Complexities in the Assessment of Alcohol Intoxication, Impairment and Harms in Naturalistic Settings

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Declaration of Originality

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Paper 3: Assessing driving-relevant cognitive performance after a multi-day alcohol-licensed music festival

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Abstract

The consumption of alcohol in public spaces such as the night-time economy (NTE) and music festivals has been linked to a host of harms experienced by patrons, such as aggression involvement and driving risk. Given the persistent and pervasive nature of risky alcohol use in the NTE and similar environments, much attention is being given to the assessment of its use and associated adverse outcomes in this context. The ability to comprehensively assess alcohol consumption, intoxication, impairment and associated harms is a key objective in public health domains. Research in this area can inform the target identification, design, implementation and efficacy of health interventions and health promotion initiatives, aimed at reducing harms among patrons.

In order to develop appropriate interventions to be deployed in naturalistic drinking environments, it is important to first comprehensively understand how alcohol along with other substances are being used in these settings (i.e., consumption and intoxication), the demographic and behavioural profile of consumers, and how these are linked with the risk and experience of harms. However, there are innate and considerable methodological and logistical challenges associated with in-situ monitoring of alcohol use, impairment and related harm outcomes. The aim of this body of work was to identify some of these challenges, as well as investigate ways to improve upon current alcohol-related monitoring and risk identification in these naturalistic environments, focusing on four primary assessment techniques: (i) retrospective self-reports, (ii) event-level self-reports, (iii) objective biometric assessments (breath alcohol and transdermal alcohol techniques) and (iv) portable electronic cognitive-impairment assessments.

Four studies were undertaken using one or a combination of the aforementioned assessment techniques: (1) a street-intercept retrospective self-report assessment of aggression

involvement between NTE patrons (N=5,078) who reported alcohol use only versus NTE patrons who reported co-consuming alcohol and illicit substances, (2) a field-based methodological study (N=14) investigating the combined use of retrospective self-reports, prospective event-level self-reports and biometric assessments to measure alcohol consumption and intoxication over a multi-day event, and (3 & 4) a two-armed (field/laboratory and laboratory) study investigating the use of a portable cognitive assessment battery to assess the residual next-day cognitive effects of alcohol consumption (Phase 1 [field/laboratory] N=13, Phase 2 [laboratory] N=52).

Study 1 found differences in retrospective aggression involvement between those who used alcohol only versus alcohol and other substances but highlighted a need for event-level measurements to further understand the relationship between substance use and harms. Thus, *Study 2* investigated the simultaneous use of the aforementioned range of assessment techniques in a high-risk and prolonged drinking setting to better understand alcohol use in these environments, finding limitations with all assessments but merit in their combined use. Finally, *Studies 3 and 4* indicated that while the deployment of portable cognitive assessments in real-world drinking settings is possible, the tasks themselves were not uniformly sensitive to detect alcohol-induced impairment at 0.08% breath alcohol concentration and that new tasks to assess impairment in these domains should be investigated. Overall, the combined findings of these studies offer a strengthened foundation on which to base and scale-up future alcohol-related assessments in naturalistic settings. However, a common theme throughout the work conducted is that alcohol-related assessments are still limited by the technology available, and complicated by the dynamic and complex nature of consumers and the environments in which they engage in these behaviours.

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Publications

Publications directly arising from the work described in this thesis:

Chapter 2: **Norman, T.**, Peacock, A., Bruno, R., Chan, G., Morgan, A., Voce, I., Droste, N., Taylor, N., Coomber, K., & Miller, P. (2019). Aggression in the Australian night time economy: A comparison of alcohol only versus alcohol and illicit drug consumption. *Drug and Alcohol Review, 38*(7), 744-749. doi: 10.1111/dar.12998

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Norman, T., Peacock, A., Ferguson, S., Kuntsche, E., & Bruno, R. (November 2018). *To Drive or Not to Drive? Alcohol Consumption and Psychomotor Performance at a Multi-day Music Event.* Oral presentation at 2018 Australasian Professional Society on Alcohol and Other Drugs conference in Auckland, New Zealand

Norman, T., Peacock, A., Bruno, R., Droste, N., & Pennay, A. (November 2017). *Additional Harms of Illicit Drug Use over Alcohol Use in the Night-Time Economy? A Propensity-Score Matched Case-Control Study.* Oral presentation at 2017 Australasian Professional Society on Alcohol and Other Drugs conference in Melbourne, Australia

Chapter 1: Introduction

1.1 Preface

The consumption of ethanol (primarily referred to as 'alcohol' herein) is a worldwide practice and use amongst the Australian population is no exception. Alcohol, a licit and widely available substance, is a national and global public health concern due to hazardous use and subsequent harms (World Health Organisation, 2018). Globally, alcohol contributes substantially to health, economic and social burden (Degenhardt et al., 2018). Increasing rates of alcohol-related problems in Australia have occurred over the past two decades, despite relatively stable population levels of consumption (Livingston, Matthews, Barratt, Lloyd, & Room, 2010). Despite these problems, most populated regions throughout Australia have business, social and cultural activities open for alcohol trade in the evening. These collectively form what is known as the night-time economy (NTE) and broadly includes areas such as pubs, clubs, licensed events, as well as more ephemeral drinking settings such music festivals. Alcohol use is prevalent throughout the NTE nationally (Miller, Bruno, et al., 2016). These spaces have drawn considerable attention as naturalistic environments in which the sale of alcohol and (over)consumption of substances actively contribute to adverse outcomes among patrons and the wider population (Wilton & Moreno, 2012).

The consumption of alcohol in spaces such as the NTE has been linked to a host of acute harms (Doherty & Roche, 2003; Peacock et al., 2016; Roche et al., 2009). Acute harms resulting from alcohol consumption are a primary contributor to alcohol being ranked by experts as the most harmful drug overall in Australia, coupled with alcohol-related chronic disease (Bonomo et al., 2019). There are several mechanistic theories behind acute alcohol-related harms in this context, both of psychopharmacological and environmental origin. Broadly understanding these mechanisms is important in contextualising *why* alcohol results in adverse outcomes, and subsequently understanding how to reduce these harms. Pharmacologically, alcohol is a central nervous system depressant. Heavy (or risky) consumption results in ‘alcohol intoxication’ and subsequent motor, cognitive, memory and sensory impairment (National Health and Medical Research Council [NHMRC], 2009). In isolation, alcohol-induced physiological impairment increases the risk of personal injury, overdose, road traffic accidents and the elicitation of aggressive behaviour (Ridolfo & Stevenson, 2001). In social contexts such as the NTE, it is theorised to further increase the risk of being involved in harms through two possible pathways: an attenuation of the cognitive capacity to deal with risky situations and by shifting the consumer’s perception of what is socially permissive (Nicholas, 2008). Physical and social environmental factors in the NTE have also been linked to an increase in the incidence and severity of alcohol-related harms, including patron density (crowding), venue operating hours, visibility of police and global level of intoxication in the setting (Doherty & Roche, 2003). Alcohol also induces adverse next-day effects, known as an alcohol hangover, resulting in physiological and cognitive impairment despite the absence of alcohol in the bloodstream (Stephens, Ling, Heffernan, Heather, & Jones, 2008; R. Swift & Davidson, 1998). Thus, there are several important dimensions that help inform us on the wider picture of alcohol use: the consumption of alcohol, the resulting intoxication from alcohol, the impairment (e.g., cognitive) that is associated with alcohol use, and the acute harms that can occur as a result.

Given the persistent and pervasive nature of risky alcohol use in the NTE and similar environments, much attention has been diverted to the assessment of its use and associated adverse outcomes in this context. The ability to comprehensively assess alcohol consumption, intoxication, impairment, and associated harms is a key objective in public health domains (Miller, Bruno, et al., 2016). Research in this area can inform the target identification, design, implementation and efficacy of health interventions and health promotion initiatives within the NTE and beyond, aimed at reducing harm among patrons in these settings. In order to develop appropriate interventions to be deployed in the NTE, it is important to first understand how alcohol (along with other substances) are being used in these settings (i.e., consumption and intoxication), the profile of consumers, and how these are linked with harms and risk. However, there are innate and considerable methodological and logistical challenges associated with in-situ monitoring of alcohol use and related harm outcomes in naturalistic settings such as the NTE. The aim of this body of work is to identify some of these challenges, as well as investigate ways to improve upon current alcohol-related monitoring and risk identification in these naturalistic environments centring on four primary assessment techniques: (i) retrospective self-reports, (ii) event-level self-reports, (iii) objective biometric assessments (breath alcohol and transdermal alcohol techniques) and (iv) portable electronic cognitive-impairment assessments.

This thesis will focus on investigating contemporary issues in the monitoring of alcohol consumption, intoxication, impairment and harms in naturalistic settings. The following sections of this chapter will discuss:

1.2) The broader pharmacological underpinnings of alcohol, in order to contextualise how the drug works, its acute profile of effects in humans and how its use can be measured;

1.3) Alcohol consumption and associated harms at a population level;

1.4) Alcohol consumption in naturalistic drinking settings, such as the NTE and music festivals;

1.5) Acute alcohol-associated harms in naturalistic settings, including gaps in our current knowledge for two specific harms: aggression involvement and driving risk;

1.6) Assessment tools used to monitor alcohol use and related harms, their strengths and weakness in naturalistic contexts, gaps in our current knowledge for their combined use to measure consumption and intoxication in these contexts, and study designs for their implementation, and;

1.7) The current research programme, including objectives, research questions and project design.

1.2 Alcohol

Alcohol has a myriad of scientific, medical and industrial uses, though one of the most salient contemporary functions is its sale as a consumption product; most commonly as a beverage used for recreational purposes (and, to a lesser extent, for religious and cultural purposes). Commercially, the three most common types of alcoholic beverage include beers, wines and spirits. All alcohol related consumables are psychotropic in nature (Brust, 2010). Psychotropic substances are those which alter brain function and result in changes to cognition, behaviour, mood or consciousness. Alcohol is widely known as increasing sociability and promoting relaxation in small to moderate doses (Roche et al., 2009), and is therefore popular as a social agent. In Australia, and the majority of countries globally, the sale of alcoholic beverages as a recreational consumable is permitted though regulated by law. This allows individuals of legal age, 18 years and older in Australia (NHMRC, 2009), to purchase a mostly unrestricted amount of the substance from licensed vendors. Indeed, alcohol is sold at a plethora of venues, including pubs, clubs, bottle shops, restaurants, events (such as music festivals), and wineries, and can be legally brewed at home. In contrast, the vast majority of other controlled psychotropic drugs are sold over the counter at pharmacies as medicines, by prescription from a medical professional or are entirely restricted substances; illegal to manufacture or possess. Given this, the accessibility of alcohol is greater than almost every other psychoactive substance in most parts of the world; rivalled only by tobacco and caffeine (Wallner & Olsen, 2008).

1.2.1 Alcohol Pharmacokinetics

Alcohol is most commonly consumed orally. Once ingested, it will undergo a process known as first-pass metabolism. This is the process of ethanol metabolism in the stomach and liver that eliminates a proportion of the drug before it enters the circulatory system (Cederbaum, 2012). Alcohol is absorbed slowly in the stomach and rapidly in the small intestine. The small intestine is coated in epithelial cells through which ethanol can pass (a process known as diffusion), arriving in capillaries and circulating through blood to the liver to be gradually metabolised by liver enzymes (hepatic metabolism). Once re-emerging from the liver, ethanol will continue to pass through the body until it is entirely metabolised or excreted through other means.

In the initial stages of hepatic metabolism ethanol is primarily broken down by alcohol dehydrogenase (Zakhari, 2006). Alcohol dehydrogenase are zinc-containing enzymes that oxidise endogenous and exogenous ethanol into acetaldehyde and are found in their highest concentrations within the liver, gastrointestinal tract and kidneys (Cederbaum, 2012). Acetaldehyde is a toxic compound and a known carcinogen (National Institute on Alcohol Abuse and Alcoholism [NIAAA], 2007). However, its residence in the body is usually short lived as it is further broken down into acetate by another enzyme called aldehyde dehydrogenase (Zakhari, 2006). Acetate is broken down in tissues, mostly outside of the liver, and turned into water and carbon dioxide. In addition to liver metabolism, ethanol is also excreted passively via the breath, urine and sweat (Zakhari, 2006).

While the majority of consumed ethanol will be eliminated by hepatic metabolisation (Zakhari, 2006), excretion of ethanol in the breath is a particularly pertinent aspect of elimination as it is one of the primary diagnostic routes for detecting its presence (and subsequent level of intoxication) in humans (i.e., breath alcohol assessments). As oxygen is breathed in from the atmosphere, it passes through the capillary walls of the lungs via tiny air sacs, known as alveoli, and into the circulatory system (Zakhari, 2006). Similarly, ethanol in the capillaries diffuse into the mucus membranes of the alveoli (in liquid form) and vaporises, filling the space of the alveoli as gas. Following this state conversion, ethanol within each sac can exit the body through exhalation. This diagnostic route is especially beneficial in naturalistic drinking settings as it offers a convenient and non-invasive means of assessing intoxication (discussed further in Section 1.6.3).

A small percentage of unchanged ethanol (approximately 1%) is also excreted via insensible perspiration (Hawthorne & Wojcik, 2006). Vapor containing ethanol gas passively exits the body through the skin as it passes through the circulatory system. It first diffuses through the blood into the epidermis, through to the stratum corneum (the outermost layer of skin comprised of dead cells) and into the atmosphere. This process happens independent of usual perspiration. As ethanol distributes through the body relative to the water content of each organ, and the skin has a low water concentration, ethanol typically emigrates through the dermis last (relative to ethanol exiting through the lungs, for example) (Hawthorne & Wojcik, 2006). Recent technological efforts have been concentrated on measuring alcohol intoxication via insensible perspiration, also known as transdermal alcohol assessment (discussed in Section 1.6.4.2). This route of assessment will also be a primary assessment of focus within this thesis.

1.2.2 Pharmacodynamics and Acute Pathophysiological Effects of Alcohol

Due to the very small size of the ethanol molecule, cell membranes within the human body are highly permeable to ethanol; once travelling through the bloodstream, it can interact with almost every cell (Brust, 2010). As a result, the effects of alcohol are diffuse, influencing many different domains of functioning including motor and cognitive. Ethanol is a glutamate antagonist, or inhibitor (Vengeliene, Bilbao, Molander, & Spanagel, 2008). Glutamate is the primary excitatory neurotransmitter in the body, and alcohol impedes a particularly type of glutamate receptor known as N-methyl-D-asparate (Vengeliene et al., 2008). Ethanol also agonises GABA (gamma-aminobutyric acid) subtype receptors by opening chloride channels, resulting in hyperpolarisation. Both glutamate and GABA are key neurotransmitters in the regulation of nerve cell activity. Ethanol acts on dopamine pathways, particularly from the ventral tegmental area to the nucleus accumbens; the motivational centre within the brain. This action is responsible for the physiologically rewarding nature of alcohol consumption, both acutely and long-term (Adinoff, 2004).

Consumption of alcohol produces a host of acute physiological and psychological characteristics known as ‘alcohol intoxication’. The amount of ethanol in the body at a given moment is commonly measured in units of grams per millilitre (g/mL) or milligrams per decilitre (mg/dL) of blood, also known as blood alcohol concentration (BAC). The acute effects of alcohol consumption vary based on the concentration of alcohol in the blood. The symptoms of alcohol intoxication, known colloquially as ‘drunkenness’, are the result of the aforementioned central nervous system depression. While the effects of intoxication can vary across individuals, they are often broadly clustered and described according to BAC levels. Most individuals drink alcohol in social settings due to the euphoric properties this intoxication brings on, as well as a sense of increased sociability at low to medium concentrations (Schuckit, 2006). However, intoxication also induces a range of adverse behavioural and motor impairments, up to and including death, at extremely high doses. Table 1.1 demonstrates a list of effects by blood alcohol concentration.

Table 1.1 Behavioural and Motor Impairment According to BAC Level

BAC (g/mL)	**Correlated behavioural/motor impairment**
0.020 – 0.099	Impaired coordination, euphoria, increased sociability
0.10 – 0.199	Ataxia, impaired cognition, poor judgement
0.20 – 0.299	Slurred speech, poor judgement, nausea and vomiting, labile mood
0.30 – 0.399	Memory lapse, labile mood
0.40 and over	Respiratory failure, coma, death

Original source: Schuckit (2006)

1.2.3 Alcohol Hangover

Alcohol consumption can also result in a delayed constellation of unpleasant symptoms after the acute phase of intoxication (also known as the ‘next-day’ or ‘hangover’ effects), even when alcohol itself is no longer detectible in the bloodstream (R. Swift & Davidson, 1998). Table 1.2 demonstrates key symptoms. Alcohol hangover is an important dimension of alcohol intoxication; over 75% of people who reported binge drinking also reported at least some symptoms of alcohol hangover following acute intoxication (Harburg, Gunn, Gleiberman, DiFranceisco, & Schork, 1993). While the severity of a hangover is typically dose-dependent, it can also vary at an individual level (i.e., some individuals are more/less susceptible to hangovers than others). While alcohol directly contributes to the hangover effect, the mechanisms through which this occurs remain somewhat nebulous. The three primary hypothesised contributors include (i) dehydration, (ii) disruption of sleep and other biological rhythms, and (iii) metabolite toxicity (R. Swift & Davidson, 1998).

Table 1.2 Symptoms of Hangover

Class of Symptoms	**Type**
Constitutional	Fatigue, weakness, and thirst
Pain	Headache and muscle aches
Gastrointestinal	Nausea, vomiting, and stomach pain
Sleep and biological rhythms	Decreased sleep, decreased REM,[1] and increased slow-wave sleep
Sensory	Vertigo and sensitivity to light and sound
Cognitive	Decreased attention and concentration
Mood	Depression, anxiety, and irritability
Sympathetic hyperactivity	Tremor, sweating, and increased pulse and systolic blood pressure

[1]Rapid Eye Movement (sleep)

Original source: Swift and Davidson (1998)

Firstly, alcohol is a diuretic, inhibiting the ability of the kidneys to conserve liquid by supressing vasopressin; an antidiuretic hormone (Epstein, 1997). The attenuated ability to preserve water in the body following alcohol consumption has been linked to post-consumption dehydration. This may be further compounded by fluid loss from other symptoms typical of a hangover: sweating, diarrhea and/or vomiting. Hangover symptoms often mirror those of mild-severe dehydration (R. Swift & Davidson, 1998). Secondly, alcohol is known to adversely influence quality of sleep, number of hours slept and general alertness by inhibiting sleep-related hormones, as well as its role in moderating GABA and glutamate (Roehrs & Roth, 2001). Finally, there is a degree of evidence that an alcohol metabolite, namely acetaldehyde, contributes to hangovers due to its reactive nature and subsequent toxicity. While acetaldehyde is not present in the blood at 0.00% BAC (i.e., when returning to sober), it has been suggested that its toxic effects persist past the acute phase of alcohol intoxication (R. Swift & Davidson, 1998).

Hangover is an important component of alcohol-related risk. Specifically, it has been theorised that alcohol contributes to an attenuation in cognitive and motor abilities that are relevant to driving safety, a key safety consideration in the NTE. This will be discussed further in Section 1.5.2.

1.2.4 Alcohol: Summary

Alcohol is a widely available consumable and is one of the few psychotropic substances that is sold commercially as a recreational drug. When consumed by humans, it is excreted and can be detected through multiple routes including hepatic metabolisation (metabolised into water and passed through the kidneys), through the breath and off the surface of the skin (insensible perspiration). It has a complex profile of effects in humans, but primarily functions as a glutamate antagonist and GABA agonist. Acutely, alcohol can produce motor and cognitive impairment. It can also produce a host of adverse next-day effects, known as an ‘alcohol hangover’, the effects of which persist after BAC has returned to zero.

1.3 Alcohol Consumption and Alcohol-Related Harms at Population level

1.3.1 Prevalence of Alcohol Consumption at Population Level

Population-level data, such as those collected through the National Drug Strategy Household Survey (Australian Institute of Health and Welfare, 2017), are useful in understanding alcohol use trends and the degree of consumption broadly. This helps to contextualise how widely alcohol is used by the general public, and why it is a subsequent substance of concern in the public health sphere. A large proportion of the Australian population have previously or do currently consume alcohol; as of 2016, approximately 90% of Australians have consumed it in their lifetime, with 77% of Australians having done so in the previous 12 months (Australian Institute of Health and Welfare, 2017). On average, Australians also first try alcohol before they are legally able to buy it. The average age that an individual first tried alcohol in Australia was 16.1 years in 2016, despite the legal age of alcohol purchase being 18 in all states and territories (Australian Institute of Health and Welfare, 2017).

The NHMRC (2009) recommends individuals consume no more than four standard drinks (40g, or 10g of ethanol per standard drink) in a single session to reduce to acute harms such as alcohol-related injury. However, there is a significant proportion of the Australian population who drink at levels that far exceed the NHMRC (2009) guidelines. This behaviour is known as 'very high risk' drinking. Approximately one in six individuals (15.4%) had consumed 11 or more standard drinks on a single drinking occasion (2.5+ times the recommended maximum intake) between 2015 and 2016 (Australian Institute of Health and Welfare, 2017). While less than one tenth of these individuals (7.1%) did so on a monthly basis or more, 15.4% of younger individuals aged between 18 and 24 years drank 11+ standard drinks on a monthly basis or more. Concern for this group is particularly salient considering that individuals under 25 are most susceptible to poorer alcohol-related decision making and a poorer response to physiological cues from over drinking than older individuals (Spear, 2004).

1.3.2 Alcohol-Related Harms at Population Level

Given that a large proportion of individuals consume alcohol at risky levels, it is also important to outline the adverse population-level effects of alcohol. While the specific alcohol-related harms pertinent to this programme of research will be discussed in Section 1.5, population data provides valuable insight into the burden that alcohol consumption has on society as a whole. This underscores the importance, from a public health perspective, of reducing harmful alcohol-related behaviours, and thus monitoring alcohol use and the complex profile of associated harms that can result from alcohol consumption.

In 2010, there were 5,554 alcohol-attributable deaths across Australia (Gao, Ogeil, & Lloyd, 2014). There were a further 157,132 alcohol-attributable hospitalisations in 2010. Disability Adjusted Life Years (DALYs) express years lost due to poor health or disability. The consumption of alcohol was responsible for approximately 136,982 DALYs for Australian men in 2010, and a further 35,223 DALYs for women (Gao et al., 2014). Years of Life Lost (YLL) expresses the amount of living years lost relative to life expectancy. Alcohol use was responsible for approximately 84,945 YLL in men and 35,223 YLL in women across Australia in 2010 (Gao et al., 2014). Alcohol related injury, including motor vehicle accidents and interpersonal violence, was the primary cause of this premature death in men, accounting for 38% of YLL. Approximately 36% of total male deaths were from injury related causes, compared to 12% of female deaths (Gao et al., 2014).

Globally, harms from alcohol are similarly stark. In 2016 alone, alcohol consumption was attributable to 2,814,000 deaths (or, in YLL, 81,959,300) from all causes, including both long-term and acute harms (Degenhardt et al., 2018). At an acute level, 438,000 of these deaths were alcohol-related injuries including motor vehicle accidents (18,381,500 YLL), while 61,500 were from interpersonal violence (3,023,800 YLL) (Degenhardt et al., 2018).

1.4 Prevalence of Alcohol Consumption in Naturalistic Contexts

Based on these data, it is apparent that alcohol consumption is widespread and contributes to significant burden both within Australian and globally. However, in addition to population level alcohol consumption, it is important to identify specific settings in which high levels of drinking occur over condensed periods of time and are subsequently considered 'high risk'. For the purposes of this body of research, I will focus on two settings of interest: the broad night-time economy, and more ephemeral but densely populated drinking environments such as multi-day music festivals.

1.4.1 Alcohol Consumption in the Night-Time Economy

Given that a function of licensed premises is the provision of alcohol to the public, these settings have emerged as primary loci of interest in health-based research (Wilton & Moreno, 2012). Objective intoxication measures such as breath alcohol concentration are key assessments of interest in this regard, as they offer insight into the momentary *severity* of alcohol intoxication amongst patrons. A Welsh street intercept study, whereby random NTE patrons were approached for an interview and breath analysis between 11pm and 3am, reported a mean BrAC reading of 0.13% g/dL for men and 0.09% g/dL for women (S. Moore, Shepherd, Perham, & Cusens, 2007). This is a high degree of general intoxication, with the average male patron almost three times the Australian legal driving threshold and the average female almost twice the legal limit. While a more recent Australian street intercept survey of over 5,000 NTE patrons in 2015, conducted between 10pm and 2am in or around licensed premises, found that the average BrAC level of respondents to be considerably lower at 0.06%, the upper quartile of this sample's readings still exceeded 0.10% (Peacock et al., 2016). Most participants (85%) in the sample reported drinking on the night of interview and were typically young with a median age of 22 years. These findings are generally congruent with population level trends of alcohol use; young individuals are most at risk of high levels of alcohol consumption. However, single-instance alcohol use is much higher than the population average.

A 2011 street intercept survey (Dealing with Alcohol and the Night-Time Economy; DANTE) of 3,949 individuals (mean age=24) in and around licensed premises in Geelong and Newcastle, Australia, further highlights the behavioural characteristics of NTE patrons (Miller et al., 2012). Of this sample, surveyed between 9pm and 3:30am, over 40% reported visiting licensed premises at least weekly and almost 30% reported being intoxicated on a weekly or greater basis. Across the sample, intoxication levels increased as the night progressed (i.e., the later in the evening participants were interviewed, the more intoxicated they were). A significant minority also reported consuming substances in addition to alcohol; just over 8% of respondents had consumed illicit drugs on the night of interview.

It is also important to note that the demonstrated levels of alcohol intoxication in NTE environments are not solely the result of beverages sold at licensed venues. Pre-drinking (also known as 'pre-loading') is the act of consuming pre-bought alcohol (e.g., alcohol purchased at a bottle shop/liquor store) at a private residence or public space before moving on to licensed venues. Pre-drinking is a significant predictor of level of intoxication in night-time settings and generally reflects a broad culture of 'determined drunkenness' (Miller, Bruno, et al., 2016). As pre-drinking is done outside of the regulated sphere of NTE and similarly licensed zones, patrons can procure and consume alcohol at levels beyond what would be permissible by venue staff if the drinking had started within these areas. As a result, research has indicated that pre-drinking results in an overall higher degree of intoxication within NTE settings (Miller, Droste, et al., 2016). In the DANTE study, almost 30% of patrons reported consuming over 6 standard drinks before even arriving at a licensed venue (Miller et al., 2012), well above NHMRC's (2009) guidelines for single instance drinking.

1.4.2 Alcohol Consumption at Music Festivals

Alcohol is also frequently used heavily in ephemeral drinking settings such as music festivals. Music events in Australia are becoming increasingly popular, with over 40% of Australians aged 18-29 attending one each year (Australian Bureau of Statistics, 2015). Music festivals can span over the course of multiple days (typically 1–5 days), are usually alcohol-licensed and attract large numbers of patrons, many of whom will reside on site (e.g., camping) for the duration. While music festivals will typically only last a few days at a time, these settings are especially relevant to alcohol and associated harm monitoring considering the high rates of alcohol use that occur at them, the potential to drink continuously over the festival period (e.g., several days), and that the continuous period people spend at these events are likely to be longer than a typical evening spent within the NTE. Further, music events are highly patronised by young people (Australian Bureau of Statistics, 2015). It is these reasons that underscore music festivals as a prominent example of a 'high-risk' naturalistic drinking setting.

Data from the 2019 Global Drug Survey, the world's largest annual online survey of substance use, provides insight on the demographic and alcohol use characteristics of Australian music festival attendees. Of the 5,155 respondents who had reported attending a music festival in 2018, 54.8% were male, with an average age of 22 (SD=6, range 16-70) (Hughes, Barratt, Ferris, & Windstock, 2019). Over half of these individuals (50.4%) had been to three or more music festivals in the previous 12 months. Almost all (95.6%) had used alcohol in the previous 12 months, 44.3% consumed alcohol at least 2 times a week (with 10.6% consuming >4 times per week) and over two thirds (67.2%) drank an average of 5 or more standard drinks per drinking session (above NHMRC's [2009] recommended single-instance limit).

In addition to the broader characteristics of music festival attendees, it is also useful to assess alcohol use behaviours while in attendance at events. An in-situ cross-sectional survey of 1410 Swedish festival attendees found that 81% of those interviewed had consumed alcohol during the event (Feltmann, Elgán, & Gripenberg, 2019). This high prevalence of consumption was coupled with a high degree of intoxication amongst the sample. Interviewees returned a median BrAC of 0.08%, while over 30% of the sample returned a result over 0.10%. High risk drinking behaviours are similarly reflected in Australian samples. A cross-sectional study of 409 Australian festival patrons in 2018 found that the median alcoholic beverage consumption was 12 standard drinks (120 grams of alcohol) in a 24-hour period while attending the event (Fernando et al., 2018); three times the NHMRC (2009) cut-off for single-instance risky drinking. Over one-fifth (23%) of the sample reported consuming over 16 standard drinks in the 24 prior to interview; at least four times the NHMRC recommendation.

1.4.3 Alcohol Consumption in Naturalistic Contexts: Summary

Compared to the broader population, risky drinking is especially prominent in NTE districts and at multi-day music festivals, with a high prevalence of both binary alcohol use (those drinking versus those not drinking) and binge-level consumption (i.e., over the NHMRC [2009] single-instance guidelines). For this reason, drinking behaviours within these loci are considered 'high-risk' when compared to the drinking characteristics of the wider population, and are thus a salient target for health research and subsequent health-promotion initiatives.

1.5 Acute Harms in the Naturalistic Contexts

A primary concern in any alcohol-licensed environment is the risk of experiencing acute harms as a result of drinking given the large amounts of alcohol being consumed and the high degree of general intoxication within these settings. As previously discussed, individuals under the age of 25 are at most risk of experiencing alcohol-related harms due to higher single-instance alcohol consumption (NHMRC, 2009), as well as poorer alcohol-related decision making and response to physiological cues from excessive drinking (Spear, 2004). This may compound the risk of adverse events occurring in spaces such as the NTE given the high proportion of young people that frequent such settings. There are a wide range of alcohol-associated harms relevant to NTE contexts. Investigating these harms and the profile of those who experience them is an emerging priority in order to drive the next frontier of alcohol-related harm minimisation initiatives. As outlined in section 1.3.2, alcohol-associated interpersonal violence and motor vehicle accidents are two marked contributors to global deaths and YLLs. While it is beyond the scope of this thesis to investigate every harm that is experienced within NTE and festival settings, the following subsections will thus discuss these two key contemporary issues to comprise the harm-related focus of the research programme: 1.) involvement in aggression in the NTE and 2.) alcohol-related cognitive impairment and associated driving risk.

1.5.1 Aggression in the NTE

Alcohol-related violence and aggressive incidents are a serious concern in the NTE. Exposure to alcohol-related aggression (such as verbal or physical incidents) or overt violence have an adverse impact on physical, psychological and community safety (Nicholas, 2006). Experimental work has causally linked alcohol use and aggression (Tomlinson, Brown, & Hoaken, 2016) and high levels of alcohol consumption in the NTE unequivocally contribute to aggression-related harms (Roche et al., 2009). Alcohol consumption is a key contributor to violence-related patient presentations at medical centres (Buss, Abdu, & Walker, 1995). Indeed, rates of aggression involvement in the Australian NTE are high. Almost 50% of 1689 participants in a 2015 street-intercept survey conducted in Canberra and Hobart, Australia, reported experiencing some form of aggression (physical, verbal and/or sexual) in and around licensed premises in the previous 3 months (Miller, Bruno, et al., 2016). Moreover, these individuals reported a median of four incidents of aggression within this time period (slightly over one incident per month). A recent meta-meta-analysis indicated that the association between alcohol and aggression does not differ greatly between perpetrator or victims of aggression (Duke, Smith, Oberleitner, Westphal, & McKee, 2017). Consequently, there is interest in assessing the function of alcohol consumption in both driving aggressive behaviour as well as increasing the risk of being aggressed on.

While there is demonstrable link between alcohol and aggression, several factors can influence associations between alcohol and involvement in aggression. For example, males are more likely to be involved in alcohol-related aggressive incidents compared to females (Copping, 2017). This is consistent with broader aggression research; an increase in risk of aggression for males is one of the most ubiquitous findings in multidisciplinary aggression studies (Barrett, Dunbar, & Campbell, 2007). However, one of the more nebulous moderating factors of alcohol-related aggression is the combined use of alcohol and illicit drugs. Illicit drugs are commonly used in combination with alcohol in NTE settings; the most frequently reported of which are cannabis, ecstasy, methamphetamine and cocaine (Pennay et al., 2017).

The simultaneous use of these substances (the use of both alcohol and illicit drugs during the same session) is associated with an increased risk of aggression broadly (Duke et al., 2017; Hyder et al., 2018). Given the high rates of aggression exposure in the NTE, preliminary research has also investigated the role of illicit drug use in aggression involvement risk within these settings specifically. Using street intercept surveys in Australia, Pennay and colleagues (2017) noted an association between any illicit drug use (reported use of illicit drug vs no reported use of illicit drug) and an increased risk of aggression involvement. While this ostensibly suggests that individuals who use illicit drugs in combination with alcohol are more susceptible to alcohol-related harms in the NTE, these analyses did not consider characteristics and behaviours that increase overall risk propensity. For example, pre-drinking increases risk of harm exposure (see 1.4.1). Further, illicit drug consumers are known to drink at levels above the population average (Pennay et al., 2017). Considering that people who consume illicit substances are also likely to engage in risky alcohol consumption practices, categorically comparing binary illicit drug use with no illicit use may not be the most accurate assessment of risk. It is currently unknown whether, after considering the spectrum of alcohol behaviours between illicit and non-illicit consumers, people who use a combination of alcohol and illicit drugs in the NTE are more at risk of experiencing aggression than those who engage in alcohol consumption only. This is important distinction to make, primarily because it will help tease apart whether illicit drug use is the primary contributor to the risk increase, or whether confounding factors (e.g., level of alcohol consumption) are also associated.

Assessing the prevalence, type and context of aggression-related harms experienced in NTE environments is important when addressing safety strategies in these contexts. Patrons in licensed zones are not a homogenous group. Latent class analyses have demonstrated that rates and types of harms experienced can vary depending on level of alcohol intoxication, demographic and behavioural characteristics (Peacock et al., 2016). Health promotion and preventative safety interventions are commonly discredited by patrons within NTE contexts due to a mismatch between the recipient’s experience and the content of the message, reducing their effectiveness (D. Moore, 2010). For example, if a preventative safety message asserts that high levels of alcohol consumption lead to experiences of aggression in the NTE, but the viewing patron has not experienced aggression in this context despite drinking heavily, the message is likely to be dismissed by that patron. Consequently, in order to maximise the effectiveness of such interventions, an important direction for harm reduction research is to further illuminate distinctions between consumers in the NTE, including differences in who consumes substance, how they consume substances and the associated harms they experience (Pennay et al., 2017). The aim of doing this is to allow future harm reduction initiatives to more specifically and effectively target the most at-risk patrons in these settings, improving alignment between initiative messaging and the patron experience. It is currently unknown whether different co-consuming illicit drug and alcohol groups experience aggression differently in the NTE context, and it remains a significant gap in the research literature.

Key Literature Gap to be Examined in this Thesis (#1):
Do different co-consuming illicit drug + alcohol groups in the NTE experience aggression differently (e.g., a greater amount or different types) when compared to alcohol only consumers?

1.5.2 Risky Driving and Alcohol-Induced Cognitive Impairment

Road vehicle accidents are a leading cause of injury and death among young people in Australia. Over three fifths of all accidental deaths for individuals aged 15-19 and 20-24 years in New South Wales were the result of a motor vehicle accident in 2014; 69% and 61% of accidental deaths, respectively (Centre for Road Safety, 2015). While road accidents are caused by a number of factors such as speeding and inattention, over 10% of casualties with known causes on the road were attributable to alcohol intoxication that year (Centre for Road Safety, 2015). Given that alcohol-related accidents are typically preventable, they have emerged as a key target for interventions and health promotion campaigns in the public health sphere (Fernando et al., 2018). Young people are salient targets for these initiatives, being most at risk of being involved in an accident while under the influence of alcohol (Keall, Frith, & Patterson, 2004). NTE settings and festivals are two prominent platforms for their delivery due to the high proportion of young individuals that frequent them, and the high levels of alcohol being consumed within them. However, many of the existing safety interventions implemented in these environments, such as free breath alcohol testing services and health messaging (e.g., anti-drink-drive messaging), are aimed at reducing the risk of patrons operating a motor vehicle while *acutely* intoxicated. However, there has been limited in-situ research on the possible *residual* effects that alcohol intoxication may have on driving ability once ethanol is no longer detectable in the blood (i.e., the 'hangover' effect discussed in section 1.2.3), and specifically, cognitive performance post-intoxication.

Cognitive performance is an important aspect of driving safety. A study of 152 young Australians aged 17 to 25 in 2018 found that better performance on cognitive tasks was significantly associated with fewer lane deviations and less speeding during a driving simulator assessment (Zicat, Bennett, Chekaluk, & Batchelor, 2018). However, cognition is comprised of several domains, and some appear to be more important than others regarding driving performance. Attention, the ability to filter information and select appropriate responses to enable goal driven behaviour (Zicat et al., 2018), is one such process. Impairment in dividing, selecting and sustaining attention over time is significantly associated with risk of crashing and committing on-road driving errors (Anstey, Wood, Lord, & Walker, 2005). A second domain, working memory, also appears to be an important dimension of driving performance. Specifically, the active maintenance of goal-driven behaviour (e.g., driving a vehicle) when faced with a distraction on the road is dependent on working memory capacity (Ross et al., 2014). A study of 46 drivers between the age of 17 and 25 found that individuals with higher working memory capacity (i.e., higher performance) on a working memory task (the “N-Back” task) performed significantly fewer driving errors while under distraction on a simulated driving test (Ross et al., 2014).

