.

7. Discussion

7.1 The Setting

The impetus for this thesis was based on the impact of the alcohol hangover on society and our limited knowledge of the phenomenon. Given the inconsistencies relating to a hangover and attention, working memory and psychomotor performance (Stephens et al., 2010), the overarching aim of this thesis was to gain a better understanding of the next day effects of a normal night's drinking on cognitive performance and human performance. Traditional measures of sleep such as using self-report (Finnegan et al., 1998) and polysomnography in laboratory settings (Rohesnow et al., 2010) have provided important insights relating to alcohol and sleep in previous research. However, adequate physiological measures were needed to accurately measure the relationship between alcohol and sleep in a natural environment in order to provide both external and internal validity of measures.

Given the lack of scientific exploration of a hangover and physical activity, this thesis also aimed to determine the impact of a night's drinking on next day physical activity through physiology measures. In addition, the thesis sought to improve the methodological approach to hangover research through investigations of expectancy and sample types (e.g. student vs non-student) as well as through the introduction of a standard test battery, and smartphone and wrist-worn technologies. A number of important findings were made in relation to the impact of a hangover on performance including an absence of expectancy effects, a presence of serial positioning effects, information processing deficits, and changes in energy expenditure, the implications of which will be discussed in this Chapter. The improved methodological approaches as well as the novel approaches to collecting data in this thesis, provided a

foundation from which future investigations. An overview of these findings will be discussed in the next section.

7.2 Overview

7.2.1 Expectancy and Cognitive Performance

The aim of the first experimental Chapter was to investigate the role of expectancy on next day performance. Expectancy is often referenced as a limitation of the naturalistic approach within the field of hangover research (Ling et al., 2010; Stephen's et al., 2008); however, by directly addressing expectancy, this thesis also demonstrated that it can be a source of inquiry. The role of expectancy is often used to explain differences in outcomes between naturalistic and laboratory based studies (Ling et al., 2010; Stephen's et al., 2008). However, within the reviews of which it has been used to account for differences in cognitive performance during a hangover, a theory of expectancy has never been described and the suggestion has not been explored.

The results from this Chapter 3 indicated that expectancy did not play a role in response time tasks involving selective and Divided Attention. Furthermore, expectancy did not interact with performance on the Attentional Set Shifting or Spatial Working Memory tasks that were not scored on response times. With regards to working memory tests of Free Recall, overall word recall was not affected by expectancy. However, closer inspection of serial position revealed that expectancy played a role in recalling items at the end of the word list, whereby participants performed better when they were hungover and were aware that the purpose of the task was to examine a hangover. This result supports a compensatory model of expectancy

at a discreet level rather than a negatively valenced model at an overall performance level as suggested by Stephens et al. (2008) and Ling et al. (2010). It is speculated that with limited cognitive ability and increased compensatory behaviour, one sacrifices the rehearsal of words from the beginning of the list in order to recall words from the end of the list when hungover. Alternatively, interference whereby, participants must time share incoming information may result in only one form of word position being recalled. However, further research is needed to investigate the underlying mechanisms implicating serial position performance during a hangover before an understanding of underlying processes around this phenomenon can be reached.

Investigations relating to intra-extra dimensional set shifting (IED) and spatial working memory (SWM) revealed that a speed accuracy trade off may have eliminated effects of hangover State (Rabbitt, 1979). The intra-extra dimensional attentional set shifting and spatial working memory tasks were not time monitored therefore participants may have sacrificed time in order to ensure more accuracy in their responses. Of note, the strategies implemented during SWM recall were significantly weaker when not hungover than when hungover. Complex tasks which measure rule acquisition and cognitive flexibility are not traditionally investigated in hangover research. It may be worthwhile for future studies to attend to complex processes of attention in addition to basic processes in order to gain a better understanding of the mechanisms affected by a hangover.

Attention and working memory performance (Stroop, Eriksen's Flanker and Free Recall) was significantly impaired during a hangover indicating that both spatial and dimensional Selective Attention (Chajut, Schupak & Algom, 2009) as well as working memory are impaired

after a night's drinking. Of note, the results from the Divided Attention task were not significant. It is unclear why Selective Attention but not Divided Attention appear to be impaired the morning after a night's drinking. However, the findings by McKinney, Coyle, Penning and Verster (2012) using the same task (trials and blocks) also showed no effect of hangover on Divided Attention. It is worth noting that the Divided Attention task used in this thesis and by McKinney, Coyle, Penning and Verster (2012) as well as Tedstone and Coyle (2004) is considerably shorter (test time of 2-3 minutes) than the dual attention tasks used by Roehrs, Yoon and Roth (1991) and Roehrs and Roth (2001; test time of 15 minutes) which found impairment in performance during a hangover. Investigations of divided attention during an alcohol hangover using the Rozelle task (test time of 2.5 minutes) also failed to show variations in performance after a night's drinking. Thus the task duration of divided attention tasks (number of blocks, trials and events) warrants further investigation.

Although some evidence suggests that short and long duration cognitive tasks are equally sensitive to performance decrements (Heslegrave & Angus, 1985), others suggest that longer duration tasks reveal mental fatigue type symptoms (Mockel, Beste & Wascher, 2015), which is of importance for investigations that aim to better understand the real life implications of changes in cognitive performance. According to Mockel, Beste and Wascher (2015) such effects of mental fatigue can be erased through breaks between testing blocks. In addition to increasing levels of mental fatigue, Mockel, Beste and Wascher (2015) also found decreasing motivation with increasing task time. Future research should consider divided attention task duration through the use of longer (10 minute) tasks using short breaks between blocks to control for mental fatigue, task related motivation measurements and separate block analyses.

The divide attention task applied in this thesis also used different visual modalities (object and numerical digit) and levels of processing. This may have resulted in a ceiling effect whereby due to the ease of task, performance was not affected by a night's drinking. According to Wickens (1984) two tasks that differ considerably (e.g. washing the dishes and listening to the radio) are likely to be easier to complete than two similar tasks (talking with a friend and listening to the radio). Wickens identifies three types of similarity; modality, memory code and stages of processing. It may be of interest to investigate divided attention performance using one modality and memory code (objects or numerical digits only) as this is likely to increase the cognitive demand and thus the difficulty of the task (Wickens, 1984). In terms of information processing, the task of identifying three odd numbers within the divided attention task requires semantic processing (late, deep), such that the meaning of the digit presented in the middle of the screen must be encoded (Craik & Lockhart, 1972). In contrast, identifying a blue box requires structural processing (early, shallow). It may be the case that as the divided attention task draws from varying levels of processes, that resources are not depleted and the task is easily completed after a night's drinking. In addition to exploring the divided attention task duration it would also be beneficial to explore the effects of using target types that require the same stages of processing, modalities or memory codes.

The results from Chapter 3 highlighted the complexity of the impact of a hangover on cognitive performance. Although expectancy did not appear to affect next day performance on total scores, it appeared to play a role at a discreet level. Furthermore, the importance of looking beyond overall performance scores in order to gain a better understanding of the mechanisms affected by a hangover was highlighted in this Chapter. Correlational analysis

revealed differences in age and reports of hangover severity. This set the scene for the next study reported in the following Chapter.

7.2.2 Cognitive Performance And A Non-Student Sample

The history of alcohol consumption identifies the public house as playing a pivotal role in society since the 19th century (Cunningham, 2013). In order to gain an accurate account of a normal night's drinking, a consideration of the public house as well as its occupants were required. It was hypothesised that the traditional student sample used in hangover research might not reflect the population of drinkers affected by hangovers in the UK and Ireland. Indeed, drinking behaviours, experience and tolerance were expected to vary throughout one's lifespan (Britton, Shlomo, Benzeval, Kuh & Bell, 2015; Alcohol Research UK, 2016).

Thus, Chapter 4 set out to investigate the next day effects of a night's drinking in a non-student sample. Testing took place in a quiet room above a public house. As expected the age of participants was considerably different to that of previous research carried out on student samples. More units were consumed in this study (Chapter 4; 15.5) than in studies 1 (Chapter 3; 12.85) and 3 (Chapters 5 & 6; 12.78) which tested student samples. Furthermore, a larger percentage (76%) of participants reported drinking in a bar or pub most frequently, in contrast, 43% of the student sample in Study 1 and 48% in Study 2 (Chapter 4) reported consuming alcohol in a pub or bar environment most frequently. More drug use was reported in this study than in any other study in this thesis.

