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Are heavy drinkers more impulsive than light drinkers?

A comprehensive multi-dimensional assessment of impulsivity in non-dependent heavy drinking young adults

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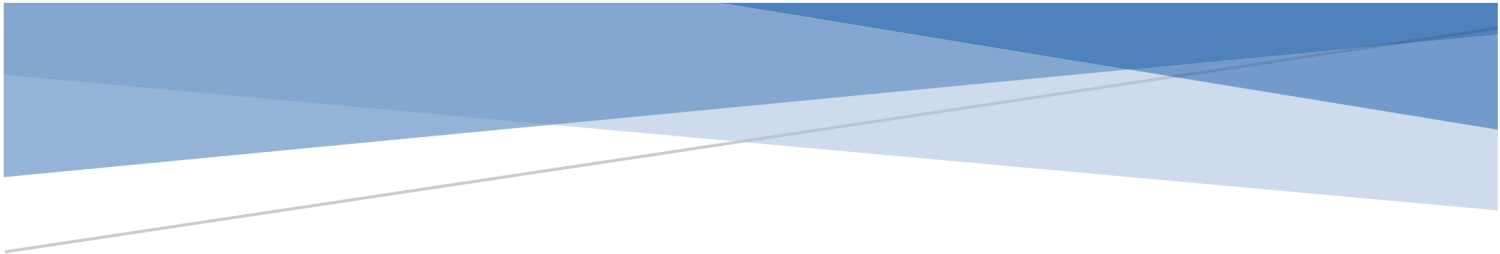
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DCLINPSY THESIS

VOLUME 1

Systematic Literature Review and Main Empirical Project

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Doctorate in Clinical Psychology (DClinPsy)

SYSTEMATIC LITERATURE REVIEW

MULTIDIMENSIONAL ASSESSMENTS OF IMPULSIVITY IN NON-CLINICAL HEAVY DRINKING YOUNG ADULTS A SYSTEMATIC REVIEW OF THE EXISTING LITERATURE

SUPERVISED BY DR. TIM MEYNEN

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ABSTRACT

Background and aims: The aim of this study was to review whether (and which) impulsivity sub-domains are elevated in groups of non-dependent alcohol misusers (e.g., heavy/hazardous drinkers, binge drinkers, etc.), relative to healthy drinking comparison groups. It set out to answer this by reviewing studies comparing groups on impulsivity multi-dimensionally – that is, *via more than one index* (at least one self-report and at least one behavioural). Comprehensively profiling non-dependent alcohol misusers' impulsivity may increase understanding of the potential mechanism(s) involved in the initial development to and maintenance of such misuse (and possibly to subsequent dependence).

Methods: The search was performed via three scientific databases (Embase, Medline and PsycINFO) and was limited to empirical studies comparing non-clinical groups of drinkers aged 18-25 years and published in English language journals. The titles and abstracts of all non-duplicate returns were screened in order to determine eligibility. A subsequent ancestry search involved screening the (titles and abstracts of papers in the) references sections of all eligible papers. Grey literature was not included. The findings of the included papers were qualitatively reviewed, before each was rated using the National Institutes for Health quality assessment tool for observational cohort and cross-sectional studies.

Results: Just eight studies were found to have compared impulsivity multi-dimensionally in groups of young adult (i.e. 18-25) non-clinical alcohol misusers, relative to comparison groups. Collectively, findings indicate that self-reported rash impulsivity is elevated in the quasi-experimental groups, whilst behavioural inhibitory control and delay discounting are *not*. Due to insufficient amounts of data, it is unclear whether response-initiation, risk-taking and reflection impulsivity may be elevated in non-clinical alcohol misusers. The quality of the eight studies included in the final review was generally rated 'fair', none being rated 'good', due to a range of potential sources of confound.

Conclusions: Across all impulsivity sub-domains assessed in these studies, only self-reported rash impulsivity appears a reliable risk factor for the maintenance (and possibly, initial development) of non-clinical patterns of alcohol misuse, at least in young adults. However, the potential inclusion of dependent drinkers across the

included studies represents a serious limitation, raising questions about findings/conclusions. Overall, more studies are needed that assess impulsivity multi-dimensionally in groups of alcohol misusers, relative to healthy drinkers; these studies should ensure better control of possible sources of confound.

I. INTRODUCTION

The misuse of alcohol poses significant problems for society and it is therefore important to enhance our understanding of it. A bio-psycho-social approach holds that certain aspects of an individual, in combination with relevant environmental ‘triggers’, increase the risk for chronic alcohol misuse. Impulsivity is reliably elevated in alcohol-dependent individuals (Jentsch & Taylor, 1999), suggesting it may be a potentially important psychological factor. Impulsivity consists of a variety of sub-domains, however, and each may share different relationships with drinking. It is important to characterise non-dependent alcohol misusers’ impulsivity, as doing so may provide insight into the potential mechanisms involved in the initial development and maintenance of alcohol misuse. The present work reviewed empirical studies to have performed multi-dimensional impulsivity assessments in non-dependent alcohol misusers.