It has long been known that acute alcohol intoxication impairs cognitive performance, and multiple studies have demonstrated adverse effects of acute alcohol consumption on specific cognitive domains including attention, memory and response inhibition (Abroms, Gottlob, & Fillmore, 2006; Dougherty, Marsh, Moeller, Chokshi, & Rosen, 2000; Marczinski & Fillmore, 2005). As previously discussed, these domains are critical processes in driving performance. However, a recent meta-analysis has demonstrated impairment in select cognitive domains as a result of the next-day effects (i.e., hangover) of heavy alcohol consumption, including sustained attention, short term memory and psychomotor speed (Gunn, Mackus, Griffin, Munafò, & Adams, 2018). Further, next-day impairment of these cognitive domains has translated into direct driving performance impairment on laboratory controlled driving simulation tests (Gunn et al., 2018). As with hangover itself, the exact mechanism behind hangover-related cognitive impairments is not clear. However, given that hangover is known to reduce sleep quality, resulting in fatigue, it is possible that impairment may (at least partially) arise from fatigue. Fatigue is known to attenuate select cognitive and motor abilities relevant to driving; both sleep deprivation (prolonged wakefulness) and partial sleep deprivation (chronic sleep restriction) can affect cognition, though to differing degrees (Alhola & Polo-Kantola, 2007). Specifically, total sleep deprivation can reduce attention, working memory and the ability to make decisions, while partial sleep deprivation can reduce attention. The effects of sleep deprivation on psychomotor performance have been shown to match or surpass those seen in alcohol intoxication. Laboratory studies have suggested that seventeen hours of continuous wakefulness can impair cognitive psychomotor performance (e.g., hand eye coordination) up to levels seen at 0.05% blood alcohol concentration; the legal driving limit in Australia (Dawson & Reid, 1997). Twenty-four hours of continuous sleep deprivation can impair these abilities up levels of 0.10% blood alcohol concentration (double the limit).

Beyond experimental studies, alcohol consumption and fatigue appear to be subjectively related to perceived driving ability in naturalistic drinking contexts. For example, a cross-sectional survey of 409 festival attendees in 2018 found that number of alcoholic drinks consumed, perceived breath alcohol concentration, license type (relating in part to proscribed legal BAC; 0.00% g/mL for learners/provisional and 0.05% for full) and number of hours slept were all strongly correlated with perceptions of in-the-moment driving safety amongst festival patrons (Fernando et al., 2018). However, half (45%) of all patrons interviewed at an event intended to drive that day despite only one in five feeling completely safe to do so (Fernando et al., 2018). Given this, there is a clear overlap between individuals within high risk drinking environments who do not feel safe to drive yet still intend on driving that same day.

Considering the impairing effects of fatigue on cognition, the high-levels of alcohol being consumed in high-risk settings such as music events and a demonstrated degree of subjective impairment amongst patrons despite many still intending to drive, an important unknown in these environments is the degree to which patrons are objectively impaired, at a cognitive level, by in-situ alcohol-use behaviours and experiences.

Key Literature Gap to be Examined in this Thesis (#2):
How impairing are the next-day effects of a prolonged experience in a naturalistic drinking setting (e.g., a multi-day music festival) on the driving-relevant cognitive domains of attention and working memory?

1.5.3 Summary of Alcohol-Related Harms

NTE settings are increasingly becoming of concern in relation to alcohol-related harms, primarily due to the high level of alcohol (and other substance) use and the high proportion of young individuals who frequent them. Two significant yet under-researched alcohol-related issues in the NTE include involvement in aggression and post-intoxication risky driving practices. While this body of work comprises a wide investigation into the use of alcohol-related assessment techniques, these two harms will be of particular focus.

1.6 Alcohol and Associated Harm Assessments

1.6.1 Alcohol Use, Impairment and Harm Monitoring in Naturalistic Settings

As outlined in Section 1.5, alcohol-related risk behaviours and harms occur in naturalistic drinking environments, and have identified two important harm-related research questions that are yet to be answered in these contexts. However, there is limited research in these settings due to a number of logistical, accessibility and methodological issues that make collecting primary alcohol-related data a complex task. A number of methods that can be utilised to investigate risk (e.g., subjective alcohol consumption, objective intoxication or objective impairment) and harms (e.g., aggression involvement), but each of these methodological techniques possess a unique set of characteristics that must be considered when setting up the foundation of study designs in such dynamic settings. Moreover, the strengths of some assessments may potentially complement the shortfalls of others, or help contextualise each other, resulting in a stronger combined assessment than if one were used on its own.

Traditional research designs have often used retrospective self-report and static biometric devices (devices that measure chemical changes in the body, such as breathalysers) to capture behaviours and experiences in the NTE. However, recent technological advances have increased the number of methodological options available to researchers. In particular, event-level self-report techniques such as prospective electronic diaries, continuous biometric assessments and portable cognitive tests, are emerging as a new line of assessments in alcohol-related research. The following section will discuss some of the available assessments for alcohol risk behaviour and harm monitoring, the types of outcomes they are useful in assessing, the contexts they are most suited to and how we might implement these, individually or combined, in naturalistic contexts to answer the questions discussed regarding alcohol use, risk behaviours and harms.

1.6.2 Retrospective Self-Reporting

Retrospective self-reporting, the reporting of recalled past behaviours or experiences by participants, has formed the majority of evidence in alcohol research over the last century (Kuntsche & Labhart, 2012). They are typically used to assess the frequency and/or level of substance consumption, other risk behaviours (e.g., pre-drinking) or past experiences/outcomes. The benefits of collecting alcohol-related retrospective self-reports of behaviour in substance use settings are numerous. For example, they often require a minimal amount of resources to collect data over a wide sample relative to other measures (Richter & Johnson, 2001). They can similarly provide a comprehensive overview of behaviours and outcomes over a wide retrospective timeframe (e.g., days, weeks or months). These advantages are particularly useful when assessing behaviours or outcomes that occur infrequently and are unlikely to be captured on a single evening. One of such outcomes, substance-related aggression involvement, is of particular concern.

As discussed in Section 1.5.1, aggression events within the NTE can have serious consequences for those involved, including adverse psychological effects, physical harm, hospitalisations, or in some cases, death. However, these events also happen relatively infrequently on an individual level. Consequently, it can be difficult for researchers to capture aggression by assessing this outcome on a given night from any given individual. In a similar vein, if an aggression event experienced by a patron is serious enough, they are unlikely to remain in the NTE and would thus be unavailable for participation in a study (Pennay et al., 2017). This makes retrospective reporting an ideal assessment for this outcome, as widening the timeframe in which researchers can capture an event occurring is well suited to low frequency but high impact events.

However, while retrospective self-report measures are widely used and convenient, they are also subject to a range of potential disadvantages that do not make them suitable for all variables and/or contexts. For example, the reliability and validity of these measures can be influenced by social desirability (the selective reporting of information based on how respondents want to be perceived) or demand characteristics (Richter & Johnson, 2001). Further, as these measures are not collected under experimental conditions where relevant covariates can be controlled (through, for example, participant selection criteria), this means that these must be adjusted for statistically rather than accounting for them in the study design. Indeed, this is particularly true in complex and dynamic drinking environments such as the NTE and music festivals, where the broad range of covariates are not always known a priori. There has also been concern in the literature regarding the reliability of retrospective self-reporting of substance use behaviours. For example, it has been demonstrated that BAC level is inversely associated with ability to retrospectively recall proximal drinking behaviours in the NTE (S. Moore et al., 2007), calling in to question the suitability of this measure to assess alcohol consumption amongst the highest risk drinkers. In these cases, objective forms of alcohol assessment may be sought as an alternative.

1.6.3 Breath Alcohol Assessments

Due to the aforementioned limitations of retrospective self-reports, they are sometimes replaced or paired with biometric measures drinking such as breath alcohol assessments. The volatilization and excretion of ethanol through the lungs allows ethanol to be detected in the breath. The amount of ethanol in the breath is directly related to its concentration in the blood, and the degree of intoxication is relative to blood alcohol concentration (Sorbello, Devilly, Allen, Hughes, & Brown, 2018). For this reason, breath assessments are a common and relatively non-invasive way to approximate levels of intoxication without need for a blood sample. Blood samples are not typically conducted in naturalistic research settings due to their invasive nature, high cost and professional pathology equipment to return a result.

Breath alcohol assessments are conducted using breathalyser device. Portable breathalysers consist of three primary components: a mouthpiece, two chambers of potassium dichromate and a photocell (Berger, 2002). Ethanol that enters the mouthpiece travels into one of the chambers and reacts with the solution, turning from its original orange colour to a hue of green. The degree of change in the colour of the solution is directly related to the concentration of alcohol in the expelled breath. The photocell then compares the change in colour against the reference chamber and produces an electrical current based on the differential. This current is converted into a readable alcohol concentration. The conversion of alcohol in the blood to alcohol expelled in the breath is based on a ratio of 2100:1, otherwise known as the partition ratio (Sorbello et al., 2018). This is an averaged ratio based on a series of studies across different individuals and devices. However, accurate interpretation of breath alcohol readings relies on the assumption that the partition ratio is accurate for the individual being assessed. In reality, this ratio can vary between 1500:1 and 3000:1 based on a number of factors including the device used, intoxication level, age, biological sex and genetic components (Sorbello et al., 2018). For this reason, the accuracy and utility of breath alcohol assessments remains a point of contention. Nevertheless, they are the most popular biometric assessments tools in NTE research settings.

Assessing intoxication in naturalistic settings with biomonitoring devices such as breathalysers is advantageous for multiple reasons. Not only does taking objective measurements eliminate the threat of recall bias, but it also eliminates social desirability bias (Campbell, Eyal, Musiimenta, & Haberer, 2016). Further, they can be quickly and portably deployed by investigating personnel. Aside from the initial cost of the device, they are also relatively inexpensive to run and maintain, requiring only disposable mouthpieces and intermittent recalibration. Given their ease of use in field-based settings, it is the tool most used in the law-enforcement context to assess ability to drive. In Australia, the legal breath alcohol limit is 0.05% (0.00% for provisional or learner drivers) and 0.08% in the United States and United Kingdom. In addition to legal assessments, they are also frequently utilised by researchers to assess intoxication of target populations and have been endorsed by field researchers above retrospective reports (S. Moore et al., 2007).

While BrAC can provide a more reliable assessment of intoxication in naturalistic settings over retrospective reports (which can only be estimated based on reported consumption), a concern with measuring breath alcohol concentration in these settings is the influence that residual alcohol in the mouth can have on the reading. Specifically, alcohol in the mouth left over from a sip of a beverage (rather than excretion through the breath) can heavily inflate BrAC readings (Riordan et al., 2017). It is consequently advised that there is at least a 10-minute interval between the consumption of alcohol and an alcohol reading. This precludes direct assessment at any given moment with NTE patrons, requiring a short delay between recruitment and assessment. However, considering breath alcohol assessments are typically paired with retrospective questionnaires or other ancillary face-to-face assessments, this limitation can be easily circumvented by administering the breath assessment at the end of the assessment battery.

A more salient methodological limitation of breath alcohol devices is that they must be operated by researchers, and only provide a static assessment of intoxication (Clapp et al., 2007). Thus, the use of traditional breathalysers in prospective, naturalistic study designs is challenging in that participants must be interrupted from their usual behaviour to undergo assessment. This limitation is not a major concern if breath assessments are conducted infrequently but can be detrimental to the ecological validity of a study if frequent (e.g., hourly) assessments are required. For this reason, recent research methodologies in naturalistic settings have begun exploring objective assessments that can be taken by the participant themselves, without need for contact with a researcher. For example, 'personal' breathalyser devices are commercially available, which are much smaller and cheaper versions of police-grade units that store readings on personal mobile devices via Bluetooth (Riordan et al., 2017). Indeed, such devices could be theoretically given to participants for regular self-assessment while drinking. However, field-based validation of these devices against police-grade breathalyser devices have shown them to consistently overestimate BAC, limiting their validity in these settings (Riordan et al., 2017). Further, breath sampling with these devices is still not an entirely passive process (i.e., participants have to remember to take regular readings, and ensure they have not consumed alcohol in the prior 10 minutes), raising concerns about participant compliance and ecological validity. Thus, event-level intoxication assessments that can be collected passively, without any input from the participant and in close to real-time, are the next logical step (discussed further in Section 1.6.4.2).

1.6.4 Ambulatory Assessments

Note: Ambulatory assessment is also known as 'ecological momentary assessment' (EMA) within psychological literature. These terms will be used interchangeably throughout the thesis.

Self-report and BrAC assessments are not the only two assessments available for use in substance-use settings; alternative or ancillary measures are also often deployed to either replace the more traditional methods or supplement their respective methodological weaknesses. Modern field-based alcohol research often includes event-level tools to assess in-situ alcohol consumption, intoxication and/or harm outcomes. These are broadly known as ambulatory assessment/ecological momentary assessment techniques, comprising any form of data collection that repeatedly assesses an event/experience in real-time (or near real-time) and in naturalistic settings (Trull & Ebner-Priemer, 2013). The primary aim of ambulatory assessment is to collect events from daily experiences while minimising retrospective biases, minimising experimenter interference and maintaining context-relevant data such as the time of recording (Trull & Ebner-Priemer, 2013).

While several ambulatory assessment techniques exist, this thesis will focus on two specific types. The first of these is electronically gathered event-level self-reports (i.e., a real-time diary). This technique, generally speaking, is used to capture *subjective* consumption related behaviours and experiences (i.e., harms) during drinking episodes. They are known as event-level reports because they are triggered by an ‘event’ of interest (such as the consumption of a beverage). The second technique of interest will be *objective* continuous biometric assessments, and specifically, transdermal alcohol monitoring. This involves the passive repeated sampling of insensible perspiration to assess for the presence of alcohol, and by proxy, alcohol intoxication (Piasecki, 2019).

The following sections with discuss event-level self-reporting and transdermal alcohol assessments, their potential utility in capturing alcohol-relevant behaviours/experiences in naturalistic drinking contexts (to, for example, collate with harm assessments or gauge risky drinking behaviours in specific settings) and the extent to which they have been utilised in these contexts to date.

1.6.4.1 Event-Level Self Reporting

Much of the extant alcohol-related research has relied on retrospective self-reporting of consumption behaviours both at high-risk but ephemeral settings such as music festival (e.g., Jenkinson, Bowring, Dietze, Hellard, & Lim, 2014; Martinus, McAlaney, McLaughlin, & Smith, 2010) and within the NTE (e.g., Miller, Bruno, et al., 2016). Retrospective, self-reported alcohol measures, while minimising response burden, introduce the possibility of response bias; over or under assessments of reported behaviour (e.g., Devaux & Sassi, 2016; Midanik, 1982). Considering this, event-level reporting (the reporting of behaviours or outcomes in-real time or close to real-time) has gained great interest in the last decade as these methods can assess behaviours as they emerge in time and space. Event-level reporting involves the repeated sampling of participants’ current behaviour and subjective experiences in a natural environment, assessing specific events (e.g., type of drink being consumed at a given time) at periodic intervals and maintaining data about the sequence and timing of events (S. Shiffman, Stone, & Hufford, 2008). These assessments can be used to prospectively measure behaviours, limiting the influence of the reconstruction processes that entail retrospective recollection and reducing reliance on memory (Moskowitz & Young, 2006). As an example of how event-level measures may be delivered, participants may be provided with a mobile phone containing an application that allows them to prospectively log each alcoholic drink they consume, or a harm they encounter. Each log would be subsequently time- and date-stamped automatically by the application. This type of assessment is particularly useful in alcohol-use contexts when considering that alcohol intoxication is known to impair memory and may subsequently hinder the recollection process (Dougherty et al., 2000; Dry, Burns, Nettelbeck, Farquharson, & White, 2012). Further, event-level self-reports are typically completed without direct contact with investigators, minimising impact of frequent assessments on naturalistic drinking practices. These techniques, while still self-reports, are considered by some to be preferential to retrospective surveys, in that they minimise recall bias and maximise ecological validity (S. Shiffman et al., 2008). Further to this, they are able to provide time-specific contextual information (e.g., social, emotional or physical) that other methods (e.g., retrospective self-reports) cannot.

In respect to the utility of event-level collections in linking risk behaviours and outcomes, there are key considerations that must be made. As event-level reports collect data in real-time, they are most useful in capturing behaviour, experiences and outcomes that happen frequently. This makes them well suited to assessing alcohol consumption in naturalistic settings where binge drinking is likely to occur. Conversely, if the behaviour or outcome of interest is relatively infrequent at an individual level, then they are subsequently unlikely to be captured within a short window of EMA collection (e.g., a night or weekend). This makes EMA techniques less practical for answering research questions that involve infrequent outcomes, than, for example, retrospective questionnaires. However, a significant strength of EMA collection over retrospective questionnaires is the enhanced ability to link alcohol behaviours with harms, as there is a clear time sequence of events (e.g., reported alcohol consumption directly prior to involvement in a harm), and both alcohol consumption and harms can be collected through this assessment.

In sum, EMA self-reporting is useful in capturing and linking alcohol consumption and frequent outcomes (e.g., harms) but less useful at capturing infrequent outcomes, while retrospective self-reports are better suited to capturing less frequent harm outcomes but are more susceptible to bias and are harder to link with alcohol risk behaviours.

1.6.4.2 Transdermal Alcohol Assessments

Emerging innovations in portable alcohol assessments have presented new options for researchers looking to measure perception independent or ‘objective’ intoxication in in naturalistic settings. One of such assessments utilises transdermal alcohol devices, self-powered wrist or leg bracelets, providing a measure of transdermal alcohol concentration (TAC) by measuring ethanol excreted through the skin in the form of insensible perspiration (as discussed in Section 1.2.1). These devices can be programmed to take readings periodically (typically 30-minute intervals), which are date stamped/timestamped and stored on an internal hard drive for later download once the device has been retrieved. Critically, recent literature has posited TAC as a way to passively and continuously measure intoxication in situations where breathalysers are not logistically feasible, or pose a risk to ecological validity (Greenfield, Bond, & Kerr, 2014b).

The potential benefits of passively measuring intoxication using transdermal devices are numerous. While breathalyser devices are an attractive alternative to retrospective reports when assessing drinking in naturalistic settings, they are limited due to the static nature of the assessments, providing a very low temporal resolution of intoxication (Clapp et al., 2007). Every assessment of intoxication requires an interaction with research personnel, which may interfere with a participant's usual drinking behaviour. This is also problematic if researchers wish to assess intoxication frequently, or over the course of a prolonged period, such as several days or weeks, requiring significant logistical consideration. Further, assessing a patron once on any given evening will not necessarily capture their peak intoxication on that evening, particularly if the assessment occurs at the beginning or end of their drinking session (Clapp et al., 2007). Transdermal monitors may circumvent this issue by *continuously* and *passively* measuring intoxication, allowing for assessments to occur when research participants and researchers are not within close proximity of each other and without input from the participant. However, with the technology in its infancy, there is a paucity of research investigating the feasibility of their use in real-world drinking environments.

One of the key questions in relation to transdermal assessments relates to the interpretability of the readings the devices provide. In particular, preliminary studies have aimed to investigate how TAC behaves in relation to BrAC in controlled settings. Dougherty et al. (2012) conducted a study with 22 regular drinkers, acutely dosing each participant to a "binge" BrAC of 0.08% (consuming one beer per every 30 minutes until the target BrAC was reached) and measuring both BrAC and TAC simultaneously. They concluded that TAC increases linearly as alcohol intake increases, and at a rate similar to breath alcohol concentration. However, they also noted that TAC readings were typically lower in magnitude that BrAC readings (i.e., the average reading was lower), and that the elimination curve of the readings (the descending curve) was longer for TAC than BrAC.

In a study by Karns-Wright et al. (2017), 61 participants were recruited, assessing TAC and BrAC after one, two, three, four and five alcohol beverages. As alcohol is excreted from the skin last (compared to other routes of excretion, e.g., breath), their analyses aimed to determine the nature of the delay in peak concentration between the two assessment techniques. They concluded that there were both dose- and sex-related differences between TAC and BrAC. Specifically, in regard to dose-related differences, the congruence between BrAC and TAC readings increased as intoxication increased. Roache et al. (2015) endorsed similar findings, assessing TAC while acutely intoxicated in a laboratory-based study of 61 adults. They administered 1, 2, 3 or 4 beers (one every 30 minutes), concluding that only 40% of individuals who consumed one beer had a positive TAC reading (>0.00%). However, this increased to 95% and 100% after 2 and 3 beers, respectively. This suggests that TAC readings appear to be less sensitive to low levels of alcohol than BrAC assessments, although this diminishes as intoxication increases. In practical terms, this may suggest that TAC is better suited to assessing higher-range drinking (e.g., over 3 standard drinks) than low range drinking. However, considering that patrons in the NTE and at festival settings typically drink at binge levels (as described in 1.4), this may not be problematic when assessing intoxication in these environments. Further, Karns-Wright et al. (2017) found that the amount of time it took to reach peak TAC (relative to BrAC) increased as the number of alcohol beverages consumed increased. Thus, the length of time it takes for the device to assess peak intoxication is negatively impacted by higher levels of intoxication. Regarding sex differences, women had a longer time-to-peak TAC than men, although this effect was also seen for BrAC between sexes.

Considering that transdermal monitors are worn devices, another important consideration is the user-experience and consequential retention rate of wearing the device within naturalistic research contexts. One of the most popular transdermal devices on the market at present, the Secure Continuous Alcohol Monitor (SCRAM; Alcohol Monitoring Systems), was developed for and continues to be marketed towards the criminal justice field in order to monitor individuals whom have received alcohol abstinence orders. It was consequently designed to prioritise robustness rather than user comfort and include features that ensure wearers cannot easily remove the device; features such as a rigid locking mechanism and tamper proof clips that keeps the band of the device closed around the ankle (Caluzzi et al., 2019). If such devices are to be adopted for use in naturalistic contexts on a volunteer basis, it is important to determine whether usability issues will be a barrier.

Marques and McKnight (2007) recruited a sample of 18 low-risk alcohol consumers in the United States, who wore SCRAM devices for a total of four weeks, conducting an informal debriefing at the conclusion of this period. Further, they conducted a focus group with seven court-mandated wearers of the device. Discomfort was cited as a key issue across both groups, particularly during exercise and sleep, but was typically worse at the beginning (i.e., the first few days) of the wearing period. Moreover, participants noted that public embarrassment (negative feelings in social situations) was an issue while wearing the device. Discomfort was also raised as a key issue in a study of 100 individuals in a post-wear survey, whom wore SCRAMs as part of an alcohol treatment program (Alessi, Barnett, & Petry, 2017). This raised notable concerns as to the feasibility of implementing transdermal devices as a research tool in naturalistic settings; if participants did not tolerate wearing the device, there are potential ethical and participant retention concerns that potential limit their use.

Despite these findings, a more recent study noted that the user-experience of young, at-risk patrons (the likely target of studies in naturalistic settings) was yet to be empirically elucidated (Caluzzi et al., 2019); that the existing studies had recruited individuals whom were mandated to wear the device (and subsequently unlikely to enjoy the experience) and/or individuals whom the devices would not be a target for such devices in the research context (low-risk alcohol consumers). The authors subsequently recruited 30 young regular drinkers across two sites in south-east Australian states, measuring their alcohol use with SCRAM devices over the course of three days. Semi-structured qualitative interviews were conducted after this period, focusing on their experiences wearing the units. The authors found that while some participants noted the devices to be uncomfortable or irritating, particularly during exercise, these impediments were individually manageable. The participants also noted that while social situations did arise from onlookers noticing the device (predominantly noting device similarly to house-arrest monitors), they were generally at ease with these interactions. Critically, they also noted that participants did not report changing their drinking behaviours as a result of wearing the device. This is an important finding, strengthening the case for the use of these monitors to improve ecological validity over breath alcohol monitors.

A final pertinent consideration to be discussed is the potential for transdermal devices to produce a Hawthorne effect (McCambridge, Witton, & Elbourne, 2014), whereby simply wearing the monitor may result in a modification of the amount of alcohol consumed by the wearer. In a study conducted by Neville, Williams, Goodall, Murer, and Donnelly (2013), 60 male participants were split into three groups and asked to either (i) abstain from alcohol use for two weeks (Groups A and B, with Group A wearing transdermal monitors) or (ii) continue alcohol consumption as normal for two weeks (Group C, who also wore transdermal monitors for the duration of the study). Results indicated that while transdermal monitors were effective at reducing consumption levels amongst the abstaining individuals (Group A vs Group B), individuals in maintenance group (Group C) neither increased nor decreased their level of consumption. This suggests that the Hawthorne effect is present in behaviour that is directed towards a *reduction* in drinking but did not affect the maintenance of normal drinking behaviour. Further, in the aforementioned qualitative study by Caluzzi et al. (2019), participants were asked whether they believed wearing the transdermal devices impacted their level of alcohol consumption. Of the 30 participants, none believed that their normal drinking behaviour had been modified by wearing the device. Based on these findings, it appears that the use of transdermal devices in the elucidation of drinking behaviours in real-world settings is unlikely to inadvertently modify drinking outcomes, unless participants are being asked to abstain from alcohol consumption.

1.6.4.3 Ambulatory Assessment: Summary

Ambulatory assessment techniques such as event-level self-reports and transdermal assessments offer alternate strategies to more traditional risk and harm assessments such as retrospective self-reports or static breath assessments. However, like their more traditional counterparts, each of these assessments endorse a unique set of strengths and weaknesses that place possible caveats on their use in naturalistic drinking settings (Piasecki, 2019). Transdermal assessments have shown early promise in their ability to overcome the ecological validity concerns that continuous BrAC measurements face in measuring intoxication, but they have not undergone rigorous validation (compared to, for example, BrAC) in-situ, nor have these devices been deployed in complex, high-risk, multi-day drinking sessions such as a festival. In the same vein, event-level self-reporting has shown promise in assessing alcohol risk behaviours (e.g., alcohol consumption) and harms, but face concerns regarding response burden on participants; specifically, participants' ability to consistently comply with assessments in complex settings that involve heavy alcohol consumption.

While each of these techniques have been adopted in substance-related research independently, there is limited research investigating the feasibility of deploying a concurrent battery of non-ambulatory assessments (e.g., retrospective self-reports) and select ambulatory techniques (both subjective and objective measurements) in dynamic real-world drinking settings. As time-based retrospective reports and ambulatory assessments can measure complimentary aspects of drinking environments (e.g., past experiences, in-situ subjective experiences and in-situ objective intoxication), it is possible that the triangulation of these techniques may result in a more comprehensive understanding of alcohol behaviours, risk and harms. Accurately assessing substance behaviours and patron experiences are core components in understanding associations between alcohol use and broad range of harms in the NTE; harms such as cognitive impairment, aggression involvement and beyond. Considering this, this thesis will further aim to pool all of the aforementioned assessment techniques into a combined battery (retrospective self-reporting, BrAC, TAC and event-level self-reporting) to determine the feasibility of their use and their individual and combined utility in high-risk, multiple-day drinking spaces.

Key Literature Gap to be Examined in this Thesis (#3):
How do we best assess alcohol consumption and intoxication (risk relevant measures) in a real-world, dynamic drinking setting? Can we use a combination of transdermal, event-level reporting and retrospective techniques to more comprehensively do so over a prolonged (e.g., multiple day) drinking session?

1.6.5 Cognitive Assessments

As discussed in Section 1.5.2, cognitive impairment is important dimension of driving risk. While directly assessing driving performance (e.g., in a driving simulator) in real world drinking environments often poses a considerable logistical challenge due to their price as well as difficulties in relocating and housing such assessment tools (Zoethout, Delgado, Ippel, Dahan, & van Gerven, 2011), tablet-based cognitive tasks have opened up avenues for the objective field testing of driving-associated performance domains. They can be portably deployed to assess cognitive impairment in environments such as the NTE, and at less expense. Similar to other methods discussed in this chapter, there is also the potential to use tablet-based cognitive assessments in conjunction with other risk-relevant assessments such as biometric intoxication assessments (breath/transdermal alcohol measures), retrospective reports or event-level reports to help contextualise the outcomes and investigate associated risk factors.

An important characteristic of cognitive assessments is their potential as wide-sweeping tests for general cognitive and psychomotor impairment from a wide range of sources simultaneously. As many cognitive tasks have been shown to be sensitive to alcohol intoxication (Zoethout et al., 2011) and other impairment-related variables such as fatigue and hangover (Gunn et al., 2018) when not acutely under the influence of substances, they are able to assess broader impairment that is not necessarily specific to a single impairing factor. Naturalistic drinking environments are dynamic and complex, and with them comes a host of potential impairment-associated factors that may occur concurrently (e.g., acute alcohol intoxication, drug intoxication, hangover, fatigue from lack of sleep). It can be difficult for traditional subjective scales to capture all of these variables in a single assessment battery. This is particularly true when a requisite of assessments in real-world situations is that they are brief in order to maximise the likelihood of the highest-risk patrons engaging with the assessment. This was recently evidenced by the dichotomy of patron risk profiles between the brief (a few minutes to complete) and full interviews (over 10 minutes to complete) in a sample of 8,664 Australian night time-economy patrons, with brief interview respondents much more likely to engage in riskier behaviours (Coomber et al., 2018). Given this, it can be hard to estimate the risk of cognitive impairment (and by proxy, driving risk) based on the accumulation of subjective scales alone. Portable cognitive assessments may be the answer to this issue.

Considering the aforementioned points, the potential benefits of cognitive assessments are threefold. Firstly, the development of portable tablet-based cognitive assessments means that cognitive impairment can be more easily assessed in-situ, improving ecological validity by capturing performance within key research and/or policy-relevant contexts. Secondly, they can be implemented to simultaneously assess impairment from a wide range of aetiologies relatively quickly, or in contexts where all of the potential impairment-relevant factors are not known. This makes these assessments ideal for assessing driving risk in high-risk contexts such as music festivals where patrons are likely to experience a host of driving-relevant impairments concurrently. Lastly, cognitive assessments can be paired with subjective measures of alcohol consumption/experiences (e.g., retrospective or event-level self-reports) and/or objective intoxication (e.g., breath alcohol assessments) to help contextualise the individual circumstances under which they are being conducted. However, portable cognitive assessments have not been extensively been utilised to assess driving-related cognitive impairment among NTE patrons in-situ. Given this, I aim to deploy a battery of three portable cognitive tests, with each test corresponding to the driving-relevant domains discussed in Section 1.5.2 (working memory and attention), to determine if naturalistic drinking environments are associated with impaired cognitive performance as measured by these tasks.

1.6.6 Study Designs to Implement Alcohol-Related Assessments

The assessments discussed (retrospective self-reports, event-level self-reports, biometric measures [breath/transdermal] and cognitive tests) can be delivered through a variety of study designs. Choosing the right assessment for a study design (or vice versa) depends primarily on the research question of the study (Piasecki, 2019), but as noted above, many of the assessments (or combination of assessments) have not yet been thoroughly investigated in high-risk drinking environments. To answer the research gaps described above, I will utilise the following three designs for implementation of the assessments:

1.) Cross-sectional street intercept: Given that many young, at-risk individuals who use substances are often missed by broad population surveys, street intercept designs aim to directly recruit them in-situ (Graham et al., 2014). This is typically achieved by randomly approaching individuals in or around licensed drinking zones, such as the in NTE, and asking them questions relevant to their drinking behaviours and experience of harms. The random nature of the sample means researchers are more likely to get a more accurate representation of the sample of interest than a typical convenience sample (e.g., through online recruitment) (Graham et al., 2014). Information can also be collected retrospectively from participants (i.e., over a large window of previous experiences), meaning that researchers are more likely to capture infrequent outcomes of interest such as aggression involvement (Pennay et al., 2017). This makes a street intercept design, using retrospective self-reports, a logical candidate to answer the first study in this body of research.

2.) Ambulatory: Ambulatory designs are conducted in-situ using prospective and repeated event-level assessments, such as transdermal assessments or electronic diaries (Trull & Ebner-Priemer, 2013). The most salient advantage of ambulatory designs is their high ecological validity. Measurements (e.g., drinking behaviours, harms experienced) are collected in real- or near real-time, and can be time sequenced. A pertinent disadvantage of this design is that, if harms occur infrequently, it is unlikely that they will be captured unless participants are being tracked for extended periods of time (e.g., months). This limitation notwithstanding, when compared to street intercept designs, it is much easier to link continuous alcohol behaviours (or other behaviours/factors of interest) with more frequent harms using ambulatory designs (Trull & Ebner-Priemer, 2013). They are thus an attractive option to assess alcohol-related consumption, intoxication and harms. However, as previously discussed, some of the assessments (or combination of assessments, including non-ambulatory) are yet to be thoroughly investigated in high-risk drinking settings, and this will be focus of the second study in this programme of research.

3.) Experimental/laboratory: Experimental designs are often carried out in laboratory settings and are advantageous in that they allow for strict control over independent and extraneous variables (Thompson & Panacek, 2006). Indeed, studies conducted in laboratory settings can have limited generalisability to real-world drinking outcomes as they do not host many or most of the influences attributable to behaviours and experiences within naturalistic drinking settings. Moreover, laboratory-based designs cannot capture outcomes over time in real-world settings either, which is a useful when linking alcohol behaviours with associated experiences. However, experimental measurements may be useful when combined with real-world ambulatory or cross-sectional data collection (Wilhelm & Grossman, 2010). For example, in the interest of understanding real-world driving risk, comparing context-relevant impairment (in-situ) relative to controlled intoxication (in an experimental setting) is meaningful from a policy standpoint. This is because real-world performance at times and in settings of interest can be judged relative to performance while intoxicated at levels deemed to be too risky safely engage in specific activities (e.g., 0.05% BAC for full-licensed drivers). Such a methodology, combining both experimental and real-world performance measures to examine cognitive impairment in real-world drinking settings, has yet to be attempted and will thus comprise the final study of this research programme.

1.6.7 Alcohol and Associated Harm Assessments: Summary

In this section I have discussed four key outcomes of interest: alcohol consumption, alcohol intoxication, alcohol-related cognitive impairment and experience of harms. Assessing alcohol consumption and intoxication in naturalistic settings is important in determining associations between alcohol-use behaviours and risk of harms, assessing the efficacy of alcohol-related interventions, and informing the development such interventions (Caluzzi et al., 2019; Piasecki, 2019). Assessments of objective impairment, such as cognitive tests, are useful in evaluating context-specific impairment from a range of potential influences (acute alcohol and hangover impairment included). These may assist in developing our understanding of risk in situations where cognitive performance is critical in the maintenance of safe behaviour; driving being a good example of this scenario. Lastly, assessing experience of harms, when coupled with relevant alcohol use measures, can highlight alcohol-associated adversity in real-world settings, and similar to alcohol consumption/intoxication, can inform the development and evaluate the efficacy of interventions. Table 1.3 demonstrates the assessments discussed within this section, the outcomes they can assess, our a priori understanding of their relative strengths and weaknesses and the studies I aim to utilise them in to answer our highlighted research gaps.

Table 1.3 Primary Data Collection Methods for Assessing Key Aspects of Risk in Naturalistic Alcohol-use Settings: Characteristics and Thesis Study Implementation

Method	Outcome	Outcome Type	Delivery Method	Data Gathered By	Response Burden	Experimenter Interference	Event Prevalence: High or Low	Temporal Resolution	Study (See Section 1.7.2)
BrAC	Intoxication	Objective	Experimental Intercept	Experimenter	High	High	High/Low	Low	1, 2, 3, 4
TAC	Intoxication	Objective	Ambulatory	Passive	Low	Low	High/Low	High	2
Cognitive Test	Impairment Driving Risk	Objective	Experimental Ambulatory	Experimenter Participant	High	High/Low	Low	Low	3, 4
Event-Level Self Report	Consumption Experience	Subjective	Ambulatory	Participant	High	Low	High/Low	High	2
Short-Term Retrospective Self Report	Consumption Experience	Subjective	Experimental Intercept	Experimenter Participant	Low	Low	High	High/Low	1, 2, 3, 4
Long-Term Retrospective Self Report	Consumption Experience	Subjective	Experimental Intercept	Experimenter Participant	Low	Low	Low	Low	1

Note: This table outlines the data collection methods relevant to the studies within this thesis and is not an exhaustive list of all possible methods. BrAC = breath alcohol concentration. TAC = transdermal alcohol concentration.

1.7 Current Research Programme

1.7.1 Overall Objective and Research Questions

The overarching aim of this programme of research was to conduct applied research examining alcohol use and harms in dynamic, complex night-time environments. Specifically, I aimed to further understand how we can better assess alcohol consumption, intoxication and impairment, to gain greater insight into the interplay between alcohol use and environmental/situational and demographic factors and to determine whether these may contribute to greater or fewer harms to patrons and the wider population.

Throughout the course of this chapter, I identified three gaps in the literature: (1) uncertainty over differences in aggression involvement between alcohol only and alcohol and illicit drug consumers within NTE contexts (Section 1.5.1), (2) a lack of investigations into the next-day effects of a prolonged experience in a naturalistic drinking setting (e.g., a multi-day music festival) on driving-relevant cognitive performance (Section 1.5.2), and (3) a dearth of studies investigating the combined use of event-level, biometric and retrospective alcohol assessments in naturalistic drinking settings to more comprehensively investigate alcohol consumption and intoxication in-situ (Section 1.6.4.3). I further discussed the methodological complexities of addressing these gaps.

This body of doctoral research was subsequently guided by the following three research questions, with each specifically looking address the aforementioned gaps by implementing and/or evaluating a combination of methodological techniques (as seen in Table 3) including: (i) retrospective self-reports, (ii) event-level self-reports, (iii) objective biometric assessments (breath alcohol and transdermal alcohol techniques) and (iv) portable electronic cognitive-impairment assessments.

Question 1: Self-reported substance use and risk of aggression involvement in the NTE

- Using combination of street intercept short-term and long-term retrospective self-reports (in order to capture our low frequency outcome), what is the risk of involvement in NTE aggression for those who combine alcohol and illicit drug use when compared to those who report alcohol use only after accounting for risk-relevant covariates such as sex, age and level of alcohol consumption?

Question 2.1 and 2.2: Event-level alcohol consumption and intoxication monitoring techniques in naturalistic settings

- In support of retrospective self-report measures in naturalistic settings, is it feasible to deploy a comprehensive battery of event-level measures (e.g., transdermal and other ambulatory assessment techniques) to capture drinking behaviours over a prolonged session in a high-risk real-world setting?
- Following on from **2.1**, does the combination of these techniques more comprehensively assess alcohol-related behaviours?

Question 3: Next-day cognitive performance assessment in naturalistic alcohol settings

- Following on from a prolonged drinking session in a complex and dynamic alcohol-use environment, is it possible to capture cognitive performance at driving-relevant timepoints using a field-deployed digital battery of cognitive tests, assessing domains relevant to driving impairment (attention/working memory)?