The results revealed decrements in Stroop, Eriksen's Flanker, Free Recall, Intra-Extra IED, SWM and Choice reaction time tasks. Results from the Stroop and Eriksen's Flanker task

performances resembled that of the student sample performance in studies 1 indicating that despite differences in drinking behaviours, the overall performance during a hangover remained comparable to that of a student sample. Interestingly differences in serial positioning results suggest that the sample and/or study design have impacted the way in which words from the beginning and end of a word list are recalled. Of note, Study 1 (Chapter 3) applied a between participants design whereas Chapter 4 applied a repeated measures design which may have contributed to variations in findings across the two chapters. The results from the extradimensional and intradimensional set shifting errors variables indicated that hangover effects only occurred in the more difficult elements of the task (extradimensional). In contrast, these results do not mirror that of Study 1. Once again, these results may reflect differences in sample and design approach. The results from the SWM task diverge from that of the IED. Here, changes in task difficulty does not appear to initiate a hangover effect. This suggests that spatial working memory is impaired during a hangover irrespective of difficulty. As in Study 1 a better strategy was applied when participants were not hungover.

In conclusion, Study 2 demonstrated both similarities and differences across cognitive performance in a non-student sample to that of previous research carried out on student samples. As the sample of non-student participants were older than that of the student sample used in study 1 (Chapter 3), it is plausible that natural age related cognitive decline may reflect differences in performance (Murman, 2015). For example, Fozard, Vercruyssen, Reynolds, Hancock and Quilter (1994) investigated age related changes in Simple Reaction Time tasks in a sample of participants aged 17-96 and found that response times increased with age. Thus, in order to distinguish between age related cognitive decline and age related hangover effects, a

direct comparison between student and non student samples under the same testing conditions should be explored.

Differences in performance across serial positioning in Free Recall, task difficulty in IED and SWM as well as the strategies applied in Free Recall and SWM indicate that further analysis is required at discreet levels of performance in order to better understand the role of cognitive systems during a hangover. In addition to this, tiredness has been highlighted within the literature (e.g. Penning, McKinney & Verster, 2012) and in Chapters 3 and 4 as the more commonly reported hangover symptom. With this considered along with the need for analysis on more in depth features of performance the hypotheses for Chapters 5 and 6 were set.

7.2.3 Attention and Alcohol Hangover

Chapter 5 aimed to investigate in depth the attentional systems affected by a hangover through the introduction of an Emotional Stroop (attention performance through presentation of emotional stimuli), Attentional Blink (detection and identification of targets using information processing, memory and attention) as well as replicating the Five-Choice Serial Reaction Time Task (5CSRTT; McKinney & Coyle, 2004; Selective Attention), Eriksen's Flanker (McKinney & Coyle, 2004; Selective Attention) and Psychomotor Vigilance Tasks (PVT; Howland et al., 2008; sustained attention). In addition to this, signal detection was applied to the Attentional Blink paradigm in order to gain insight into information processing and decision making during a hangover.

The results revealed that Emotional Stroop performance was impaired after a night's drinking. The analyses indicated that responses to all item types (control, social and physical)

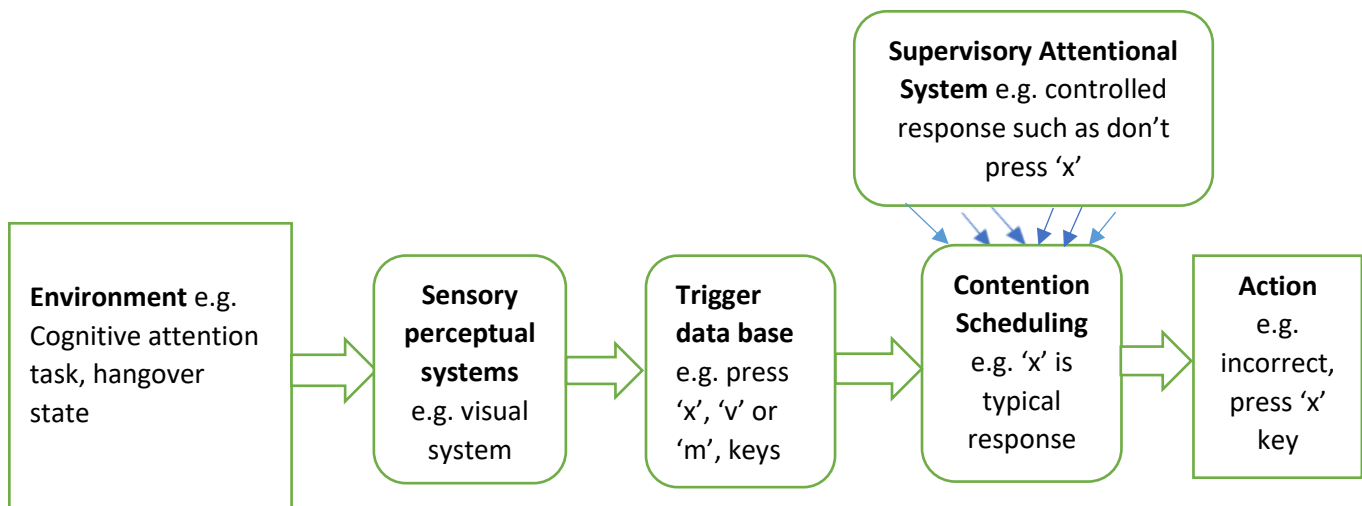
were slower during a hangover. However, responses to social threat words were not significantly slower during a hangover but were during no hangover testing. It was speculated that this may reflect test anxiety rather than general anxiety. Physical threat words were responded to faster than control words in both hangover and no hangover sessions indicating that physical threat anxiety was not present at either session (Mathews & MacLeod, 1985). It is also plausible that decreased response times to physical threat words represent an evolutionary response that is present in both hangover and no hangover states.

The results from the Attentional Blink analysis revealed that the magnitude of the Attentional Blink did not appear to change when hungover. However, the severity of the Attentional Blink was more distinct when participants were hungover, and recovery from Attentional Blink is slower during a hangover also. It is suggested in Chapter 5. that these results indicate that temporal aspects of attention were impaired after a night's drinking. The signal detection analysis indicated that the criterion did not change across States. However, significant changes in the discrimination index showed that an individual's ability to discriminate between signal and noise is diminished during a hangover. Thus, the signal detection analysis has contributed to our knowledge of the internal decision-making processes activated during attention tasks while hungover.

It is worth considering the theoretical framework of attention to action processes to help account for the results of the signal detection analysis. Norman and Shallice (1986) propose that sensory and perceptual structures activate a trigger data base whose contents determine the selection of component schemas based on how well the trigger base contents match the trigger conditions (Norman & Shallice, 1986). They suggest that during this selection

process conflicts among schemas may occur and in these instances conflict resolution must be provided. Here schemas must surpass a particular activation threshold to be selected. Such processes are difficult so in order to simplify the experience, Norman and Shallice (1986) propose that contention scheduling occurs so that familiar operations can reduce the number of conflicting schemas by instigating automatic responses. Indeed, Shallice (1988; 2002) identifies two types of attention to action processes, contention scheduling which refers to a system whereby actions are automatically triggered e.g. routine actions such as driving a car, and a Supervisory Attentional System which involves novel and complex instances whereby automatic responses are not satisfactory and strategies must be developed during automatic attentional processes. Such 'willed' responses can be used to inhibit or enhance one's actions. It requires an executive influence and conscious control as well as more activation and inhibition than contention scheduling. It may therefore be speculated that during a hangover, the activation levels and processes by which schemas excite and inhibit each other may be more chaotic which results in the thresholds for the signal and appropriate response selection (normally mediated automatically as part of a skilled behaviour), are not attained at the right time and in the right order. Likewise, the noise created during the activation of the supervisory attentional system (complex and/or novel tasks) when one is hungover creates an environment whereby hungover participants are unable to control the selection of schema and thus the discrimination between noise and signal (schema) is challenged (Figure 7.1). Responses may then be slowed to maintain accuracy. If this were the case, signal to action impairment could help to explain diminished performance across a range of tasks. Nonetheless, this is speculative and further research is needed to explore this theory.

Figure 7.1. Proposed theory of impaired attention to action during a hangover adapted from Norman and Shallice (1980)



As expected Selective Attention and Psychomotor Vigilance responses were impaired during a hangover. In terms of PVT, there were significantly more lapses in the hangover State than in the no hangover State indicating a diminished ability to sustain attention when hungover. The 5CSRTT displayed overall slowed responses during a hangover. As a result, it appears that decision making on this task does not differ significantly across States or Orders and that decision making during a non-screen operated Selective Attention is not affected by a hangover.

In summation, the results from Chapter 5 provide evidence to suggest that mood valenced, psychomotor and Selective Attention response times and Attentional Blink severity increase during a hangover. Moreover, one's limited ability to discriminate between targets and noise, may contribute to the increase time needed to response to targets during a hangover.