1.1) ECONOMIC, HEALTH AND SOCIAL COSTS ASSOCIATED WITH ALCOHOL MISUSE

In terms of the overall economic impact of alcohol misuse, Balakrishnan *et al.* (2009) have estimated that, in 2005-2006, expenditure related to alcohol consumption cost the National Health Service (NHS) in England and Wales £3 billion, or 3.2 per cent of total NHS expenditure. The Institute of Alcohol Studies estimates that in 2009/2010, there were 1.4 million alcohol-related ambulance journeys (35% of the total; NHS, 2012) and that between 40-70 per cent of Emergency Department attendances are attributable to alcohol (Drummond *et al.*, 2005, Consortium, 2010). Substantial additional costs arise from crime and violence, private and informal health and care, lost income due to unemployment, public services such as social care, criminal justice and fire services, work absenteeism and alcohol-related accidents and injuries. Thus, the Cabinet Office (2003) estimated that, in the years 2001-2002, alcohol-related crime cost England and Wales around £11.7 billion and alcohol-related lost productivity was estimated at £6.4 billion. Accordingly, the National Social Marketing Centre (Lister *et al.*, 2008) estimate the total social cost of alcohol to England in 2006-2007 to have been £55.1 billion.

In broad terms, elevated levels of alcohol consumption are detrimental to one’s physical and mental health, both directly and indirectly. Medically, reliable evidence

indicates that alcohol consumption increases risk for (in no particular order) various forms of cancer, dementia, osteoporosis, pancreatitis, ischaemic heart disease, epilepsy, hypertension and cirrhosis of the liver – as well, of course, as AUDs themselves (Rehm *et al.*, 2003, Balakrishnan *et al.*, 2009). Alcohol misuse is associated with a range of (other) mental health problems, including major depression, bipolar disorder, certain anxiety disorders (e.g., social phobia, panic disorder, post-traumatic stress disorder) and schizophrenia (Helzer & Pryzbeck, 1988, Kessler *et al.*, 1997). More indirectly, heavy drinkers are at elevated risk of traffic accidents, drownings, falls, violence and suicide (Balakrishnan *et al.*, 2009, Gronbaek, 2009).

Alcohol misuse also has a range of implications for those other than the drinker. Possibly the most salient cost incurred by others relates to fetal alcohol spectrum disorder (FASD), which may manifest in birth defects, including characteristic abnormalities of the upper lip and eyes and neurodevelopmental disorders (Gmel & Rehm, 2003). Additionally, the risk of miscarriage, stillbirths and underweight births are all elevated. Navarro, Doran and Shakeshaft (2011) report that family members often suffer domestic violence, neglect, abuse and poverty, frequently culminating in separation and/or family breakdown. Alcohol-related aggression also has overt consequences in the forms, for example, fights, stabbings, shootings and fire destruction (Smith, Branas & Miller, 1999).

Given the associated burdens, Lee and Forsythe (2011) argue that alcohol is more dangerous than heroin. Furthermore, it seems likely that these burdens will worsen as the number of people reporting harmful alcohol consumption increases. For example, in 1988 around a quarter of men and ten per cent of women in the UK reported alcohol misuse, but in 2006 these figures had risen to a third of men and a fifth of women (Office for National Statistics, 2001, NHS Information Centre, 2008).

I.II) DEFINITIONS AND PREVALENCE OF ALCOHOL USE DISORDERS

The current version of the World Health Organisation's (WHO) International Classification of Diseases (ICD-10; 1992) identifies two forms of diagnosable alcohol use disorder (AUD); these are termed 'harmful alcohol use' and 'alcohol dependence'. Harmful alcohol use is defined as

A pattern of psychoactive substance use that is causing damage to health. The damage may be physical (e.g., hepatitis) or mental (e.g., depressive episodes secondary to heavy alcohol intake). Harmful use commonly, but not invariably, has adverse social consequences: social consequences in themselves, however, are not sufficient to justify a diagnosis of harmful use.

Such individuals do not demonstrate evidence of physical dependence (i.e. ‘tolerance’ and a withdrawal syndrome upon cessation of drinking).

Alcohol dependence, on the other hand, is defined as:

A cluster of behavioural, cognitive and physiological phenomena that develop following repeated substance use and that typically include a strong desire to take the drug, difficulties in controlling its use, persisting in its use despite harmful consequences, a higher priority given to alcohol use than to other activities and obligations, increased tolerance and sometimes a physical withdrawal state.