1.7.2 Design of Project

Four individual studies were undertaken aimed at answering our research questions:

- **Study 1:**
    - In order to address question 1, study 1 extracted secondary data from the Patron Offending and Intoxication in Night-Time Entertainment Districts ([POINTED] Miller et al., 2015; Miller et al., 2013) and Drug and Alcohol Intoxication and Subsequent Harm in Night-Time Entertainment Districts ([DASHED] Miller, Bruno, et al., 2016) projects. These projects shared similar methods, comprising street intercept surveys with NTE patrons on Friday and Saturday evenings in seven separate Australian cities. Participants (N=5078) retrospectively self-reported their alcohol and illicit drug consumption on the night of interview, as well as their involvement in aggression in/around licensed venues in the previous 3 months. This study aimed to compare differences in a pertinent alcohol associated harm outcome (aggression involvement) between individuals who reported alcohol use only and those who reported combined alcohol and illicit drug use (including inter-exclusive drug group comparisons) using self-reported measures.
- **Study 2:**
    - In order to address questions 2.1 and 2.2, study 2 comprised the deployment of a multi-faceted alcohol assessment battery at a four-day music festival. Fifteen participants were tracked using two biometric measures of intoxication (breath alcohol and transdermal alcohol), prospective drink logs completed via smartphone application and retrospective self-reports of consumption twice daily. This study aimed to more comprehensively assess alcohol-related

behaviours in a high-risk environment using the complete battery, as well as the feasibility of concurrently collecting these measures in such an environment.

- **Study 3:**
    - To address question 3 a pilot study was conducted, whereby thirteen participants completed three objective measures of cognition (N-Back, Arrow Flankers and Rapid Visual Information Processing) in a controlled laboratory (experimental) setting while sober (0.00% BrAC). They were then acutely dosed with alcohol and completed the same tasks at varying levels of the alcohol curve (0.00%, 0.05% ascending, 0.08% and 0.05% descending). Finally, the same participants attended a four-day music festival (at which they all consumed alcohol) and completed the cognitive assessment battery prior to departure from the event while at 0.00% BrAC. This pilot study aimed to compare post-festival cognitive performance (while sober) in relation to dose-dependent alcohol impairment.
- **Study 4:**
    - Following the findings of Study 3, an additional investigation into the sensitivity of the N-Back, Arrow Flankers and Rapid Visual Processing tasks to the effects of acute alcohol intoxication was conducted. Specifically, this study aimed to experimentally address whether the tasks deployed in Study 3 were sensitive to the effects of an acute alcohol dose of 0.08%, and thus suitable to use as referent measures for cognitive performance assessments in real-world drinking settings.

Chapter 2: Aggression in the Australian night-time economy: A comparison of alcohol only versus alcohol and illicit drug consumption

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2.1 Preface

Aggression is a significant harm in night-time alcohol-use settings, and its experience can result in severe psychological or physical adversity. Measuring aggression involvement is complex however, primarily due to the relatively low frequency (at an individual level) of it occurring on a given night, and the fact that, should the aggression event be severe enough, the patron is unlikely to be available for interview at an event-level. Given this, retrospective reports are an attractive solution to determine prevalence of aggression in these settings, and differences in aggression involvement between different high-risk groups attending the NTE.

This chapter uses retrospective reports to investigate differences in aggression involvement between select alcohol and co-consuming alcohol and illicit drug groups. It also utilises a specific statistical technique – inverse probability of treatment weighting – to account for broader risk propensity, or covariates, as these must be otherwise accounted for in the retrospective study design.

The aim of this study is to elucidate group differences in aggression involvement between substance use groups in an alcohol-use setting, focusing on the use of retrospective reports to capture a broad and representative sample of NTE patrons.

2.2 Abstract

Background: Associations between substance use and aggression may be amplified by simultaneous alcohol and illicit drug use. This study aims to compare differences in involvement in past aggression between people who use different substances while accounting for broader risk propensity.

Methods: Self-reported data on past 3-month involvement in verbal and physical aggression (victim or perpetrator) were drawn from interviews conducted in night-time entertainment districts in seven Australian cities (n=5078). Using Inverse Probability of Treatment Weighting techniques, participants who reported alcohol versus alcohol and illicit drug use on the night of interview (including ecstasy, cannabis and other illicit stimulant subgroups) were weighted on the basis of drug use risk covariates (e.g., alcohol consumed, gender) to determine differences in involvement in aggression involvement.

Results: After weighting for covariates, individuals who reported consuming any illicit drug + alcohol and ecstasy + alcohol combinations were more like to be involved in physical (33% and 105%, respectively) and verbal (36% and 116%, respectively) aggression in the previous 3-months when compared to those who consumed alcohol only. Cannabis + alcohol and other illicit stimulant + alcohol combinations were no more likely to be involved in either forms of aggression.

Conclusions: The likelihood of having been involved in past aggressive incidents was higher among those who reported any illicit drug + alcohol and ecstasy + alcohol combinations than those who reported alcohol exclusively, after accounting for covariates. These findings highlight individuals that may benefit most from the development of tailored health promotion/preventative safety interventions in night-time settings.

2.3 Introduction

While acute alcohol consumption has been causally linked to aggression, links between illicit drug use and aggression are more complex (Tomlinson et al., 2016). Associations between acute substance use and aggression may be amplified by simultaneous alcohol and illicit drug use. For example, preliminary research has suggested a link between recurrent acute combined methamphetamine and alcohol use and an increase in subjective drug-related aggression, but not for combined ecstasy and alcohol use (Leslie et al., 2017). However, it is less clear whether people who simultaneously use substances are more at risk of experiencing aggression involvement in the real world. Previous studies have found associations between categorical illicit substance use (e.g. reported drug use vs no reported drug use) and increased involvement in aggression in the night-time economy (Peacock et al., 2016; Pennay et al., 2017). However, these comparisons do not account for the presence of simultaneous alcohol use between illicit drug groups. It is currently unclear whether taking illicit drugs and alcohol simultaneously is associated with an elevated risk of aggression in the NTE when compared to alcohol-only use. Unpacking differences in aggression involvement between substance use groups (e.g., alcohol only vs methamphetamine + alcohol) is pertinent to the application of substance-based health initiatives. Such initiatives may target at-risk populations or specific substances.

Further, between-subject comparisons among people who report illicit drug use and non-illicit consumers do not always account for other possible acute and phenotypic influences: characteristics relevant in the propensity to engage in risky or harmful behaviours such as gender, pre-drinking behaviours, age and level of alcohol consumption (Peacock et al., 2016). These influences may have bearing on observable harm outcomes beyond the influence of the substances themselves. In other words, it is possible that individuals who are likely to engage in illicit drug practices are also more likely to experience aggression because of extraneous characteristics and not solely due to their use of illicit substances. As illicit substance use takes place in naturalistic settings, experimental research designs are not feasible. As such, other methods must be sought to control for potential confounds. Various analytic approaches have been used to address confounders in at-risk groups. Inverse Probability of Treatment Weighting (IPTW), a marginal structural technique, can be applied to minimise the influence of broader risk propensity between those who report illicit drug use and those who do not. As trait and behavioural baseline differences across groups can influence the estimation of an effect, the benefit of using propensity score techniques such as IPTW is that it allows for the statistical control of these differences (Andrade, 2017). Further, it can highlight areas of covariate distribution in circumstances where there is insufficient overlap between the treatment and control groups; a limitation of traditional regression analyses (Stuart, 2010).

Using a large sample size across seven Australian cities, the aim of this study was to compare the association between substance use reported on the night of interview by NTE patrons (alcohol only vs alcohol + illicit drug use) with past 3-month involvement in aggression in the NTE using a technique that reduces confounding. We also aimed to investigate differences in involvement in aggression between those who report alcohol only use and those who report specific illicit drug-type use (with no other current-session poly use, e.g., ecstasy and alcohol).

2.4 Methods

2.4.1 Procedure and Setting

Data were extracted from two studies: Patron Offending and Intoxication in Night-Time Entertainment Districts ([POINTED] Miller et al., 2015; Miller et al., 2013) and Drug and Alcohol Intoxication and Subsequent Harm in Night-Time Entertainment Districts (Miller, Bruno, et al., 2016). These studies shared similar methods, comprising street intercept surveys with NTE patrons on Friday and Saturday evenings (typically 9pm – 2am) in Melbourne, Sydney, Geelong, Perth and Wollongong (November 2011 to June 2012; POINTED), and Hobart and Canberra (April to December 2015; DASHED). Interviewers systematically approached every third patron walking through thoroughfares or waiting in venue queues and administered a structured questionnaire. Patrons who did not wish to complete the full interview were offered a brief interview containing key items. Both projects were approved by the Human Research Ethics Committees of participating universities.

2.4.2 Key Measures

Involvement in aggression. Self-reported experiences of aggression in the previous 3 months were collected (‘Have you been involved in any [verbal]/[physical] aggression in/around licensed venues during the past 3 months [yes/no]’). Definitions of aggression were left to the interpretation of individual participants.

Patron characteristics and current-night substance use. Participants reported age, gender, current night-out alcohol consumption (number of standard drinks), current night-out illicit drug use (presence and drug type) and pre-drinking behaviour (binary consumption of alcohol before arriving at licensed venues). Interview times were recorded. These covariates were selected based on previous research in the NTE (Hyder et al., 2018; Peacock et al., 2016).

2.4.3 Analyses

The combined sample comprised 8670 participants. Participants who reported no alcohol consumption (n=1130) or had missing drug use responses (n=45) were excluded. A further 2417 participants were removed due to missing data on at least one covariate (age n=30, gender n=36, drinks consumed n=2349, hour of interview n=2). Brief interviews did not measure alcohol consumption quantity, comprising most exclusions. The final sample comprised 5078 participants.

All analyses were performed using the *teffects* command in Stata 14 (StataCorp, 2015). Multivariate binary logistic regression analyses computed propensity scores for cases in each group based on pre-specified risk covariates: pre-drinking (binary), number of standard drinks consumed, hour of interview, age and gender. Weighted comparisons of physical and verbal aggression outcomes (based on the propensity score) were then conducted to determine the average treatment effect (ATE) for those reporting current night simultaneous alcohol and *any illicit* drug use (including poly illicit drug use) versus alcohol only (referent category). Weighted comparisons were also conducted to compare alcohol only consumers versus alcohol and three illicit drug subgroups (*ecstasy*, *cannabis* and *other illicit stimulant* [use of cocaine and/or methamphetamine, grouped due to insufficient statistical power when studied independently]. Illicit drug subgroups excluded illicit polydrug cases.

2.5 Results

Table 2.1 Sample Characteristics

	Total (*n*=5078)	**Alcohol Only** (*n*=4601)	**Alcohol + Any Illicit**[#] (*n*=477)	**Alcohol + Ecstasy** (*n*=153)	**Alcohol + Cannabis** (*n*=125)	**Alcohol + Other Stims** (*n*=105)
Male (%)	59.0	57.4	74.6	72.5	81.6	72.4
Age (Md, IQR)	23 (20-27)	23 (20-27)	22 (20-25)	22 (19-24)	22 (20-26)	23 (21-26)
City						
Melbourne (%)	28.7	29.0	26.0	6.5	36.8	40.0
Wollongong (%)	13.1	13.5	9.2	8.5	8.8	12.4
Sydney (%)	16.0	15.8	18	24.2	12.0	12.4
Perth (%)	7.0	7.3	3.8	0	4.0	5.7
Geelong (%)	5.2	5.2	6.1	7.9	4.0	5.7
Hobart (%)	14.0	13.9	15.1	22.8	19.2	2.9
Canberra (%)	15.0	15.4	21.8	30.1	15.2	20.9
Interview time (Md, IQR)	23:00 (22-24)	23:00 (22-24)	24:00 (23-1)	24:00 (23-1)	23:00 (23-1)	24:00 (23-1)
Std Drinks (Md, IQR)	7 (4-10)	7 (4-10)	10 (6-15)	10 (6-15)	8 (5-12)	12 (8-20)
Pre-drinking (%)	63.5	62.0	77.4	81.1	75.2	77.1
Physical Aggression (past 3 month; %)	10.7	9.9	18.2	24.8	15.2	15.2
Verbal Aggression (past 3 month; %)	14.6	13.8	23.1	32.7	21.6	11.4

[#] = Includes poly illicit drug use. IQR, Interquartile range

2.5.1 IPTW Average Treatment Effect

Participants who reported consuming only alcohol had a 10% (95% CI [9%, 11%]) probability of being involved in physical aggression and a 14% (95% CI [13%, 15%]) probability of being involved in verbal aggression incidents (past three months). Illicit drug + alcohol and ecstasy + alcohol combinations were significantly more likely to be involved in verbal and/or physical aggression than alcohol only (see Table 2.2). Cannabis + alcohol and other stimulant + alcohol combinations were not significantly more likely to experience physical and/or verbal aggression than alcohol only.

Table 2.2 IPTW Average Treatment Effect Increase/Decrease Across Drug Type

	Past 3-Month Physical Aggression			**Past 3-Month Verbal Aggression**		
	ATE (95% CI)	z	p>|z|	ATE (95% CI)	z	p>|z|
Alcohol + Any Illicit (n=477)						
Increase/Decrease	0.05 (0.02 – 0.09)	2.93	**0.003**	0.08 (0.04 – 0.13)	3.86	**<0.001**
Alcohol + Ecstasy (n=153)						
Increase/Decrease	0.11 (0.03 – 0.18)	2.77	**0.006**	0.16 (0.07 – 0.25)	3.59	**<0.001**
Alcohol + Cannabis (n=125)						
Increase/Decrease	0.03 (-0.03 – 0.10)	1.00	0.318	0.05 (-0.02 – 0.13)	1.38	0.166
Alcohol + Other Illicit Stimulants (n=105)						
Increase/Decrease	0.06 (-0.04 – 0.15)	1.19	0.234	0.02 (-0.07 – 0.11)	0.41	0.680

Note: ATE indicates percent increase/decrease in absolute risk compared to alcohol only; 1=100%). Positive ATE difference = increase of risk. Referent category was those who consumed alcohol only. Group n includes alcohol/drug cases. The ‘other illicit stimulant’ subgroup comprises cocaine and methamphetamine use. The diagnostic test for covariate balance was not statistically significant and a visual inspection of the weighted propensity scores for each observation indicated the overlap assumption had been met.

2.5.2 Relative Risk

Relative risk was calculated for significant IPTW groups. Any illicit + alcohol combinations were 33% more likely to be involved in physical aggression and 36% more likely to be involved in verbal aggression than alcohol only consumers. Ecstasy + alcohol combinations were 105% more likely to be involved in physical and 116% more likely to be involved in verbal aggression.

2.6 Discussion

After controlling for covariates, analyses indicated an increased likelihood of past 3-month involvement in aggression for the any illicit + alcohol and ecstasy + alcohol groups. These findings add to previous NTE research (Hyder et al., 2018; Peacock et al., 2016; Pennay et al., 2017) which indicates a general link between illicit drug use and increased likelihood of involvement in aggression.

While largest effect was seen in the ecstasy + alcohol subgroup, the mechanism behind the increase (over, for example, cannabis + alcohol) is not clear. Isolated ecstasy use has been demonstrated to promote social connectedness (Wardle, Kirkpatrick, & de Wit, 2014) and is not known to acutely elicit aggression (Hoaken & Stewart, 2003). It is therefore unlikely that the acute combination of ecstasy and alcohol is directly responsible for the increase in aggression involvement compared to alcohol only consumers. Indeed, these finding are also contradictory to the findings of Leslie et al. (2017), which indicated a broad increase in aggression for methamphetamine + alcohol use, but not ecstasy + alcohol use. However, underlying personality differences or unobserved behavioural characteristics between ecstasy + alcohol consumers and other groups may mediate the relationship between in-the-event substance use and past 3-month aggression involvement in this setting. For example, people who report ecstasy use are more likely to have higher novelty-seeking scores than other drug consumers (Dughiero, Schifano, & Forza, 2001). It may be simply that individuals who use this drug alongside alcohol may have a propensity to 'go out' more frequently, or spend longer in the NTE than other groups, and thus a greater risk of exposure to incidental aggressive incidents. In respect to the non-significant increase in experiences of aggression for the methamphetamine + alcohol subgroup when compared to alcohol only, in contrast with previous findings, it may be that (i) individuals in this subgroup under-reported aggression, or (ii) the combined effect of these substances on aggression is less pronounced in the NTE when compared to the broader settings explored in Leslie et al. (2017). Regardless, more thoroughly exploring the relationship between substance consumption, time spent in the NTE and aggression involvement is an important direction for future research.

Our findings may have important implications regarding health initiatives in the NTE. Harm reduction initiatives (e.g., education messaging) aimed broadly at people who use 'illicit drugs' are often discredited by recipients because of a mismatch between the message and the targets' experience (D. Moore, 2010). As noted by Pennay and colleagues (Pennay et al., 2017), new harm reduction approaches targeting illicit drug related issues in the NTE must first consider differences in the harms experienced and behavioural profile between drug groups in order to be effective. Given that our findings indicate a general augmented likelihood of past aggression involvement for people who report the simultaneous consumption of ecstasy + alcohol above alcohol-only and other illicit drug groups, we have highlighted a key marker for people who have had a greater likelihood of experiencing these harms. While their experiences may not be directly related to the use of these substances, the development and evaluation of focused health promotion and/or preventative safety interventions, tailored specifically for this group, may be effective at reducing the future likelihood of aggression involvement amongst patrons more likely to have had experienced adverse aggression-related outcomes in or around Australian licensed premises.

2.6.1 Strengths and Limitations

Through use of a combined dataset from two projects, this study allowed us to examine the relationship between reported substance consumption and past involvement in aggression across a large sample drawn from seven Australian cities. Additionally, POINTED and DASHED data represents a diverse range of NTE patrons across multiple settings. It should be emphasised that the measures within this study do not provide a direct association between in-the-event substance consumption and aggression involvement on a specific night. While they are useful in drawing associations between past aggression involvement and reported behaviour that we assume is typical based on current night reports, the temporality of our self-reported aggression and substance consumption measures (i.e., *past* aggression versus *current* substance use) precludes a judgement of in-the-event risk for these groups. In other words, while some groups are more likely to have experienced aggression based on their current-night reported behaviour, risk while under the influence of a combination of specific substances is still unknown. In a similar vein, our measure of illicit drug use (i.e., current night use) may not have identified all people who have engaged with illicit substances in sessions prior to interview (including those categorised as alcohol only participants). Conversely, individuals who reported current-night illicit drug use and past aggression involvement may have been involved in that event while under the influence of alcohol only, or no substances at all. However, a methodological justification for the aforementioned limitations has been previously outlined (Pennay et al., 2017); while not perfect, this methodology has been balanced to minimise response bias in our substance use measures while maximising our ability to capture aggressive incidents that would otherwise (e.g., at an event level) be extremely difficult to identify due to their low frequency. A second limitation of this study is the omission of the brief interviews from the POINTED sample. This may have resulted in an underrepresented subset of more at-risk patrons (Coomber et al., 2018). Finally, while covariates were included to minimise confounding within the sample, it is likely there are additional unobserved factors that contribute to illicit drug consumption and that these were subsequently unaccounted for in our analyses.

2.6.2 Conclusion

Using a large sample size across multiple Australian cities and a methodology that aimed to reduce confounding, this study suggests an association between select current-night illicit drug + alcohol combinations and an increased likelihood of past aggression involvement in the NTE compared to patrons who reported current-night alcohol use only. Within our sample, these findings highlight ecstasy + alcohol consumers as the most likely group to have been involved in past aggressive incidents. This group may be a potential target for tailored health promotion and preventative safety interventions in the NTE. However, given the temporality of the variables used in this study, the underlying mechanism behind the increase in past aggression involvement is not clear. Future research should aim to explore the relationship between in-the-event substance consumption, aggression involvement and time spent in the NTE.

2.7 Acknowledgements

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Chapter 3: Combining breath and transdermal alcohol measurement, ecological momentary assessment and retrospective self-reports to measure alcohol-consumption and intoxication across a multi-day festival

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3.1 Preface

The previous chapter investigated substance group differences in a pertinent harm outcome – aggression involvement - using retrospective self-report techniques to collect both the substance use behaviour and the outcome if interest. This was a necessary design considering the nature of aggression involvement in naturalistic settings, as discussed in the previous chapter. However, the findings of this study highlighted a considerable limitation of exclusively retrospective designs; it is extremely difficult (if not impossible) to identify causal links between risk behaviours of interest (e.g., alcohol consumption or intoxication) and harms of interest when assessing them retrospectively. To this end, event-level assessments – measures of behaviour or experience at or proximal to it occurring – are much more useful. While these designs are less feasible for outcomes like aggression involvement, they are more applicable when linking risk behaviours with harms that are more frequent. Further, being able to comprehensively assess risk behaviours solely can be helpful when designing and assessing interventions in night-time settings.

As highlighted in Section 1.6, there are several emerging assessment tools that can theoretically assist us in measuring alcohol consumption and intoxication in naturalistic settings. However, some of these tools have not been heavily utilised in naturalistic alcohol research (e.g., transdermal alcohol technology), or in combination with other traditional or emerging measures such as retrospective or EMA self-reports. The aim of the following chapter was to assess the feasibility of implementing a combined battery of transdermal and breath alcohol, event-level self-report and retrospective assessments to measure alcohol and intoxication – relevant risk factors in alcohol-related harms – in a dynamic and prolonged drinking session (in this case, a multi-day music festival).

3.2 Abstract

Background: Comprehensively investigating alcohol-related behaviours in the context of a dynamic multi-day alcohol-licensed event is important for understanding and minimising patron risk. We aimed to assess the measurement utility of implementing a multi-dimensional alcohol assessment battery using biometric data collection, real-time drink logs and retrospective self-report measures over the course of a 4-day music festival.

Methods: Fourteen adults participated (n=7 male, mean age 21.9 years). Breath and transdermal alcohol concentration (BrAC and TAC respectively) were measured using breathalysers and transdermal alcohol bracelets. A real-time drink log was completed via smartphones on initiating each drink, and a retrospective questionnaire was administered up to twice daily throughout the event (6 timepoints total).

Results: While almost all participants (92.9%) logged significantly fewer drinks in real-time than they retrospectively reported via the twice-daily questionnaires, logs provided important contextual information including the types of drinks consumed and drinking intensity. Compared to BrAC, TAC provided a better understanding of the time course of intoxication, indicating highest alcohol consumption outside of static BrAC assessment windows. However, BrAC provided better assessment of present state: all participants were 0.00% BrAC at departure despite over two-fifths (42.9%) of the sample's last TAC reading exceeding 0.00%.

Conclusions: As standalone assessments, each method possessed limitations. As a combined battery, they were successfully administered simultaneously, resulting in a more comprehensive overview of alcohol consumption/intoxication over the prolonged drinking session. However, the marked burden of simultaneous administration should be considered, and measures should be chosen judiciously based on research needs.

3.3 Introduction

In addition to more traditional drinking settings such as pubs and clubs (collectively known as the Night-Time Economy [NTE]), multi-day alcohol-licensed events have emerged as a popular activity amongst young people. Such events, such as music festivals, typically span over the course of two to five days, are usually alcohol-licensed and attract large numbers of patrons, many of whom will reside on site (e.g., camping) for the duration. While ephemeral, settings such as these are relevant in the public health sphere considering that alcohol is sold at them, there is the potential to drink continuously over event (e.g., several days), and that the continuous period people spend at them is likely to be longer than a typical evening spent within the NTE (i.e., they are 'prolonged' relative to a typical single drinking occasion). Music events, whether they be single day or multi-day affairs, are also heavily patronised; two-fifths (41%) of Australians aged 18-24 years report attending music concerts each year (Australian Bureau of Statistics, 2015), emphasising the popularity of music-related entertainment spaces among young individuals. Despite existing cross-sectional studies indicating heavy alcohol use by patrons in prolonged drinking environments such as multi-day music events (Fernando et al., 2018; Jenkinson et al., 2014), little is known about the timeline or specifics of drinking behaviours (e.g., heaviest periods of use/types of alcohol used), intensity of drinking (drinks per hour/day), or intoxication levels over the course of time. Given this, there is a need for a more comprehensive, multi-dimensional assessment of alcohol consumption and intoxication to further understand patterns of alcohol use in these contexts, as well as guide future health promotion initiatives.

The majority of extant research aiming to understand alcohol use at multi-day events has relied on retrospective self-reporting of consumption behaviours (e.g., Jenkinson et al., 2014; Martinus et al., 2010). Retrospective, self-reported alcohol measures, while minimising response burden, introduce the possibility of response bias; the over or under assessments of reported behaviour (e.g., Devaux & Sassi, 2016; Midanik, 1982). A host of technologies have become available to help address this limitation. For example, ecological momentary assessment (EMA) self-report techniques (e.g., real-time drink logs) have been frequently and successfully used in substance research (Saul Shiffman, 2009). EMA self-reports involve the repeated sampling of participants' current behaviour and subjective experiences in a natural environment, assessing specific events (e.g., amount and type of drink being consumed) at periodic intervals and maintaining data about the sequence and timing of events (S. Shiffman et al., 2008). This assessment can be used to prospectively measure behaviours, limiting the influence of the reconstruction processes that entail retrospective recollection and reducing reliance on memory (Moskowitz & Young, 2006). They can also be administered without direct contact with investigators, minimising impact of frequent assessments on naturalistic drinking practices. These techniques, while still self-reports, are thus considered preferential to retrospective surveys in that they minimize recall bias and maximise ecological validity (S. Shiffman et al., 2008) and can provide time-specific contextual information (e.g., social, emotional or physical) that other methods cannot.

However, a potential limitation of EMA self-reports is the lack of complimentary objective intoxication assessments. In order to get a more comprehensive picture, they are best coupled with supporting biometric measures of alcohol intoxication such as breath, blood or transdermal alcohol concentration (Del Boca & Darkes, 2003). While breath alcohol measurements remain a popular objective assessment in alcohol-related research, repeated in-situ breath assessments entail a host of considerations including response burden and subsequent disruption to natural drinking practices (Clapp et al., 2007). Continuous transdermal assessments offer a possible solution. Approximately 1% of ethanol is excreted through the skin (Robert Swift, 2003). Leg or wrist-mounted transdermal alcohol devices determine ‘transdermal alcohol concentration’ (TAC) and can provide frequent, unobtrusive assessments of alcohol intoxication that are temporally more detailed than other biometric approaches. TAC increases linearly as alcohol intake increases, and at a rate similar to breath alcohol concentration (Dougherty et al., 2012). However, due to the length of time alcohol takes to metabolise through the skin, there is generally a time delay of 1-2 hours between peak BrAC and TAC measures (with the delay increasing at higher alcohol concentrations) and TAC has a longer elimination curve than BrAC (Karns-Wright et al., 2017). Weighted against these caveats, transdermal measurements are a blinded, non-invasive solution to repeated biometric alcohol assessments, placing little burden on participants (Caluzzi et al., 2019). In prolonged, dynamic real-world drinking environments such as music festivals, where the maintenance of natural behaviours is critical, transdermal assessments may assist in passively providing a more comprehensive insight into patron intoxication over the course of the drinking session. Greenfield and colleagues (Greenfield, Bond, & Kerr, 2014a; Greenfield et al., 2014b), on review of studies utilising transdermal assessments in both research and practical contexts, posited them as a possible ‘gold standard’ for intoxication assessment, particularly in settings where the size and strength of beverages is not known and have to be assumed if using self-report measures. However, transdermal monitors surprisingly remain markedly underutilised in research investigating heavy drinking in public spaces, as well as in combination with other measures of intoxication and consumption. A recent systematic review by van Egmond and colleagues (van Egmond, Wright, Livingston, & Kuntsche, 2020) noted that ambulatory studies combining transdermal and EMA self-report measures have only assessed consumption amongst populations drinking a maximum of 12.4 standard drinks per week, the same amount an average festival patron will consume in a 24 hour period (Fernando et al., 2018). Thus, there is a clear need to evaluate the combination of these measures among more heavy-drinking populations and in a broader range of drinking contexts.

Breath alcohol, transdermal alcohol, EMA and traditional retrospective measures are potentially complimentary in measuring different aspects of in-situ alcohol use and/or accounting for the specific limitations of other methods. Precisely measuring alcohol use and alcohol-related behaviours in multi-day drinking environments is not only important in furthering our understanding the dimensions of alcohol use over time, but also in driving the direction of strategies aimed at alcohol consumption reduction and minimising alcohol related harms (Fernando et al., 2018; Martinus et al., 2010). To date, no studies have attempted to administer continuous objective and repeated subjective alcohol assessments, in conjunction with traditional retrospective and BrAC assessments, to more comprehensively measure consumption and intoxication in-situ. Using a multi-dimensional battery of biometric alcohol assessments (breath alcohol/transdermal alcohol readings), EMA self-reports (real-time alcohol consumption log) and retrospective self-reports, we aimed to explore the individual and complementary utility of these measures in assessing consumption (e.g., number of drinks, drink type, time of drink) and objective intoxication over a real-world alcohol-licensed event.

3.4 Methods

3.4.1 Design and Setting

This study comprises a repeated measures design, collecting data over the course of a multi-day (4-day, 3-night) Australian music festival (approximately 7,000 patron capacity) in the first quarter of 2018. The festival attended by participants was an open-air event, set in a field, with accommodation predominantly comprising tents and vehicles brought by patrons. The music festival did not allow patrons to bring their own alcohol; all beverages had to be purchased on-site. This policy was enforced by a car search on arrival to the event, as well as roaming security throughout the campsite areas. Beverages available for purchase included wine, pre-mixed spirits, beer and cocktails. The research team received approval from festival organisers and the University of Tasmania Human Research Ethics Committee (ref# H0016125) to operate on-site during the festival.

3.4.2 Participants

Recruitment took place via digital social media advertisements during January and February 2018. Participants were directed to a screening questionnaire via these advertisements, assessing study inclusion and exclusion criteria. Inclusion criteria included: age 18-34 years (encompassing the largest proportion of festival patrons by age, whom are also the most likely to binge drink and are most susceptible to alcohol related harms (Australian Bureau of Statistics, 2015; Spear, 2004); English as a first language; completed high school or equivalent; frequent alcohol consumption (minimum consumption of two standard alcoholic beverages on one occasion in the preceding month); body mass index between 18.5 and 29.9; and able to attend the festival for all days (including camping on-site). Participants were excluded for: recent illicit drug use (preceding 6 months); regular tobacco use; a history of a significant medical/mental condition; history of alcohol or drug use or dependence disorder, and/or; use of alcohol at hazardous or harmful levels (evident via a score of 16 or higher on the Alcohol Use Disorders Identification Test ([AUDIT] Saunders, Aasland, Babor, de la Fuente, & Grant, 1993).

Of the 136 individuals who completed an initial screening questionnaire, 15 were selected as meeting all inclusion/exclusion criteria and were contacted for participation (our maximum participant capacity based on transdermal device availability). Most ineligible applicants scored >16 on the AUDIT (66.2% of total applicants), were regular tobacco consumers (25.7%), had recently used illicit substances (23.5%) or had a history of or a current mental health condition (8.1%). One participant was removed from the sample post-event due to a malfunction of their EMA equipment during extraction and subsequent data loss. Despite being removed from the sample, the participant successfully completed all assessments while at the festival. The final sample comprised 14 participants, 50% of whom were male, with a mean age of 21.9 years (SD=3.57, range 18 to 29). Participants received admission into the festival as reimbursement for participation and all had attended at least one festival prior to participation.

3.4.3 Measures

Breath and Transdermal Alcohol Concentration

BrAC was measured using Andatech AlcoSense Prodigy S breathalysers (certified to Australian standard #AS3547). These devices have a detectable BAC range of 0.000% to 0.400%, and an accuracy of ±0.005% at 0.100%. TAC readings were taken using Secure Continuous Remote Alcohol Monitoring (SCRAM) devices (Alcohol Monitoring Systems, Inc.), which passively took a sample every 30 minutes.

It is important to note that the measurement scaling between TAC and BrAC is not uniform. Specifically, corresponding peak TAC is typically lower in magnitude than BrAC (14). Given this, while BrAC and TAC will be compared in this study, they should not be considered equivalent. BrAC is measured as grams of alcohol per 210 litres of air. As specified by Alcohol Monitoring Systems, TAC is measured as grams of alcohol per 1470 litres of air.

Real-Time Drink Log (EMA Self-Report)

Real-time drink logs were collected using a purpose-built custom smartphone application, carried throughout the course of the festival by participants on a specialised smartphone provided by the research team (in addition to carrying their personal device). Participants were instructed to log the consumption of every alcoholic drink in standard drink units (1 unit = 10g alcohol) as well as specifying type of alcohol being consumed (i.e., spirits, pre-mixed spirits, beer, cider, wine, alcoholic energy drinks and other). Participants were briefed with the NHMRC standard drink guide to assist with alcohol consumption estimation (National Health and Medical Research Council, 2009).

Retrospective Alcohol Consumption

A retrospective questionnaire was administered face-to-face a maximum of twice daily during the event with Android tablets using REDCap (Harris et al., 2009) software (once in the morning and evening). Participants were asked to estimate the number of standard drinks consumed since last interview (6-hour reporting period during the day and 18-hours overnight).

Please note: Harm-related items (e.g., experiences of personal injury, aggression, etc.) were also collected during the morning retrospective questionnaire. These data, and how they fit in with the findings of Chapter 3, are discussed in Section 6.3.1.

3.4.4 Procedure

Details of the study were discussed with participants at an orientation session prior to the festival. The consumption or non-consumption of alcohol at the festival was left entirely up to the participant. Other than face-to-face sessions with the research team and during EMA self-reports, participants were asked to behave as they normally would in the festival environment. A static meeting time was established for the morning and evening face-to-face data collections, comprising the retrospective report and breath alcohol assessment. Participants completed a session on the evening of the first day, the morning and evening of the second day, the morning and evening of the third day and the morning of the fourth day (6 timepoints total; see Table 3.1). Individual sessions for each participant did not exceed 30 minutes.

Upon arrival, transdermal monitors were installed on the ankle of each participant. They were asked to avoid getting the device wet or in close proximity to alcohol (e.g., spillages). Monitors were worn until the end of the festival period and collected transdermal alcohol readings every 30 minutes from installation. The fit of each monitor was routinely assessed during face-to-face sessions, which were conducted in an on-site purpose-built private gazebo. In addition to face-to-face data collections, participants were asked to log all drink events on a mobile phone they received from the project team with a pre-installed dedicated EMA application, as well as carry the provided phone with them at all times until the end of the monitoring period. The EMA application logged the time and date of responses. This was done without face-to-face contact with the research team in order to keep the festival experience as uninterrupted as possible. Participants were offered free snacks (e.g., chocolate bars, potato chips) on presentation of each testing session as additional incentive to attend.

Table 3.1 Participant Assessment Schedule Over Festival

Time (Timepoint)	Task
	First Day
1pm – 4pm	Fitted with SCRAM transdermal monitor Provided phone with EMA application to keep for festival duration
4:30pm – 5:50pm (Timepoint 1)	Retrospective questionnaire Breath-alcohol analysis
	Second Day
10:30am – 11:50am (Timepoint 2)	Retrospective questionnaire Breath-alcohol analysis
4:30pm – 5:50pm (Timepoint 3)	Retrospective questionnaire Breath-alcohol analysis
	Third Day
10:30am – 11:50am (Timepoint 4)	Retrospective questionnaire Breath-alcohol analysis
4pm – 5:50pm (Timepoint 5)	Retrospective questionnaire Breath-alcohol analysis
	Fourth Day
10:30am – 11:50am (Timepoint 6)	Retrospective questionnaire Breath-alcohol analysis Removal of SCRAM transdermal monitor Retrieval of phone with EMA application

3.5 Results

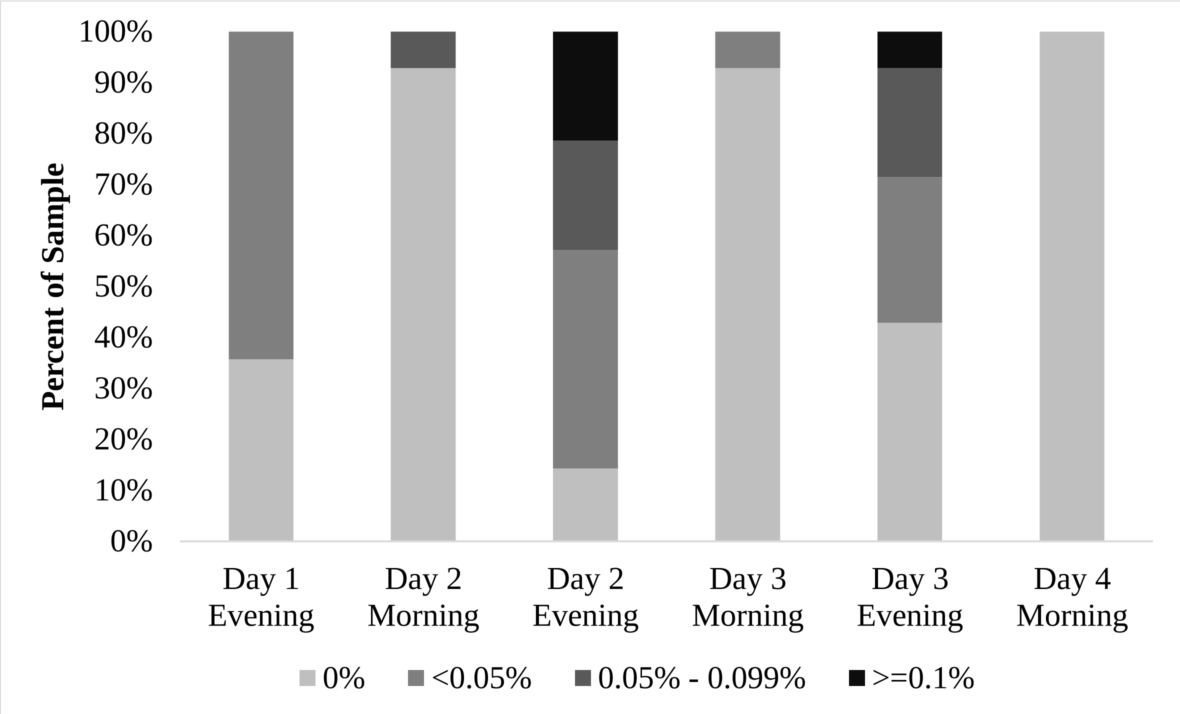
3.5.1 Assessment Compliance

All 14 participants attended all collection timepoints for all four days of the event, with a 100% compliance rate for the retrospective and breath alcohol assessments. One participant's transdermal monitor was removed on the second day due to discomfort (trouble sleeping and chaffing around the ankle) and was left off for the remainder of the event. All other participants (n=13) wore their transdermal device for the full festival duration.