7.2.4 Real Time Data Collection And The Alcohol Hangover

Finally, smartphone and wrist-worn technologies were introduced to incorporate real time measures of alcohol consumption, physical activity and sleep in hangover research. The results revealed a difference of over 3 drinks between next day retrospective recall of alcohol consumed and real time hourly app recall indicating that next day subjective reports of alcohol consumption may not accurately reflect the number of drinks consumed. As expected the objective sleep analysis revealed later sleep times during a hangover than when not hungover. Subjective reports of sleep and wake time did not differ from objective measures but surprisingly, subjective and objective wake times did not correlate indicating that they were not related. It was proposed that these results may reflect accelerometry inaccuracies in differentiating between sleep, sedentary and non-wear time. It was not predicted that sleep quality ratings would be related to objective measures as Landry, Best, and Liu-Ambrose (2016) demonstrated inconsistencies between these measures, however sleep quality and satisfaction correlated with objective sleep efficiency which suggests that subjective interpretations of sleep may be somewhat accurate. In conclusion, subjective and physiological measures of sleep provide varied insights into hangover research which may help account for increased levels of fatigue during a hangover. These findings suggest that sleep efficiency may be a contributor to next day feelings of tiredness. Therefore, future studies might explore traditional pharmacological and non-pharmacological therapies for sleep disruptions in a cohort of hungover individuals.

In terms of physical activity, a larger proportion of the day was spent in sedentary activity when hungover than when not. A smaller proportion of the day was spent engaging in

vigorous activities when hungover than when not hungover. In addition to this, more METs (Metabolic equivalent of Task) were expended applying vigorous activity when not hungover than when hungover. These results indicated more sedentary and less vigorous activity during a hangover and it is speculated in Chapter 6 that this may be due to engaging in activities in a more slowed manner when hungover. This is a relatively new avenue of research in relation to the hangover experience with limited scope within the literature for comparisons.

From this Chapter, it can be seen that the use of smartphone technologies increase the accuracy of data collection pertaining to alcohol consumption. Accelerometers also provided beneficial physiological data pertaining to activity and sleep which should be considered in future naturalistic approaches.

7.3 Impact and Applications

The introductory Chapter in this thesis highlighted the prevalence of alcohol consumption and estimated hangovers experienced in the UK and Ireland. The discussion of societal costs and potential dangers of an alcohol hangover (Censuswide, 2015; Prime Minister's Strategy Unit, 2004) set the scene to discuss the importance of investigating the alcohol hangover, and cognitive and human performance. On reflection, the results from the subjective, objective and physiological investigations on performance within this thesis have considerable practical implications as well as applications for the methodological approaches used by researchers in the field. The following sections will discuss day to day practical applications and the methodological applications of the findings.

7.3.1 Daily Activities

Attention, working memory and psychomotor performance are vital processes needed to carry out almost all daily tasks. For example, Rose et al. (2015) demonstrated that all of these processes are required to plan and monitor breakfast making. Here participants were required to cook 5 simulated foods that would be ready to serve at the same time. There was a countdown timer for each food type and participants could use a stop/start button to control cooking time. Working memory was employed as participants were required to recall and hold the progress of food. Attention was required to monitor the time/clock and psychomotor performance was required in order to place the cutlery in the correct places.

In addition to challenging the performance of day to day activities in the home the results from this thesis indicate serious implications for both civil and military pilots. Indeed, human performance is deemed to be a contributing factor in around 80% of aviation crashes (Baker & Lamb, 1992; Guohua, 1994; National Research Council, 1980). Judgement and decision making are imperative piloting skills (Adams, 1993). As well as impairment in routine piloting tasks involving attention, working memory and psychomotor performance, findings relating to signal detection in this thesis also indicate impairment in one's ability to separate the signal from the noise which implicates one's ability to make decisions. In an article published by the Flight Safety Foundation (Skybrary, 2016). Two types of human operation errors take place which may result in aircraft accidents: Category 1 errors occur when a pilot intends to carry out an action, does so but carries it out incorrectly and the desired goal is not achieved. Such errors in execution are considered to involve attentional lapses and failures of memory (Skybrary, 2016). On the other hand, category 2 errors occur when an inappropriate action is taken, this is

associated with a failure in judgement, information processing and decision making (Reason, 1990; Skybrary, 2016). This indicated that hangover related impairment findings are likely to increase the likelihood of both category 1 and 2 piloting errors.

Although the 5CSRTT showed no difference in decision making time, it should be highlighted that this was likely due to an overall increase in move and response times in this task which further emphasises the alcohol hangover's harmful effects on response times which are also likely to impair a pilot's ability to adequately perform. Pilot training programmers acknowledge that in emergency events, a pilot's reaction is often time sensitive so as a result, pilots are required to memorise a Quick Reaction Handbook during training (Crosland, Wang, Ray, Michelson & Hutto, 2018). Nonetheless, the speed of execution is likely to be contributed to by the current state of the individual operating the aircraft as well as learned behaviours (Apoorvagiri & Nagananda, 2018). To date Airline companies consider the excretion of alcohol as a marker of the end of the effects of alcohol (bottle to the throttle). It is proposed that airline companies should go beyond enforcing an 8-12 hour 'bottle to the throttle' rule (Federal Aviation Administration, 1971; Civil Aviation Requirements India, 2015; Newman, 2004) and implement a rule which considers the time needed for an alcohol hangover to wear off once alcohol has left the system. It is noteworthy to consider that Seafarers are also required to have no more than 0.05% blood alcohol in the body for masters, officers and other mariners while carrying out marine duties (International Transport Workers' Federation, 2017). Marine operations are also subject to high levels of human error (Apostol-Mates & Barbu, 2015) and seafarer operations are also likely to incorporate similar cognitive processes to that of airline pilots. Therefore, it is also speculated that the implementation of a rule whereby seafarers are

required to not be in a hungover state during the operation of sea vessels will be beneficial to marine safety.

The intellectual and manual demands of medical surgery are also likely to be challenged during a hangover. Decision making, team cooperation, communication and technical skills applied during surgery are all subject to human error. Indeed, it is estimated that 40-50% of hospital errors take place in operating theatres (Brennan, Leape & Laird, 1991; Cuschieri, 2006; Kohn, Corrigan & Donaldson, 2000). The evidence of impaired cognitive and human performance in this thesis warrants the consideration of hangover effects and the role they might have on human performance errors during complex procedures such as medical operations. In support of this, using 16 medical students (N=16; Study 1) and six experienced laparoscopic surgeons (Study 2), Gallagher et al. (2011) demonstrated surgical performance differences between hungover and non-hungover participants relating to time, errors made and diathermy (surgical technique involving the heat of a body part using electric current) while completing a virtual surgery simulation. In all cases, participants that were experiencing a hangover performed worse than those who were not. Despite this, Gallagher et al., (2011) suggests that surgeons may not be aware of impact that a previous night's drinking may have on their ability to carry out surgeries. Taken together with the findings from this thesis, it is recommended that The Royal College of Surgeon (2018) should consider revising their code of practice in order to acknowledge the dangers of operating the day after alcohol consumption.

As Stated in Chapter 6, reductions in sleep efficiency and energy expenditure during a hangover have practical implications for the armed forces. Sleep disruptions in military personnel are already a major concern (Lentino, Purvis, Murphy & Deuster, 2013). Military

trainees report an acknowledgement of diminished ability to perform daily physical training (Macera, Aralis, Rauh & MacGregor, 2013). Alcohol is a regularly abused substance within the armed forces (Iversen et al., 2017) which has been shown to lower functioning and job productivity (Waller, McGuire & Dobson, 2015). However, the relationship between alcohol use, and sleep and physical activity is likely to have been over looked by the military as limited attention has been given to the relationship of sleep, alcohol and next day performance. Moreover, until the inception of this thesis work, physical activity after a night's drinking was traditionally measured through self-report measures (e.g. Verster, van Herwijnen, Olivier & Kahler, 2009). With the importance of sleep and energy expenditure on armed forces duties, and the effects of hangover on sleep found in this thesis, factors which can reduce heavy drinking in the Armed Forces can improve productivity. It is therefore proposed that practical applications such as the exploration of safe pharmacological and non-pharmacological therapies should be implemented in order to increase sleep efficiency and energy expenditure after a night's drinking, while long term strategies are being developed to reduce factors that contribute to alcohol misuse in the Armed Forces.

To date, there are no easily accessed objective means of identifying an alcohol hangover. Therefore, it may also be useful for The Road Safety Authority, the Royal College of Surgeons and Aviation and Marine companies as well as employers across a wide range of disciplines to implement standardised (in hangover research) cognitive tasks such as the Stroop, PVT and Eriksen's Flanker task in order to identify hangover related impairment before vehicle and work related operations are carried out. Such tasks can be administered in five minutes or less (Roach, Dawson & Lamond, 2006; McKinney, 2003), therefore it may be practical to pursue

the development of a smartphone application that can be launched across a variety of platforms and locations to deliver these measures.