For the pragmatic purposes of clinical diagnosis, the ICD-10 criteria define the above disorders categorically, as either present or absent. In reality, though, they exist along a continuum of severity. Thus, the National Institute for Health and Clinical Excellence (NICE; Drummond *et al.*, 2011) refers to mild, moderate and severe dependence. Similarly, the latest (fifth) version of the American Psychiatric Association’s (APA) Diagnostic and Statistical Manual of Mental Disorders DSM-V; Association (2013b) integrates the two disorders included in the manual’s fourth edition, alcohol abuse (broadly equivalent to harmful alcohol use) and alcohol dependence, into a single disorder called ‘alcohol use disorder’, with mild, moderate and severe sub-classifications.

In addition to the above, several other, non-diagnostic yet maladaptive, patterns and levels of alcohol consumption have been described. In the UK, one unit of alcohol is defined as 8 grams of pure ethanol. Department of Health guidelines (1995) recommend that males should not regularly consume more than four units of alcohol

per day and females no more than three; similarly, the Chief Medical Officers (Officers, 2016) advise that females and males should not exceed 14 units of alcohol per week. Those consuming below these recommended limits are considered to be at low risk of health or social harm. Those who routinely drink above these levels, but who have not as yet experienced alcohol-related harm, can be termed 'hazardous drinkers': that is, they are at increased risk for harm in the future (Drummond *et al.*, 2011). Research studies tend to use the alternative, yet broadly synonymous terms 'heavy social drinkers' or 'heavy drinkers' to refer to such individuals; and indeed this latter term is used to refer to such drinkers from here on in. The RCP (1986) defines 'harmful' drinking as the consumption of more than 50 units per week by men and more than 35 units by women (i.e. the RCP definition is independent of that forwarded by the WHO in ICD-10). 'Binge' drinking is defined as men consuming more than 8 units, and women drinking more than six, in a single drinking session (Unit, 2004).

The Alcohol Needs Assessment Research Project (ANARP) found the prevalence of alcohol dependence in England to be 6 per cent in men and 2 per cent in women aged 16-64 (Drummond *et al.*, 2004). This translates to around 1.1 million alcohol-dependent people in 2000, with a similar survey suggesting an increase to 1.6 million by 2007 (McManus *et al.*, 2009). Unhealthy yet non-diagnostic levels and patterns of alcohol consumption are even more prevalent. Thus in 2008, 21 per cent of men and 15 per cent of women were drinking at 'hazardous' levels. A further 7 per cent of men and 5 per cent of women were identified as harmful drinkers and 21 per cent of men and 14 per cent of women as binge drinkers. Overall, McManus *et al.* (2009) estimate that 24 per cent of English adults (33% of men and 16% of women) consume alcohol in a manner that is either potentially or currently harmful.

Overall, the foregoing illustrates that people engage in a range of diagnosable and non-diagnosable patterns and levels of maladaptive alcohol consumption, with any given individual probably engaging in different patterns/levels at different times across their life. For example, individuals who go on to subsequently develop alcohol dependence presumably consume alcohol at a lower, though still unhealthy (e.g., harmful alcohol use), level at a prior point. It therefore seems reasonable to assert that AUDs themselves exist on a continuum with normality, with certain individual and environmental risk factors making an individual, at any given time, more or less

likely to drift towards (or indeed away from) the ‘clinical’ end of this continuum. It is therefore vital that we increase our understanding of such risk factors.

I.III) MODELS OF ALCOHOL (AND OTHER DRUG) DEPENDENCE

A variety of different approaches have been forwarded to account for the phenomena of alcohol and other drug dependence. These approaches occur at three broad levels of explanation: 1) biology; 2) psychology and; 3) the environment (Teesson *et al.*, 2013). They are by no means mutually exclusive; indeed, a great deal of overlap exists between them. These approaches, along with some of their key empirical findings, are outlined below.

I.III.I) THE BIOLOGICAL APPROACH

This approach incorporates two sub-levels of explanation: one at the genetic level and one at the level of abnormalities in brain structure and function. The former contends that certain individuals inherit an increased likelihood/vulnerability of developing alcohol misuse via their genes – a position supported by family¹, adoption² and twin studies³. For example, a family study reported by Merikangas *et al.* (1998) found that 36 per cent of the relatives of those with either harmful alcohol use or dependence also had a diagnosis of one of these disorders, compared to just 15 per cent of the relatives of controls (see also Goodwin, 1989, Bierut *et al.*, 1998). Whilst suggestive, such studies do not allow for a separation of genetic and environmental influences – something that adoption and twin studies *are* able to do. Adoption studies indeed suggest a significant genetic influence in adoptees’ vulnerability to alcohol use disorders (Schuckit, Goodwin & Winokur, 1972, Goodwin *et al.*, 1973, Goodwin *et al.*, 1974, Goodwin *et al.*, 1977, Bohman, Sigvardsson & Cloninger, 1981, Cloninger, Bohman & Sigvardsson, 1981, Heath, 1995). Twin studies have produced further

¹ Family studies compare the rates of disorder amongst family members of individuals with a diagnosis of an alcohol use disorder against the rates amongst family members of individuals without an alcohol use disorder.