3.5.2 Objective Intoxication: BrAC

BrAC readings were grouped into four distinct categories: no alcohol present (0.00%), under the Australian legal breath alcohol driving limit (<0.05%), moderately intoxicated (0.05% - 0.099%) and heavily intoxicated (>=0.1%). Over half (57%, n=8) of the sample had at least one breath alcohol reading of 0.05% or above during the event; 14% (n=2) had a breath alcohol reading at or above 0.10%. The highest proportion of heavily intoxicated individuals (according to BrAC) occurred on the evening of the second day, with 21% (n=3) of the sample over or equal to 0.10% BrAC. There was an equal proportion of moderately intoxicated participants on the evening of the second and third days (21%, n=3). All participants recorded 0.00% BrAC on the morning of the final day (pre-departure). See Figure 3.1 for a full breakdown of BrAC groups by assessment timepoint.

Figure 3.1 Breath Alcohol Concentration by Festival Assessment Timepoint

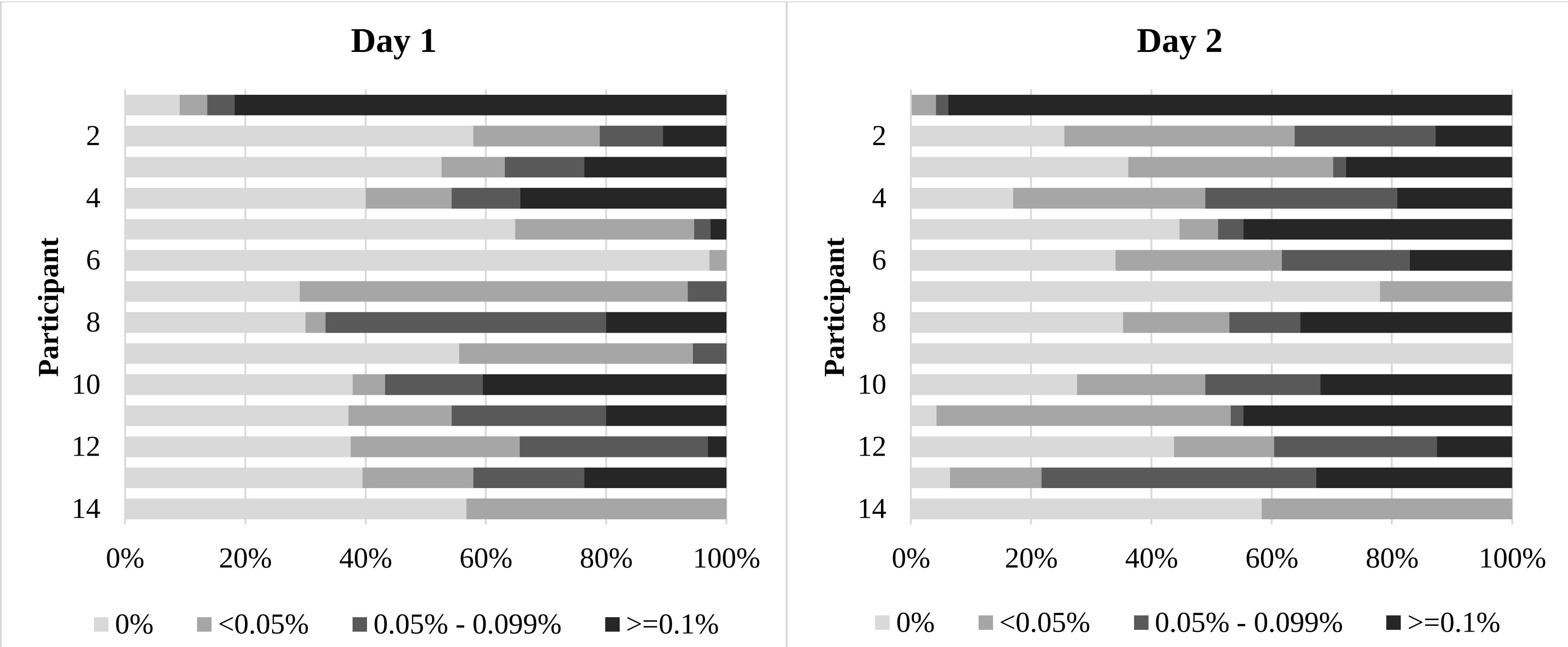


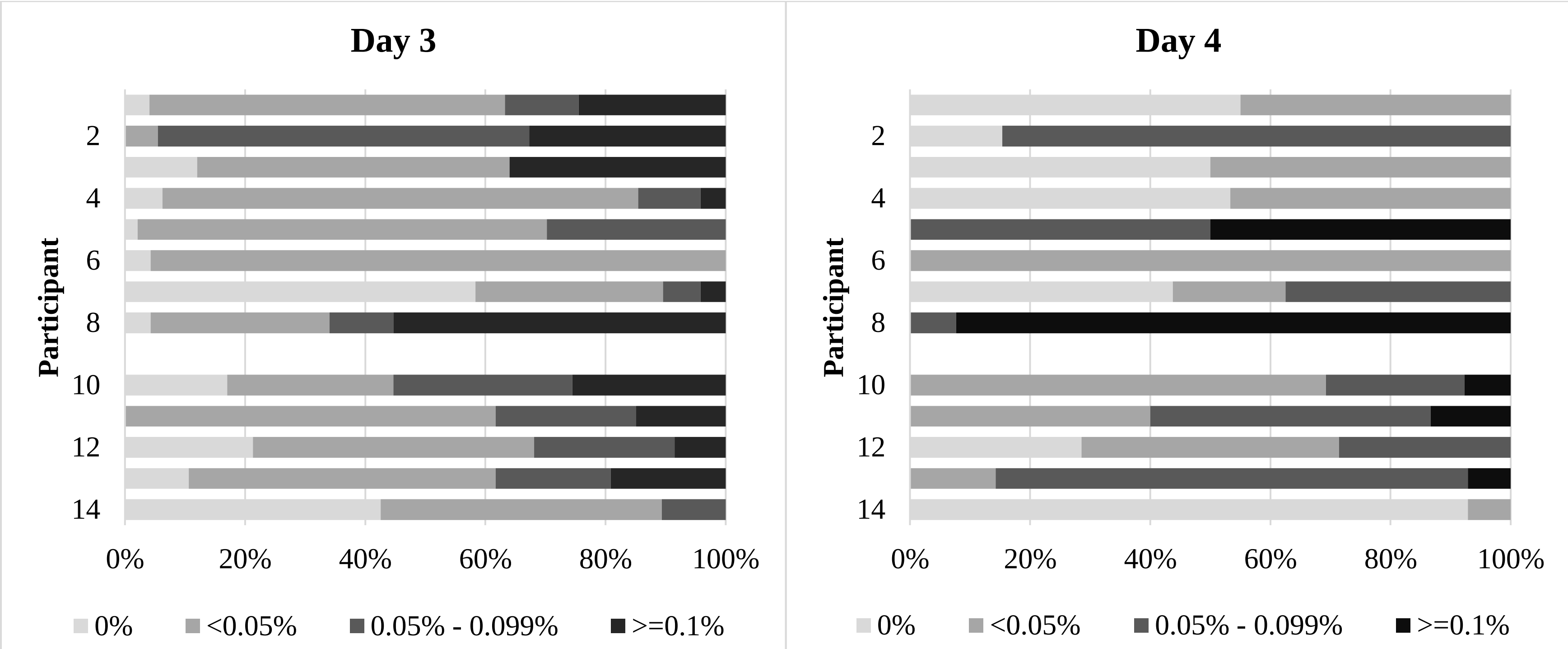
3.5.3 Objective Intoxication: TAC

All timestamped TAC measurements were rounded to the nearest 15 minutes for analysis. The transdermal devices took an average of 142.7 readings (SD= 3.7, range 133 to 146; n=13) per person. As seen in Figure 3.2, a large proportion of readings over each festival day indicated alcohol intoxication, including TAC >0.10%. Across the sample, 69.8% of total readings were above 0.00%. Peak raw TAC typically occurred in late evening and early hours of the morning; often much later than the evening BrAC assessments, even after considering an average TAC to BrAC delay of 2-3 hours at high levels of alcohol consumption (Karns-Wright et al., 2017). Further, TAC readings were occasionally positive on evenings where BrAC assessments returned a negative result.

Several suspected environmental interference events were detected within the TAC data files. These are identified by sharp incline and decline of the TAC curve that do not represent the typical absorption and elimination rate; <0.05g/dL per hour absorption and <0.025 g/dL elimination per hour if peak TAC <0.15 g/dL or <0.035g/dL if peak TAC >0.15 g/dL (Barnett, Meade, & Glynn, 2014). Figure 3.3 demonstrates TAC and BrAC readings from one participant over the course of the festival, including a suspected interference event (the sharp peak and descend after 60 hours). See Appendix A for TAC and BrAC readings for each participant, several of which also contain spurious TAC peaks and valleys.

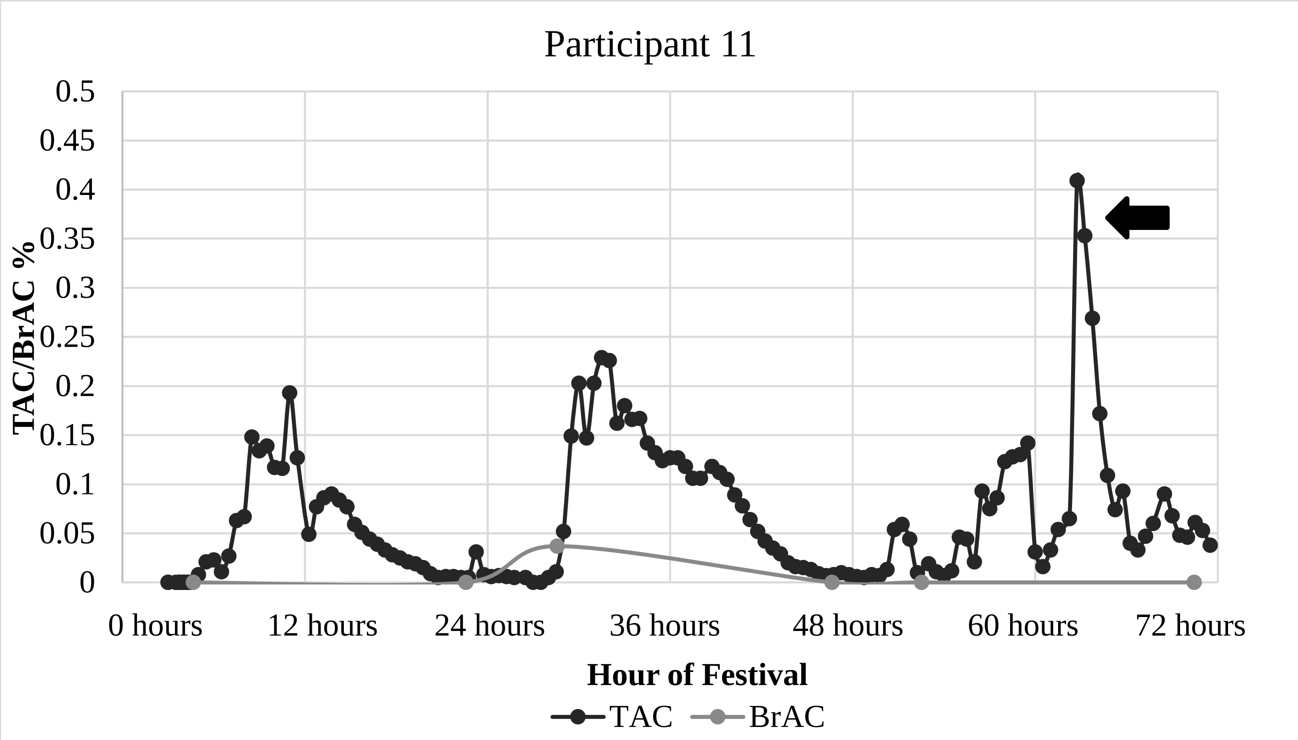
Figure 3.2 TAC-group Percentages Across all Four Days of the Festival by Participant





Note: Data are raw TAC values (g/dL). As TAC readings have delayed and variable onset up to 4 hours from current state BAC (Marques & McKnight, 2007), days 1, 2 and 3 cut off at 4am the following day.

Figure 3.3 Participant Example of TAC Plotted Against BrAC over Festival



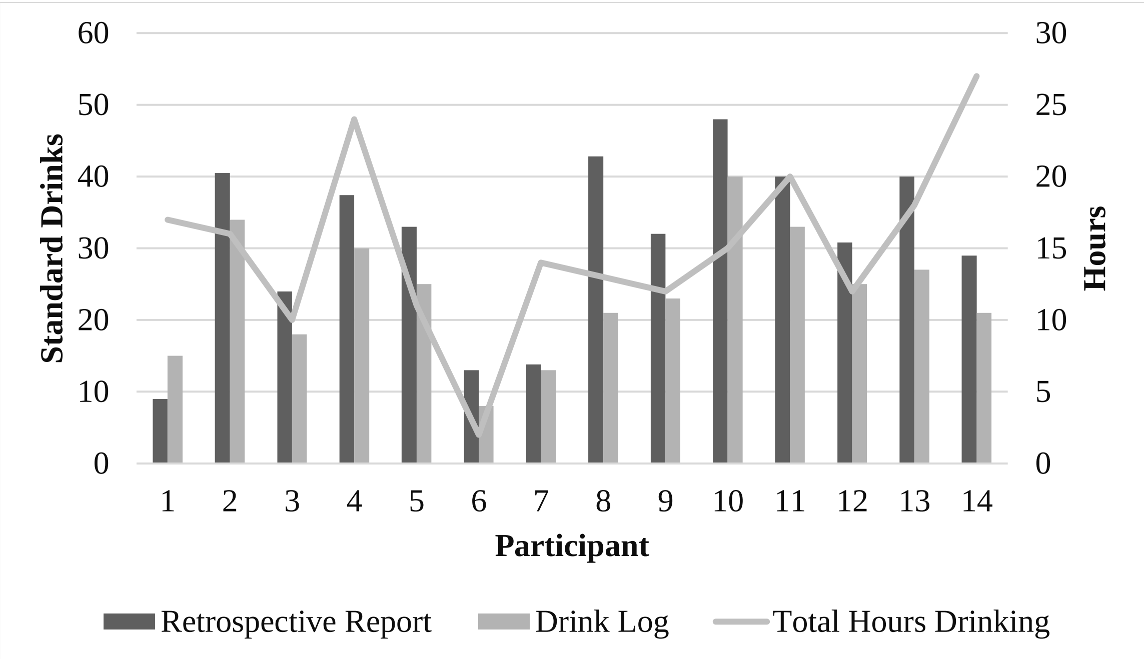
Note: Suspected environmental alcohol interference curve indicated with an arrow. TAC timestamps have not been adjusted to account for variable delay (other than being rounded to the closest 15 minutes).

3.5.4 Subjective Consumption: Retrospective Reports and Drink Log

Participants prospectively submitted a mean of 14.4 alcohol drinking logs (a consumption event involving any quantity of alcohol; SD=5.02, range 5 to 23), with a mean of 1.7 standard drinks consumed per log (SD=0.86) and 23.8 (SD=8.76, range 8 to 40) standard drinks over the festival. They logged an average of 15.1 total hours drinking over the festival (subtracting time of last drink log from time of first drink log each day; SD=6.20, range 2 to 27), with an average drinking intensity (drinks per hour of drinking) of 1.8 standard drinks (SD=0.84, range 0.78 to 4). Of the 209 responses (some participants consumed more than one type of beverage per log), spirits were the most frequently consumed (40.7% of drinks, n=85), followed by beer (23.4%, n=49), pre-mixed spirits (16.3%, n=34), wine (8.6%, n=18), cider (8.1%, n=17), alcoholic energy drinks (1.9%, n=4) and cocktails (1.0%, n=2).

Participants reported a higher number of standard drinks on the retrospective questionnaire (morning/evening), indicating a mean consumption of 31 drinks (SD=12.04, range 9 to 48) over the event (minimum discrepancy between questionnaire and log = 0.8 standard drinks, maximum = 21.8 standard drinks). A repeated measures ANOVA indicated significant mean difference between reporting type and number of drinks reported, $F(1,13)=19.63$, $p=.001$. Figure 3.4 demonstrates standard drinks consumed for each reporting method and total hours drinking by participant.

Figure 3.4 Standard Drinks Consumed (Retrospectively Reported and Logged) and Total Hours Drinking by Participant



Note: ‘Total hours drinking’ was calculated by adding the total time of first drink log to time of last drink log for each festival day.

3.6 Discussion

The aim of this study was to compare the individual and complementary utility of these measures in assessing consumption (e.g., number of drinks, drink type, time of drink) and objective intoxication over a multi-day licensed event. Our battery was successfully administered, with a 100% compliance rate for the retrospective reports and breath alcohol assessments. Participants also engaged with the drink log, with an average of over 14 logs per participant during the event.

Regarding the objective intoxication measurements, highest TAC readings often occurred at different times and days than highest BrAC readings, indicating that the heaviest periods of intoxication occurred outside of BrAC assessment windows (irrespective of the up to 3-hour detection delay in TAC measurements at high levels of alcohol consumption). While almost 70% of total transdermal readings across the sample indicated the presence of alcohol, our infrequent breath alcohol assessments occasionally completely missed intoxication over the course of the day. Though the high percentage of positive TAC readings will be partially attributable to the longer alcohol elimination curve of this assessment route, TAC still captured instances of intoxication throughout the event that BrAC did not. Further, while they have a linear relationship, the magnitude of TAC is not equivalent to BrAC (i.e., is typically lower) which limits the ability to make direct comparisons of raw values [although significant efforts are currently being made to convert TAC to estimations BrAC; (Devaux & Sassi, 2016)]. However, within naturalistic drinking contexts, this research demonstrates the utility of transdermal monitoring in providing high-temporal information about periods of intoxication and changes in intoxication over-time in a context where frequent (e.g., hourly) breath assessments would pose a considerable risk to ecological validity. If BrAC had been relied on as a sole biometric measure of intoxication, the static nature of these data would have often precluded us from capturing the heaviest periods of intoxication over the course of the drinking event. The importance of having a continuous measure of intoxication to assess prolonged periods of drinking is twofold. Firstly, it may assist in the validation of consumption self-reports; for instance, whether there may be missing EMA drink logs over an extended period of time. Secondly, it can provide a broad overview of time spent intoxicated, as well as indicating the heaviest periods of intoxication when these otherwise would have been missed by static biometric assessments.

Conversely, our findings also demonstrate a marked limitation of TAC, and subsequent advantage of BrAC, when assessing intoxication in a real-world setting. Prior to departure from the event, over 40% of the sample had a TAC reading above zero while all corresponding breath assessments were 0.00%. The delayed nature of transdermal measurements, compared to breath alcohol intoxication, limits their ability to provide time-critical measures of intoxication state. This may be particularly important, for instance, when assessing legal ability to drive home from the event or other aspects of intoxication relevant to real-world policy. Because the degree of delay can vary depending on level of consumption and individual differences (Karns-Wright et al., 2017), it is difficult in this context to determine the precise level of intoxication, as it would temporally map to BrAC, at a given time based on TAC alone. Despite this, it is important to note that this limitation may be (at least partially) a result of transdermal technology being in the early stages of development and refinement. ‘New generation’ transdermal monitors are currently being developed, with laboratory validation of early prototypes indicating a faster alcohol detection rate than existing devices such as the SCRAM (Fairbairn & Kang, 2019). However, these new devices are yet to be evaluated in a naturalistic drinking context. Investigating the real-world performance of the new-wave transdermal monitors is an important direction for future research; if they can indeed provide a more time-sensitive assessment of intoxication, this would overcome one of the largest limitations of the previous generation devices.

There were several instances of suspected environmental interference events in our transdermal readings, identifiable by the spurious curves of the TAC event (i.e., a sharp incline and decline). Environmental interference has been noted in previous field-based transdermal collections (Luczak, Rosen, & Wall, 2015) and can occur whenever there is a high concentration of alcohol or alcohol-based products in close proximity to the device. This is problematic in naturalistic contexts where, by definition, researchers do not have control over environmental factors. While transdermal assessments can provide continuous, high temporal sensitive resolution of alcohol presence, raw TAC readings in these contexts likely need to undergo pre-processing/cleaning to remove such anomalies before meaningful interpretations can be made about the true curve of intoxication. While previous literature has outlined attempts at rule-based cleaning, there is yet to be a clear consensus on how to do this (van Egmond et al., 2020). Further, considering that SCRAM devices only take readings every 30 minutes, it can difficult to tell if a spike in the curve is a true drinking event, or if it is simply interference; particularly if corresponding self-report measures are susceptible to sub-optimal reporting compliance and cannot be relied on to corroborate them. New generation transdermal monitors that take readings more frequently than SCRAMs (e.g., every few minutes) may help ameliorate uncertainty around environmental contamination as they provide greater clarity of the curve (van Egmond et al., 2020). Regardless, BrAC assessments collected by trained personnel are less susceptible to environmental and individual interference. They are consequently complimentary to transdermal assessments in that they can be integrated to provide reliable measures of present-state intoxication at static but policy-relevant intervals.

Another finding of note was the significant disparity of self-reported drinks consumed between reporting methods. EMA logs appeared to underestimate consumption when compared to retrospective reporting. Our findings are contrary to previous research that suggests retrospective reports underestimate total alcohol consumption when compared to smartphone-based prospective logs in broader naturalistic drinking environments (Kuntsche & Labhart, 2012; Poulton, Pan, Bruns, Sinnott, & Hester, 2018). EMA compliance in substance use research is estimated at 75% (Jones et al., 2018). A possible explanation for this ostensible underestimation may be that drink log compliance tapered as a function of response burden, fatigue or intoxication. Conversely, it is possible that participants overestimated their consumption during retrospective reports. An evident solution may be to add a 'missed drinks' component as part of the EMA log, assisting participants to report any drinks they had previously failed to log. This would help distinguish between report differentials caused by participant omissions and those caused by other factors (e.g., response bias), however may still be problematic if participants are too intoxicated or fatigued to respond (Labhart et al., 2019).

The drink log component of the battery was useful in both prospectively assessing number of standard drinks consumed, drinking intensity and type of drink consumed. These are important considerations in any prolonged drinking setting as it provides drinking *context* in addition to static consumption quantity. For example, over 40% of drinks reported during the festival were spirits, despite the fact that the festival did not sell them (pre-mixed spirits, which were sold at the festival, were assessed separately). This indicates that a large percentage of the drinks consumed by our sample were brought into the festival, even though the event strictly prohibited the consumption of externally purchased alcohol. Given this, it may also be useful to include an assessment of 'drink source' within the drink log (e.g., whether the drink was purchased on-site or brought), which could provide a better understanding of the circumvention of licensing restrictions by patrons. In these respects, in addition to consumption quantity, drink logs can help identify key beverage targets for alcohol-reduction interventions and policy in these settings, such as increasing searches for patrons bringing in external spirits to an event. However, as exemplified by the drink consumption differential between self-reported measures, continuous biometric measures (e.g., transdermal) are also valuable in addition to self-reports in that they could help identify drinking that has been missed due to response burden (EMA logs) or misestimations (retrospective reports), corroborate self-reports and improve the overall richness of the data in this setting.

Finally, it is important to consider that while each assessment provided unique information in this particular alcohol-use context, the accumulated burden of deploying all assessments at once may not be warranted depending on the context or research question being investigated. For example, while our self-reported measures provided an assessment of number of drinks consumed and important contextual information surrounding this drinking, such assessments are less likely to be useful in contexts that incentivise the misreporting of drinking behaviour (e.g., contingency management therapy or mandated monitoring). In these scenarios, objective measurements are preferential, and the ancillary use of subjective measures is not as useful. Similarly, if the research question being investigated is solely centred on static periods of intoxication (e.g., at a critical timepoint) and the time course of intoxication is not of concern, passive intoxication monitoring with transdermal devices is not warranted. In essence, while our findings indicate that all measures can be deployed at once and have unique strengths in such dynamic and prolonged drinking settings (albeit weighted against unique weaknesses), researchers should judiciously select a combination of measures that harmonise with their research needs.

3.6.1 Strengths and Limitations

To our knowledge, this was the first study to successfully deploy a concurrent combination of breath and transdermal alcohol measurements, EMA techniques and self-report measures over a multi-day heavy alcohol-licensed event. It demonstrates strengths and weaknesses of each measure in this setting, as well as the potential utility of their combined use in broader real-world drinking settings. However, there are several important caveats in relation to our findings. Firstly, given the small sample used, the reported behaviours are not necessarily representative of all festival attendees; our intention was only to assess the utility of the measures in a naturalistic context. Similarly, these measures are not a catch-all in regard to the alcohol-related outcomes. For example, in the festival context, the residual effects of intoxication may have subsequent implications for policy relevant activities (e.g., driving home), something not captured with this battery. While it would have been beneficial to compare TAC and BrAC within an assessment timeframe (e.g., a period of several hours) to aid TAC interpretation, the number of BrAC readings were too sparse for full comparisons. If the temporal aspects of TAC recording can be standardised, the direct comparison of BrAC and TAC measurements in public drinking settings is a possible direction for future investigations. Finally, our exclusion criteria precluded the riskiest subset of festival attendees (e.g., individuals who reported illicit drug use or scored >16 on the AUDIT). It is possible that compliance would not have been as strong with these individuals and will need to be further explored.

3.6.2 Conclusions

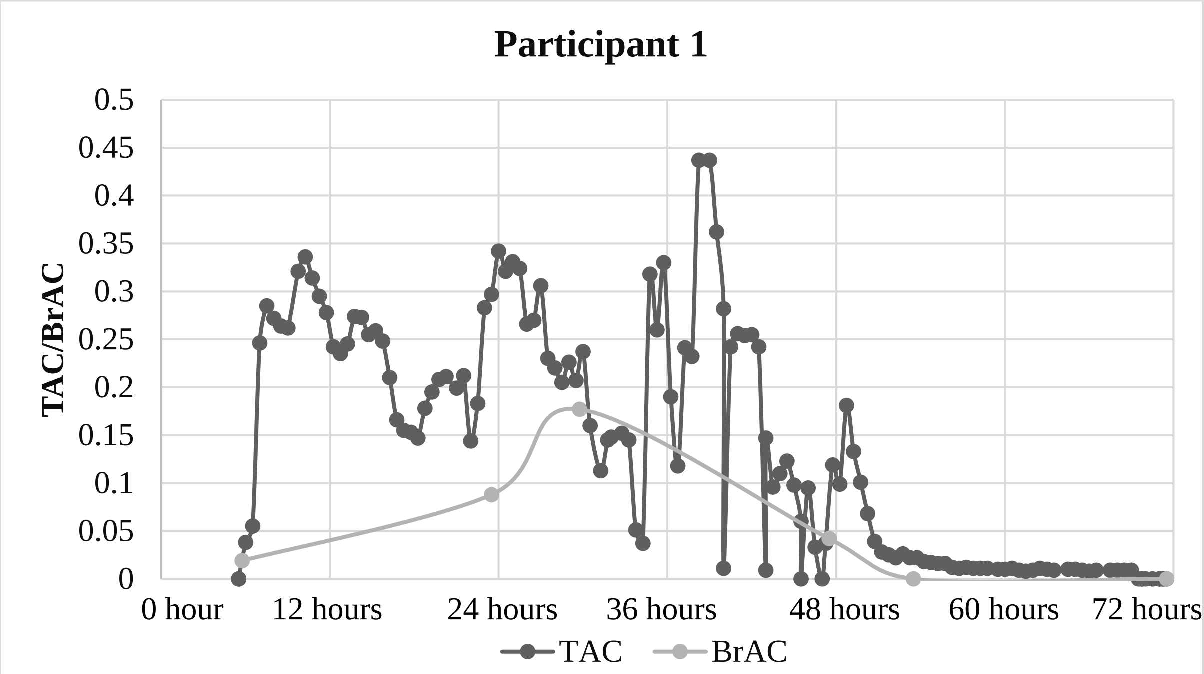
Our findings demonstrate that, in isolation, all tested measures possessed limitations. These notwithstanding, when combined, the assessments were successfully administered as a battery to provide a more comprehensive overview of alcohol-related intoxication and consumption over the course of a multi-day licensed event. When assessing alcohol use in naturalistic environments with heavy average alcohol consumption such as music festivals, it is recommended that data is collected using a judiciously selected battery of measures rather than relying on a single given assessment. However, our findings also reinforce that improvements to transdermal alcohol technology, such as a reduction in detection latency and minimising the influence of external alcohol interference, would greatly benefit researchers in continuously capturing objective intoxication in these drinking settings.

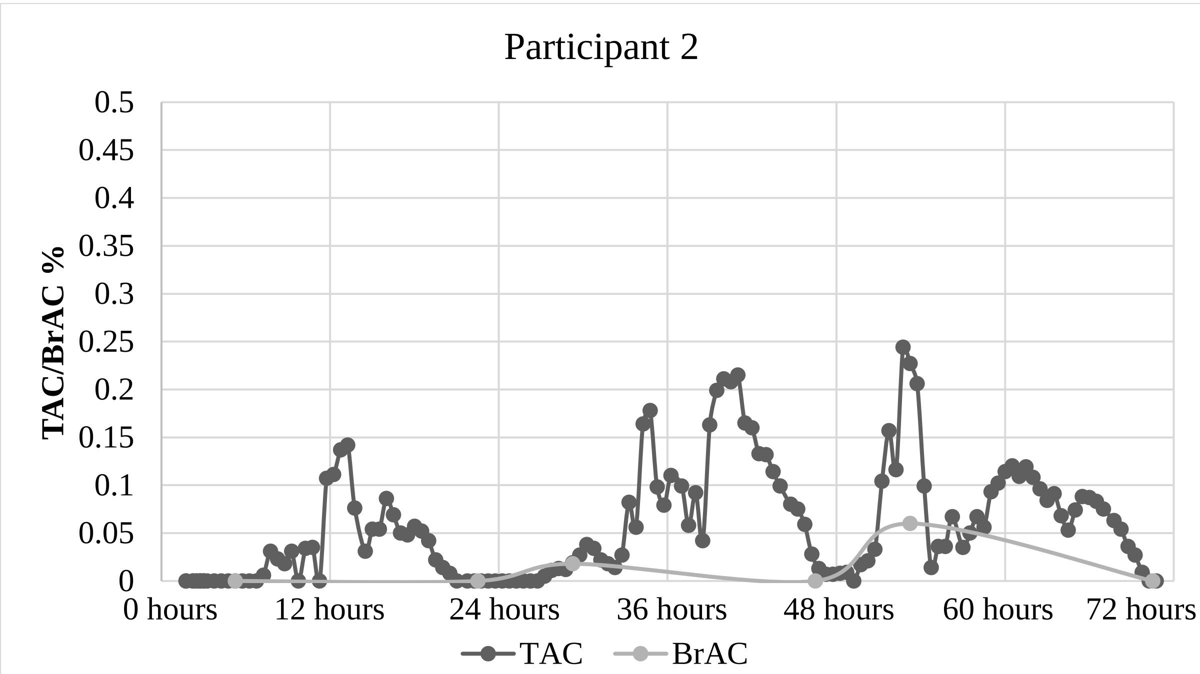
3.7 Acknowledgements

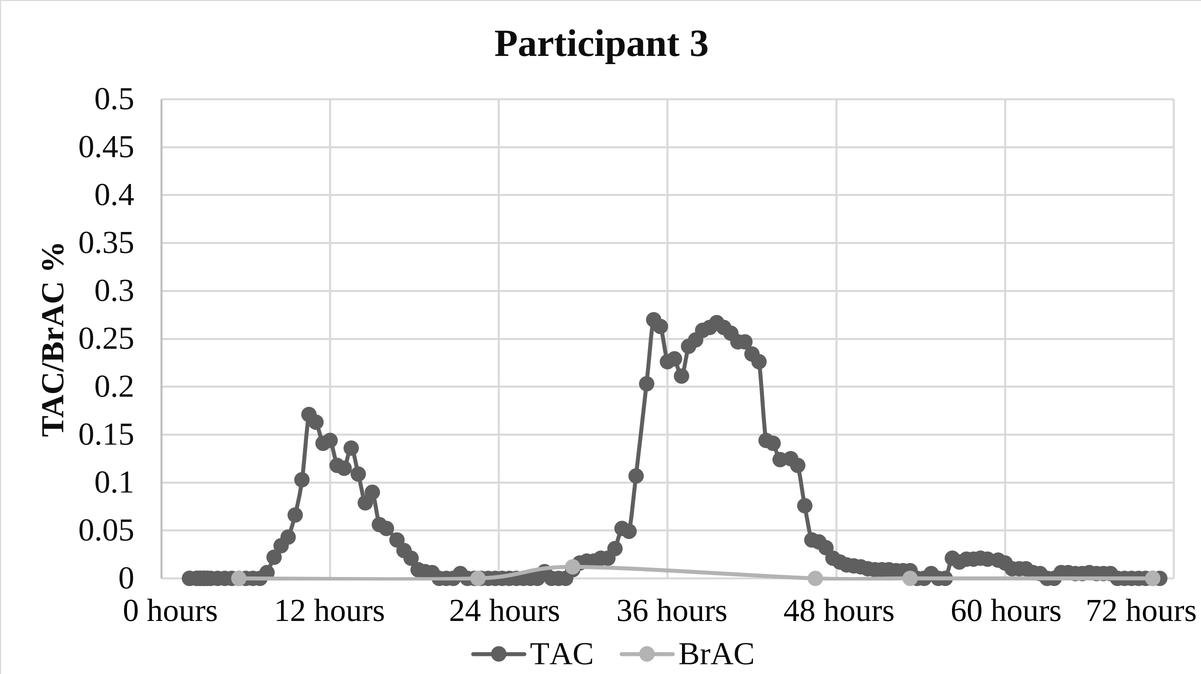
Thomas Norman is funded by the Australian Research Training Program. Amy Peacock is supported by a National Health and Medical Research Council research fellowship. The National Drug and Alcohol Research Centre at UNSW Australia is supported by funding from the Australian Government under the Drug and Alcohol Program.