In addition to standardised tasks it would also be beneficial for an application to collect age, gender, weight, and water, food and alcohol consumption in order to estimate the previous night's alcohol consumption (e.g. using algorithm used by Seidl & Jensen, 2000) and, anticipated and subjective hangover severity. Finally, with the development and popularity of wrist-worn technologies it may also be useful to implement physiological measures such as sleep, heartrate and temperature into a hangover measurement application. Recently, BACtrack (2019) have released keyring sized breathalysers that can be synced to their android or apple applications which could also be implemented to eliminate the possibility of intoxication.

To date, Hangover Meter (apple) is the only application available which aims to measure an alcohol hangover using physiological information. It does so by measuring the number of hand shakes made within a timeframe (Uren, 2019). However, tremors in isolation are not an adequate indicator of an alcohol hangover (Swift & Davidson, 1998). Thus, Hangover Meter cannot sufficiently predict the presence of a hangover or its severity.

The proposed application would first require a breath alcohol concentration measurement. Provided BAC equalled or approached zero, a series of subjective, objective and physiological measures would be collected and all output measures would be converted to z scores in order to convert scores to a common metric form which a threshold could be established.

7.3.2 Methodological applications

Bruce (2006) argues that one reason why scientific research on heavy social drinking is as important as research on alcoholism is because there are more heavy social drinkers than individuals with alcohol dependence. This in turn indicates that there are more alcohol hangovers experienced by social drinkers than by those with a diagnosed alcohol condition. With this logic, it is therefore paramount that a concise methodology is established for testing the effects of an alcohol hangover in social drinkers as the societal impact of a hangover may otherwise be misinterpreted. The findings from this thesis contribute to this pursuit through research relating to the sample and context, design, analysis, tasks and physiological apparatus used. These will be discussed in the proceeding sections.

7.3.2.1 *Sample and Context*

Research carried out in Chapter 4 highlighted the variation in drinking behaviours of non-students in a pub environment. An unexpected finding relating to demographic information was that of drugs and in particular cannabis use. It may be worthwhile to consider that testing students in a university environment may incite a reluctance to disclose information on stigmatised behaviours (Harrison & Hughes, 1997) relating to illegal drug use. Such response bias was evidently not an issue when testing took place outside of a university environment. As the prevalence of illegal drug use is increasing (National Advisory Committee on Drugs and Alcohol, 2016), researchers may seek to further emphasise the confidentiality of participation in such experiments. Although, most hangover related interactions from the non-student sample were comparable to student samples, serial position, spatial working memory

and intra-extra dimensional set shifting varied from a student sample. More alcohol was consumed by the non-student sample in this Chapter than by the student samples in Chapters 3 and 5 and units consumed has been shown to correlate with hangover severity (Penning et al., 2013), therefore until a comparison of effect sizes between student and non-student samples are compared, caution should be taken when attributing evidence from student studies to hangover effects on non-student individuals.

7.3.2.2 *Design*

Chapter 3 shows that expectancy with regard to the purpose of the study is unlikely to affect performance in an alcohol hangover State. Aside from one discreet measure (serial position), dependent variable scores for task performance showed no significant differences between expectancy and no expectancy Conditions. These results do not support the previous argument by Stephens et al., (2008) and therefore it appears that the concealment of experimental aims are not required in this context. Although Stephen's et al., (2008) highlighted concerns of expectancy effects in a naturalistic setting, the implications would also be likely to affect the laboratory environment as blinding is also imperfect in the laboratory e.g. the presence of alcohol in beverages can be easily identified. Nonetheless, concerns around blinding in alcohol hangover and performance research appear to be unsubstantiated and therefore the design of future naturalistic and laboratory research may not need to be concerned with the disclosure of experimental aims.

7.3.2.3 Analysis

Many hangover investigations seek to ask whether or not a hangover affects performance (e.g. Lemon et al., 1993; McKinney & Coyle, 2004), however as our understanding of the hangover develops, it may be more useful to ask *why* a hangover affects performance. Grange, Stephens, Jones and Owen (2016) looked beyond central tendencies in a choice reaction time task which highlighted the usefulness of applying novel analyses to alcohol hangover research in order to gain a better understanding of the hangover phenomenon. Their findings suggested a reduction in information processing and increased levels of caution during a hangover which helps us to interpret the differences in reaction time measures across States. The application of signal detection also helps to address the question of *why* performance is impaired. As discussed in section 7.1.3, the results from Chapter 5 revealed a disruption in information processing (separating signal from noise) but the cut off thresholds (criterion) used for detecting a signal do not appear change across States. From such analyses we can begin to question the root causes of the hangover's effects on cognitive systems and apply evidence based cognitive theory to the processes that are affected. Therefore, the analytical implications of this thesis relate to a need for novel analyses in hangover research in order to gain a more comprehensive understanding of the hangover's effects on performance.

Mixed effects modelling may be implemented on Attentional Blink data in order to identify fixed and random effects. This approach is more powerful than the tradition approaches which use by-subject analysis (Murayama, Sakaki, Yan & Smith, 2014). The model can be used to account for both participant level and item level variations of the criterion and discrimination index which in turn would provide additional information on target and

distractor discrimination, and decision making changes that occur during a hangover (DeCarlo, 1998, 2011; Rouder et al., 2007).

7.3.2.4 *Tasks*

In a similar manner, the use of novel tasks such as the Attentional Blink and Emotional Stroop provide new information relating to the hangover's impact on performance. Task selection is at the nub of hypothesis testing; therefore, time must be taken to choose appropriate tasks. Perry and Hodges (1999) argue that when investigating attention, selective, divided and sustained attention tasks should be implemented. These tasks have now become somewhat established in the field of hangover research, therefore it has possibly come to a time to view these tasks as objective indicators of the hangover State and to introduce alternative tasks that may help us gain a more extensive understanding of systems such as attention after a night's drinking. For example, the introduction of Attentional Blink to hangover research in this thesis demonstrated specific temporal decrements in attention relating to visual processing which are implicated in selective, divided and sustained attention and have practical consequences for day to day activities after a night's drinking e.g. driving (Raymond, Shapiro & Arnell, 1992).

The introduction of tasks not traditionally used in hangover research across all cognitive systems were beyond the scope of this thesis. However, concerns relating to the comparability of computer vs non-computer based tasks were considered (Noyes & Garland, 2008). Noyes and Garland (2008) showed that equivalence between computer and non-computer tasks measuring the same phenomenon cannot be assumed. Therefore, with views of future

comparisons a non-computer generated (5CSRTT) task was used in addition to 1 and 2 choice response time tasks in this thesis to investigate psychomotor performance. Also, efforts were made to gain further insight into Free Recall performance by use of serial positioning in Free Recall tasks.

7.3.2.5 *Physiological measures*

The use of modern technologies in this thesis has been fruitful. The methodological implications of our findings suggest that caution is required when alcohol consumption is retrospectively recalled as consumption is likely to be underestimated. In addition, the use of accelerometry in hangover research now offers researchers who wish to adequately measure sleep and physical activity a means of doing so in a naturalistic environment without researcher manipulation. The fast pace of technological development should be taken advantage as Chapter 6 highlights the advantage of implementing such technologies in order to gain real time measures during a hangover. For example, a promising development of a wearable BAC monitor (BACtrack Skyn; BACtrack, 2018) may offer insight into the rise and fall of blood alcohol concentrations during and post drinking session and how it relates to cognitive performance. Once validated, hangover researchers might benefit from the ease of wrist worn real time measures of BAC levels.

7.4 Limitations

No experimental research is without limitations. On reflection, two observations made during data collection are of note. Firstly, the introduction of the CANTAB in Chapters 3 and 4 as a standardised battery for future studies was not successful as it resulted in considerable time

added to testing sessions. For example, the IED, Choice Reaction Time and SWM tasks took on average 5-10 minutes each to complete (Centre for Disease Control and Prevention, 2018). Here, participants were required to complete other tasks and questionnaires as well as this with no compensation for their time. As a result, it is possible that participants grew anxious to complete the study and it is believed that this is apparent in the task related motivation questions in Chapters 3 and 4 (which included the CANTAB). Figure 7.2 demonstrates an example of a response sheet from Chapter 3 (CANTAB, no incentive and longer in duration) and Chapter 5 (No CANTAB, incentive of sleep and activity data, and shorter in duration). Thus, it is suggested that future research consider the impact of time and compensation in hangover research as the unpleasant experiences of a hangover are unlikely to be well matched to long periods of testing.