² In adoption studies, rates of disorder amongst adoptees are examined, given their biological and adoptive parents’ disorder status. This allows for examination of the respective effects of genetic (i.e. status of biological parents) against environmental effects (i.e. the status of adoptive parents) in vulnerability to disorder.

³ In twin studies, concordance rates between identical (or monozygotic; MZ) twins, who share 100 *percent* of their genes, are compared against concordance rates in fraternal (or dizygotic; DZ) twins, who share only around 50 *percent* of their genes. Environmental factors for any given twin pair are considered to be equal, meaning that a greater level of diagnostic similarity amongst MZ twins, relative to DZ twins, is interpreted as indicating that genetic factors contributed to the disorder.

evidence for a significant genetic component, with estimates of the heritability of alcohol dependence ranging from 39 to 60 per cent of the total variance (Hrubec & Omenn, 1981, Kendler *et al.*, 1992, Kendler *et al.*, 1994, Heath, 1995, Kendler, Davis & Kessler, 1997, Prescott *et al.*, 1997, Prescott & Kendler, 1999, True *et al.*, 1999).

Although convincing, the exact nature of this underlying genetic vulnerability remains elusive, with the search for candidate genes being inconsistent and inconclusive thus far (Malhotra *et al.*). Given the phenotypic variability of alcohol use disorders, it is likely that genetic influences involve multiple genes or incomplete expression of several major genes (Kendler, 1999, Schuckit, 1999). Nevertheless, linkage studies⁴ have produced evidence for loci on chromosomes one and seven, and suggestive linkage on chromosome two, with alcohol dependence (Reich *et al.*, 1998, Foroud *et al.*, 2000); and candidate gene association studies⁵ have identified variants of more than 20 genes that contribute vulnerability towards alcohol dependence, including genes for the major neurotransmitter systems (GABA, glutamate, serotonin, dopamine and acetylcholine) and genes involved with alcohol metabolism (alcohol dehydrogenase and aldehyde dehydrogenase), among others (Edenberg & Foroud, 2006, R Kranzler & J Edenberg, 2010).

Regarding brain abnormalities, those with alcohol dependence demonstrate chronic levels of under-activity within mesocorticolimbic dopamine (DA) circuitry (e.g., see reviews by Grace, 2000, Weiss & Porrino, 2002, Diana *et al.*, 2003, Volkow *et al.*, 2004). These tracts, commonly referred to as the 'reward' system, incorporate dopaminergic projections from the brain's ventral tegmental area (VTA) to the nucleus accumbens (NAcc), amygdala, anterior cingulate gyrus (ACG) and prefrontal cortex (PFC). These pathways are thought to serve important adaptive functions regarding 'naturally rewarding' stimuli, such as food or sex (Kelley & Berridge, 2002). Thus, in healthy individuals, DA transmission in the VTA is transiently elevated on exposure to such stimuli, serving to direct attention, decision-making and behaviour towards their procurement (via DAergic projections to the NAcc, striatum, anterior cingulate cortex (ACC) and other prefrontal regions; Schultz, Dayan & Montague,

⁴ In genetic linkage studies, the inheritance of a trait or disorder amongst family members is determined by examining whether one or more genetic markers across the 23 chromosomes segregate with the disorder.

⁵ Candidate gene association studies use a similar form of linkage mapping to linkage studies, but are allele-based, rather than locus-based. Thus, such studies examine whether alleles of a given gene are more or less common in those with a trait or disorder than in those without.

1997). The reasons for the underactivity in alcohol-dependent individuals are at present unclear, but are thought to involve both genetically-predisposing factors and chronic alcohol intake as part of a diathesis-stress relationship (Crabbe, 2002).

Robinson and Berridge (Robinson & Berridge, 1993, 2000) argue that, in certain individuals and under certain conditions, repeated consumption of an abusable drug can produce enduring alterations in the structure and function of the brain's reward circuitry. Consequently, the drug comes to 'hijack' the DAergic MCL system (Lubman, Yucel & Pantelis, 2004), with excessive levels of incentive salience attributed to the drug and associated stimuli, at the expense of natural reinforcers. As detailed further in the Introduction of the main empirical project of this thesis (p. 49), manifestations of this hijacking include craving (Pomerleau *et al.*, 1983, Cooney *et al.*, 1987, McCusker & Brown, 1995, Reid *et al.*, 2006) and characteristic autonomic responses (e.g., increased heart rate, salivation) in the presence of alcohol and associated stimuli (Pomerleau *et al.*, 1983, Kaplan *et al.*, 1985, Cooney *et al.*, 1987, McCaul, Turkkan & Stitzer, 1989, Payne *et al.*, 1992, McCusker & Brown, 1995, Reid *et al.*, 2006).