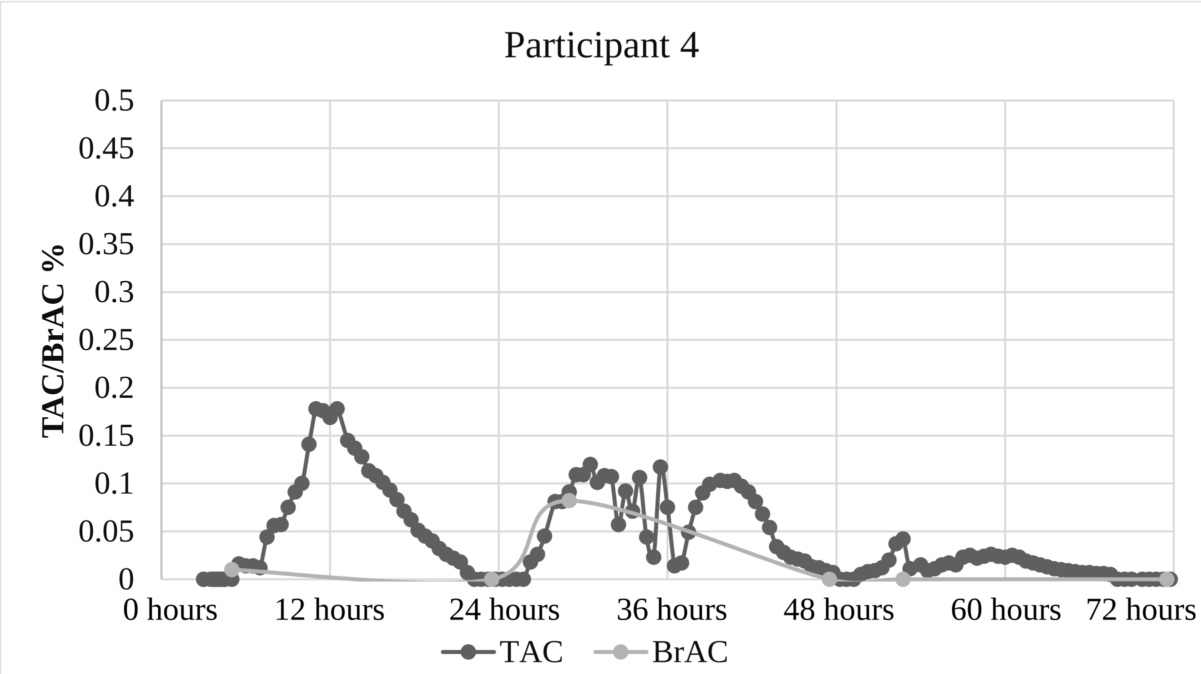
3.8 Appendix A

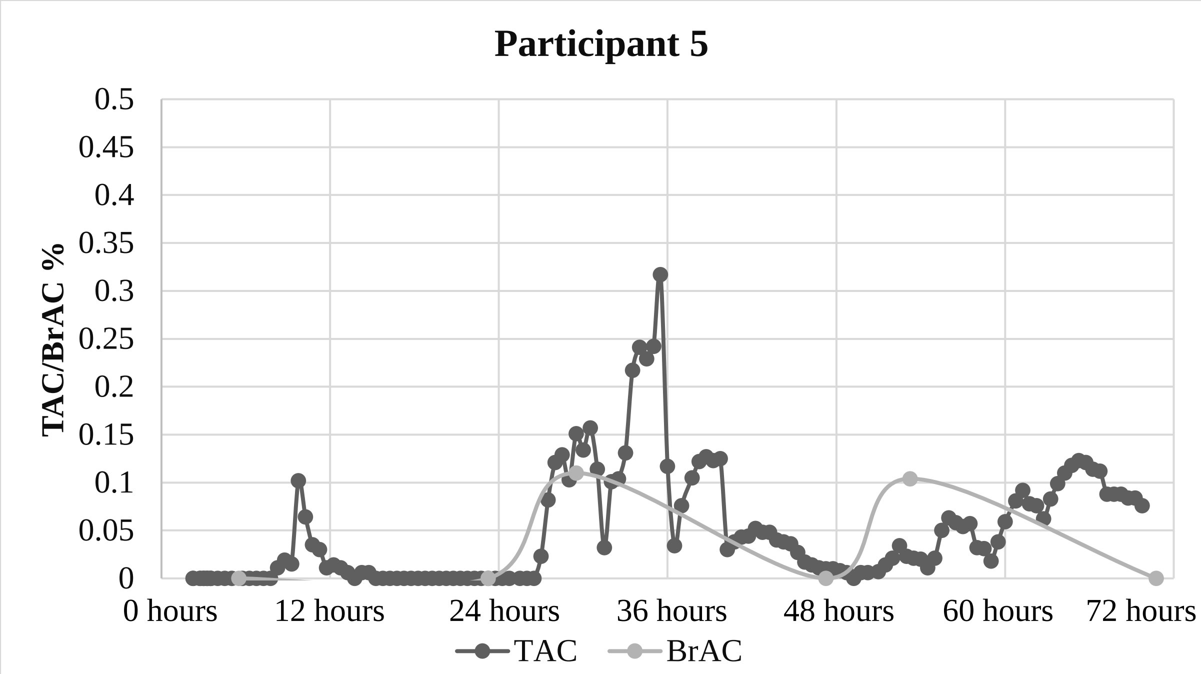
TAC and BrAC over Course of Festival by Participant

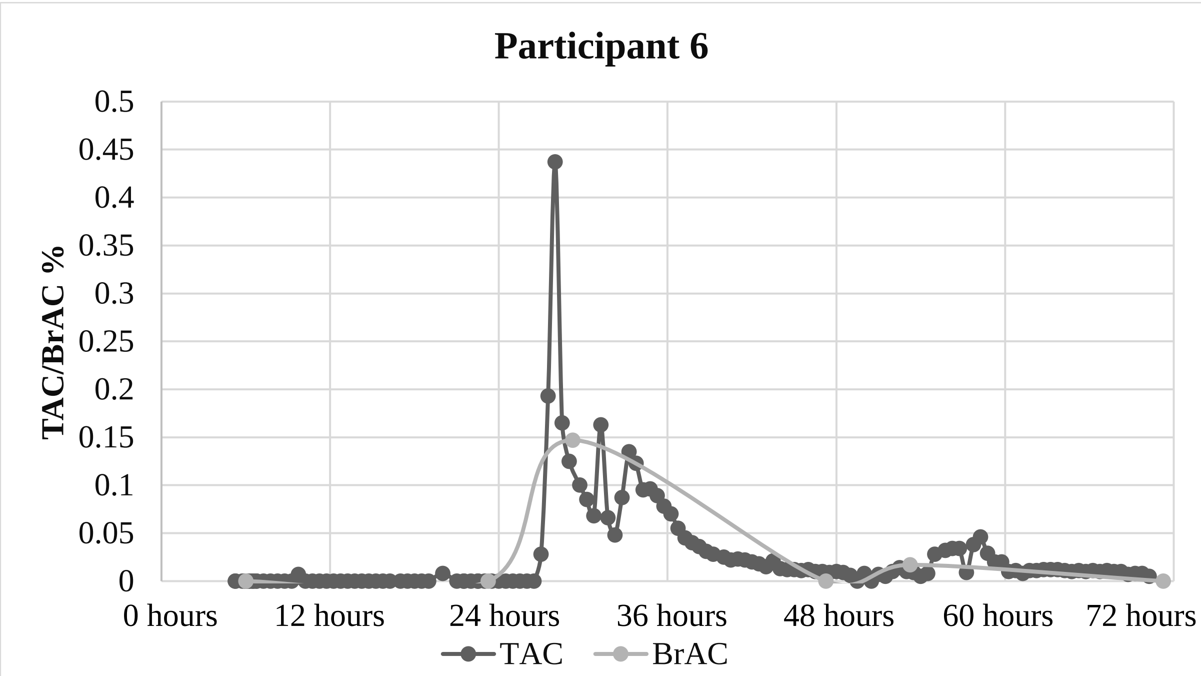


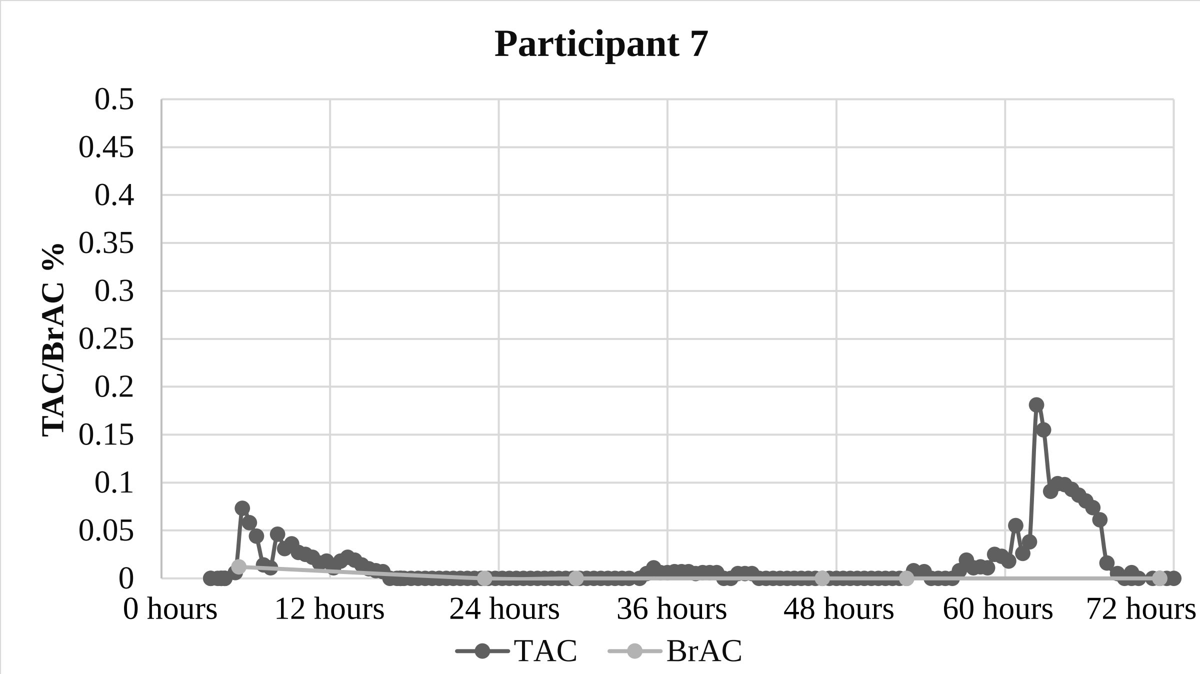


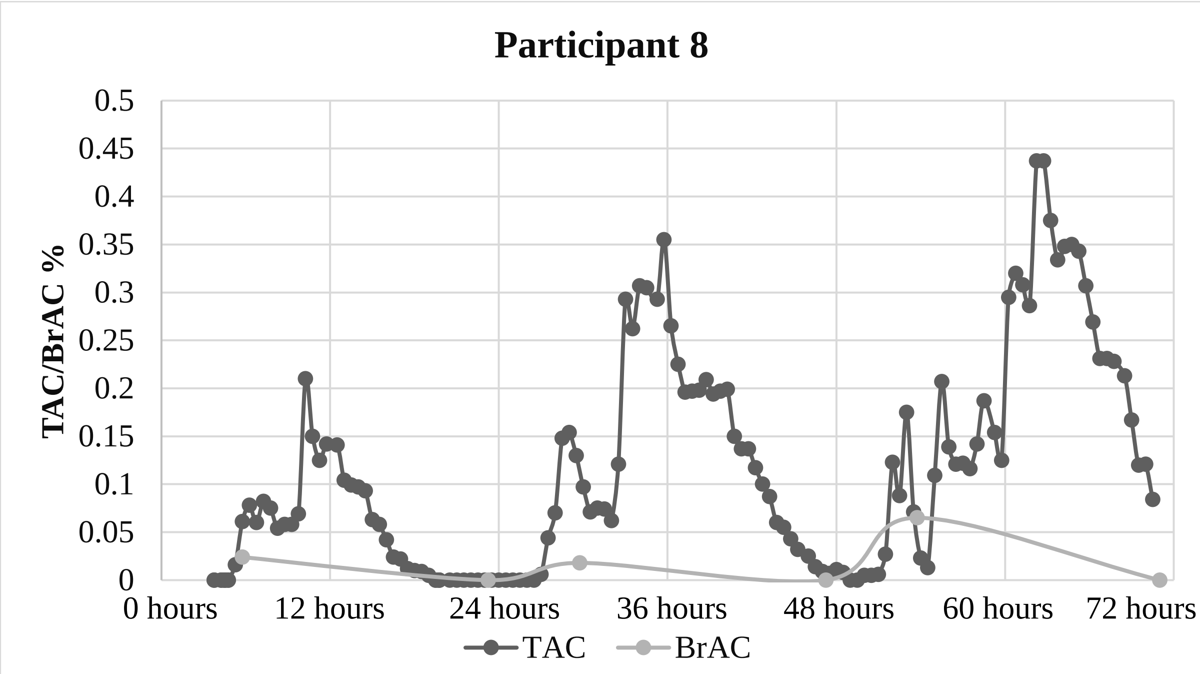

Participant 3
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC

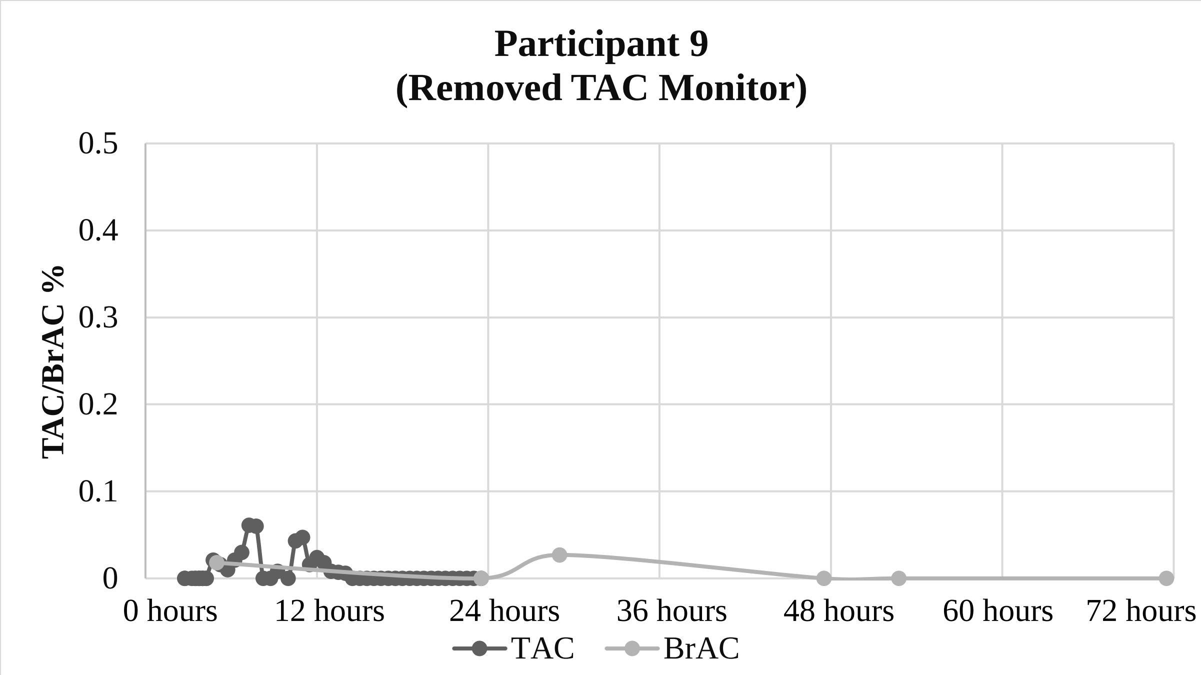

Participant 4
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC


Participant 5
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC

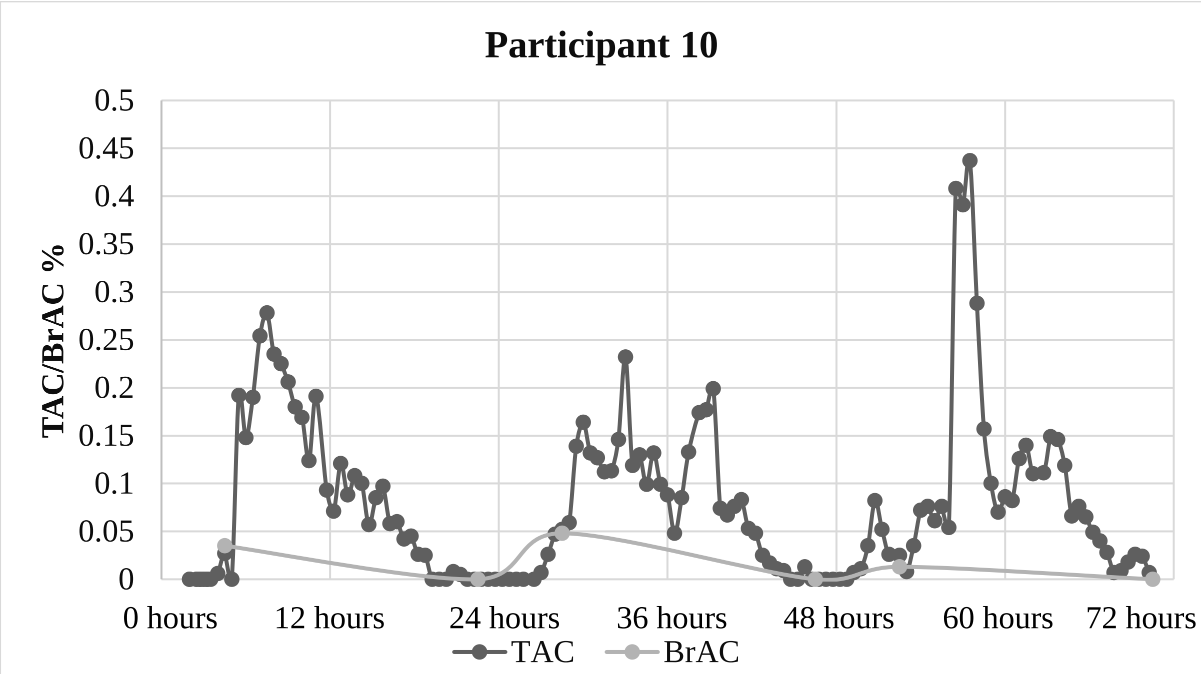

Participant 6
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC


Participant 7
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC

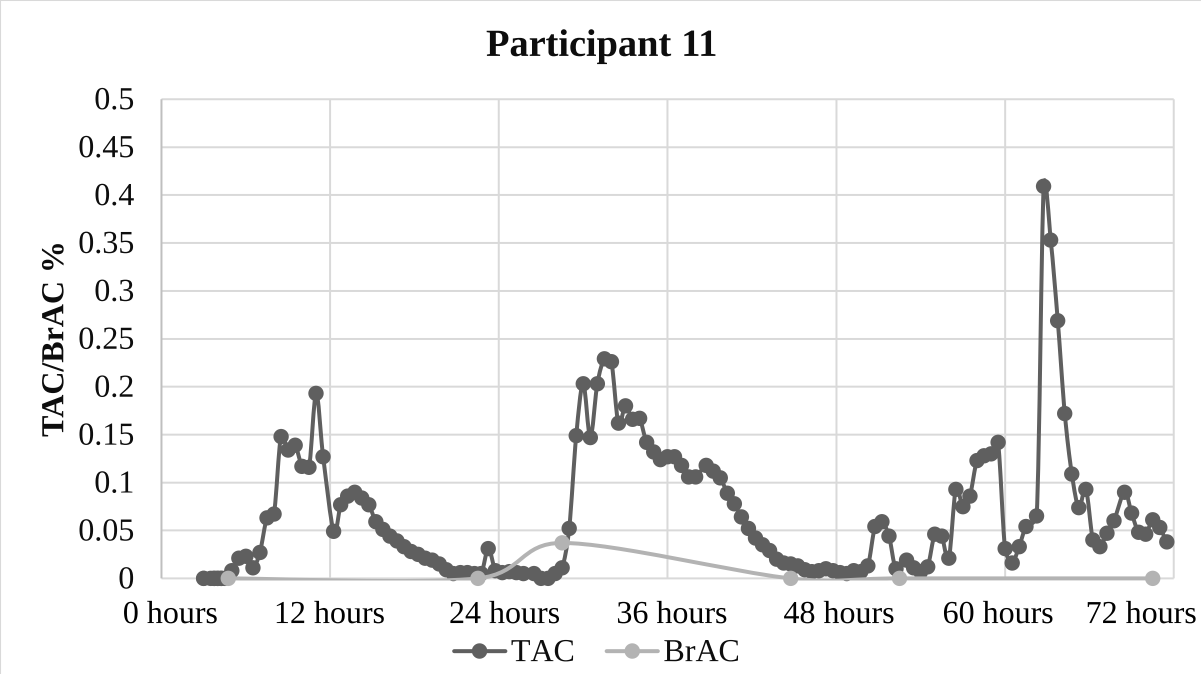

Participant 8
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC



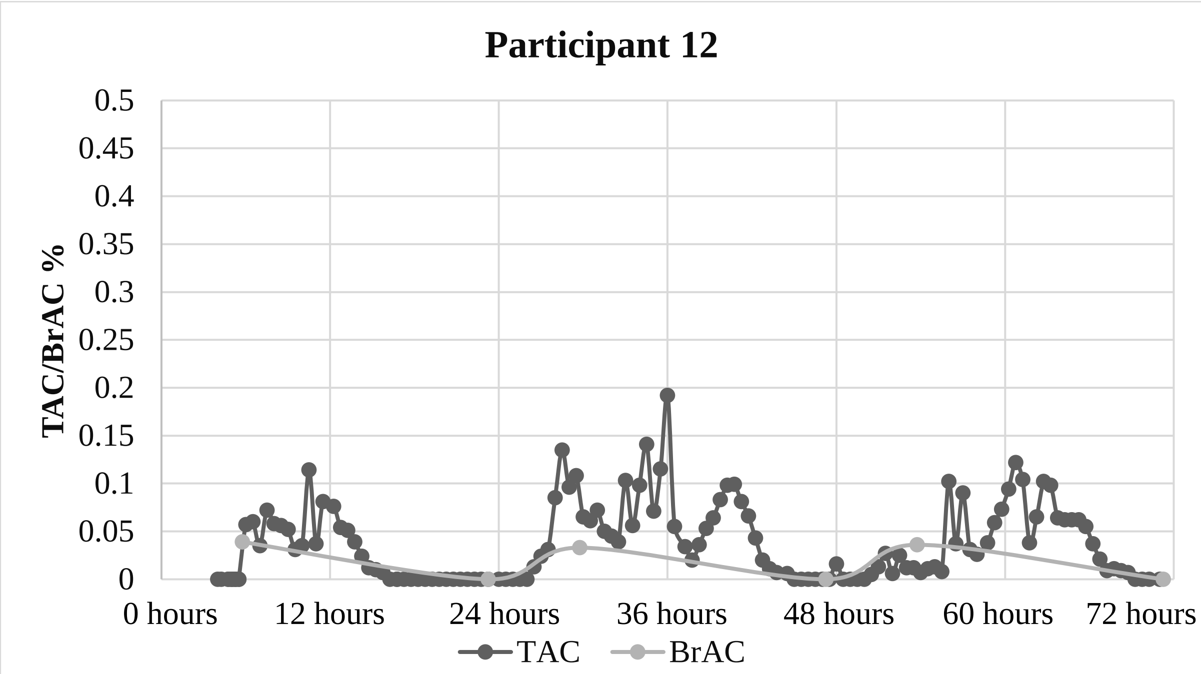
Participant 9
(Removed TAC Monitor)
TAC/BrAC %
0.5
0.4
0.3
0.2
0.1
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC



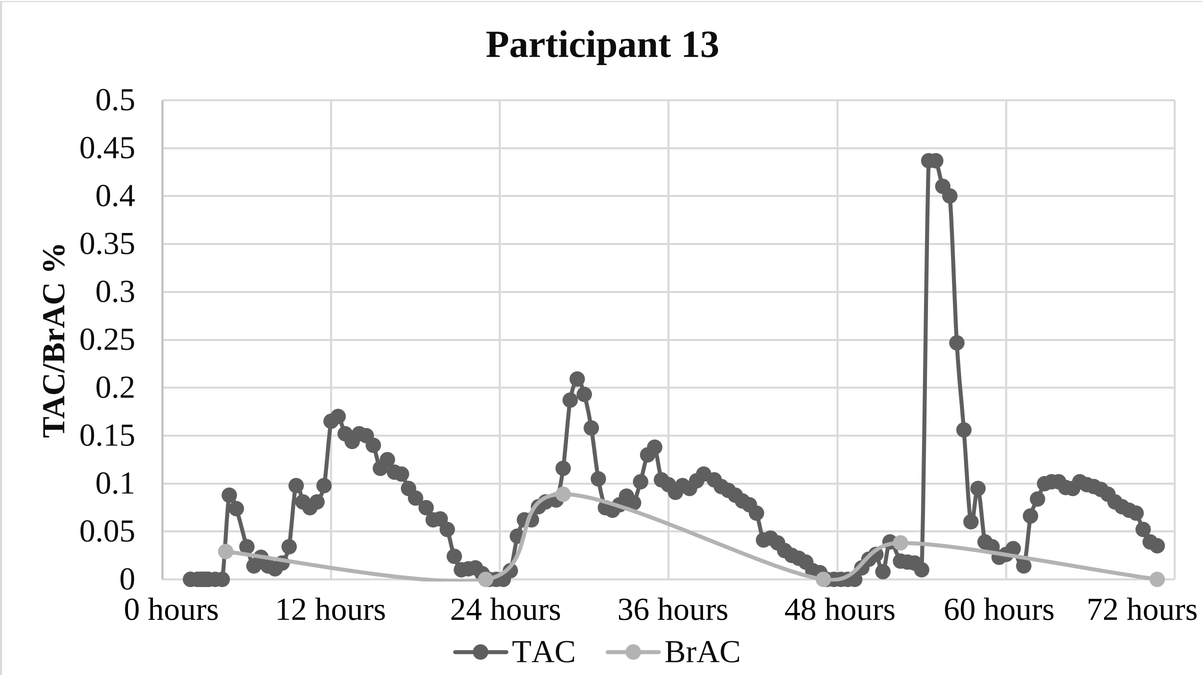
Participant 10
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC



Participant 11
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC



Participant 12
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC


Participant 13
TAC/BrAC %
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 hours
12 hours
24 hours
36 hours
48 hours
60 hours
72 hours
TAC
BrAC

Chapter 4: Assessing driving-relevant cognitive performance after a multi-day alcohol-licensed music festival

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Norman, T., Peacock, A., Ferguson, S. G., Kuntsche, E., & Bruno, R. (under review). Assessing driving-relevant cognitive performance after a multi-day alcohol-licensed music festival. *Experimental and Clinical Psychopharmacology*.

4.1 Preface

Chapter 3 investigated the use of a combined battery of ambulatory and retrospective measures to assess alcohol intoxication and consumption in a dynamic and prolonged naturalistic drinking session. While these measurements represent one facet of risk in drinking settings (i.e., acute alcohol use), alcohol hangover is another factor of interest – with the potential to contribute to harms such as driving accidents - that has not been adequately investigated in a naturalistic environment. Moreover, given the dearth of research investigating this issue in-situ, no pre-existing methodology exists to base our investigation on. Thus, we aimed to conduct a study, using a battery of portable cognitive tests, to investigate post-alcohol-consumption cognitive impairment in a real-world, dynamic drinking environment. Further to our aim, we also had to choose a drinking setting that posed an element of risk. Considering that music festivals often continue for several days, that alcohol is commonly consumed by patrons during its course, and that individuals frequently drive home from these events, we targeted this setting.

4.2 Abstract

Background: The possibility of residual impairment of cognitive performance after licensed multi-day music events is particularly important given that many patrons drive home. We aimed to compare sober performance on driving-relevant cognitive tasks at the end of a four-day festival with performance at varying levels of the breath-alcohol curve.

Methods: Participants (n=13; the same cohort of individuals described in *Chapter 3*) completed three tasks (Arrow Flankers [AF], N-Back and Rapid Visual Information Processing [RVIP] tasks) measuring selective attention, working memory, and sustained attention at a breath alcohol concentration (BrAC) of 0.00%, 0.05% (ascending and descending) and 0.08% following acute dosing in a controlled laboratory setting. Participants then attended a 4-day music festival, with task performance and BrAC assessed pre-departure on the final day.

Results: All participants consumed alcohol in the 24-hours prior to festival departure but recorded 0.00% BrAC at testing. Participants made a greater number of attentional errors on the selective attention task (AF) pre-departure than at 0.00% and 0.05% BrAC in the laboratory. Pre-departure performance on working memory (N-Back) did not significantly differ from, or was better than, all laboratory performance timepoints. Sustained attention performance (RVIP) was predominantly poorer during laboratory assessments than at the festival.

Conclusions: Despite performance on the tasks being generally better at the festival than when acutely intoxicated in the controlled setting, some impaired attentional performance was observed pre-departure relative to 0.00% and 0.05% BrAC. These findings suggest that, in addition to acute alcohol intoxication, policy makers should consider including messages about the dangers of residual impairment in driver safety campaigns targeting festival goers.

4.3 Introduction

Approximately 40% of Australians aged 18-24 years attend music events each year (Australian Bureau of Statistics, 2015), with a significant percentage of these events comprising music festivals. As multi-day festivals are often situated in rural or semi-rural regions, many patrons choose to drive to and from these events. Young drivers aged 21-29 are at greatest risk of being involved in automobile accidents, particularly if they have been consuming alcohol (Bates, Davey, Watson, King, & Armstrong, 2014; Regev, Rolison, & Moutari, 2018). The majority of music festival patrons consume alcohol during the event (Martinus et al., 2010), with a median consumption of 12 standard drinks (Fernando et al., 2018); three times the National Health and Medical Research Council's threshold for risky single instance drinking (National Health and Medical Research Council, 2009). The combination of heavy alcohol use and a young patron demographic consequently highlights music festivals as transient but high-risk settings for risky driving and subsequent harms.

Multiple studies have demonstrated adverse effects of acute alcohol consumption on domains of cognition, including attention, working memory and response inhibition (Abroms, Fillmore, & Marczinski, 2003; Abroms et al., 2006; Dougherty et al., 2000; Marczinski & Fillmore, 2005). Importantly, cognitive impairment has also been demonstrated in select domains as a result of the next-day effects (i.e., hangover) of heavy alcohol consumption, including direct driving ability, attention, memory and psychomotor speed (Gunn et al., 2018). Given that the majority of festival patrons consume alcohol, it is possible that adverse residual effects extend into sober post-event driving windows which may result in a reduction of cognitive processes relevant to driving safety. The is concerning when considering the number of patrons who drive home after festivals, both on a national and global scale. However, alcohol-related impairment is not universal across all cognitive domains and its effects are typically dose-dependent at both an acute and residual level. It is thus important to assess which domains and to what degree individuals may be residually impaired by alcohol consumption in the festival context.

In addition to alcohol consumption, fatigue is also a factor of concern in regard to driving safety. Multi-day festivals are densely populated and noisy environments; musical acts will often continue after midnight. For these reasons, patrons are likely to experience some degree of sleep deprivation throughout the course of the festival. Fatigue is known to attenuate select cognitive and motor abilities relevant to driving; both sleep deprivation (prolonged wakefulness) and partial sleep deprivation (chronic sleep restriction) can affect cognition, though to differing degrees (Alhola & Polo-Kantola, 2007). Specifically, total sleep deprivation can reduce attention, working memory and the ability to make decisions, while partial sleep deprivation can reduce attention. The effects of sleep deprivation on psychomotor performance have been shown to match or surpass those seen in alcohol intoxication. Seventeen hours of continuous wakefulness can impair cognitive psychomotor performance (e.g., hand eye coordination) up to levels seen at 0.05% blood alcohol concentration (Dawson & Reid, 1997); the legal driving threshold in Australia. Twenty-four hours of continuous sleep deprivation can impair these abilities up to levels of 0.10% blood alcohol concentration (double the limit).

In line with experimental impairment-related alcohol and fatigue research, a recent cross-sectional study identified that number of alcoholic drinks consumed, perceived breath alcohol concentration, license type (relating in part to proscribed legal BAC; 0.00% g/mL for learners/provisional and 0.05% for full) and number of hours slept were all strongly correlated with perceptions of in-the-moment driving safety amongst festival patrons (Fernando et al., 2018). However, half (45%) of all patrons interviewed at an event intended to drive that day despite only one in five feeling completely safe to do so (Fernando et al., 2018). There is a clear overlap between individuals at music events who do not feel safe to drive yet still intend on driving that same day. The potential for risky driving behaviours has sparked cause for driving-related safety strategies at music festivals. Indeed, there are efforts at some music festivals to both increase awareness of driving risks (e.g., messaging around alcohol, drugs, fatigue and driving) and reduce the risk of drink driving (e.g., free breath testing). However, the extent to which a compounding combination of residual alcohol impairment (i.e., sober impairment), fatigue, as well as other festival related factors (e.g., poor nutrition, dehydration) may contribute to driving-related deficits in this context is yet to be elucidated empirically.

To date, no studies have attempted to investigate the objective effect of residual alcohol intoxication or fatigue on the impairment of driving ability, or its associated cognitive processes, at the conclusion of a multi-day music event or other prolonged drinking setting. The objective of the present study was to compare performance on attention and working memory tasks at the conclusion of a multi-day music event with performance at varying levels of acute alcohol intoxication in a controlled environment (0.00%, 0.05% [ascending and descending limb] and 0.08% g/mL). Specifically, we aim to assess whether performance on any component of these tasks is poorer after festival attendance when compared with performance while acutely intoxicated.

4.4 Methods

4.4.1 Design and Setting

This study utilised a repeated measures quantitative design, comprising two phases:

1.) A single laboratory-based experimental session in which an acute alcohol dose was administered, and cognitive task performance was assessed across the BrAC curve (up to peak of 0.08%). This established baseline performance at 0.00% BrAC and the subsequent effects of intoxication in a controlled setting; and

2.) A field study involving the same individuals, in which objective measurements of intoxication and cognitive task performance were taken in-situ at conclusion of attending a four-day music festival.

Data collection took place at two sites: the laboratory phase at the University of Tasmania Hobart campus between January and February 2018; the festival phase at an Australian music festival (patron capacity of 7,000) in the first quarter of 2018. The festival attended by participants was an open-air event, set in a field, with accommodation predominantly comprising tents and vehicles brought by patrons. This study was approved by the University of Tasmania Human Research Ethics Committee (ref# H0016125) and approval to operate on-site was provided by festival organisers

4.4.2 Participants

Participants were recruited online via social media advertisements (the same cohort of individuals recruited in *Chapter 3* of this thesis). Inclusion criteria included: aged 18-34 years, encompassing the largest proportion of festival patrons by age, whom are also the most likely to binge drink and are most susceptible to alcohol related harms (Australian Bureau of Statistics, 2015; Spear, 2004); English as a first language (to ensure question and task comprehension); completed high school or equivalent; frequent alcohol consumption (minimum consumption of two standard alcoholic beverages on one occasion in the preceding month to ensure alcohol familiarity); normal or corrected-to-normal vision; normal sleep patterns; body mass index between 18.50 and 29.9; and able to attend the festival for all days (including camping on-site). Participants were excluded for: recent illicit drug use (preceding 6 months); regular tobacco use; a history of a significant medical/mental condition, a history of an alcohol or drug dependence disorder or use of alcohol at hazardous or harmful levels (evident via a score of 16 or higher on the Alcohol Use Disorders Identification Test [AUDIT]) (Saunders et al., 1993).

Of the 136 individuals who completed an initial screening questionnaire, 15 met eligibility criteria (53% male; mean age 21.9 years, SD 3.6, range 18-29). Most ineligible applicants scored >16 on the AUDIT (66% of total applicants), were regular tobacco consumers (25%), had recently used illicit substances (23%) or had a history of or a current mental health condition (8%). Participants received admission into the festival as reimbursement for participation and all had attended at least one festival prior to participation. Participants were not encouraged by the researchers to consume alcohol as part of the festival experience; the consumption of alcohol at the festival was at the discretion of the participant.

4.4.3 Measures

Cognitive Assessment Battery

A cognitive assessment battery was compiled to measure cognitive domains that are related to driving, guided by the International Council on Alcohol, Drugs and Traffic Safety's experimental guidelines (Verster, Seithikurippu, Ramaekers, & de Gier, 2009), and are known to be acutely affected by acute alcohol intoxication (Zoethout et al., 2011). Participants completed the assessments four times during the laboratory session (0.00%, 0.05% [ascending and descending limb] and 0.08% BrAC) and on the final morning of the festival (0.00% BrAC). The assessment battery included three primary assessments:

1.) Arrow Flankers (AF; Eriksen & Eriksen, 1974): This task assessed selective attention. It required the participant to react to a central stimulus - an arrow pointing left or right - by selecting the arrow key indicating the corresponding direction. The central stimuli are presented with *flankers*; two congruent or incongruent arrows (arrows pointing in the same or opposite direction to the central stimulus, respectively), neutral stimuli (squares) or no-go suppressors (crosses) to both the left and right of it. Participants were asked to not respond to no-go trials. There were 80 trials, with congruent, incongruent and neutral flanking stimuli comprising 30% of these each. The final 10% comprised suppressor trials. Difference between neutral and incongruent flanker trial RT (incongruent RT), difference between congruent and neutral trial RT (congruent RT), RT of correct responses, number of incorrect responses for all trials, and percent of no-go errors (responses to the suppressor condition [response inhibition]) were recorded.

2.) Rapid Visual Information Processing (RVIP; Wesnes & Warburton, 1983): This task assessed sustained attention. The RVIP is a task in which single digits appear sequentially (600ms inter-stimulus interval) inside a white box centre-screen. Participants were asked to respond as quickly as possible whenever there were a specific three number sequences (three even or three odd numbers in a row). There was a total of 300 trials; 8% comprised targets (n=24) and the sequence was randomly presented. RT of correct responses and percent of correct responses were recorded.

3.) N-Back (Jonides et al., 1997): This task assessed working memory. It displayed a sequence of letters (15 stimuli every 20 seconds), and for each letter the participant had to decide if it matched the letter that preceded it by *n* places in the series. For example, in the two-back version of the test, the participant responded if the presented letter was the same as the one presented two trials previously. The 1-Back, 2-Back and 3-Back were all included in the battery, with each respective task increasing in difficulty. Targets comprised 20% of the 35 total 1-back trials (n=7) and of the 80 total 2-back and 3-back trials (n=16 each). Percentage of correct responses were recorded.

Questionnaire

A questionnaire was completed by participants on arrival to the laboratory and on the final morning of the festival using a 9.7” Samsung tablet S2 using REDCap software. The questionnaire included: Alcohol Hangover Severity Scale (AHSS, Penning et al., 2013), a 12 item questionnaire assessing hangover severity using an 11 point Likert scale; number of standard drinks consumed in previous 24 hours (1 standard drink = 10g of alcohol); illicit drug use in previous 24 hours (yes/no); Karolinska Sleepiness Scale (KSS), a single-item assessment of subjective fatigue using a 1-9 Likert scale (Kaida et al., 2006) and hours sleep in the previous 24 hours (including napping). Participants at the festival also retrospectively self-reported their alcohol consumption twice daily on each of the festival days.

Breath Alcohol Concentration

Breath alcohol concentration (BrAC) was measured at each intoxication timepoint (in the laboratory) and on the final morning of the festival using Andatech AlcoSense Prodigy S police-grade breathalysers. These devices have a detectable BAC range of 0.000% to 0.400%, and an accuracy of ±0.005% at 0.100%.

4.4.4 Procedure

Laboratory

Participants who met initial screening requirements were asked to attend a 4-hour laboratory session (commencing 11am), abstaining from alcohol and caffeine for 24 hours and food 4-hours before attending. Weight and height were measured. A preliminary breath assessment was conducted to rule out on-arrival intoxication. The cognitive tasks to be completed during the session (AF, N-Back, RVIP) were explained both verbally and using instruction sheets. The questionnaire was completed, and participants undertook the cognitive test battery (on an electronic tablet) at 0.00% BrAC. They were given one-minute trials of each task prior to baseline testing.

Following the baseline cognitive assessment, an alcoholic beverage was administered comprising vodka, 400mls of soda water and 40mls of low-calorie hazelnut flavoured syrup. The quantity of alcohol provided was calculated according to the Widmark equation (Dry et al., 2012) allowing a target BrAC of 0.08% to be reached. They were given ten minutes to orally consume the beverage. As retention of mouth alcohol can influence breathalyser sensitivity (Spector, 1971) they were instructed to avoid retaining the beverage in their mouth for longer than five seconds. They were encouraged to drink the beverage at a steady pace throughout the administration period. Participants rinsed their mouths with water after administration to further eliminate alcohol mouth retention. Except for a standard amount of still water (250ml) provided upon request, participants were not able to consume any other fluids for the duration of the experimental session. A post-consumption breath assessment was immediately taken, with participants undergoing the psychomotor battery once breathalyser readings indicated that the participant was at 0.05% BrAC on the ascending limb of the alcohol curve. Participants once again completed the battery when identified as being at 0.08% BrAC on the ascending limb (or at peak BrAC if they did not reach 0.08%) and at 0.05% BAC on the descending limb. BrAC readings were taken every ten minutes post-consumption until the participant had completed all psychomotor assessments.

Festival

The festival attended by participants was an open-air event, set in a field, with accommodation predominantly comprising tents and vehicles brought by patrons. Participants travelled independently to the festival (up to 3 weeks post laboratory testing), presenting to members of the research team at the ticketing tent on arrival for an orientation between 1pm and 4pm. They were directed to the research camp: the meeting place for subsequent data collection. Participants were required to establish a static meeting time (between 9:30am and 11:30am) for the assessment on the final morning of the festival to be completed. This session comprised a questionnaire, a breath alcohol assessment and completion of the cognitive test battery (on an electronic tablet), completed under silent conditions in an on-site purpose-built private gazebo. Other than the face-to-face session with the research team, participants were asked to behave as they normally would in the festival environment. They were not asked to be at any specific breath alcohol level for testing on the final morning.

4.4.5 Data Analysis

All statistical analyses were conducted using IBM SPSS Statistics 19. One participant was removed from the sample post-event due to a high breath alcohol reading (0.07%) on the final day of the festival. One more participant was removed after reporting illicit drug use to minimise the effect of confounds. The final sample for analysis comprised 13 participants, 53% of whom were male (Mean age = 23.5, SD = 3.7, Range 18 to 29).