Figure 7.2 Example of task related motivation responses in Chapter 3 (A) and Chapter 5 (B).

A

How difficult do you think this task will be?

Very difficult Not very difficult

How much effort will you put into doing this task?

Very little effort a lot of effort

How well do you think you will do on this task?

Not very well very well

B

How difficult do you think this task will be?

Very difficult Not very difficult

How much effort will you put into doing this task?

Very little effort a lot of effort

How well do you think you will do on this task?

Not very well very well

The second main limitation of this thesis is the reliability of the GENEActiv watches. Esliger et al., (2013) has validated and calibrated the GENEActiv watches with high levels of validity ($r=.97$) and reliability (intrainstrument=1.8%, interinstrument=2.4% variability); and although the advantages of accelerometry largely outweigh the disadvantages, the shortcomings must also be acknowledged. Through personal use of the watch it was evident that instances occurred shortly after awakening where the wearer was not identified as being in a wakeful State. This may skew the findings and future studies should take caution when considering the accuracy of wake time measures. Moreover, through discussions with another researcher using accelerometry (also GENEActiv) we identified that in some instances the watch did not log activity correctly and in these instances a 24 hr sleep time from 11:59 to 11:59 was observed. Thus, it may be worthwhile to consider alternative actigraphy materials such as the ACTi heart (2018) in order to find a device that is less error prone.

7.5 Further Considerations and Future Directions

In brief this thesis has shown that impairment in cognitive and human performance occurs in individuals the day after alcohol consumption. Given the complexity of cognition, coupled with the methodological issues in the field, this thesis also highlights the need to focus on processes and procedures in depth to help understand *why* performance is affected. On an experimental level, further work is needed in relation to applying cognitive theory to deficits experienced during a hangover. Fundamental cognitive concepts such as the perception of motion are paramount to the interaction between an individual and their environment (Gibson, 1979). Although several studies have investigated driving while hungover (Verster, 2007; Verster et al., 2014a; 2014b), none have investigated *why* driving is impaired. Using cognitive

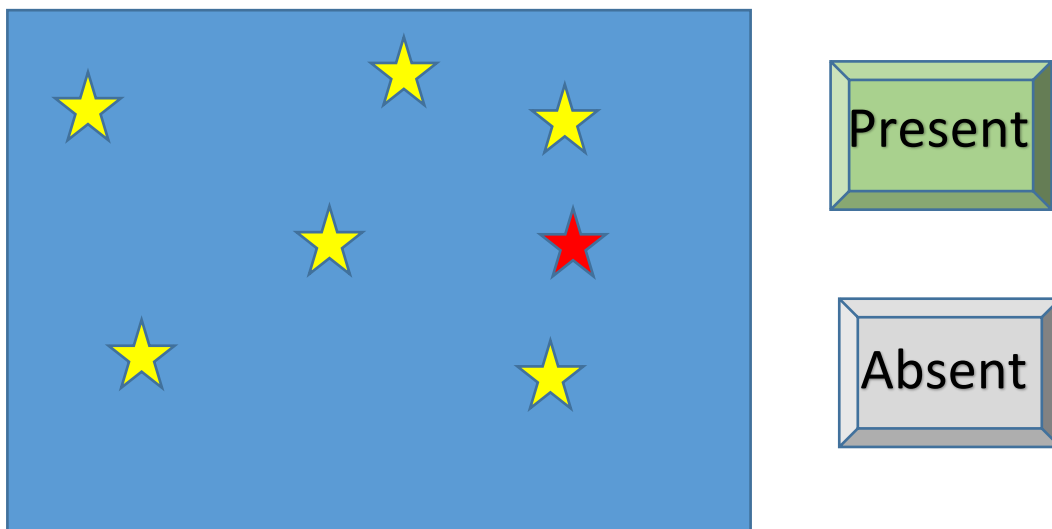
theory, future studies should seek explanations for the impairment of day to day activities such as this. In addition to the interactions between the individual and the environment, the interactions that occur between individuals are equally important. We rely heavily on language to function in the world (Welsh & Welsh, 2008), yet despite this, the impact of a hangover on language has yet to be explored in any form. Changes in speech during ecstasy and alcohol intoxication have already been demonstrated using recording devices (Bedi et al., 2014; Schiel, 2011) and it would be both interesting and beneficial to apply comparable psycholinguistic assessments to hangover research. From this, exploratory research into social interaction and cognition may provide us with a broader view of the external impact of one's hangover State.

Future cognitive research in hungover individuals may benefit from the consideration of automatic/involuntary and controlled/conscious processes when choosing cognitive performance tasks (Shiffrin & Schneider, 1977; Schneider & Shiffrin, 1977). As one becomes an experienced driver, driving becomes automatic. However, in difficult driving conditions, driving may become controlled. Similarly, routine work related exercises may be carried out below the level of conscious awareness (automatic). Thus, in order to gain a comprehensive understanding of the real life implications of a night's drinking, one must consider automatic as well as controlled processes in the evaluation of cognitive task outcomes. Automatic processes may be captured by the involuntary processing of information within the visual field (Eriksen's Flanker task) and conscious processing may be considered through the response inhibition of incongruent items within the Stroop task. Nonetheless, isolated automatic and controlled processes may be difficult to capture. For example, with practice, controlled responses to incongruent items (Stroop) may become automatic (Schiffrin & Schneider, 1984).

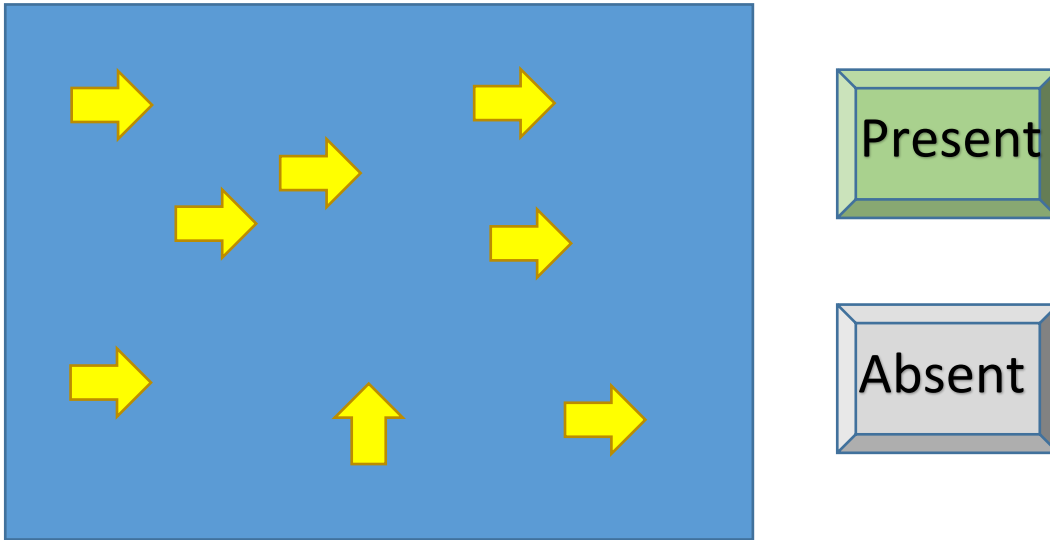
In order to examine automatic and controlled visual processes in isolation, it is proposed that future studies may apply a visual search task to hangover studies. Visual search is engaged in many day to day tasks including driving to work or picking an item from a grocery store shelf. There are two types of visual search; pre-attentive and attentive. Pre-attentive visual search is characterised by the processing of target and distractors in parallel (Treisman, 1988). Here, the processing is automatic, and target and distractors often differ in colour or orientation. Two examples are presented in the figure below.

Figure 7.3 Samples of *pre-attentive* visual search using automatic processing. Targets differ by the feature of colour *or* orientation.

(a) RED STAR- PRESENT OR ABSENT?