I.III.II) THE PSYCHOLOGICAL APPROACH

Psychological approaches incorporate a wide range of different accounts for alcohol misuse that differ in the emphases they each place on various phenomena or mechanisms. There is only space to 'scratch the surface' here and for a thorough overview, the reader is directed towards West (2006). Put simply, psychological models fall into one of four broad categories: behavioural models, cognitive models, personality models and models of rational choice.

Behavioural theories tend to focus on directly observable aspects of addiction phenomena. Cue exposure theory, for example, appeals to classical conditioning processes and posits that cues that are repeatedly present at the time of drug-administration come to elicit a conditioned response (CR) – termed 'cue-reactivity' (Heather & Greeley, 1990, Drummond *et al.*, 1995). Conditioned stimuli (CS) may be exteroceptive, such as the smell of alcohol or the sight of a pub, or interoceptive, such as low mood or cognitions about drug effects (Greeley, Swift & Heather, 1992, Drummond *et al.*, 1995). The possible nature of the CR is a source of debate: whilst some researchers argue it to be primarily appetitive, others contend that it concerns a

homeostatic response opposite to the drug in question's acute effect(s). Either way, exposure to a CS is thought to underlie craving and may help to account for why an individual who has been abstinent for a prolonged period can nevertheless continue to experience craving (Heather & Greeley, 1990). Another group of behavioural models account for alcohol and other drug dependence via recourse to operant conditioning (West, 1989, Altman *et al.*, 1996).

Cognitive models of alcohol misuse include those focusing on cognitive biases and those focusing on expectancies of alcohol and other drug use, among other accounts. The former propose that the loss of control observed in alcohol and other drug dependence can be accounted for by automatic and pre-conscious cue-processing of stimuli associated with the drug in question. Thus, alcohol-related cues are evaluated 'pre-attentively' and are prioritised, triggering somatovisceral, behavioural and cognitive responses. This information-processing is subjected to automatic attentional and interpretative biases, which enhance the addict's awareness of both their physiological arousal and certain action-tendencies and cognitions. There is clear overlap between these models and cue exposure-based models. Cognitive bias models can account for observations that alcohol misusers demonstrate selective interference effects for alcohol-associated words in modified 'alcohol' Stroop tasks (e.g., Johnsen *et al.*, 1994, Stetter *et al.*, 1995, Sharma, Albery & Cook, 2001). Expectancy theories propose that alcohol misuse is related to the extent to which the individual expects that alcohol consumption will deliver a desired effect. For example, level of alcohol consumption is positively correlated with positive expectancies (e.g., social and physical pleasure, tension reduction, greater sociability, etc.) and inversely correlated with negative expectancies (Christiansen & Goldman, 1983, Brown, Christiansen & Goldman, 1987, Reich, Goldman & Noll, 2004).

Possibly the most well-known personality model of addiction is Cloninger's (Cloninger, 1987) tridimensional personality theory. This model proposes that there are three fundamental personality dimensions – novelty-seeking, harm avoidance and reward dependence – and that the interaction between these dimensions explains a large amount of the variance in a given individual's vulnerability towards alcohol and other drug dependence. The model specifies two distinct sub-types of alcohol dependence – Type I and Type II – which each comprise different constellations of novelty-seeking, harm avoidance and reward dependence. Type I alcohol dependence

is said to be associated with a later onset, less genetic involvement, characterised by moderate severity and fewer problem behaviours, with a personality profile of low novelty-seeking, high harm avoidance and high reward dependence. Type II alcohol dependence, on the other hand, occurs in adolescence or early adulthood, has a large genetic loading, is characterised by a more severe presentation and is associated with criminal behaviour, with a personality profile of high novelty-seeking, low harm avoidance and low reward dependence (Cloninger, Sigvardsson & Bohman, 1996). Other personality models of addiction include Eysenck's three-factor personality theory (e.g., see Roos, 1977a, b) and McRae and Costa's five-factor theory (e.g., see Conway *et al.*, 2003, Miller & Lynam, 2003).

Possibly one of the most well-known of the rational choice models, Skog's Choice Theory of addiction (Skog, 2000, Skog, 2003) asserts that, in some sense, addicted individuals *choose* to engage in alcohol and/or other drug consumption, on the basis that they are not physically *forced* to engage in the behaviour. This model argues that the *appearance* of lack of control is in fact brought about due to conflicting choices predominating at different times: sometimes the choice to continue taking the drug predominates, whilst at other times, the choice to abstain predominates.