Self-reported alcohol consumption was analysed to determine the extent to which participants consumed alcohol over a) the course of the event and b) in the 24 hours prior to departure. Pre-departure breath alcohol readings were analysed to ensure all participants were not acutely affected by alcohol at the time of festival testing. Subjective ratings of sleepiness, hangover and hours slept were then compared between the laboratory and festival, using paired samples t-tests, to determine differences in these impairment-relevant factors.

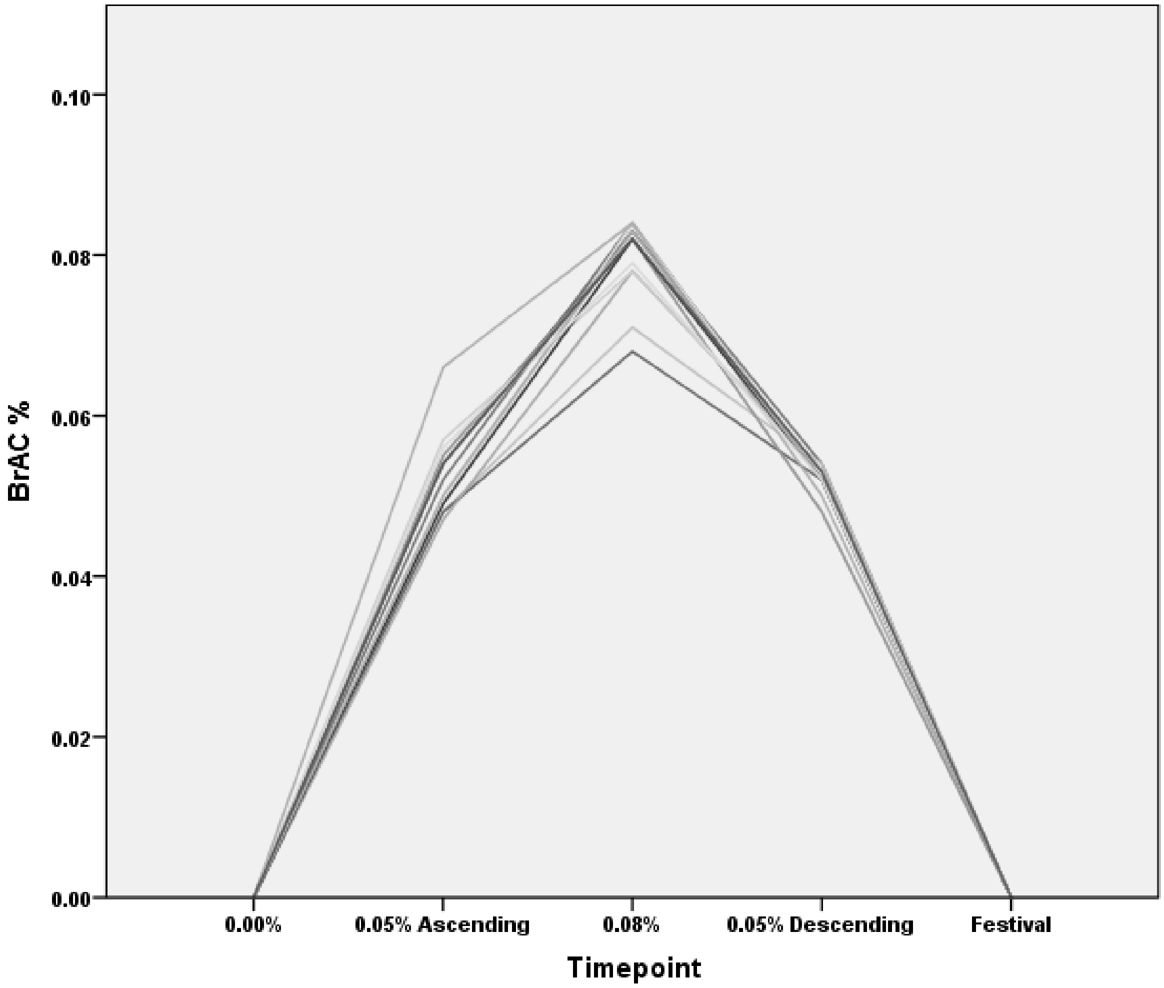
Paired comparisons between the baseline laboratory timepoint (0.00% BrAC) and the intoxicated laboratory timepoints (0.05% ascending, 0.08% and 0.05% descending) were conducted to assess cognitive task sensitivity to acute alcohol consumption (i.e., to determine the extent to which alcohol acutely impaired task performance within our sample). While an *a priori* power calculation was not conducted, given our small sample size, additional Bayesian paired samples T-tests were conducted to compute Bayes Factors (testing the null hypothesis) between baseline laboratory performance and each level of the controlled intoxication performance. Repeated measure ANOVAs were then performed to compute the main effects of timepoint (each laboratory and festival assessment) on the cognitive task outcomes. Mauchly's test was undertaken to assess for violations of sphericity, with Greenhouse-Geisser corrections applied as necessary. Statistically significant main effects underwent paired comparisons to determine differences between the festival outcomes with those at each varying degree of intoxication in the laboratory (0.00% festival BrAC vs 0.00% laboratory BrAC, 0.05% laboratory BrAC [ascending and descending limb] & 0.08% laboratory BrAC). Magnitude of these differences (Cohen's *d*) was uniformly calculated and used to aid interpretation, with effect sizes >0.40 considered as meaningful.

4.5 Results

4.5.1 Laboratory BrAC

All participants were assessed and determined to be at 0.00% BrAC during the baseline measure of cognitive performance. Mean BrAC at the 0.05% ascending timepoint was 0.052% (SD=0.001, range 0.047 to 0.066). Mean BrAC at the 0.08% timepoint was 0.080% (SD=0.001, range 0.068 to 0.084). Mean BrAC at the 0.05% descending timepoint was 0.052% (SD=0.002, range 0.048 to 0.054). See Figure 4.1 for individual BrAC readings at each assessment timepoint.

Figure 4.1 BrAC Readings at Cognitive Assessment Timepoints (N=13)



4.5.2 Pre-Assessment BrAC and Festival Alcohol Consumption

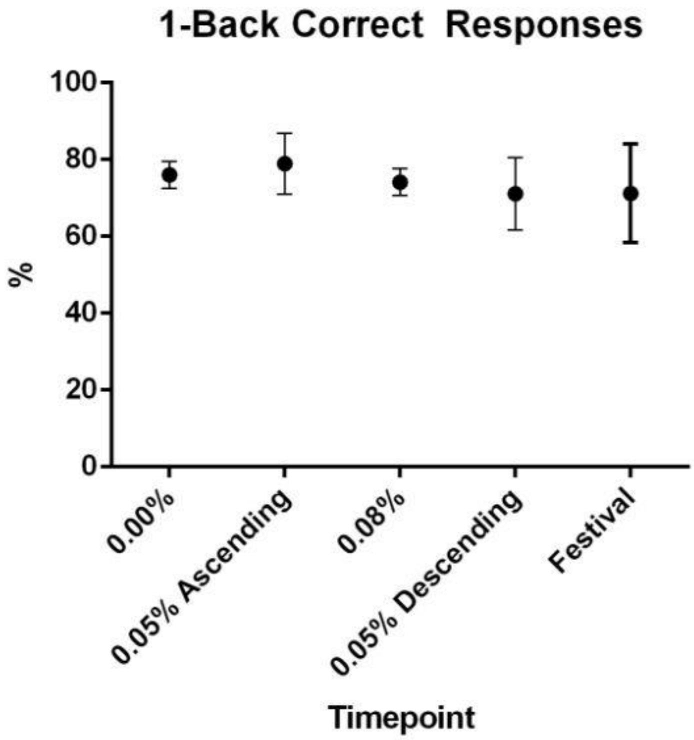
All analysed participants returned a breath alcohol assessment of 0.00% on arrival to the laboratory, as well as the morning before leaving the festival. Participants self-reported consuming an average of 23.5 standard drinks over the course of the 72-hour event (SD=9.1, range 8 to 40) and 10.6 standard drinks in the 24 hours before the festival assessment (SD=5.5, range 2 to 18). All participants consumed alcohol in the 24 hours prior to conclusion of the event.

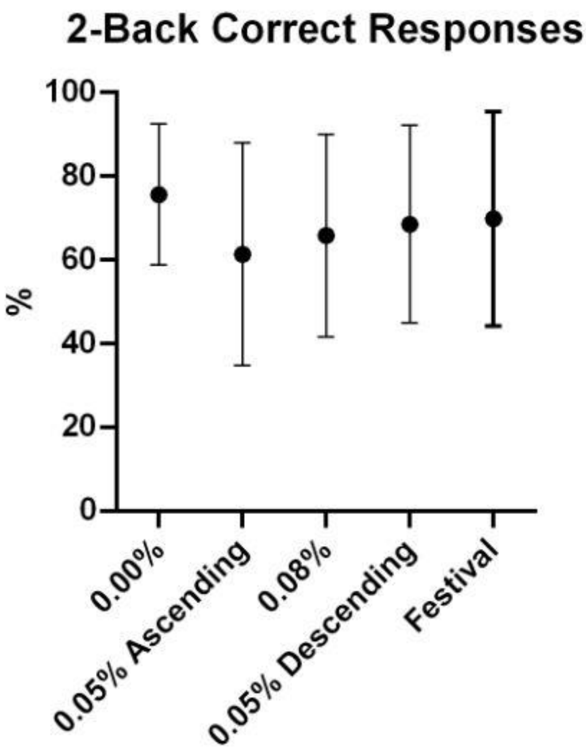
4.5.3 Subjective Sleepiness, Hangover and Hours Slept

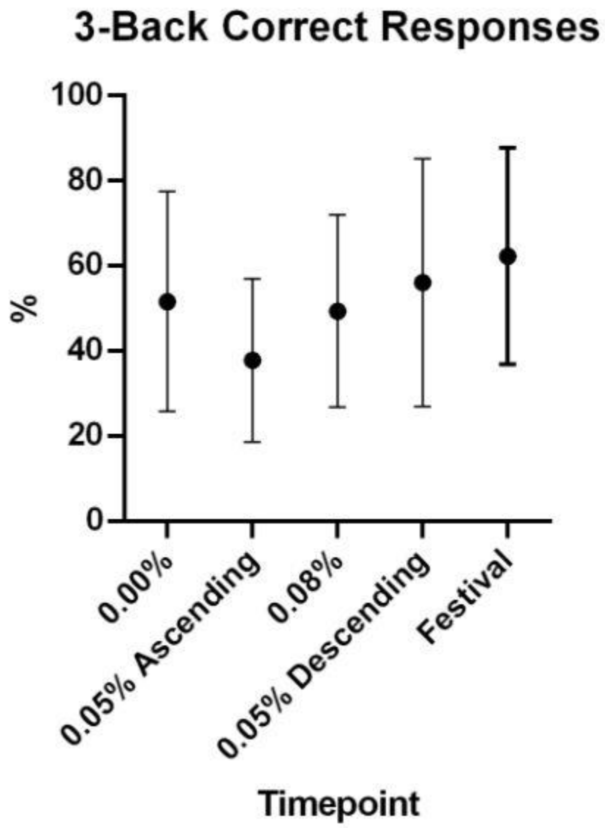
In the laboratory session, participants reported 8.1 hours of sleep in the previous 24 hours (SD=1.3, range 6 to 10), a mean KSS score of 3 (alert; SD=1.6, range 1 to 6) and an average AHSS score of 0.8 (SD=0.7, range 0.2 to 2.5). On the last day of the festival, participants reported 6.5 hours sleep in the previous 24 hours (SD=1.6, range 3 to 9), a mean KSS score of 5.6 (neither alert nor sleepy; SD=2.0, range 2 to 8) and a mean AHSS score of 2.2 (SD=1.1, range 0.7 to 4.5).

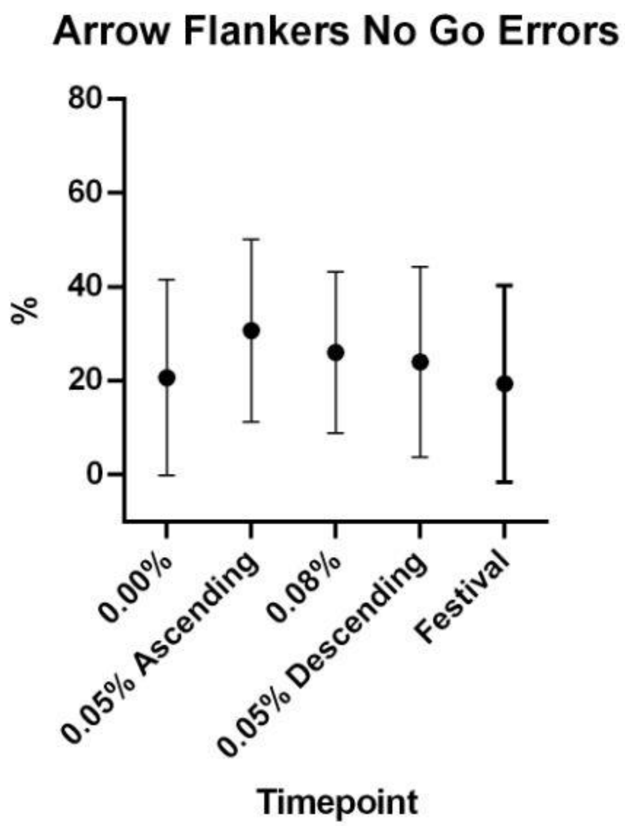
Paired samples t-tests were performed to assess for differences in these measures between the festival and laboratory timepoints. At the festival, participants reported significantly greater subjective sleepiness, t(12)=3.770, *p*=.003, 95% CI [1.10, 4.13], BF^{10}=13.7 (E%=1.14e-4), greater mean rating of hangover severity, t(12)=4.126, *p*=.001, 95% CI [0.64, 2.07], BF^{01}=63.2 [E%=2.57e-6), and fewer hours slept in previous 24 hours, t(12)=3.433, *p*=.005, 95% CI [0.58, 2.58], BF^{01}=27.0 (E%=5.51e-5) than reported in the laboratory.

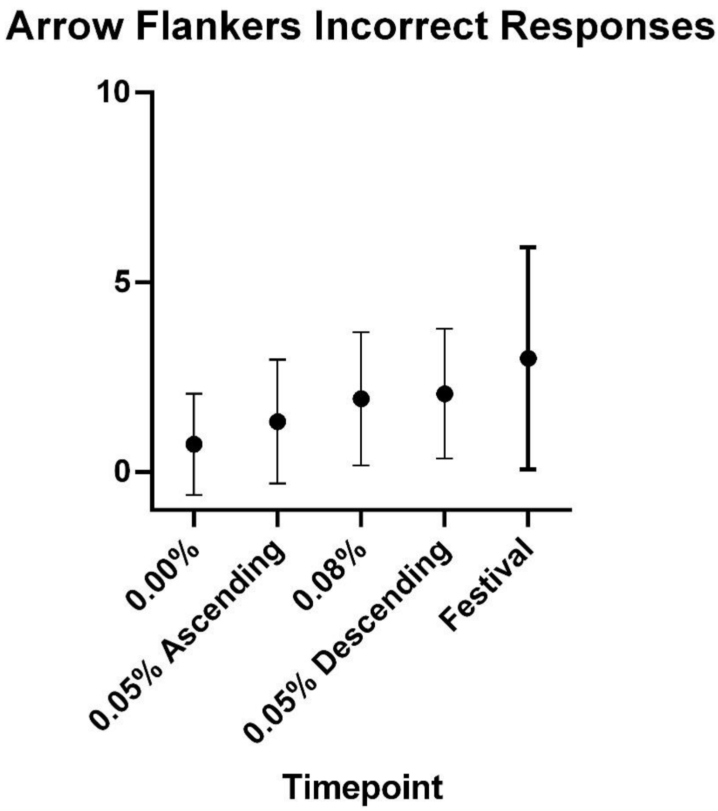
Figure 4.2 Laboratory and Festival Cognitive Task Descriptive Statistics (N=13)

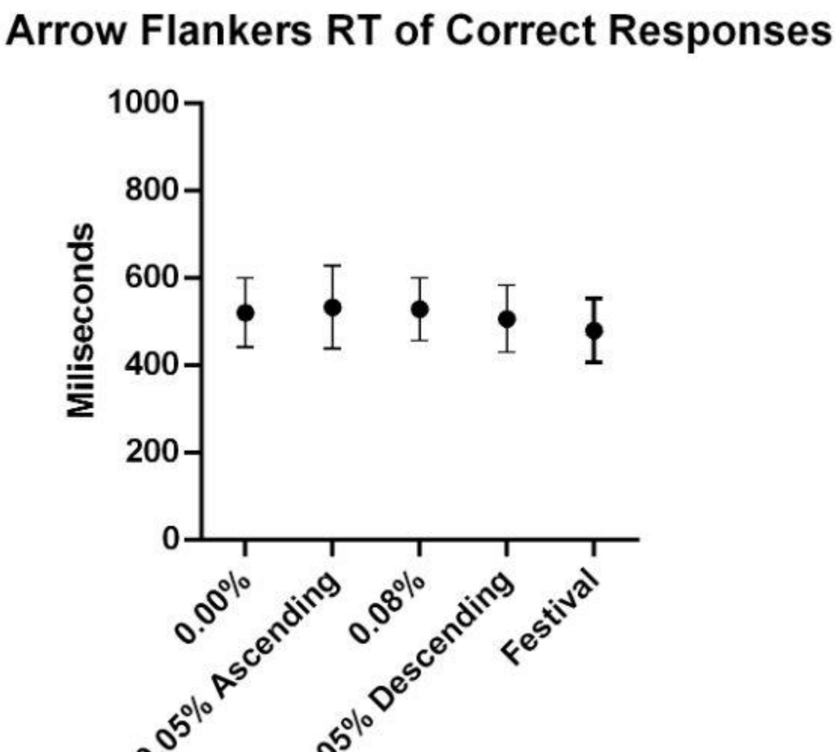


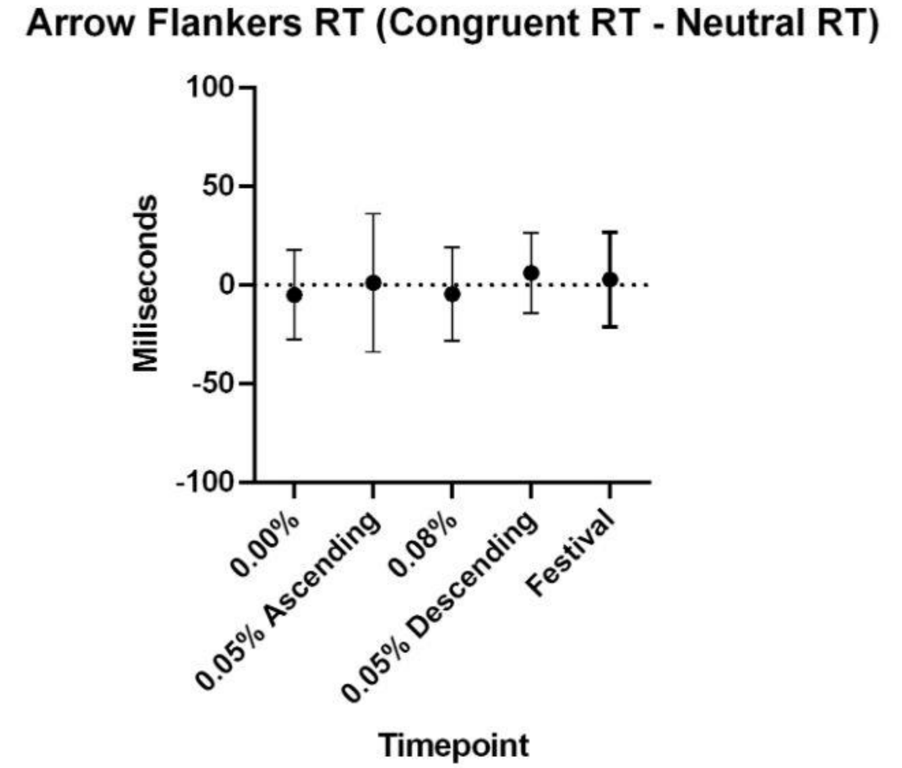


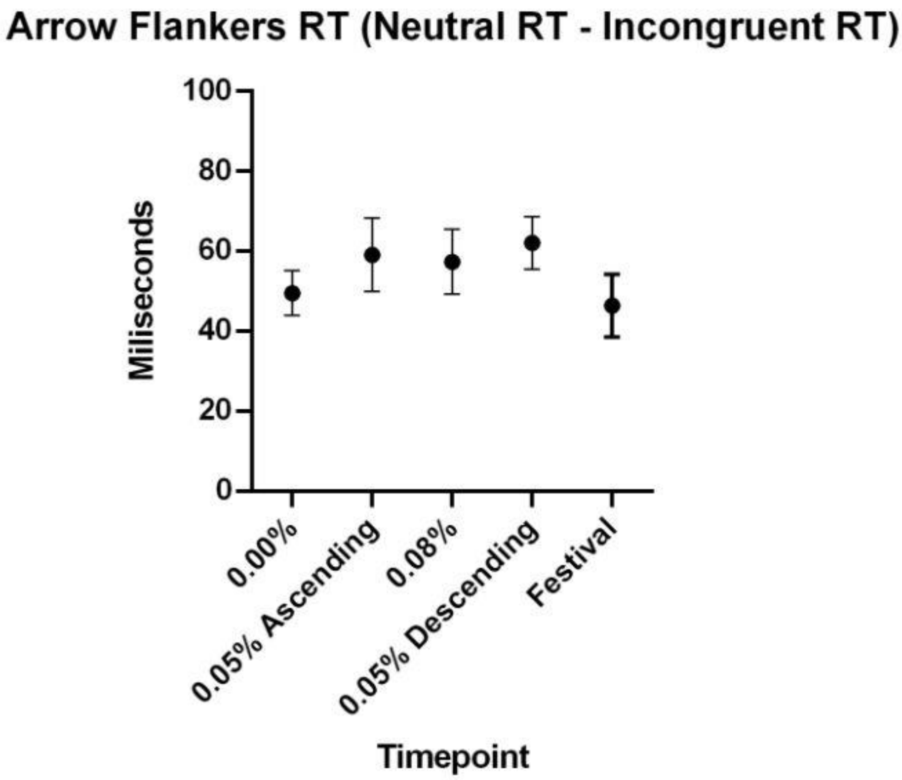

3-Back Correct Responses
100
80
60
40
20
0
%
0.00%
0.05% Ascending
0.08%
0.05% Descending
Festival
Timepoint

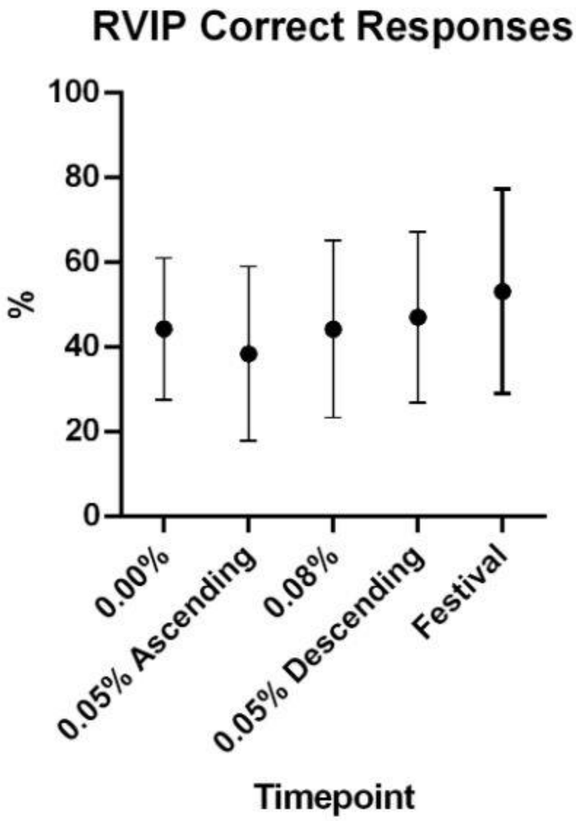

Arrow Flankers No Go Errors
80
60
40
20
0
%
0.00%
0.05% Ascending
0.08%
0.05% Descending
Festival
Timepoint

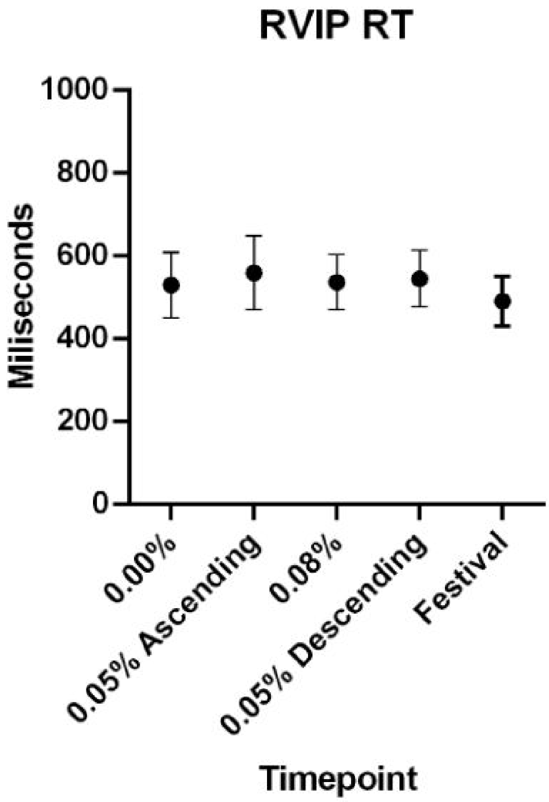

Arrow Flankers Incorrect Responses
10
5
0
0.00%
0.05% Ascending
0.08%
0.05% Descending
Festival
Timepoint


Arrow Flankers RT of Correct Responses
1000
800
600
400
200
0
Miliseconds
0.00%
0.05% Ascending
0.08%
0.05% Descending
Festival
Timepoint


Arrow Flankers RT (Congruent RT - Neutral RT)
Miliseconds
100
50
0
-50
-100
0.00%
0.05% Ascending
0.08%
0.05% Descending
Festival
Timepoint


Arrow Flankers RT (Neutral RT - Incongruent RT)
Miliseconds
100
80
60
40
20
0
0.00%
0.05% Ascending
0.08%
0.05% Descending
Festival
Timepoint





Note: Data points = means. Error bars = standard deviation. RT = reaction time.

4.5.4 Cognitive Performance: Task Sensitivity to Acute Alcohol Intoxication in a Controlled Setting

See Figure 4.2 for task performance descriptive statistics and Table 4.1 for comparison of timepoints within the laboratory session (i.e., 0.00% lab performance vs each intoxication timepoint). When compared to 0.00% BrAC, task performance was significantly sensitive to impairment (i.e., reduced performance) during the stimulatory phase (0.05%) for the RVIP, 2-back and 3-back with medium to large effect sizes. While none of the tasks were significantly sensitive (compared to 0.00%) to impairment at peak of intoxication (0.08%), AF incorrect responses, AF no go errors and 1-back/2-back correct responses had effect sizes ≥0.40. AF incorrect responses were significantly poorer during the descending limb of the alcohol curve (0.05% BrAC) when compared to 0.00%, with a large effect size. No other indicators were significantly different from 0.00% BrAC at this timepoint.

Table 4.1 Summary of Effects: Laboratory Baseline vs Controlled Intoxication Performance

	Paired Comparisons: Laboratory Baseline (0.00% BAC) vs Laboratory Intoxication Levels								
	.05%^			**.08%**			**.05%˅**		
	p	***d***	***BF^{01} (E%)***	***p***	***d***	***BF^{01} (E%)***	***p***	***d***	***BF^{01} (E%)***
Selective Attention: Arrow Flankers									
Incongruent RT, ms (Incongruent - Neutral)	0.576	0.16	3.11 (.017)	0.354	0.27	2.43 (.019)	0.181	0.39	1.59 (.006)
Congruent RT, ms (Congruent - Neutral)	0.882	-0.04	3.56 (.016)	0.480	-0.20	2.86 (.018)	0.311	-0.29	2.25 (.020)
RT Correct Responses, ms	0.829	0.06	3.58 (.016)	0.953	-0.02	3.43 (.017)	0.389	0.25	3.08 (.017)
Total Incorrect Responses	0.478	0.20	2.85 (.018)	0.089	0.51	0.96 (.002)	**0.003**	1.02	0.07 (9.04e-6)
No Go Errors, %	0.083	0.52	0.91 (.002)	0.139	0.44	1.32 (.005)	0.282	0.31	2.12 (.021)
Sustained Attention: Rapid Visual Information Processing									
RT, ms	**0.022**	0.73	0.33 (.001)	0.741	0.09	3.42 (.016)	0.341	0.27	2.37 (.019)
Correct Responses, %	**0.013**	0.80	2.20 (.020)	0.881	0.04	3.59 (.016)	0.516	-0.19	3.36 (.016)
Working Memory: N-Back									
1-Back, % Correct	0.191	-0.40	1.59 (.005)	0.165	0.410	1.48 (.006)	0.088	0.051	0.95 (.002)
2-Back, % Correct	**0.030**	0.68	0.41 (.001)	0.173	0.40	1.53 (.006)	0.292	0.31	2.16 (.020)
3-Back, % Correct	**0.013**	0.802	0.22 (.003)	0.881	0.04	3.56 (.016)	0.516	-0.19	2.96 (.017)

Note: Positive *d* value indicates better baseline (0.00% BrAC) performance, negative *d* indicates poorer baseline performance. Reaction time includes correct responses only. BF^{01}(E%) = Bayes Factor (Error %).
 # = Greenhouse-Geisser correction applied
^ = Ascending limb
˅ = Descending limb

4.5.5 Cognitive Performance: Festival vs Controlled Laboratory Intoxication

See Table 4.2 for a summary of effects between post-festival and controlled intoxication timepoints. AF incorrect response performance at the festival was significantly poorer than at the 0.00% and 0.05% BrAC levels in the laboratory, with large and medium effect sizes respectively. This may have been the result of a speed-accuracy trade off, with participants also performing the task significantly faster at the festival than all timepoints in the laboratory (medium - very large effect sizes). While there were no statistically significant effects for the AF No Go task, there was an effect size of over 0.40 for the 0.05% ascending timepoint, indicating poorer performance while acutely intoxicated. RVIP performance at the festival was significantly better at the festival than at the 0.05% ascending and 0.08% BrAC levels in the laboratory, with large and medium effect sizes, respectively. There were no significant effects for the 1-Back task, however there were effect sizes over 0.40 for the 0.00% and 0.05% timepoints, indicating possible poorer festival performance than while sober and on the ascending limb of intoxication in the laboratory. There were no significant effects across the 2-back timepoints. There was a significant, large effect at the 0.05% level for the 3-back, indicating better performance at the festival than while on the ascending limb of intoxication. Further, while non-significant, the 0.08% level had an effect size >0.40, indicating better festival performance than at peak intoxication.

Table 4.2 Summary of Effects: Festival Performance vs Controlled Intoxication Performance

	Main Effect: Timepoint			**Paired Comparisons and Bayes Factors: Last Day (0.00% BAC) vs Laboratory Intoxication Levels**											
				0.00%			**.05%**$^{\wedge}$			**.08%**			**.05%**$^{\vee}$		
	F	***p***	**ηp²**	***p***	***d***	***BF₀₁* *(E%)***	***p***	***d***	***BF₀₁* *(E%)***	***p***	***d***	***BF₀₁* *(E%)***	***p***	***d***	**BF₀₁ (E%)**
Selective Attention: Arrow Flankers															
Incongruent RT, ms (Incongruent – Neutral)	0.51[#]	0.616	0.041	0.924	-0.03	3.58 (.016)	0.796	0.07	3.49 (.016)	0.598	0.15	3.16 (.017)	0.288	0.31	2.14 (.020)
Congruent RT, ms (Congruent – Neutral)	0.569	0.686	0.045	0.101	-0.49	1.05 (.003)	0.372	-0.26	2.49 (.019)	0.548	-0.17	3.05 (.016)	0.727	-0.10	2.40 (.016)
RT Correct Reponses, ms	6.561	**<.001**	0.353	**0.001**	1.140	0.03 (7.62e-6)	**<0.001**	1.277	0.02 (1.33e-5)	**<0.001**	1.517	<0.00 (7.11e06)	**0.043**	0.627	0.55 (8.01e-4)
Total Incorrect Responses, %	4.250	**0.005**	0.262	**0.013**	-0.81	0.21 (.002)	**0.015**	-0.789	0.24 (7.99e-4)	0.22	-0.36	1.80 (.022)	0.24	-0.34	1.91 (.021)
No Go Errors, %	1.471	0.226	0.109	0.703	-0.12	3.36 (.016)	0.127	0.45	1.24 (.005)	0.219	0.36	1.80 (.022)	0.193	0.38	1.65 (.006)
Sustained Attention: Rapid Visual Information Processing															
RT, ms	2.971	**0.029**	0.198	0.102	0.492	1.05 (.003)	**0.004**	0.984	0.08 (6.15e-5)	**0.040**	0.637	0.52 (9.95e-4)	**0.005**	0.955	0.10 (1.34e-5)

Correct Responses, %	2.577	**0.049**	0.177	0.095	0.502	1.01 (.003)	**0.022**	0.727	0.33 (.001)	**0.030**	0.684	0.41 (.001)	0.101	0.493	1.05 (.003)
Working Memory: N-Back															
1-Back, % Correct	1.441	0.233	0.093	0.175	-0.400	1.55 (.006)	0.111	-0.500	1.09 (.013)	0.387	-0.249	2.55 (.019)	0.154	0.018	3.59 (.016)
2-Back, % Correct	0.932	0.454	0.072	0.644	-0.13	3.26 (.002)	0.359	0.26	2.45 (.020)	0.568	0.16	3.01 (.017)	0.606	0.15	3.18 (.017)
3-Back, % Correct	2.948	**0.029**	0.197	0.301	0.300	2.20 (.024)	**0.013**	0.807	0.21 (.002)	0.169	0.406	1.51 (.006)	0.554	0.169	3.06 (0.017)

Note: Positive *d* value indicates better festival performance, negative *d* indicates poorer festival performance. RT = reaction time. Reaction time includes correct
responses only. BF^{01}(E%) = Bayes Factor (Error %).
 # = Greenhouse-Geisser correction applied
^ = Ascending limb
v = Descending limb

4.6 Discussion

The aim of this study was to compare sober post-festival performance on working memory (N-Back), sustained attention (RVIP) and selective attention (AF) tasks against performance at varying levels of controlled intoxication, to assess for driving-relevant cognitive impairment in the festival context. While greatest impairment was observed during acute intoxication in the laboratory, a significantly greater number of attentional errors (incorrect responses on the AF task) were recorded by participants at the festival than at 0.00% and 0.05% ascending BrAC in a controlled setting.

Before analysing cognitive performance, it was first critical to determine whether, at a subjective level, participants were adversely affected by the 'festival experience' compared to their baseline levels in a controlled setting. In line with previous research (e.g., Fernando et al., 2018; Jenkinson et al., 2014), participants reported consuming alcohol in considerable quantities during the event; three times greater than recommended in a single-instance by the National Health and Medical Research Council (NHMRC, 2009). They also reported sleeping significantly fewer hours on average in the previous 24 hours than they had reported in the laboratory, while simultaneously reporting a greater degree of sleepiness. These differences are pertinent in contextualising the subjective state of individuals following a multi-day music festival, having reported the greatest amount of subjective impairment (both in terms of fatigue and residual alcohol effects) in the festival phase of testing.

In regard to our selective attention task, mean RT of correct responses on the final morning of the festival was significantly faster than all laboratory timepoints (0.00%, 0.05% ascending and descending limb, and 0.08% BrAC). However, total incorrect responses on the final day of the festival saw a significant, large increase (i.e., impairment) over the 0.00% and

0.05% ascending limb timepoints, while differences between the 0.08% and 0.05% descending limbs were non-significant. This suggests that, compared to the sober and early (stimulatory) phase of acute alcohol intoxication in the laboratory, participants performed the task faster at the detriment of overall accuracy relative to 0.00% and 0.05% ascending BrAC. Interestingly, the number of errors made at the festival paralleled those seen at the peak and descending limb timepoints (0.08% and 0.05% respectively), while the sensitivity comparisons in a controlled setting indicated impairment at these levels when compared to the baseline 0.00% BrAC (with a non-significant medium effect at 0.08% and a significant large effect at 0.05% descending). This is an important finding, offering preliminary evidence that aspects of post-festival attentional performance may be impaired to levels akin to the peak (0.08%) and the sedation (0.05%) limbs of intoxication.

This finding may suggest that, at an attentional level, patrons respond to stimuli faster after a festival when compared to their controlled sober performance but are more prone to making errors in their responses. Indeed, such an impairment could have implications in driving contexts. Attention is widely accepted as an important cognitive component in driving safety and suboptimal attentional performance is responsible for a host of accident-causing attentional errors (Hoel, Jaffard, Boujon, & Elslande, 2011). For example, drivers may fail to identify appropriate information from a visual image (looking but failing to see appropriate stimuli in a timely manner) or fail to appropriately respond to identified hazards (Trick, Enns, Mills, & Vavrik, 2004). While the mechanism behind such a speed accuracy trade-off is unclear in this context, one possible explanation is that a hungover and/or fatigued state elicits an attentional apathy towards a given task, resulting in a faster but more careless attentional state.

Pre-departure festival performance on the RVIP (both RT and correct responses), our measure of sustained attention, was significantly better than all controlled laboratory timepoints expect for the baseline (0.00% BrAC), and 0.05% descending timepoints, while the laboratory comparisons indicated sensitivity to acute alcohol consumption at the 0.05% ascending level only. This suggests that impairment on this task was primarily detected on the stimulatory phase of acute alcohol intoxication and was not significantly influenced by alcohol hangover or fatigue at the festival. Given that a recent meta-analysis has shown the next-day effects of alcohol consumption to be associated with a decrement in sustained attention performance (Gunn et al., 2018) and our participants were significantly more subjectively hungover and fatigued when compared to their laboratory assessments, this finding is unprecedented. However, it is important to note that our task did not take into consideration the potential for compensatory responding by participants.