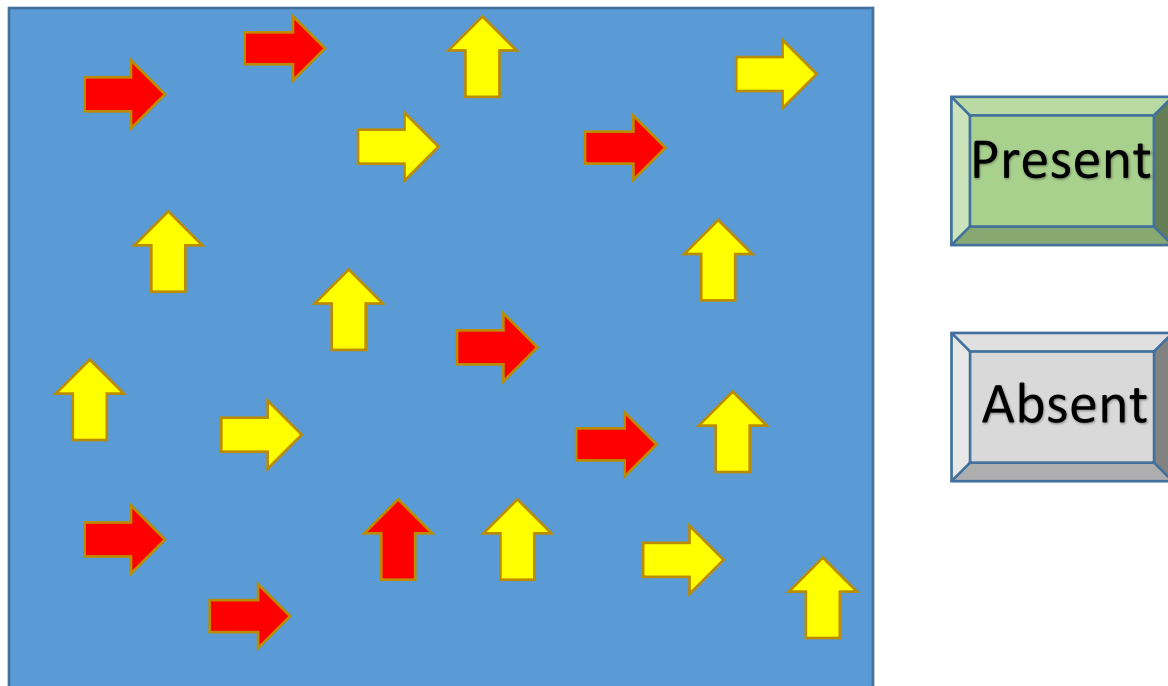
(b) VERTICAL ARROW- PRESENT OR ABSENT?



In these examples, the targets 'pop out' from the distractors and in such instances, the set size (number of distractors) does not affect response times (Joseph, Chun & Nakayama, 1997). Therefore, in order to confirm automatic (pre-attentive) visual search one can alter the number of distractors and plot the mean response times (y-axis) against the set size (x-axis). This should provide a slope of zero (Wolfe, 2005). However, when two or more attributes determine the target, a conscious (attentive) visual search occurs, otherwise known as a serial self-terminating search (Wolfe, 2005). An example is shown in Figure 7.4

Figure 7.4 Sample of *attentive* visual search using controlled processing. Target differs by the feature of colour *and* orientation.

RED VERTICAL ARROW- PRESENT OR ABSENT?



During attentive visual search, the difficulty can be increased through the set size of distractors presented (Treisman & Gelade, 1980). As the results from the signal detection theory analysis of the Attentional Blink task in this thesis revealed discrepancies in one's ability to discriminate between target and distractors when hungover, a visual search task with varying levels of task difficulty may provide additional information on target discrimination. In addition to investigating automatic and controlled visual attention, cognitive and hangover researchers may also consider applying signal detection theory analysis at varying difficulty levels of the

attentive visual search to investigate whether the discrimination index varies with task difficulty.

In relation to methodological shortcomings, future research should seek to repeat the novel use of apparatus and approaches used in this thesis in order to address the test-retest reliability of the findings in Chapters 3, 4, 5 and 6. The development of a consensus on the alcohol hangover definition is beneficial to the scientific research as future studies that use this definition will be investigating the same phenomenon (van Schrojenstein Lantman et al., 2016). In the same light, it may also be useful to develop a similar consensus on methodology with experts in the Alcohol Hangover Research Group. For example, a free battery of tasks developed by cognitive experts could be shared across hangover researchers and a universally agreed upon procedure for laboratory and naturalistic research with considerations of specific controls such as time of day, duration and experimental design would ensure highly controlled environments that would also produce appropriately comparable data. Future research may also develop an independent freeware application with similar items to that used in chapter 6 (p.276) which measures real time alcohol consumption. The application may also be adapted to collect hourly mood and performance measures to track hangover onset, duration and recovery in a natural environment. Such investigation will develop our ability to determine safe driving and working times for individuals following alcohol consumption.

On a final note, many avenues of hangover research are left to be explored. The progress made in this thesis, however will hopefully help to develop our understanding of the relationship between an alcohol hangover, cognition and human performance.

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9. Appendices

9.1 Appendix 1. Questionnaires



School of Psychology, Ulster University, Magee

Names of investigators:

Chief investigator: Dr. Kieran Coyle (kb.coyle@ulster.ac.uk)

PhD student: Lydia Devenney (devenney-L2@email.ulster.ac.uk)

Informed Consent Form

Participants will be asked to attend testing on two occasions. The study involves a short questionnaire and five computer based cognitive tasks per session. Participants will also be asked to wear an accelerometer

Information gathered from this study is confidential, however, confidentiality will be broken if the information obtained reveals that there is a chance of harm to oneself or another person.

I understand that all data will be stored in a locked cupboard on Ulster University premises for 10 years and analysed in a completely confidential manner with regard to my identity, and that I am free to withdraw my consent and terminate my participation at any time without penalty.

I understand that the aims of the research project will be explained at the end of the experiment and that any questions that I might have will be answered.

I understand that I am responsible for returning the GENEActiv accelerometer after testing.

Signed _____

Date _____

Acute Hangover Scale

Please rate how you feel right now on the following rating scales. Circle a number from 1 to 7 for each item.

	None	Mild			Moderate			Incapacitating
Hangover	0	1	2	3	4	5	6	7
Thirsty	0	1	2	3	4	5	6	7
Tired	0	1	2	3	4	5	6	7
Headache	0	1	2	3	4	5	6	7
Dizziness/faintness	0	1	2	3	4	5	6	7
Loss of appetite	0	1	2	3	4	5	6	7
Stomach ache	0	1	2	3	4	5	6	7
Nausea	0	1	2	3	4	5	6	7
Heart racing	0	1	2	3	4	5	6	7

How long do you hangovers usually last? _____

How long do you anticipate this hangover to last? _____

Short Michigan Alcoholism Screening Test (SMAST 13)

Please circle the appropriate answer.

- | | | |
|---|-----|----|
| 1. Do you feel you are a normal drinker? | Yes | No |
| 2. Do your spouse or parents worry or complain about your drinking? | Yes | No |
| 3. Do you ever feel bad about your drinking? | Yes | No |
| 4. Do friends or relatives think you are a normal drinker? | Yes | No |
| 5. Are you always able to stop drinking when you want to? | Yes | No |
| 6. Have you ever attended a meeting of Alcoholics Anonymous? | Yes | No |
| 7. Has drinking ever created problems between you and your spouse? | Yes | No |
| 8. Have you ever gotten into trouble at work because of drinking? | Yes | No |
| 9. Have you ever neglected your obligations, your family, or your work for 2 or more days in a row because you were drinking? | Yes | No |
| 10. Have you ever gone to anyone for help about your drinking? | Yes | No |
| 11. Have you ever been in the hospital because of drinking? | Yes | No |
| 12. Have you ever been arrested even for a few hours because of drinking? | Yes | No |
| 13. Have you ever been arrested for drunk driving or driving after drinking? | Yes | No |

Are you currently experiencing feelings of guilt?	Yes	No
---	-----	----

Please indicate using the aid below, how many units of alcohol you consumed last night.

1.5 units  Small glass red/white/rosé wine (125ml, ABV 12%)	2.1 units  Standard glass red/white/rosé wine (175ml, ABV 12%)
3 units  Large glass red/white/rosé wine (250ml, ABV 12%)	2 units  Pint of lower-strength lager/beer/cider (ABV 3.6%)
3 units  Pint of higher-strength lager/beer/cider (ABV 5.2%)	1.7 units  Bottle of lager/beer/cider (330ml, ABV 5%)
2 units  Can of lager/beer/cider (440ml, ABV 4.5%)	1.5 units  Alcopop (275ml, ABV 5.5%)
1 unit  Single small shot of spirits* (25ml, ABV 40%)	



Number of:

Small Glasses of Wine _____
 Standard Glasses of Wine _____
 Large Glasses of Wines _____
 Pints of Low-strength lager _____
 Pints of High-strength lager _____
 Bottles of Lager/cider _____
 Cans of Lager/cider _____
 Alcopops _____
 Shots of Spirits _____

Units _____

Did you consumed more units than you intended?

Yes ☐ No ☐

Are you currently experiencing feelings of guilt?

Yes ☐ No ☐

Please answer the following questions in relation to last night and this morning.

At what time did you begin drinking alcohol?

At what time did you stop drinking alcohol?

At what time did you go to bed?

At what time did you wake up this morning?

How long did it take you to fall asleep?