I.III.III) THE SOCIOCULTURAL APPROACH

The twin studies described above estimate the heritability of alcohol dependence at between 39 and 60 per cent of the total variance, leaving substantial proportions of variance accounted for by environmental factors. Indeed, evidence consistently implicates the importance of specific environmental factors in the risk of alcohol misuse (Teesson *et al.*, 2013). One environmental 'route' concerns an individual's family (Hawkins, Catalano & Miller, 1992), with various mechanisms suggested. Perhaps most directly, parents and other family members can model alcohol intake. For example, the initiation and frequency of adolescents' alcohol use is associated with parental drug use. Evidence also suggests that permissive attitudes towards alcohol and other drug use by parents increases the likelihood of children using drugs. Also, substance misuse tends to be greater in conditions characterised by family discord, low levels of family bonding or poor or inconsistent behavioural management techniques by parents (Hawkins *et al.*, 1992).

Outside of the family, a given individual's alcohol and other drug use is highly associated with peer attitudes towards alcohol and other drugs (Newcomb, Maddahian & Bentler, 1986, Fergusson & Horwood, 1997).

The wider sociocultural context is also important. Those who misuse alcohol and other drugs are more likely to come from lower socioeconomic backgrounds (Anthony, Warner & Kessler, 1994, Hall, Johnston & Donnelly, 1999). For example, they are more likely to have performed poorly at school, to have completed fewer years of education and to have grown-up in areas with high rates of crime (Medicine, 1996).

I.III.IV) SUMMARY

As outlined above, a range of different accounts have been forwarded in order to try to explain the development of alcohol and other drug misuse. Clearly, alcohol misuse is an incredibly complex phenomenon, comprising biological, psychological and environmental components, which must all be considered as part of a biopsychosocial model (Marlatt & VandenBos, 1997). Nevertheless, our increasing knowledge base concerning the brain abnormalities observed in alcohol misuse seems to hold much promise with regards to accounting for some of its most central phenomena.

I.IV) PREFRONTAL ABNORMALITIES IN ALCOHOL (AND OTHER DRUG) DEPENDENCE

The abnormalities within and throughout DAergic MCL circuitry, described in Section I.III.I above, include the PFC. More specifically, in a comprehensive review of the evidence, Jentsch and Taylor (Jentsch & Taylor, 1999) suggest that chronic exposure to drugs of abuse induces both structural and functional abnormalities within the PFC, especially the orbitofrontal cortex (OFC), anterior cingulate gyrus (ACG) and dorsolateral PFC (DLPFC) (Volkow *et al.*, 1993, London *et al.*, 2000, Robinson *et al.*, 2001)⁶. OFC function seems important in processing a stimulus's affective valence and selecting appropriate responses; the ACG in inhibiting pre-potent reflexive responses; and the DLPFC in the monitoring of strategically-guided

⁶ Based on observations that alcohol-dependent patients with two or more detoxifications show greater prefrontal dysfunction(s) than those detoxified not more than once, Loeber and colleagues (Loeber *et al.*, 2009a, Loeber *et al.*, 2009b, Loeber *et al.*, 2010) contend that alcohol withdrawal induces neurotoxic lesions within the PFC.

behaviour and working memory (Aron, Robbins & Poldrack, 2004). Collectively, these processes relate to self-control and impulsivity; and so dysfunctions within the OFC, ACG and DLPFC would thus be expected to bring about deficits in these abilities. Consistent with this, around half (five out of 11) of the DSM-5 criteria (Association, 2013a) for alcohol use disorder describe seemingly impulsivity-related phenomena. For example, criterion two states that ‘there is a persistent desire or unsuccessful efforts to cut down or control alcohol use’, criterion six describes ‘continued alcohol use despite having persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of alcohol’ and criterion eight refers to ‘recurrent use of alcohol in situations in which it is physically hazardous’. Indeed, Robinson and Berridge (Robinson & Berridge, 1993, 2000) contend that elevated impulsivity, together with cue-reactivity and attentional biases⁷ account for the core symptoms of addiction: compulsive drug-seeking and consumption despite profound adverse consequences and relapse. The foregoing has been complemented by a wealth of studies using self-report and/or behavioural methods reporting greater levels of impulsivity in those with alcohol dependence. Before detailing findings in this area, it is necessary to first define what is meant by the term ‘impulsivity’.

I.V) DEFINING AND MEASURING IMPULSIVITY

Though a multitude of definitions of impulsivity exist, most incorporate the following features: a tendency towards maladaptive behaviour, problems with response-inhibition, the gratification of ‘automatic’ urges/impulses and a low propensity to reflect prior to decision-making – especially that of a ‘risky’ nature (Robbins, Curran & de Wit, 2012). Thus, impulsivity is not a unitary construct (de Wit & Richards, 2004), the current consensus holding that it consists of at least two broad, distinct yet related, dimensions. Thus, for example, Gullo & Dawe (2008) have identified the dimensions of ‘reward drive’ (RD) and ‘rash impulsivity’ (RI). These dimensions refer, respectively, to the extent to which one is sensitive to incentives (as manifested in the tendency to engage in appetitive behaviour when exposed to signals of reward) and to the ability to modify or inhibit pre-potent (reward-drive-initiated) behaviour in order to avoid potentially aversive consequences.