Cognitive compensatory responding, or the compensatory maintenance of cognitive performance in the face of stressors (e.g., fatigue), has been demonstrated in recent electroencephalography studies (Wang, Trongnetrpunya, Samuel, Ding, & Kluger, 2016). Specifically, the recruitment of anterior frontal regions of the brain, regions not typically associated with performance prior to the introduction of stressors, are hypothesised to assist with cognitive load during periods of fatigue. Compensatory responses are temporary and taper off after continued assessment (Wang et al., 2016). The RVIP is a measure of the ability to sustain attention over time. However, our task only ran for 300 trials over a short period of a few minutes. It is possible that, given the brevity of our task, participants were able to effectively compensate during the festival assessment, resulting in an increase in performance over a short period of time. Such compensation may have also been associated with the selective sensitivity to intoxication seen in our controlled comparisons, with impairment in the stimulation phase of intoxication only. It may be that individuals are able effectively compensate for intoxication once past the initial stimulatory phase of intoxication, resulting in a return (albeit temporary) to baseline performance during this assessment. However, given that festivals are often in rural settings, and often involve lengthy drives back to urban regions, it is important to consider that cognitive compensation may not last the length of time it takes to drive back home from the event, resulting in a tapering of performance over time. Consequently, it would be beneficial to investigate post-festival sustained attention over a longer period to determine if compensatory responding is a factor of consideration in this context, and if so, for how long this effect remains.

The N-Back task, assessing working memory, was administered at three levels of difficulty in ascending order. Sensitivity analyses indicated no significant effects for the 1-Back between controlled baseline performance and performance while intoxicated. The 2-Back task was sensitive at the ascending limb (0.05% BrAC) only. Our alcohol sensitivity findings at these levels partially correspond with previous literature, finding that the impairing effect of alcohol at 0.08% BrAC on N-Back performance was dependent on cognitive load, with significant effects exclusively at the 3-Back level (Gundersen, Grüner, Specht, & Hugdahl, 2008). Performance on the 1-Back and 2-Back did not significantly differ between the pre-departure festival and laboratory timepoints. Given that acute intoxication was not impairing enough to elicit an observable difference in performance for the 1-Back, it is possible that this level of the task is simply not demanding enough, in respect to cognitive load, to adequately detect impairment in this context. As the 3-Back is the most cognitively demanding of the three tasks, it is the most likely to detect working memory impairments. However, 3-Back performance in the controlled environment between baseline (0.00% BrAC) and the intoxication levels was poorer at the 0.05% ascending limb only, with festival performance significantly better than this.

4.6.1 Strengths and Limitations

This was the first study to assess cognitive performance following a licensed multi-day music event, as well as compare post-event and controlled intoxication performance. While preliminary findings of this study do indicate possible attentional impairment at the conclusion of the festival, several important caveats should be considered. Firstly, our measures of cognitive performance were not uniformly sensitive to intoxication across the curve (i.e., impairment while acutely intoxicated relative to sober performance), and some did not detect acute intoxication-related impairment at all (up to 0.08% BrAC). While our sample was small and had limited experimental power, the sensitivity of these tests to acute intoxication should be further investigated to ensure that all aspects are highly sensitive to alcohol-related impairment (up to 0.08% BrAC) among individuals demographically similar to the festival-attending population. This would provide a more assured experimental foundation on which to recruit additional participants and increase power for further analyses, or possibly highlight a need to identify tests that are more sensitive than those deployed in this study to ensure impairment can be adequately detected.

Secondly, our subjective impairment measures did not necessarily encapsulate all performance-relevant factors; there may be relevant influences that were not assessed during the course of the event (e.g., food consumption), which should be further investigated.

Thirdly, ethical and methodological considerations precluded recruitment from the highest-risk subset of the population, including those who regularly consume illicit substances, drink heavily and/or regularly consume tobacco. Indeed, the excluded subset may have included those with a higher propensity to engage in risk behaviours associated with cognitive performance attenuation. Our sample may have subsequently underestimated the level of post-festival impairment that would be experienced by these individuals.

Finally, despite marked efforts to provide participants with a controlled testing environment at the festival (e.g., quiet conditions and an enclosed space), it is possible that there were more distractions present at the festival. It is difficult to discount that this may have had some influence on the data. It is thus recommended that future studies aim to replicate the original testing environment as closely as possible.

4.6.2 Conclusions

Real-world driving-related performance after multi-day events is an important but under-investigated line of research. While the broadest driving-relevant cognitive impairment was detected during acute alcohol doses in a controlled setting, festival performance on the error component of our selective attention task was poorer than at 0.00% and 0.05% BrAC in a controlled setting. This is an important preliminary finding, suggesting that the absence of blood alcohol acutely is not necessarily indicative of unimpaired cognitive performance and that other factors related to multi-day drinking settings (e.g., hangover, fatigue) may result in driving-related cognitive deficits. While these findings need to be replicated in a larger sample, they suggest that policy makers should consider including messages about the dangers of residual cognitive impairment in driver safety campaigns targeting festival goers.

4.7 Acknowledgements

We would like to thank the festival organisers for their support and permission to operate on-site, as well as our participants for their contribution to this research.

Chapter 5: Arrow Flankers, N-Back and Rapid Visual Information Processing Tasks: Sensitivity to Alcohol-Induced Impairment Among Young Alcohol Consumers

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5.1 Preface

Chapter 4 investigated the use of a portable battery of cognitive tests (Arrow Flankers, N-Back and RVIP) to assess post-festival cognitive performance relative to performance across three levels of the alcohol intoxication curve: 0.00% BrAC, 0.05% ascending, 0.08% (target peak) and 0.05% descending. However, initial within-person sensitivity analyses between 0.00% BrAC and the latter three levels revealed inconsistent or non-statistically significant difference in task performance despite being acutely intoxicated.

As the aim of the previous chapter was to utilise the battery of tasks to assess alcohol-related next-day impairment (i.e., hangover), it is important to ensure that the tasks detect acute intoxication-related impairment relative to 0.00% BrAC. While a sensitivity analysis was conducted in *Chapter 4*, the previous study was predominantly a pilot study to assess the viability of the novel methodology in-situ. It is thus possible that the effect of intoxication on task performance was not large enough to be detect impairment with the small sample size used (n=13), or a detect change in performance from alcohol impairment. The following chapter will subsequently briefly repeat the sensitivity analysis described in Section 4.5.4, with the recruitment of additional participants to increase statistical power.

5.2 Abstract

Background: Portable cognitive assessments are a potentially important tool in the assessment of the objective next-day effects of alcohol intoxication. However, it is currently unclear how sensitive some of these tasks are as a measure of acute alcohol-induced impairment. The aim of this study was to assess the sensitivity of a battery of cognitive tests to acute alcohol impairment in a controlled setting.

Methods: Participants (n=52) completed three objective cognitive tasks (Flankers, N-Back and Rapid Visual Information Processing, RVIP tasks) measuring selective attention, working memory, and sustained attention at a target breath alcohol concentration (BrAC) of 0.00%, 0.05% (ascending and descending) and 0.08% following acute dosing in a controlled laboratory setting.

Results: All aspects of the Flankers task were non-significant across the intoxication curve when compared to 0.00% BrAC, indicating that the task was not sensitive to this level of acute alcohol intoxication. N-Back impairment differed across the curve depending on the load factor (i.e., difficulty) of the task, but saw the greatest impairment on the ascending limb when compared to 0.00% BrAC. The RVIP was significant at the 0.05% ascending level only when compared to 0.00% BrAC.

Conclusions: While some aspects of the tasks were sensitive to intoxication, it would be beneficial for future field-based impairment assessments to find attention- and memory-specific tasks that are highly sensitive to the impairing effects of acute alcohol intoxication, characterised by consistent impairment detection across most or all of the alcohol curve.

5.3 Introduction

Assessing alcohol-related driving impairment in naturalistic settings, including the next-day effects of alcohol consumption, is important to guide future public health policy, health promotion initiatives and interventions. Deploying tasks that can detect alcohol impairment is critical in achieving this. Specifically, when assessing cognitive domains known to be adversely impacted by specific levels of acute alcohol intoxication (e.g., attention), it is important for tasks measuring performance on these domains to successfully detect impairment relative to baseline (e.g., sober) performance. While driving simulators are sensitive to changes in performance from low-level alcohol intoxication relative to 0.00% BAC, they are infrequently used in field research due to their high cost and other logistical considerations (Zoethout et al., 2011). Given this, the use of more affordable and portable cognitive tasks is a possible solution as a proxy measurement to assess alcohol-related impairment in driving-relevant cognitive domains. It has been demonstrated that both attention and working memory are related to driving performance (Tabibi, Borzabadi, Stavrinos, & Mashhadi, 2015; Van Dyke & Fillmore, 2015), and are both impaired by alcohol (Zoethout et al., 2011). Therefore, deploying tasks that measure performance in these cognitive domains under controlled (e.g., laboratory) conditions, then comparing in-situ cognitive performance with the baseline (or referent) measurements, can help determine relative impairment. Referent measurements can include performance while not under the influence of alcohol (i.e., 0.00% BrAC), or while acutely intoxicated at levels relevant to real-world policy (such as the Australian legal driving limit of 0.05% BrAC). However, to conduct such a methodology, it is important to first ensure that the tasks being delivered to participants are sensitive to the impairing effects of acute alcohol intoxication, relative to 0.00% BrAC.

Chapter 4 outlined the use of the Arrow Flankers (measuring selective attention), N-Back (working memory) and Rapid Visual Information Processing (RVIP; sustained attention) tasks, to compare objective performance after acute alcohol consumption under controlled conditions with performance after a multi-day alcohol consumption session. However, when assessing the sensitivity of the task to the impairing effects of acute alcohol consumption in a controlled setting, up to 0.08% BrAC, our results did not yield uniform impairment of performance (characterised by non-significant *p* values and weak effect sizes) across the alcohol curve. This was further highlighted by inconclusive Bayes factors at various levels of the curve.

It is currently unclear whether the Arrow Flankers, N-Back and RVIP tests are subsequently sensitive enough for testing alcohol impairment amongst our sample of young (<35 years of age) alcohol consumers, or whether our findings were the result of low statistical power due to a small sample, with only 13 participants initially trialled. Moreover, it may be the case that alcohol impairs performance at one level of the curve (e.g., 0.05% ascending), but not at another (e.g., 0.08%) due to, for example, the stimulatory and sedative (biphasic) effects of alcohol intoxication (Addicott, Marsh-Richard, Mathias, & Dougherty, 2007). This was indicated by our preliminary findings in *Chapter 4* and has been demonstrated in other cognitive assessments (Zoethout et al., 2011). Considering this, we aimed to once again test these tasks for the sensitivity of alcohol-related impairment (i.e., reduced performance with intoxication), increasing our sample to a group of over 50 individuals to increase statistical power.

5.4 Methods

5.4.1 Design and Setting

This study utilised a repeated measures quantitative design. A single laboratory-based experimental session was conducted with each participant, in which an acute alcohol dose was administered, and cognitive/psychomotor performance was assessed across the BrAC curve (0.0%, 0.05% ascending, 0.08% and 0.05% descending). This established baseline performance at 0.00% BrAC and the subsequent effects of alcohol in a controlled setting. This study was approved by the University of Tasmania Human Research Ethics Committee (ref# H0016125).

5.4.2 Participants

Participants were recruited via social media advertisements. Inclusion criteria included: aged 18-34 years, encompassing individuals most likely to binge drink and are most susceptible to alcohol related harms (Australian Bureau of Statistics, 2015; Spear, 2004); English as a first language (to ensure question and task comprehension); completed year 12 or equivalent; frequent alcohol consumption (minimum consumption of two standard alcoholic beverages on one occasion in the preceding month to ensure alcohol familiarity); normal or corrected-to-normal vision; normal sleep patterns and; a body mass index between 18.50 and 29.9. Participants were excluded for: recent illicit drug use (preceding 6 months); regular tobacco use; a self-reported history of a significant medical/mental condition or history of alcohol or drug abuse or dependence disorder; or use of alcohol at hazardous or harmful levels (evident via a score of 16 or higher on the Alcohol Use Disorders Identification Test [AUDIT]) (Saunders et al., 1993).

A total of 52 individuals were recruited for the study, 53% of whom were female, with a mean age 23.0 years (SD= 3.2, range 18 to 31). Fourteen of the participants included in this study were the same participants described in *Chapter 4*.

5.4.3 Measures

Cognitive/Psychomotor Assessment Battery

A cognitive and psychomotor assessment battery was used to measure cognitive domains that are related to driving, guided by the International Council on Alcohol, Drugs and Traffic Safety's experimental guidelines (Verster et al., 2009). These are the same measures utilised in *Chapter 4* of this thesis. However, the 'total errors' component of the Arrow Flankers task was omitted from further analysis as significant effects were seen in the field-based analysis of *Chapter 4*.

Breath Alcohol Concentration

Breath alcohol concentration (BrAC) was measured using an Andatech AlcoSense Prodigy S police-grade breathalyser. This device meets Australian standards that are consistent with those applied in law enforcement contexts.

5.4.4 Procedure

Participants who met initial screening requirements were asked to attend a 4-hour laboratory session (commencing 11am), abstaining from alcohol and caffeine for 24 hours and food for 4-hours before attending. Weight and height were measured. A preliminary breath assessment was conducted to rule out on-arrival intoxication. The cognitive tasks to be completed during the session (RVIP, N-Back, AF) were explained both verbally and using instruction sheets. The questionnaire was completed, and participants undertook the cognitive test battery (on a tablet) at 0.00% BrAC. They were given one-minute trials of each task prior to baseline testing.

Following the baseline cognitive assessment, an alcoholic beverage was administered comprising vodka, 400mls of soda water and 40mls of low-calorie hazelnut flavoured syrup. The quantity of alcohol provided was calculated according to the Widmark equation (Dry et al., 2012) allowing a target BrAC of 0.08% to be reached. They were given ten minutes to orally consume the beverage. As retention of mouth alcohol can influence breathalyser sensitivity (Spector, 1971) they were instructed to avoid retaining the beverage in their mouth for longer than five seconds. They were encouraged to drink the beverage at a steady pace throughout the administration period. Participants rinsed their mouths with water after administration to further eliminate alcohol mouth retention. Except for a standard amount of still water (250ml) provided upon request, participants were not able to consume any other fluids for the duration of the experimental session. A post-consumption breath assessment was immediately taken, with participants undergoing the psychomotor battery once breathalyser readings indicated that the participant was at 0.05% BrAC (or as close to) on the ascending limb of the alcohol curve. Participants once again completed the battery when identified as being at 0.08% BrAC on the ascending limb (or at peak BrAC if they did not reach 0.08%) and at 0.05% BrAC (or as close to) on the descending limb. BrAC readings were taken every five minutes post-consumption until the participant had completed all psychomotor assessments. Participants were allowed to leave the laboratory once they had reached ≤0.03% BrAC.

5.4.5 Data Analysis

All statistical analyses were conducted using Jamovi 0.9.6 and G*Power software.

Firstly, power calculation for a repeated measures design was conducted to ensure that adequate statistical power would be achieved using our sample. With an alpha = 0.05, it was determined that there would be 93.7% power to detect a moderate effect (Cohen's d = 0.4) with our sample size of 52 individuals. It was subsequently deemed that there was sufficient power for analysis.

To determine level of intoxication at administration of the cognitive tests across the sample, mean BrAC was calculated at the 0.00%, 0.05% ascending, 0.08% and 0.05% descending timepoints.

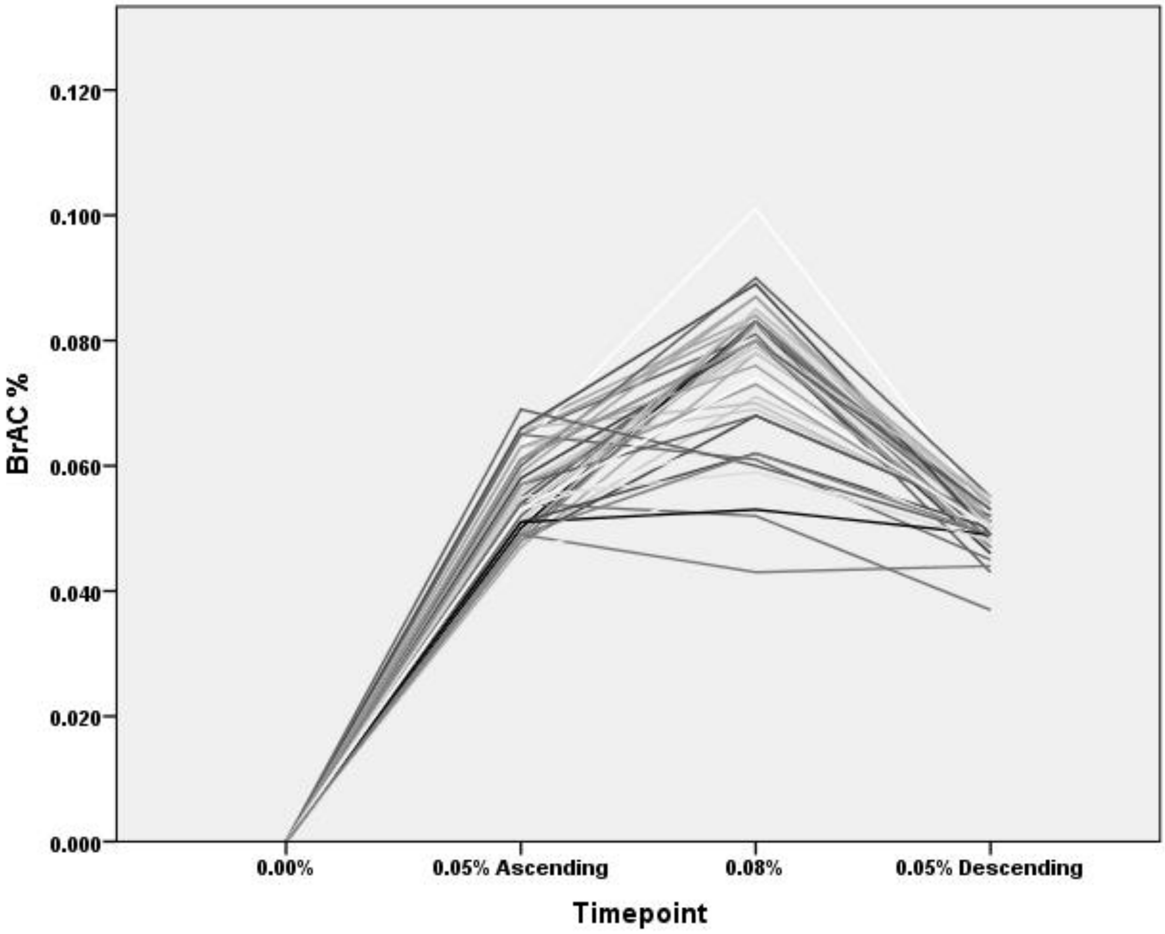
Repeated measure ANOVAs were performed to compute the main effects of timepoint (each laboratory assessment) on the cognitive/psychomotor outcomes. Paired comparisons between the baseline laboratory timepoint (0.00% BrAC) and the intoxicated laboratory timepoints (0.05% ascending, 0.08% and 0.05% descending) were conducted to assess cognitive task sensitivity to acute alcohol consumption (i.e., to determine the extent to which alcohol acutely impaired task performance within our sample). Additional Bayesian paired samples T-tests were conducted to compute Bayes Factors (testing the null hypothesis) between baseline laboratory performance and each level of the controlled intoxication performance. Mauchly's test was undertaken to assess for violations of sphericity. To minimise concerns of inflation of Type I errors, effect sizes were computed to assess magnitude of differences between timepoints. Effect sizes >0.40) were considered meaningful and interpreted.

5.5 Results

5.5.1 BrAC

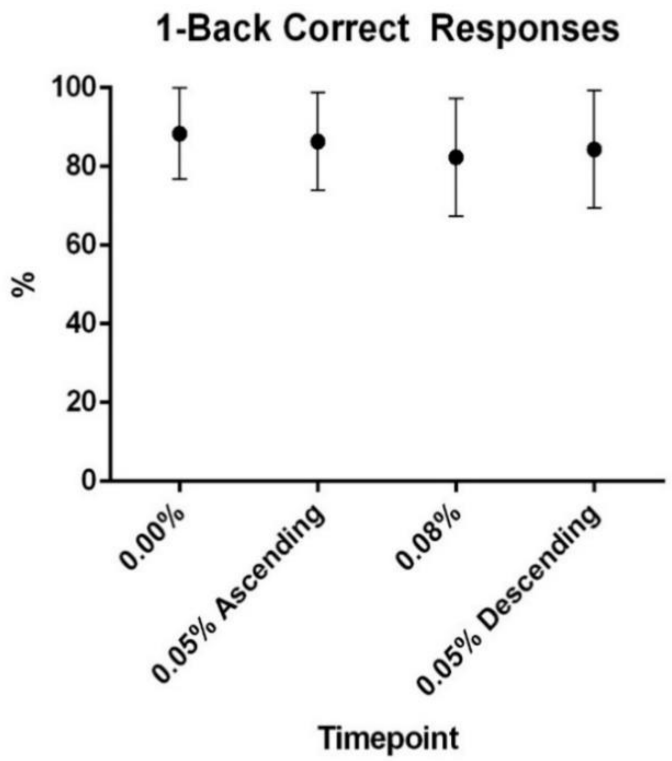
All participants had their BrAC assessed and determined to be at 0.00% during the baseline measure of cognitive performance. Mean BrAC at the 0.05% ascending timepoint was 0.055% (SD=0.006, range 0.046 to 0.069). Mean BrAC at the 0.08% timepoint was 0.072% (SD=0.011, range 0.043 to 0.101). Mean BrAC at 0.05% descending timepoint was 0.050% (SD=0.003, range 0.037 to 0.055). See Figure 5.1 for individual BrAC readings at each assessment timepoint.

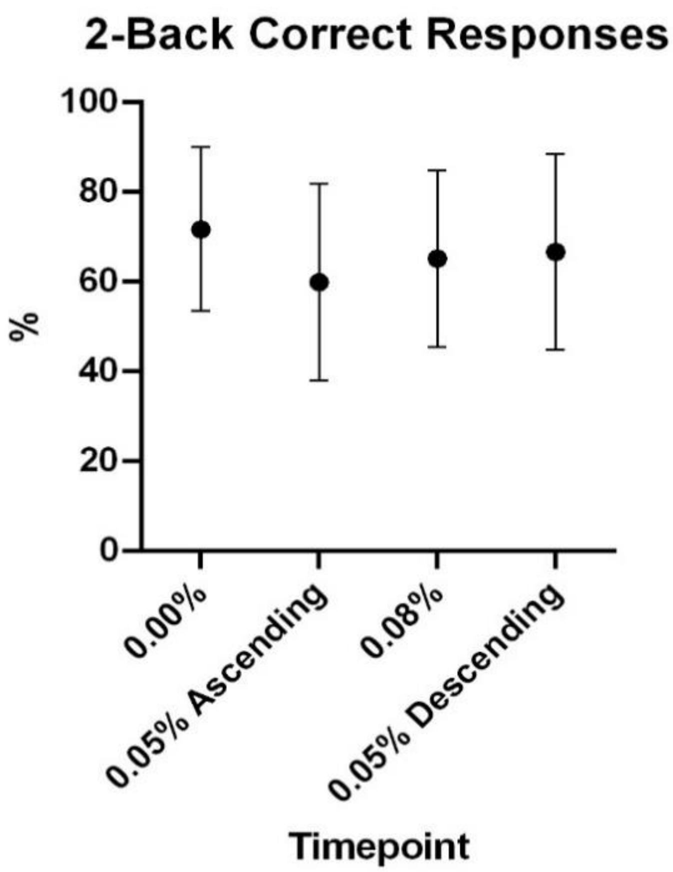
Figure 5.1 Participant Breath Alcohol Readings at Cognitive Testing Timepoints

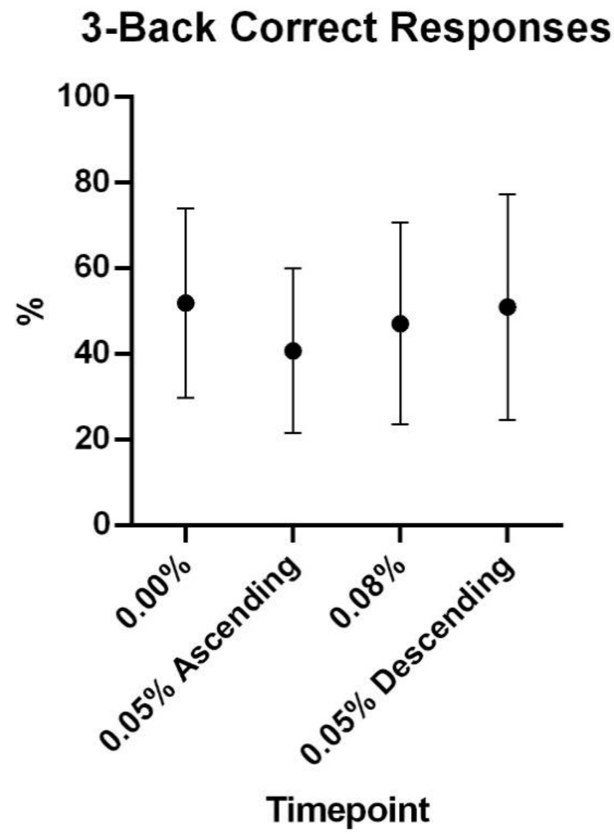


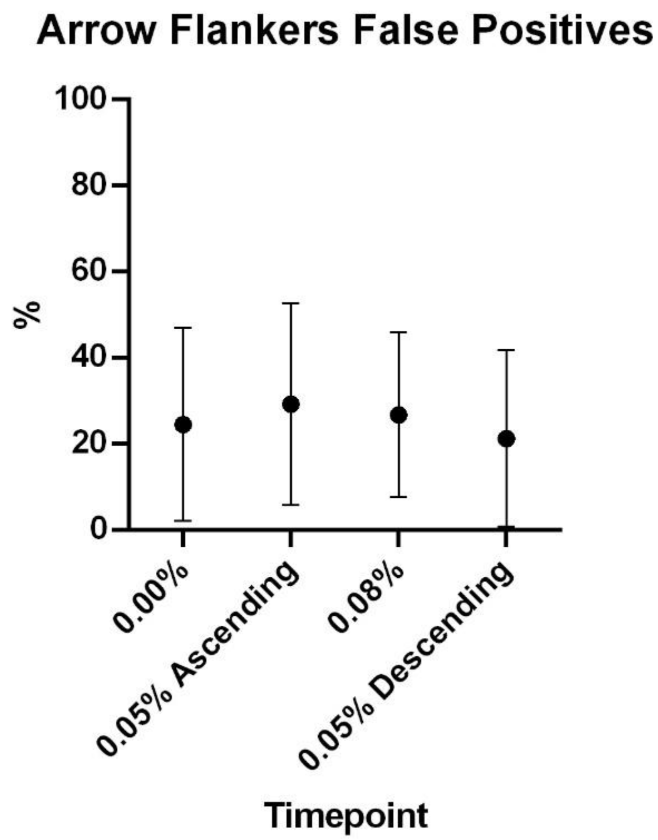
5.5.2 Cognitive Performance: Task Sensitivity to Acute Alcohol Consumption

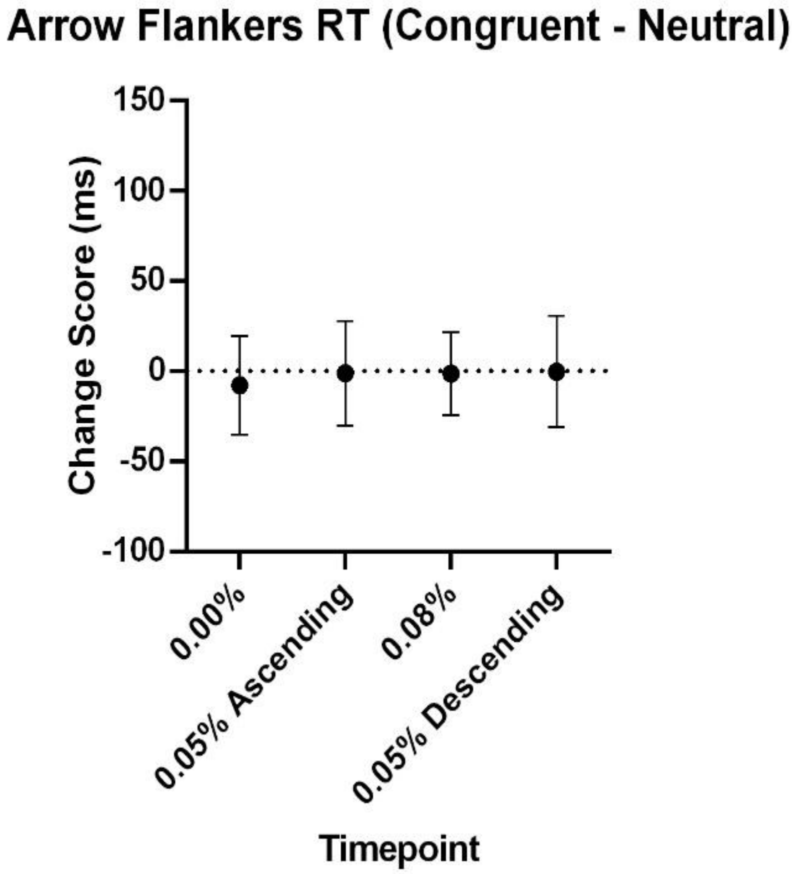
Figure 5.2 Cognitive Task Descriptive Statistics for Sensitivity Analysis (N=52)

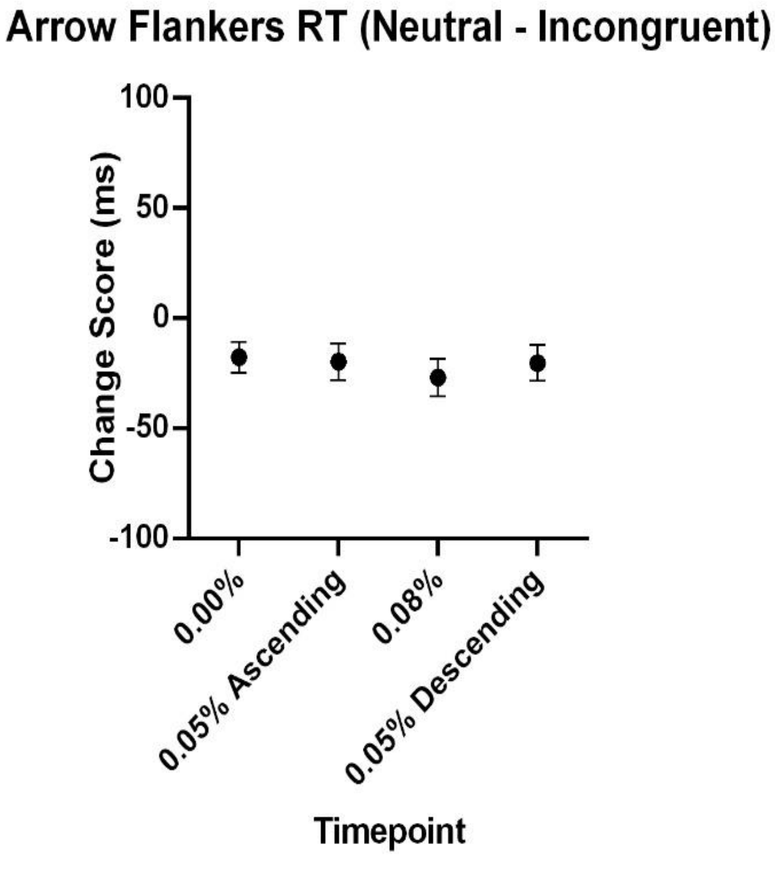


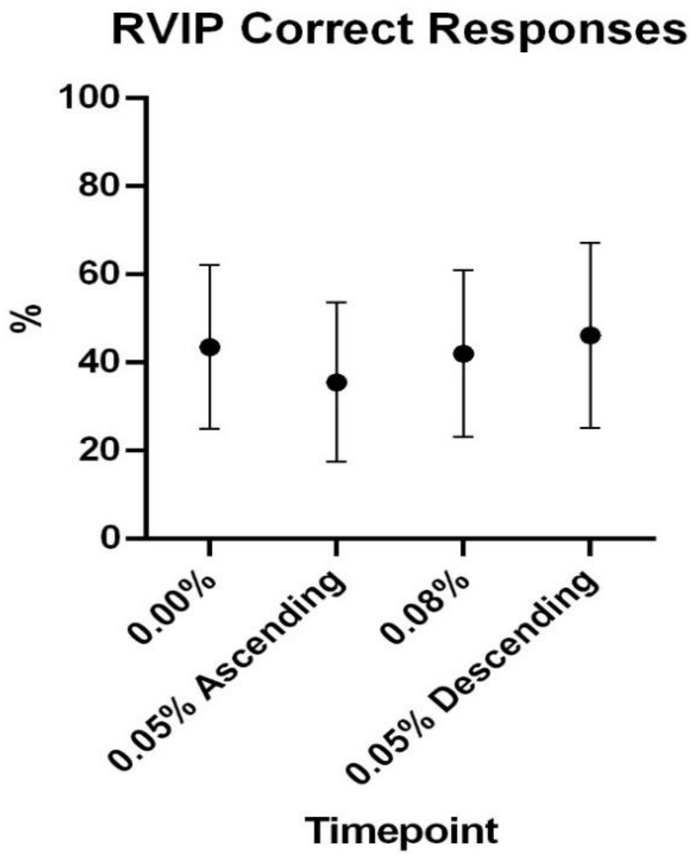


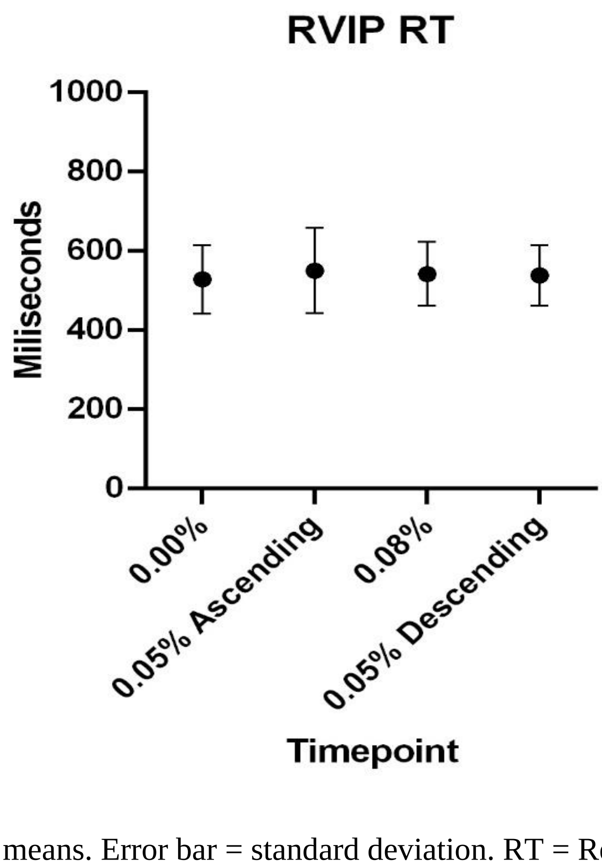

3-Back Correct Responses
100
80
60
40
20
0
%
0.00%
0.05% Ascending
0.08%
0.05% Descending
Timepoint


Arrow Flankers False Positives
100
80
60
40
20
0
%
0.00%
0.05% Ascending
0.08%
0.05% Descending
Timepoint


Arrow Flankers RT (Congruent - Neutral)
150
100
50
0
-50
-100
Change Score (ms)
0.00%
0.05% Ascending
0.08%
0.05% Descending
Timepoint


Arrow Flankers RT (Neutral - Incongruent)
100
50
0
-50
-100
Change Score (ms)
0.00%
0.05% Ascending
0.08%
0.05% Descending
Timepoint





Note: Data points = means. Error bar = standard deviation. RT = Reaction Time. Ms = milliseconds.

See Table 5.1 for task performance descriptive statistics and Table 2 for comparison of timepoints within the laboratory session (i.e., 0.00% lab performance vs each intoxication timepoint). When compared to 0.00% BrAC, task performance on the RVIP was significantly poorer at the ascending phase of 0.05%, with small effect size, while there were no significant differences at any other timepoint. 1-Back performance was significantly poorer at the 0.08% and 0.05% descending levels as compared to 0.00%, although effect sizes were small. 2-Back performance was poorer at the 0.05% ascending and 0.08% levels, with a medium and small effect size respectively, while 3-Back performance was significantly poorer at the 0.05% ascending level only with a medium effect size. All other effects were non-significant with a small magnitude.

Table 5.1 Summary of Effects: Laboratory Baseline vs Controlled Intoxication Performance

	Paired Comparisons: Laboratory Baseline (0.00% BAC) vs Laboratory Intoxication Levels								
	.05%^			**.08%**			**.05%˅**		
	p	***d***	***BF01 (E%)***	***p***	***d***	***BF01 (E%)***	***p***	***d***	***BF01 (E%)***
Selective Attention: Arrow Flankers									
Flankers RT Impairment, ms (Incongruent – Neutral)	0.707	0.05	6.18 (8.77)	0.113	0.22	1.98 (9.24)	0.588	0.08	5.75 (6.04)
Flankers RT, ms (Congruent – Neutral)	0.151	-0.20	2.46 (6.94)	0.188	-0.18	2.87 (4.90)	0.122	-0.22	2.10 (8.69)
No Go Errors, %	0.098	-0.24	1.73 (3.88)	0.417	-0.12	4.69 (4.79)	0.351	0.13	4.24 (4.80)
Sustained Attention: RVIP									
Reaction Time, ms	0.269	-0.17	3.41 (9.33)	0.287	-0.16	3.56 (9.63)	0.607	-0.08	5.40 (1.29)
Correct Responses, %	**0.032**	0.33	0.68 (2.02)	0.842	0.03	6.01 (1.38)	0.214	-0.19	2.92 (8.27)
Working Memory: N-Back									
1-Back, % Correct	0.266	0.16	3.55 (4.75)	**0.012**	0.36	0.32 (1.09)	**0.045**	0.31	0.94 (1.82)
2-Back, % Correct	**<0.001**	0.59	0.01 (1.19)	**0.019**	0.35	0.46 (1.74)	0.121	0.22	2.02 (4.12)
3-Back, % Correct	**<0.001**	0.57	0.01 (1.88)	0.116	0.29	1.96 (4.08)	0.771	0.04	6.18 (4.56)

Note: Positive *d* value indicates better baseline (0.00% BrAC) performance, negative *d* indicates poorer baseline performance. Reaction time includes correct responses only. BF^{01}(E%) = Bayes Factor (Error %).
^ = Ascending limb
˅ = Descending limb

5.6 Discussion

The aim of this study was to compare Arrow Flankers, RVIP and N-Back task performance, while at 0.00% BrAC, with performance at varying levels of the alcohol curve (0.05% [ascending and descending] and 0.08%) to assess respective test sensitivity to acute alcohol intoxication. This was necessary in order to ensure that the measures in our test battery are suitable as referent categories for future in-situ cognitive assessments.