How many hours of sleep did you get last night?

Since alcohol consumption has ceased, have you eaten?

Have you consumed caffeine e.g. coffee, energy drink? If so, please specify.



Please evaluate last night's sleep below.

1: Extremely

2: Quite

3: Slightly

4: Neither

5: Slightly

6: Quite

7: Extremely

Good

Bad

1 — 2 — 3 — 4 — 5 — 6 — 7

Satisfying

Not Satisfying

1 — 2 — 3 — 4 — 5 — 6 — 7

Restful

Not restful

1 — 2 — 3 — 4 — 5 — 6 — 7

Refreshing

Not refreshing

1 — 2 — 3 — 4 — 5 — 6 — 7

Light

Deep

1 — 2 — 3 — 4 — 5 — 6 — 7



Demographic and alcohol consumption measures

Gender _____ Age _____

Weight _____ Height _____

Do you smoke? _____ If so, how often do you smoke? _____

For how long have you been smoking? _____

Do you smoke cannabis? _____ If so, How often do you smoke? _____

For how long have you been smoking cannabis? _____

Do you take any other drugs? If so, please specify. _____

How old were you when you had your first drink? _____

How often do you drink? (use a typical month as reference)

Less than once a week ☐

Once –twice per week ☐

Three –five times a week ☐

Six times – every day ☐



How many drinks do you usually have in one sitting?

- Less than three drinks ☐
- Three – five drinks ☐
- Six- seven drinks ☐
- Eight drinks or more ☐

For how long have you been drinking in this way? _____

What is the largest number of drinks you have consumed at any one sitting?

- Less than three drinks ☐
- Three – five drinks ☐
- Six- seven drinks ☐
- Eight – ten drinks ☐
- Eleven – thirteen drinks ☐
- Thirteen or more ☐

How often have you drank this amount of alcohol at any one sitting?

- Less than once a year ☐
- Once – Twice a year ☐
- Three – Six times a year ☐
- Once – Twice a month ☐
- More than once a month ☐

How often do you consume alcohol to reach a State of intoxication?

- Less than once a year ☐
- Once – Twice a year ☐
- Three – Six times a year ☐
- Once a month – Twice a month ☐
- Every time you drink ☐

When you usually have an alcoholic drink, where do you have it?

- In a pub or bar ☐
- In a club or nightclub ☐
- At home or at the home of friends ☐
- Somewhere else ☐

Mood assessment

Place a mark across the horizontal line at a position which indicates how you feel at the moment in relation to the two words.

Alert	-----	Drowsy
Contented	-----	Discontented
Calm	-----	Excited
Troubled	-----	Tranquil
Strong	-----	Feeble
Mentally Slow	-----	Quick-witted
Muzzy	-----	Clear-headed
Tense	-----	Relaxed
Attentive	-----	Dreamy
Incompetent	-----	Proficient
Happy	-----	Sad
Antagonistic	-----	Friendly
Interested	-----	Bored
Withdrawn	-----	Sociable
Depressed	-----	Elated
Self-centred	-----	Outward-going
Well co-ordinated	-----	Clumsy
Lethargic	-----	Energetic

Many thanks for your participation.



Chief Investigator: Dr. Kieran Coyle

PhD student: Lydia Devenney

The effects of a night's drinking on energy expenditure and attention

This study is an investigation into the effects of an alcohol hangover on energy expenditure and attention. It is estimated that over 520,000 people go to work hung-over each day in the UK and in addition, the hangover is valued at costing the economy around £6.4 billion a year (Prime Minister's Strategy Unit, 2004).

However, despite our growing knowledge of society's drink culture, there have been an insufficient number of studies aimed at understanding the cognitive and energy deficits that may surface during an alcohol hangover and furthermore, result in poor work performance.

So far, the number of studies investigating this phenomenon are unsubstantial. This study aims to add to current research in order to gain a better understanding of the hangover

It is anticipated that with methodological issues addressed, participants who report a hangover may show deficits in aspects of attention and engage in less physical activity.

Please contact Lydia Devenney or Dr. Kieran Coyle at the following email addresses Devenney-L2@email.ulster.ac.uk, kb.coyle@ulster.ac.uk if you have any further questions about this study.

Many Thanks for your participation.

A handwritten signature in black ink that reads 'Lydia Devenney'. The signature is written in a cursive style and is positioned above a horizontal line.

Lydia Devenney

(PhD student)

If you are concerned about your drinking please seek help and advice from the following:

drinkaware.co.uk
for the facts

DrinkSmarter

Every drink adds up to more than you think

<http://www.drinksmarter.org/>



Call **Alcoholics Anonymous** National Helpline on 0845 769 7555

or email help@alcoholics-anonymous.org.uk



Drinkline is the national alcohol helpline.

Call: 0800 917 8282



Telephone: 02075669800

Email: contact@alcoholconcern.org.uk

Pre task Visual Analogue Scale assessing task related motivation

How difficult do you think this task will be?

Very difficult ----- Not very difficult

How much effort will you put into doing this task?

Very little effort ----- a lot of effort

How well do you think you will do on this task?

Not very well ----- very well

Post task Visual Analogue Scale assessing task related motivation

How difficult did you find this task?

Very difficult ----- Not very difficult

How much effort did you put into doing this task?

Very little effort ----- a lot of effort

How well do you think you did on this task?

Not very well ----- very well

Free Recall Word Lists

Army

Bolt

Bowl

Break

Dame

Cork

Dust

Desk

Gate

Flag

Badge

Honk

Bush

Brake

Drill

Chalk

Graph

Fence

Knife

Grave

Medal

Paper

Sheep

Shark

Snare

Shell

Canary

Buckle

Coffin

Carpet

Fiddle

Collar

Kettle

Grocer

Shovel

Office

Spider

Pocket

Army

sponge

9.2 Appendix 2. A Pearson's Correlation Of Performance And Subjective Measures (Chapter 3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.AGE	1			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.SLEEP	-0.02	1		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.AHS	-.44**	-0.05	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.UNITS	-.22	-.18	.74**	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. SA RT (INNEAR)	-0.09	-.18	.43**	.216	1	-	-	-	-	-	-	-	-	-	-	-	-	-
6. SA RT (INFAR)	-.114	-.27*	.43**	.209	.86**	1	-	-	-	-	-	-	-	-	-	-	-	-
7. SA ERRORS	-0.07	.10	<i>0.040</i>	<i>0.014</i>	.108	.126	1	-	-	-	-	-	-	-	-	-	-	-
8. STROOP	0.03	0.02	<i>0.037</i>	<i>.101</i>	.222	.195	-.135	1	-	-	-	-	-	-	-	-	-	-
9.STROOP ERRORS	-0.04	0.08	-.153	.212	0.071	0.034	.64**	-0.06	1	-	-	-	-	-	-	-	-	-
10. FREE RECALL	-0.06	-0.04	-.111	-.118	-.173	-.24*	-.137	-.36**	-0.076	1	-	-	-	-	-	-	-	-
11. DA RT CTRL	.11	0.01	-.175	<i>-0.060</i>	.3*	.16	.100	.194	.116	-.154	1	-	-	-	-	-	-	-
12. DA RT PRPL	.36**	.12	-.266	.216	0.07	-0.05	-.229	.111	.181	0.005	.48**	1	-	-	-	-	-	-
13. DA ERRORS	.15	-0.05	-.34*	.37*	.39**	.26*	.39**	.123	.24*	-.24*	.177	.123	1	-	-	-	-	-
14. IED ERRORS	0.06	-0.02	<i>.100</i>	.33*	.18	.183	0.09	.135	0.092	-.198	0.095	-0.025	.16	1	-	-	-	-
15. SWM ERRORS	0.06	.12	.218	.205	.19	.172	.28*	0.011	.122	-.35*	.207	.143	.36**	.38**	1	-	-	-
16. SWM STRATEGY	0.01	0.04	.213	.261	.11	0.021	0.03	-.37**	0.074	.31**	-0.049	-.158	-.102	-0.052	-.102	1	-	-
17. TRANQUILLITY	-0.05	0.06	-.36*	.280	-0.08	-0.099	-.3*	.16	-.27*	0.012	-0.085	-.27*	-.162	0.047	0.068	.167	1	-
18. ALERTNESS	.12	0.033	-.64**	-.49**	-.16	-.204	-.14	0.03	-.13	-0.016	-0.060	-.17	-.148	-0.031	0.014	.134	.73**	1

*p<0.05, **p<0.01 AHS= acute hangover scale, units= alcohol units consumed on the previous night, SA RT (INNEAR)= selective attention reaction times incompatible near, SA RT (INFAR)= selective attention reaction times incompatible far, DA RT CTRL= Divided Attention central, DA RT PRPL=Divided Attention peripheral, IED= intra extra dimensional task, SWM=spatial working memory task. Note: AHS and Units correlations were carried out on participants in hangover State only and are presented in italics