⁷ Cue-reactivity and attentional biases are discussed in more detail on page 118 of the Introduction of the main empirical project of this thesis.

Existing behavioural and self-report instruments for assessing impulsivity can be classified as broadly mapping-on to these two components (for more detailed descriptions of most of the self-report and behavioural measures mentioned below, see Appendix 1). Behavioural tasks tapping RD traditionally quantify either an individual's preference for small, immediate rewards over larger but delayed rewards ('delay discounting'; Bickel & Marsch, 2001) or their preference for larger but less certain rewards over smaller but more certain ones ('probability discounting'; Green, Myerson & Ostaszewski, 1999). With respect to self-report scales, RD is closely aligned with measures designed to tap the behavioural approach/activation system (BAS; Gray & McNaughton, 2000), such as Carver and White's (1994) BAS scales and Torrubia *et al.*'s (2001) sensitivity to reward scale.

In terms of RI, the two most widely-used behavioural indices are the stop signal task (SST; Logan, 1994) and the go/no-go task – both of which specifically assess inhibitory control/response-inhibition; that is, the ability to override a pre-potent 'go' response (e.g., a button-press) when an infrequent 'stop' signal (requiring withholding of the button-press) is given. In terms of self-report scales, those tapping the central features of RI include the Barratt impulsiveness scale, version 11 (BIS-11; Patton, Stanford & Barratt, 1995), the sensation seeking scale (SSS; Kolin, Price & Zoob, 1964), the impulsiveness scale of Eysenck and Eysenck's (1978) I₇ and the positive urgency, negative urgency and (lack of) premeditation subscales of the UPPS-P (Lynam *et al.*, 2006).

The definition of impulsivity given above includes behaviours described as 'risky'. Although RD and RI may account for risky behaviour via inhibition failure(s) or a focus on the short-term 'thrill' (rather than long-term consequences), risk-taking seems to be a distinct aspect of impulsivity (Meda *et al.*, 2009). The balloon analogue risk task (BART; Lejuez *et al.*, 2002) is possibly the most widely-used measure here. The participant must balance potential rewards against potential losses, with those who prioritise the former judged as being greater in risk-taking. Risk-taking is also often indexed via the conceptually similar Iowa gambling task (IGT; Bechara *et al.*, 1997).

At present, a relatively unstudied aspect of impulsivity in alcohol misuse is 'reflection impulsivity' (Kagan, 1966), that is, 'deficits in the gathering and evaluation of information during the decision-making process' (Solowij *et al.*, 2012). Reported by

Caswell *et al.* (2015) to be distinct from other forms of impulsivity, this is often indexed via the beads task (Phillips & Edwards, 1966), in which more impulsive individuals tend to sample less information before coming to a decision. It is also often indexed via the information sampling task (IST; Clark *et al.*, 2006).

Although impulsivity has traditionally been conceptualised as a stable, internal disposition (e.g., McCrae *et al.*, 2000, Costa & McCrae, 2006), it in fact seems to undergo pronounced reductions from adolescence to young adulthood (i.e. between around 18 and 25 years; Arnett, 2000), as conscientiousness, constraint and self-control all increase (e.g., Roberts, Caspi & Moffitt, 2001, 2003, Donnellan, Conger & Burzette, 2007, Blonigen *et al.*, 2008, Vaidya *et al.*, 2008). This progressive reduction in impulsivity can be contextualised within the broader developmental maturation of executive functions that occurs during late adolescence and is related to corresponding maturation of the frontal lobes (Blakemore & Choudhury, 2006).

I.VI) ELEVATED IMPULSIVITY IN ALCOHOL DEPENDENCE

The Introduction of the main empirical project of this thesis details the elevated impulsivity observed in alcohol dependence (p. 52). Briefly, then, an abundance of studies indicates that those with alcohol dependence show reliable elevations (across both self-report and behavioural indices) in RD (Petry, 2001, Johnson, Turner & Iwata, 2003, Bjork *et al.*, 2004, Mitchell *et al.*, 2005, Boettiger *et al.*, 2007, Mitchell *et al.*, 2007, Sprah & Novak, 2008, Bobova *et al.*, 2009, Lyvers *et al.*, 2014), RI (von Knorring, Orelund & von Knorring, 1987, Hallman *et al.*, 1990, Ketzenberger & Forrest, 2000, Bjork *et al.*, 2004, Goudriaan *et al.*, 2006, Chen *et al.*, 2007, von Diemen *et al.*, 2008, Lawrence *et al.*, 2009, Cangemi *et al.*, 2010, Schmaal *et al.*, 2013, Petit *et al.*, 2014, Zhou *et al.*, 2014) and risk-taking (Fein, Klein & Finn, 2004, Goudriaan *et al.*, 2005, Dom *et al.*, 2006b, Noël *et al.*, 2007, Kim, Sohn & Jeong, 2011) impulsivity sub-domains. Few studies have explored potential differences in reflection impulsivity between alcohol dependent individuals and healthy controls. In one of the only such studies, however, Lawrence *et al.* (2009) found these individuals to demonstrate significantly higher reflection impulsivity (via the IST), relative to controls.