Reflecting our findings in *Chapter 4*, Arrow Flankers reaction time in face of distraction (congruent – neutral stimuli RT and neutral – incongruent stimuli RT) did not significantly differ between 0.00% BrAC and any level of the intoxication curve. Similarly, there was no significant effect between post-festival performance on these measures and any level of the intoxication curve. Considering this, these aspects of the Flankers task do not appear to be necessarily sensitive to acute alcohol intoxication amongst our sample of young adults, nor did our preliminary results in *Chapter 4* indicate that post-festival performance was significantly affected relative to any level of the alcohol curve. This subsequently casts doubt on the efficacy on this element of the AF task to measure alcohol-related impairment (acutely, or as a referent category to the next day effects of alcohol consumption).

This finding is surprising considering that acute alcohol intoxication has been demonstrated to adversely impact attentional ability that requires participants to divide their attention between stimuli before responding (Dougherty et al., 2000). However, one possible explanation for these findings lies within alcohol myopia theory. Alcohol myopia theory posits that, during alcohol intoxication, attentional resources are reduced and are subsequently allocated to the most salient of events in a given situation (Mocaiber et al., 2011). In the task configuration presented to participants, they were asked to respond based on the orientation of the centre arrow while ignoring the distracting flanking arrows. It may be the case that, due to alcohol myopia narrowing attention to the most salient feature of the task - the central arrow – the distracting arrows have an attenuated influence on reducing reaction time as they are outside of the participants' attentional scope. If this is the case, this aspect of the task is not necessarily sensitive to the specific effects of acute alcohol intoxication. While the Arrow Flankers task still provides components sensitive to alcohol-induced impairment within real-world settings (e.g., incorrect responses; as demonstrated in *Chapter 4*), and could thus continue to be deployed in the assessment battery, our findings indicate that that RT in the face of distraction, as measured by this AF task, provides limited information in informing the effects of alcohol-related impairment.

Intriguingly, the 'No Go' facet of the AF task was also non-significant across all levels of intoxication relative to 0.00% BrAC, with ≤0.20 effect sizes. A popular model of cognitive control theorised by Fillmore and Vogel-Sprott (1999) describes acute alcohol-related cognitive deficits as impairment of inhibitory control rather than attention; also known as the alcohol disinhibition model. According to this model, alcohol impairs the ability to inhibit behavioural responses. This model has been demonstrated experimentally at lower BrACs than our target of 0.08% (Weafer & Fillmore, 2008). Given this, we would have expected impaired performance among our sample, compared to baseline, for the inhibitory control dimension of AF. However, the inhibitory control tasks used in previous studies were standalone assessments and were not integrated into a multi-dimensional task, as was the case in this study. The primary measure of AF is attentional performance in the face of distraction, not response inhibition (i.e., avoiding incorrect 'no go' responses), and may not have adequately assessed changes in response inhibition under these conditions. Given this, it is recommended that an additional test measuring response inhibition independently (e.g., a Stroop assessment or traditional Go/No Go task) be administered along with the test battery. However, if this is the case, it will be important to ensure the task is effective in a timely manner, considering the length of the battery is already quite long (between 10 and 15 minutes).

Performance on the N-Back was dependent on the load factor of the task (i.e., 1-Back, 2-Back or 3-Back), with the tasks sensitive to intoxication at differing arms of the alcohol curve. For the 1-Back task, performance was significantly poorer at peak intoxication (0.08%) and at 0.05% on the descending curve. As the load factor increased, sensitivity shifted towards the ascending curve, with performance poorer at 0.05% ascending and 0.08% during the 2-Back and 0.05% ascending only during the 3-Back. It is possible that this was the result of the acute tolerance effect (Fillmore, Marczinski, & Bowman, 2005), with task performance predominantly being negatively affected on the stimulatory (ascending) arm of intoxication, up to peak, before the effect decreasing into the sedation (descending) arm. However, this was not the case for the 1-Back. Considering the 1-Back is the easiest version of the task, this may have further been the result of compensatory responding (Wang et al., 2016), or lack thereof. Specifically, it is possible that, given the relative ease of the 1-Back compared to the 2- and 3-Back, participants did not actively compensate for their alcohol-induced reduction in cognitive capacity (by trying harder than they would if their BrAC was at 0.00%) to the same degree as they did for the harder tasks, resulting in worse relative performance compared to baseline (0.00% BrAC). Regardless, the N-Back test did appear to capture alcohol impairment during select arms of the curve (albeit with small effect sizes) and is subsequently a possible comparator for future field cognitive testing.

Reaction time on the RVIP task did not significantly differ across timepoints, indicating that acute alcohol intoxication did not speed up or slow down reactions to the task relative to 0.00% BrAC. While there were no significant impairments across the peak and descending arm of curve, there was a small significant effect at the 0.05% ascending timepoint. Interestingly, this finding mirrored our laboratory findings in Chapter 4, with 0.05% ascending the only timepoint at which significantly impaired performance was observed relative to 0.00% BrAC. This further suggests that sustained attention, as measured by the RVIP, is predominantly impaired during the ascending phase of intoxication within our sample, with a tapering off of measurable impairment at peak intoxication and into the descending curve.

In sum, the tasks deployed in this study were not uniformly sensitive to the effects of acute alcohol intoxication amongst our sample. This has implications for their deployment in future field-based research projects. Specifically, while some tasks identified impairment across some aspects of the alcohol curve, it would be beneficial for future projects aiming to assess impairment in naturalistic settings to identify tasks that are more sensitive to the effects of acute alcohol intoxication among samples of a similar size. It is possible that the sample within this study was still not large enough to detect the small magnitude of the effects for some tasks, but considering the marked logical challenges associated with recruiting very large samples for a dual-pronged laboratory/field study described in *Chapter 4*, investigation more context-appropriate tasks is warranted.

5.6.1 Strengths and Limitations

This study was a continuation of our cognitive assessment study outlined in *Chapter 4*. Considering the small sample size used in the previous chapter, a considerable strength of this study was an increase in statistical power for our analyses of task sensitivity to acute alcohol intoxication. This was a necessary step in minimising the likelihood of an underpowered analysis and resulting Type II errors. However, a pertinent limitation of this study was the failure to reach our target BrAC for the peak of the curve (0.072 mean BrAC, compared to our target BrAC of 0.08%). While this falls within the 12.5% uncertainty coefficient attracted by the Widmark Formulation (Gullberg, 2007), it does mean that participants were not as intoxicated, and thus potentially not as acutely impaired, as we had aimed for. However, previous literature has indicated that these cognitive domains should be impaired at this level of intoxication (Zoethout et al., 2011), indicating that failure to detect impairment is likely a function of task sensitivity and not non-impairment of the domain itself. Further, despite this limitation, 0.05% BrAC is the primary target threshold relevant to real-world policy in the context of impaired driving, being the legal driving limit within Australia and many other countries globally.

5.6.2 Conclusions

Mirroring the laboratory-based findings in *Chapter 4*, performance in many of the cognitive tasks deployed in our assessment battery were not impaired (either uniformly or entirely across the curve) by acute alcohol intoxication, despite an increase in statistical power. The findings of this study, while somewhat unprecedented in light of previous literature and cognitive theory, pave the way for the development of a more refined field-based cognitive assessment battery. Specifically, it would be beneficial for future field-based impairment assessments to find attention- and memory-specific tasks that are highly sensitive to the impairing effects of acute alcohol intoxication, characterised by consistent impairment detection across most or all of the alcohol curve at intoxication levels relevant to driving policy.

5.7 Acknowledgements

We would like to thank our participants for their contribution to this study.

Chapter 6: General Discussion

6.1 Introduction

Alcohol use and the outcomes associated with its use in real-world settings are complex, dynamic and diverse, and so too are the methods required to comprehensively assess them. Focussing on alcohol consumption, intoxication, impairment and associated harms, the aim of this thesis was to better understand the patron experience through use of select assessment techniques: (i) retrospective self-reports, (ii) event-level self-reports, (iii) objective biometric assessments (breath alcohol and transdermal alcohol techniques) and (iv) portable electronic cognitive-impairment assessments. While the individual studies proposed in this programme were conducted in varied environments (e.g., club districts, music festivals and a laboratory), all three complemented each other in furthering our understanding of, and ability to, assess alcohol-related behaviours and outcomes in naturalistic drinking settings; settings encompassing a high degree of risk to patrons.

The first study (*Chapter 2*) in this programme of research addressed differences in involvement in past-3-month aggression between different co-consuming alcohol and illicit drug subgroups (on a given night out) through a traditional retrospective self-report methodology and subsequent statistical controlling. The resulting publication was one of the first in this field to tease apart differences in this outcome between substance use groups, while also accounting for relevant risk covariates including sex, age, pre-drinking, alcohol consumption and time of night.

Cross-sectional intercept designs are useful for recruiting large, demographically varied samples as was necessary for *Study 1*, however the results from this study highlighted the challenges of determining a causal link between naturalistic substance use behaviours and outcomes using retrospective techniques. To assess harms that happen frequently to patrons, assess more specific substance consuming subgroups within naturalistic contexts (e.g., patrons who consume illicit drugs in addition to alcohol), or simply gauge alcohol consumption and/or intoxication in relevant high-risk settings over multiple days, other techniques are available but have not been heavily researched in high-risk settings. In the second study (*Chapter 3*) I recruited an at-risk sample of festival patrons to investigate the feasibility and utility of a combined battery of traditional consumption and intoxication measures (retrospective reports and BrAC) and ambulatory techniques (event-level reports and TAC) in a dynamic real-world alcohol-use setting. The use of event-level alcohol consumption and intoxication assessment tools is critical in linking in-the-event alcohol use and experiences of harms, and further understanding the relationship between the two. However, prior to this study, some of these assessments, or combination of assessments, were yet to be evaluated in-situ. *Study 2* was a field-based methodological study that aimed to descriptively refine our understanding of current subjective and objective field measures of alcohol use in dynamic, high-risk environments. *Chapter 3* found marked limitations with individual assessments but highlighted the potential for more a comprehensive understanding of alcohol behaviours in such contexts using a combined battery.

While event-level measures of alcohol use (i.e., consumption and intoxication) are useful to determine general risk of harms while acutely intoxicated, risk may also extend beyond the acute phase and into the next-day phase (the ‘hangover’) due to alcohol-related *impairment*. However, our ability to assess for such impairment in the field is, at present, underdeveloped. Thus, the third study (*Chapter 4)* aimed to investigate the use of an objective impairment cognitive test battery, aiming to measure impairment in cognitive domains relevant to driving performance (i.e., driving-relevant impairment) as a result of attending a multi-day alcohol-licensed setting. Given that there are considerable logistical challenges associated with explicitly measuring driving performance in real-world contexts, this was the first study to attempt to measure driving-relevant cognitive performance amongst festival patrons using a portable battery of cognitive assessments. This study yielded mixed results in the field, with significant impairment in some aspects of the battery (e.g., Arrow Flankers total errors) but non-significant small and moderate effects across the rest. Further, our analysis of task sensitivity to the effects of acute alcohol intoxication yielded small and moderate non-significant effects across the alcohol curve for many aspects of the tasks. Thus, I conducted an additional controlled investigation, with a larger sample size and subsequent increase in statistical power, to ensure the sensitivity of our assessment battery to alcohol-related impairment (*Chapter 5*). However, impairment sensitivity to alcohol consumption was not uniform among our larger sample either, raising concerns about the suitability of this battery to assess acute alcohol impairment, or its use as a measure of cognitive impairment in the field. Despite this, this study highlights the need for a more refined portable cognitive assessment battery to assess driving risk in-situ.

The primary findings of the studies contained within this thesis are outlined in Table 1. These findings will be integrated below to discuss the evidence base for future alcohol intoxication-, consumption-, impairment- and harm-related research in naturalistic drinking settings.

Table 6.1 Summary of Key Thesis Findings

Study and Research Question	Chapter	Primary Data Collection Assessment(s) Used	Study Design(s) Used	Key Findings and Conclusions
Study 1, Question 1	2	Retrospective self-report	Street Intercept	After accounting for sex, alcohol consumption, time of interview and pre-drinking covariates, individuals reporting any illicit drug and alcohol consumption and ecstasy and alcohol consumption were more likely to report retrospective past aggression in the NTE when compared to individuals whom reported current-night alcohol use only. A prospective design would have further elucidated the relationship between substance use and aggression, but retrospective measures were necessary to capture aggression involvement as it is such an infrequent harm.
Study 2, Question 2 and 2.1	3	BrAC TAC Retrospective self-report (short-term) Event-level self-report	Ambulatory	The combined assessment battery was successfully deployed in a multi-day, high-risk naturalistic drinking setting, with participants completing all face to face assessments and all but one participant wearing their transdermal monitors for the duration of the music festival. Each method had limitations. Specifically, we saw erratic spikes and dips in the transdermal alcohol readings that were not consistent with behaviour of the curves in controlled settings. Further, we suspected that compliance for the event-level self-report assessments was suboptimal. However, the combined battery resulted in a more comprehensive understanding of alcohol consumption and intoxication over the course of the multiple day drinking session.

Study 3, Question 3	4	Cognitive Test BrAC Retrospective self-report (short-term)	Experimental	While findings indicated possible cognitive impairment after residence in a multi-day drinking setting, both the laboratory- and field-based results were mostly inconclusive due to a suspected lack of statistical power (resulting in further exploration of the laboratory findings in Chapter 5; see below). However, the portable cognitive assessments were successfully deployed, paving the way for larger in-situ samples in future studies if the assessments themselves are found to be necessarily sensitive.
Study 3, Question 3	5	Cognitive Test BrAC	Experimental	Mirroring the laboratory-based findings in Chapter 4, performance on many of the cognitive tasks deployed in our assessment battery was not impaired (either uniformly or entirely across the curve) by acute alcohol intoxication, despite an increase in statistical power. The findings of this study, while unprecedented in light of previous literature and cognitive theory, pave the way for the development of a more refined field-based cognitive assessment battery with a greater sensitivity to alcohol-induced impairment. Specifically, it would be beneficial to identify tasks assessing working memory and attention that are highly sensitive to the effects of acute alcohol intoxication, up to 0.08% BrAC.

6.2 Intoxication, Aggression and Retrospective Reports (*Research Question 1*)

While retrospective self-report is an assessment approach with well-defined limitations (Richter & Johnson, 2001), its use was necessary in order to assess a relatively infrequent individual-level harm like aggression involvement. This is particularly salient as I was analysing a wider array of substance *subgroups* than simply ‘alcohol-only consumers’, such as alcohol consumers who simultaneously consume varied illicit substances. While a prospective design would have, from a methodological standpoint, been more appropriate to investigate in-the-event aggression amongst substance groups, it would have been extremely logistically challenging to get a sufficient quantity of events of interest using such a design. Specifically, the challenges of a prospective design in this substance use context are twofold. Firstly, given the limited detection window of experiencing aggression (i.e., one evening, rather than the previous three-month timeframe deployed in our study), and the relative infrequency of patrons experiencing aggression over even a prolonged period, capturing the outcome itself would have been extremely difficult. Secondly, given the large number of co-consuming groups investigated (e.g., alcohol and ecstasy, alcohol and methamphetamine, etc), recruiting enough participants in each group within a prospective design would have been too costly to be feasible. However, this does mean that the results of my study could only indicate *associations* between behaviour in the NTE (substance use) and past experiences, relying on a ‘forecasting’ approach when predicting risk of future involvement. This is also problematic because it provides little insight into the mechanisms behind differences in aggression between groups and was the primary limitation of *Chapter 2*. Mechanisms are important to understand as they can be directly targeted to combat the experience of such a harm.

While we did account for a range of covariates, our analysis in *Chapter 2* did not account for other factors relevant to substance consumption, like time spent ‘out’ in the setting of interest, which could in turn influence the period for possible to exposure to these experiences by patrons. However, leading on from the work conducted in this thesis, future research could investigate further factors associated with substance use in NTE settings, to help inform us of relevant covariates for later analyses; for example, energy drink consumption has recently been identified as a correlate of an increased likelihood of verbal aggression within the NTE (Hyder et al., 2018). While it was not feasible to street-intercept survey another (at minimum) 5,000 patrons to fill in another piece of this complex puzzle, the findings in *Chapter 2* do help narrow down the most at-risk group (i.e., ecstasy and alcohol co-consumers) regarding aggression involvement in these settings. Subsequently, future research projects could aim to directly target riskier groups, heavily reducing the number of overall participants required for analysis. For example, future research may include the recruitment of group-specific patrons using an online survey (e.g., alcohol-only consuming patrons and ecstasy/methamphetamine/cocaine/cannabis + alcohol consuming patrons), assessing frequency of use, time spent out in NTE settings and aggression involvement. Using such a methodology, patrons of interest can be directly recruited, rather than passively picked up as a systematic random sample, while maintaining generalisability that has been strengthened by our previous understanding of the types of outcomes they experience in-situ.

6.3 Measuring Intoxication and Impairment in Naturalistic Settings (*Research Question 2.1 and 2.2*)

6.3.1 Event-Level Reporting

Measuring drinking and other substance use behaviours is important as it provides an indication of substance-related *risk*. Individuals who consume higher levels of alcohol, and within shorter timeframes, are at greater risk of experiencing acute harms (Rehm, 2011). Event-level reporting is a useful technique for gathering time-specific drinking behaviour and other drinking-relevant contextual information that is difficult to ascertain through simple retrospective techniques, such as those deployed in *Chapter 2*. As discussed in the previous section, the use of event-level self-report measures can also be used in conjunction with retrospective techniques to provide a richer understanding of behaviours in naturalistic contexts, as was the focus of *Chapter 3*. It is at present the gold standard technique in terms of understanding the time sequence of events over prolonged drinking sessions. However, it is also limited in that it has a high degree of response burden, requiring participants to repeatedly respond to surveys, either via time-based sampling protocols or on an ad-hoc basis. In prolonged drinking settings, this can cause issues related to suboptimal compliance, as was highlighted as a potential issue in *Chapter 3*, and has also been found in broader research contexts (Wen, Schneider, Stone, & Spruijt-Metz, 2017).

Given this, it is apparent that future research in this domain needs to investigate ways in which we can improve event-level self-reporting response compliance in naturalistic drinking settings. This is going to be a difficult obstacle when faced with both (i) dynamic environments in which the data is being collected, and (ii) a wide range of participant behavioural profiles that may attenuate or augment compliance depending on, for example, the substance(s) being consumed or level of use. The event-level drink reporting in *Chapter 3* was designed as an ad-hoc measure, requiring participants to autonomously report drinking whenever it occurred. This was done to minimise response bias, tightening the window between the behaviour occurring and the reporting of that behaviour. Unfortunately, this protocol was susceptible to compliance issues (relative to retrospective reports, or biometric measures), as participants may have forgotten to report, were too intoxicated to report, or were otherwise preoccupied, without being actively reminded by the application. It is therefore unsurprising that this study saw fewer reported drinks when compared to the corresponding retrospective report the morning following drinking, even with previous literature suggesting EMA reporting should result in more drinks reported (Labhart et al., 2019).

As discussed in *Chapter 3*, a possible workaround for future studies in these settings may include a *call back* or *missed drinks* component as part of the EMA protocol. In addition to the ad-hoc reporting by participants, it may be useful to include a prompted report feature (e.g., several times each day) allowing participants to report any drinks that they had failed to report in the previous 3-6 hours. Indeed, this approach would comprise a combination of event-level self-reporting and short-term retrospective self-reporting, while maintaining the benefits of both. Specifically, the time-relevant component of EMA reporting will remain mostly intact, providing researchers with a better understanding of the drinking timeline, while the retrospective component will assist with counteracting any non-compliance (e.g., missed drinks) during the assessment period. Reinforcing EMA compliance is an important direction for future research in this domain to ensure that drinking behaviours can be comprehensively assessed. However, if adequate compliance cannot be achieved through additional structural measures, this further bolsters our rationale for ancillary data collection like continuous biometric assessments (the standing of which will be further discussed in 6.3.2) so that future studies can crosscheck event-level reports with more objective measures.

Once our event-level measures of alcohol consumption can more accurately assess drinking behaviours in these contexts, be they event-level reports, retrospective reports, biometric assessments or a combination of all of these, the next step is to implement an assessment of various alcohol-related harms to the greater in-situ assessment battery. This should be done so that researchers can tie in event-level drinking behaviours with acute harms experienced during the course of the drinking session, to better understand how drinking (and other substance use) contributes to the risk and experience of harms in a wide range of drinking-contexts.

As an example of how this may be implemented, I refer back to the study conducted in *Chapter 3*. A range of acute alcohol-related harms experienced by participants was collected during the retrospective component of this study on a once-daily basis (though, for the purposes of our methodological investigation, were not relevant to the aim of this chapter and thus not described). Table 6.2 outlines the harms reported by participants during this study. A similar battery could be deployed in future research, but rather than conducting these assessments retrospectively as was done in *Chapter 3*, we could augment the existing EMA component with an ad-hoc or regularly scheduled assessment to maximise the temporal resolution of our harm collections, much in the same way as we have done for drinking behaviours. This would shift them from a short-term retrospective measure to an event-level measure, maximising our ability to link alcohol-use behaviours with subsequent experience of harm within a specific drinking session. Importantly however, this will only be feasible for harms that we predict will be frequent enough to be captured this way in a short assessment period (e.g., a night, weekend or festival). This assessment methodology is unlikely to be useful for harms like aggression involvement, because as evidenced in *Study 1*, this particular harm has a relatively low outcome *n* over a 3-month period, even with a primary sample of >5,000 people. With that said, we did see a number of more prominently experienced harms in our small sample during *Study 3* (e.g., accidents, more alcohol use than planned, spending more money than planned), and these are the types of harms that may be the focus of such an assessment protocol. Conversely, such a methodology may also entail ethical issues in terms of needing to intervene if participants report specific harms, which would need to be considered in design.

Table 6.2 Harms Experienced Over Course of Festival (Data Collected During Retrospective Assessment in *Chapter 3*)

N = 14	Day 1 *n* (%)	Day 2 *n* (%)	Day 3 *n* (%)	**Any Day *n* (%)**
Substance Use				
More alcohol than planned	3 (21.4)	4 (28.6)	4 (28.6)	**9 (64.3)**
More tobacco than planned	2 (14.3)	4 (28.6)	1 (7.1)	**4 (28.6)**
Consumed other recreational drug	0 (0)	0 (0)	1 (7.1)	**1 (7.1)**
Property				
Lost or damaged your valuable items	0 (0)	1 (7.1)	1 (7.1)	**2 (14.3)**
Spent more money than planned	4 (28.6)	3 (21.4)	0 (0)	**5 (35.7)**
Stolen something	0 (0)	1 (7.1)	0 (0)	**1 (7.1)**
Social				
Did embarrassing things	1 (7.1)	2 (14.3)	1 (7.1)	**3 (21.4)**
Did something you regretted	1 (7.1)	2 (14.3)	1 (7.1)	**4 (28.6)**
Caused shame or embarrassment	0 (0)	1 (7.1)	0 (0)	**1 (7.1)**
Verbal argument with stranger	0 (0)	1 (7.1)	0 (0)	**1 (7.1)**
Verbal argument with known	1 (7.1)	0 (0)	0 (0)	**1 (7.1)**
Health				
Had an accident, injury or fall	0 (0)	1 (7.14)	3 (21.43)	**4 (28.57)**
Vomited unintentionally	0 (0)	1 (7.14)	1 (7.14)	**2 (14.29)**
n Any Harm	7 (50)	8 (57.1)	5 (50)	**12 (85.7)**

Note: The following items received no endorsement from participants: Consumed cannabis; Used medication to get high; Broke/damaged something; Deliberately pushed/shoved/got into a fight with someone; Vomited intentionally to continue drinking; Passed out as a result of drinking; Had sex that could have led to an unwanted pregnancy or sexually transmitted infection.

The deployment of combined event-level self-report protocols (i.e., those including both drinking behaviour and harm assessments), paired with the other event-level assessments described in this body of work (e.g., transdermal assessments), is important going forward because data on alcohol consumption/intoxication can be tied in with resulting harms. This provides us not only with an overview of how we can reduce patron risk in terms of their drinking behaviours and characteristics in specific high-risk settings, but also the key outcomes of which these behaviours and characteristics are associated. While the study described in *Chapter 3* could not achieve this (in this case, in the festival environment) with such a small sample size, this study did give us a proof of concept in order to deploy a similar battery on a larger scale, after first taking into account the findings of this study (such as future amendments to improve compliance). This will ultimately help inform harm reduction and health promotion interventions in naturalistic settings of interest. Indeed, while it is possible to link alcohol use with adverse outcomes through medical reports at hospital admission for example (Trefan et al., 2019), this does not provide an in-depth picture across the whole spectrum of adverse alcohol-related outcomes, typically precluding outcomes that are not acutely or physically serious enough to warrant admission (Pennay et al., 2017).

6.3.2 Transdermal Assessments

In addition to event-level reports, transdermal assessments seem like a promising way forward in measuring objective intoxication in naturalistic settings due to the practical advantages espoused in previous research (Piasecki, 2019). However, the majority of existing transdermal research (e.g., Dougherty et al., 2012; Fairbairn & Kang, 2019) has used transdermal monitors in controlled (e.g., laboratory) settings, the findings of which are perhaps not generalisable to field-based research due to the myriad of external factors that may attenuate performance of the device [e.g., alcohol contamination, environmental interference, loosening fit of the device (Marques & McKnight, 2007)]. Unfortunately, as outlined in *Chapter 3*, the readings from the SCRAM monitors in our field-based examination did not behave the way we would have expected them to.

Specifically, we observed erratic increases and decreases in alcohol concentration, up to 0.40% (which was perplexing considering the magnitude of TAC has been demonstrated to be lower than BrAC). Not all participants had aberrant readings, and the readings did provide some indication of drinking behaviours in circumstances that would have otherwise been completely unknown, however it does call into question the reliability of raw SCRAM readings to measure binge-level intoxication in prolonged naturalistic drinking settings. This is especially true if they are being used as standalone assessments of intoxication in these settings, with no other measures to cross-validate the readings. As they currently stand, their use is particularly problematic because of high level of resources required to deploy them, both in financial terms and in manpower. As of writing, SCRAM devices cost over $2,000 AUD per device, excluding ongoing daily monitoring costs. They also require significant training to set up and install on participants. If these devices are not as reliable as we had hoped, the cost might not be worth the potential gain over and above more traditional methods such as breath testing and event-level self-reporting which are considerably cheaper and less burdensome to administer (albeit with their own limitations).

Indeed, transdermal alcohol technology is still in its infancy. Going forward with research in this area, it is going to be important to comprehensively validate the performance of SCRAM and similar devices against current ‘gold-standard’ intoxication measurements (e.g., BrAC), understand the factors that can influence their performance (e.g., sex, age, consumption level, environmental interference), and figure out a way to accurately clean the intoxication curves based on these variables. It is also worth considering that controlled alcohol doses within laboratory settings do not necessarily mirror real-world drinking behaviours, and more sporadic or intense consumption in-situ may have contributed to the unusual curves otherwise not detected in the laboratory. Prior to understanding the impact of these factors, it is going to be very difficult to continue to deploy SCRAMs as standalone intoxication assessments in real-world settings. Encouragingly, there have been some attempts at developing conversion equations to estimate BAC based on a TAC readings (Luczak et al., 2015), but nothing that has been extensively validated as of the time of writing. If a validated conversion equation comes to fruition, transdermal devices will be much more attractive to researchers and it will significantly improve their ease of use and interpretability in naturalistic settings, so long as environmental interference can also be minimised.

A new generation of transdermal technologies are also being developed, such as the BACtrack Skyn. Unlike the SCRAM, this device is a wrist-mounted monitor the size of a small wrist watch and has shown promising results in prototype testing (Fairbairn & Kang, 2019). Specifically, Fairbairn and Kang (2019) demonstrated that the Skyn prototypes had a considerably reduced detection latency, with peak intoxication (~0.08% BrAC) occurring one hour prior to the non-prototype SCRAM devices. This is a dramatic improvement and is welcome in light of the time-lag issues described in *Chapter 3*. However, they also had a higher device failure rate (e.g., failure to take readings or otherwise function correctly) than the SCRAM devices, which may call into question their utility in real-world contexts where robustness is critical and replacement devices are not necessarily easily obtainable from researchers. Therefore, on official release of the Skyn devices, it will be important to both re-validate them in a controlled laboratory setting, but also assess their functionality in field settings with an emphasis on user-friendliness, reliability (i.e., device failure rate) and reading performance against existing biometric devices.

Despite the limitations, this technology offers great potential in both the research and clinical domains. If the uncertainties surrounding transdermal alcohol assessments can be overcome, we may be looking at a revolution in how we capture event-level alcohol behaviours. This will have far reaching implications, not only in terms of new NTE and festival policy that is elucidated from a better understanding of risky alcohol consumption, but also in treatment of alcohol use disorders. For example, we could look at implementing these devices to assess high-risk co-consuming NTE patrons (such as the high-risk groups described in 6.2) to more accurately assess intoxication and its link to acute harms. This can already be done to some degree with EMA and breath alcohol assessments, but without the compliance issues or response burden; an issue that is likely augmented among the most at-risk individuals (Coomber et al., 2018). Further, beyond their existing use in the criminal justice context, this technology could be extended into alcohol-related treatment programs as an active element of recovery, or for individuals simply looking to cut down on their drinking (e.g., Alessi et al., 2017; Dougherty et al., 2014). Specifically, the devices could be used to identify times in which individuals are most at risk of consuming alcohol, or locations in which they are most at risk (combining transdermal monitors with GPS tracking, for example), allowing an open and objective view into the drinking patterns of each client and allowing for the tailoring of personalised programs based on these data. Further, as described by Alessi et al. (2017), even simply wearing monitors without specific intervention has been demonstrated to reduce drinking for individuals undergoing alcohol-related outpatient treatment.

6.4 Assessing In-Situ Objective Cognitive Impairment (*Research Question 3*)

Our investigations in *Chapter 3* centred on the assessment of alcohol consumption and intoxication; known risk factors for the experience of acute harms in naturalistic settings. However, there is another component of risk to patrons that has not been heavily investigated in these environments. Specifically, acute alcohol intoxication can lead to adverse residual effects that can affect cognitive and motor function and this is potentially problematic when considering that many individuals who drink in public domains then drive the next day (most notably in ephemeral drinking settings such as music festivals). *Chapter 4,* our field-based pilot study, was unfortunately underpowered and yielded limited interpretable findings in regard to the outcome of interest (cognitive impairment) but showed promising results in terms of the feasibility of implementing a portable cognitive test battery to assess driving-related impairment. While perhaps not as robust or direct as other measures of driving impairment, such as a driving simulator, portable cognitive tests are advantageous in that they are a middle ground between feasibility of deployment (i.e., bringing the test to the setting) in dynamic settings and association with our key outcome of interest. This is especially true when considering that the assessment of driving impairment post-alcohol-intoxication in a controlled setting is unlikely to be wholly generalisable due to a host of extraneous factors relating specifically to the setting of interest (e.g., amount and quality of sleep, food intake, general fatigue). This was an encouraging finding as it paves the way for future cognitive assessments in-situ using similar portable tablet-based technology, while remaining a relatively cost-efficient and easy to deploy solution.

Unfortunately, on further investigation into the sensitivity of the tests in measuring alcohol-induced impairment in *Chapter 5*, our results indicated that our chosen driving-relevant task performance was not uniformly sensitive across the alcohol curve, up to a peak

BrAC of 0.08%. This was unprecedented considering these domains have been demonstrated to be impaired by the effects of acute alcohol intoxication (Zoethout et al., 2011). While some of the possible theoretical mechanisms behind these findings were discussed, such as compensatory responding, biphasic effects and alcohol myopia theory, it does suggest that impairment detection for these tasks does not increase linearly as intoxication increases, and that some were only sensitive during the ascending or descending curves. This makes the use of controlled baseline performance for these tasks, across the alcohol curve (at least up to 0.08% BrAC), less attractive as referent variables for later field-based measurements (although not completely unusable) due to the unstable impairment detection. Ideally, we would identify tasks that detect impairment (relative to 0.00% BrAC) across the entire curve.

Going forward, it is going to be important to further investigate the validity of the Arrow Flankers, N-Back and RVIP tasks in detecting alcohol-induced cognitive impairment. Specifically, it should be noted that our average peak intoxication during this study slightly undershot our target BrAC (mean=0.072%), and it would be useful to assess impairment at higher BrACs to determine whether this makes a different relative to 0.00% BrAC. However, despite missing our peak BrAC, 0.072% is still well above the policy-relevant legal driving threshold of 0.05% in Australia, and as impairment was detected in some tasks at lower BrACs, it appears that the phase of intoxication (e.g., absorption/elimination) seemed to be more important than the level of intoxication. Further, the tasks were specifically selected for their relation to driving-relevant cognitive domains but are certainly not exhaustive in regard to their relevance to this risk outcome. It would be useful to assess other driving-relevant cognitive tasks, that are deliverable on portable devices, to see if these perform any better than the three used within *Chapter 4* and *Chapter 5*.

Once normative data amongst our sample of interest can be collected, and we can be confident that the chosen tests being deployed are relevant to our outcome of interest and necessarily sensitive across the alcohol intoxication curve, deploying these in a two-pronged laboratory and field study with a larger sample will be the next step. This is critical to answering a key question that has not been empirically tested in such naturalistic drinking environments. While the chapters described in this thesis could not definitively answer the question as to whether (or the degree to which) the driving abilities of patrons are impaired post-festival, it has laid the foundation by providing a working field-based methodology, so long as valid tests can be identified for the sample and context of interest.

It is also important to highlight that this methodology can be used to answer additional risk or harm outcomes in the field and is not necessarily limited to driving risk. Indeed, the types of tests to be used in future impairment-related studies will depend on the research question. In the case of driving-related impairment, which has quite far reaching policy implications, it will be important to further test and refine the battery of cognitive assessments discussed in this body of research. However, these and/or other tests, depending on the cognitive domain of interest, could also be tailored to suit a host of performance-dependent activities, such as the ability to operate certain machinery while at work (e.g., in industrial workplaces) or engage in cognitively demanding high-risk tasks (such as air traffic controllers). While some workplace-centred tests exist for fatigue-related impairment, such as the Occupational Safety Performance Assessment Test (Petrilli, Jay, Dawson, & Lamond, 2005), what is required is a broader range of assessments, compiled into a battery, that are sensitive to a wide scope of impairment. Impairment tests do not necessarily have to be related to alcohol intoxication, as was the focus within this body of research, but could be baseline-tested against whichever impairing factor may be relevant to the context (such as high workload, stress, other substance use, etc). This is critically important going forward as other substances become available for public use too. For example, as medicinal and recreational cannabis becomes more widespread, simple breath testing is no longer sufficient to ensure the absence of acute impairment.

In this sense, portable cognitive assessments are great ancillary measures to event-level assessment models as they can cast a broad net over risk factors relevant to impairment in a context of interest. Specifically, it can be extremely difficult to quantify impairment from one factor alone (e.g., alcohol consumption), and this is especially true if multiple factors are involved but are not necessarily known a priori. Cognitive assessments are better at capturing global impairment (or risk) without the having to necessarily measure all extraneous variables. However, contrarily, their assessment does require a reliable baseline measure of performance which is not always logistically feasible on a large scale. For example, for their use in the festival setting, the interpretation of final-day cognitive performance is relatively meaningless unless patrons can also be assessed prior to their attendance, and this is further compounded by the time it takes to instruct participants how to accurately perform the tests. This means that they are very useful when trying to answer research questions such as driving-related impairment, where participants can be recruited beforehand, but may be harder to implement as an intervention in these settings; akin to how breath alcohol assessments are used now, but covering residual impairment rather than acute intoxication.

It is also important to note that many cognitive tests aimed at assessing impairment, such as the tasks within the Penscreen software used in *Chapter 4* and *Chapter 5*, were developed primarily for use in controlled laboratory settings. Given this, and as aforementioned, the tasks are often quite challenging to learn, deal with relatively arbitrary stimuli and are not always intuitive for test naïve participants. This makes their deployment, particularly in field-based settings where external stimuli are less controllable, much more challenging than they could otherwise be. Given this, future investigations into field-based impairment assessments might look at further developing more patron-friendly version of the tasks, validated against their traditional counterparts, that will make their use in naturalistic settings more engaging. For example, if the tests can be converted into a videogame style task with engaging/intuitive objectives and interesting animations (an early version of such a test is currently available as part of the DRUID assessment [Impairment Sciences, Inc]), it may be easier to both teach patrons how to take the assessment and capture their attention for the duration assessment without sacrificing the challenge of the test.

6.5 Conclusions

In this body of work, we have assessed primary outcomes relevant to alcohol consumers in naturalistic drinking spaces: intoxication, consumption, impairment and experience of harms. The studies conducted have bolstered the foundation to further investigate some key areas of concern, including aggression involvement and driving risk, but have also highlighted some key methodological questions that need to be answered before this can be achieved. Measuring alcohol-related variables is complicated by the dynamic and complex nature of consumers and the environments in which they engage in these behaviours, and it seems unlikely that there will be a one-size-fits-all assessment for these outcomes in the near future. Using a combined collection of different assessments, such as event-level assessments, retrospective assessments and cognitive assessments is the obvious solution at this stage, but many of these assessments (e.g., transdermal devices and portable cognitive tasks) are emerging technologies that have not been thoroughly evaluated in-situ and will require further examination.

Unfortunately, devising solutions to these issues is going to be more difficult than I first anticipated. Many of the techniques discussed are expensive to run on a large scale, and despite best efforts there are still logistical issues surrounding them. Comfort and accuracy deficits with transdermal devices, possible response burden with event-level self-reporting, and issues with cognitive test sensitivity will all need to be further investigated and refined. Researchers are currently in the difficult position of trying to optimise the assessments that are currently available to us, while also constantly playing catch-up with new innovations. However, if it is possible to make sense of the tools available, we will be in a much better position to more comprehensively understand and/or evaluate risk factors and harms in risky real-world settings. This will in turn help develop evidence-based interventions and health promotion strategies to combat harms in these environments, creating safer, more enjoyable recreational spaces for all.

Chapter 7: References

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