9.3 Appendix 3. A Pearson's Correlation Of Performance And Subjective Measures (Chapter 4)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.SLEEP	1.	-	-	-	-	-	-	-	-	-	-	-	-
2. TRANQUILLITY	0.09	1.	-	-	-	-	-	-	-	-	-	-	-
3. ALERTNESS	-0.03	0.46	1.	-	-	-	-	-	-	-	-	-	-
4. SWM STRATEGY	0.15	0.07	0.09	1.	-	-	-	-	-	-	-	-	-
5. FREE RECALL	-0.05	-0.28	-0.11	0.16	1.	-	-	-	-	-	-	-	-
6. CRT CORRECT	-0.26	-0.09	-0.05	-0.18	0.08	1.	-	-	-	-	-	-	-
7. STROOP (RT)	-0.11	0.02	0.09	-0.05	-0.14	0.04	1.	-	-	-	-	-	-
8. IED EXTRA	-0.22	0.02	-0.10	-0.08	-0.11	0.11	0.07	1.	-	-	-	-	-
9. IED INTRA	0.12	-0.14	-0.25	-0.06	0.14	0.01	-0.01	0.22	1.	-	-	-	-
10. AGE	0.06	0.18	0.24	-0.13	-0.12	0.20	0.14	0.09	0.24	1.	-	-	-
11. SA RT (INNEAR)	-0.11	-0.05	-0.15	0.02	-0.14	-0.09	0.00	0.21	0.13	-0.06	1.	-	-
12. AHS	-0.15	0.12	0.11	0.09	-0.26	0.01	0.19	0.19	-.34*	-0.10	-0.17	1.	-
13. Total units	-0.14	0.14	0.14	-0.07	-0.04	0.19	0.13	0.28	-0.11	0.15	-0.06	.38*	1.

*p<0.05, **p<0.01 AHS= acute hangover scale, units= alcohol units consumed on the previous night, SA RT (INNEAR)= selective attention reaction times incompatible near, IED= intra extra dimensional task, INTRA=intra dimensional errors, EXTRA=extradimensional errors, CRT RT=choice reaction time task mean latency of correct responses, SWM STRAT=spatial working memory task strategy variable.

9.4 Appendix 4. A Pearson's Correlation Including Performance And Subjective Measures (Chapter 5)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. AHS	10.00	-	-	-	-	-	-	-	-	-	-	-	-
2. Units	.19	10.00	-	-	-	-	-	-	-	-	-	-	-
3. Stroop Control	-.22	-0.09	10.00	-	-	-	-	-	-	-	-	-	-
4. Stroop Social	.22	.17	-.16	10.00	-	-	-	-	-	-	-	-	-
5. Stroop Physical	-0.04	0.04	-0.03	.48*	10.00	-	-	-	-	-	-	-	-
6. Atten. Blink T2	.42*	.20	-.13	0.01	-0.07	10.00	-	-	-	-	-	-	-
7. Choice Move	-.24	0.09	0.09	.18	.28	-.17	10.00	-	-	-	-	-	-
8. Choice Return	-0.04	-0.05	0.07	-0.04	0.03	-.32	.53**	10.00	-	-	-	-	-
9. Incompnear S. A	-0.03	.16	-.14	.20	.41*	-.21	.25	.17	10.00	-	-	-	-
10. Real Time Alc.	.29	.57*	.27	.37	-.30	.30	.13	.10	-.23	10.00	-	-	-
11. Alertness	.11	-.21	0.04	-.13	-.30	0.01	0.01	-.28	-0.03	-.13	10.00	-	-
12. Tranquillity	.12	.13	-.22	-0.02	-0.08	-.13	.17	0.04	.29	-.26	.21	10.00	-
13. Age	.16	.20	-.12	.15	0.01	0.02	0.02	-.49*	-.10	-0.03	.23	0.03	10.0
													0

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.OBJECTIVE BEDTIME	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. OBJECTIVE EFFICENCY	.12	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-
3.OBJECTIVE ELAPSED TIME	-.12	-.32	1.0	-	-	-	-	-	-	-	-	-	-	-	-
4.OBJECTIVE RISE TIME	-.16	-.22	.39	1.0	-	-	-	-	-	-	-	-	-	-	-
5.OBJECTIVE SLEEP TIME	0.02	.46*	.71**	.27	1.0	-	-	-	-	-	-	-	-	-	-
6.OBJECTIVE ACTIVITY PERIOD	0.01	-.58**	-.32	.25	-.62**	1.0	-	-	-	-	-	-	-	-	-
7.SUBJECTIVE BED TIME	.46*	-.15	-0.07	-.14	-0.09	.21	1.0	-	-	-	-	-	-	-	-
8.SUBJECTIVE ONSET LATENCY	.23	-0.05	0.00	-.29	-0.06	0.00	.25	1.0	-	-	-	-	-	-	-
9.SUBJECTIVE TOTAL SLEEP	.20	.11	-.27	-.42*	-.23	0.08	-0.02	.39	1.0	-	-	-	-	-	-
10.SUBJECTIVE WAKE TIME	.41*	.25	-.22	.22	0.03	-.21	0.04	0.02	.41*	1.0	-	-	-	-	-
11.QUALITY	-.25	.46*	0.05	.18	.36	-.24	-.33	-.32	.12	.12	1.0	-	-	-	-
12.SATISFACTION	-.35	.43*	.13	0.04	.43*	-.38	-.53**	-.14	.10	.10	.64**	1.0	-	-	-
13.RESTFULNESS	-.32	.31	.17	-0.08	.38	-.43*	-.51**	-.36	0.09	.13	.74**	.75**	1.0	-	-
14.REFRESHINGNESS	-.27	.35	-0.01	-0.09	.18	-.29	-.54**	-.19	0.08	.11	.70**	.70**	.76**	1.0	-
15.LIGHT/DEEP	.14	.17	-0.02	-.14	.10	-.34	-0.05	.20	.36	.36	-0.05	0.03	0.06	-.19	1.0

*. Correlation is significant at the 0.05 level (2-tailed).

**.. Correlation is significant at the 0.01 level (2-tailed).

9.6 Appendix 6. Correlation of Physical Activity and Cognitive Performance Measures (Chapter 6)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.Sedentary	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2.Light	0.02	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3.Moderate	-.37	0.09	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.Vigorous	-.47*	0.00	.36	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5.age	0.07	.22	0.00	0.08	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-
6.EStroopHControl	.41*	0.00	.25	-0.06	0.07	1.0	-	-	-	-	-	-	-	-	-	-	-	-
7.EStroopHSocial	.43*	.19	.36	.10	.22	.41	1.0	-	-	-	-	-	-	-	-	-	-	-
8.Lapses (PVT)	-.28	-0.09	.34	0.06	.24	-.12	0.01	1.0	-	-	-	-	-	-	-	-	-	-
9.Hchoicemove	-.27	-.13	.43*	-0.01	0.08	-.10	0.05	.65	1.0	-	-	-	-	-	-	-	-	-
10.Hchoicereturn	-.27	-.13	.28	.40*	-.22	0.06	0.03	.51	.54	1.0	-	-	-	-	-	-	-	-
11.Incompnear	-.32	-0.09	.40*	-0.06	-0.01	-.23	0.03	.44	.27	0.05	1.0	-	-	-	-	-	-	-
12.HVigilance	-.29	-.14	-0.03	.12	-0.04	-.27	-.14	.33	.22	.15	.26	1.0	-	-	-	-	-	-
13.AHS	-0.08	.31	-0.04	.14	.16	-.18	-.09	-.24	-.31	-.11	-.03	-.50	1.0	-	-	-	-	-
14.Units	0.01	.34	0.04	0.03	.20	-0.07	0.03	.16	.23	-.11	.03	0.04	.19	1.0	-	-	-	-
15.Real Time Alc.	-.17	-.13	.20	.30	-0.03	.25	-.18	-.27	-.04	-.01	-.43	-.39	-.09	.10	1.0	-	-	-
16. Tot. Sleep (mins)	-0.06	.13	.31	-0.03	-.21	.38	.24	.10	.22	0.04	0.06	.18	-.40	.26	0.09	1.0	-	-
17.Tranquility	0.02	-.15	0.08	0.05	-0.06	-.12	.12	-.11	-.15	-.28	.21	.13	.19	.35	-.19	-.12	1.0	-
18.Alertness	.14	-0.03	.20	.28	.11	.13	.27	-.21	-.22	-.25	0.07	0.00	.29	.26	-0.07	-	.80	1.0
																0.08		

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