This elevated impulsiveness may be either causative or consequential (or both) of sustained alcohol misuse. As mentioned above, there is evidence that chronic drug abuse leads to prefrontal dopaminergic hypofunction (e.g., Loeber *et al.*, 2009a,

Loeber *et al.*, 2009b, Loeber *et al.*, 2010). Conversely, premorbid trait impulsivity has been implicated as a risk factor for subsequent problematic drug use (2000, Fernie *et al.*, 2013). Interestingly, the relative importance of different impulsivity sub-domains may change across the development of AUDs: whilst difficulty delaying reward seems more associated with the initial engagement in substance use, premorbid impairments in inhibitory control seem more associated with the subsequent development of dependence (2008).

I.VII) ELEVATED IMPULSIVITY IN NON-DEPENDENT HEAVY DRINKERS?

The research quoted above principally involves those with long-term, chronically-relapsing patterns of alcohol dependence. Since addiction theory (e.g., Robinson & Berridge, 1993, Jentsch & Taylor, 1999, Robinson & Berridge, 2000) considers such individuals to be at the ‘end-point’ of a progressive development, so one might expect those with non-dependent yet heavy patterns of alcohol misuse to also show elevated impulsivity. At present, however, this is unclear.

In terms of behavioural indices of RD, heavier drinkers have been shown to demonstrate greater levels of delay discounting of hypothetical monetary and alcohol-related rewards, relative to light drinkers (Vuchinich & Simpson, 1998, Kollins, 2003, Field *et al.*, 2007, Rossow, 2008, Moore & Cusens, 2010, Murphy & Mackillop, 2012). However, the association between alcohol misuse and delay discounting seems equivocal, as null results have been reported in a number of other studies (e.g., MacKillop *et al.*, 2007, Reimers *et al.*, 2009, Fernie *et al.*, 2010, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016). Self-report indices, on the other hand, have more reliably yielded positive findings, however, with Franken and Muris (2006), Pardo *et al.* (2007) and Hamilton *et al.* (2012) all reporting higher BAS scores in heavy, relative to light, drinkers.

Concerning behavioural measures of RI, a number of studies have found heavier drinkers more impulsive in their responses (Colder & O'Connor, 2002, Smith & Mattick, 2013), although a host of others (e.g., Fernie *et al.*, 2010, Henges & Marczinski, 2012, Papachristou *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016) have reported no group differences. In terms of self-reported RI, a number of cross-sectional and longitudinal studies suggest that elevated impulsivity corresponds with increased alcohol intake and

related problems in non-alcohol-dependent adolescents and adults alike (Vuchinich & Calamas, 1997, Waldeck & Miller, 1997, Gunnarsson *et al.*, 2008, Carlson, Johnson & Jacobs, 2010, Fernie *et al.*, 2010, Hamilton *et al.*, 2012, Lyvers *et al.*, 2012, Moreno *et al.*, 2012, Papachristou *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016); although Rose and Grunsell (2008), Balodis, Potenza and Olmstead (2009) and Harvanko *et al.* (2012) have all reported null results.

Compared to studies examining RD and RI, fewer have examined risk-taking. Nevertheless, Fernie *et al.* (2010) reported that riskier performance on the BART (but, interestingly, neither response inhibition nor delay discounting) predicted levels of alcohol consumption and alcohol-related problems (see also Courtney *et al.*, 2012, Fernie *et al.*, 2013). Similarly, several cross-sectional and prospective studies have reported binge-drinking adolescents and university students to show poorer performance on the IGT, relative to non-bingers (Goudriaan, Grekin & Sher, 2007, Xiao *et al.*, 2009, Moreno *et al.*, 2012, Xiao *et al.*, 2013). However, Ashenhurst, Jentsch and Lara (2011), Claus and Hutchison (2012) and Ahmadi *et al.* (2013) all failed to find a significant association between risk-taking on the BART and alcohol misuse.

As in dependent samples, few studies have examined reflection impulsivity in non-dependent light and heavy drinkers. Relatively recently, Townshend *et al.* (2014) reported binge-drinkers to be more impulsive on the IST, compared to non-binge drinkers. However, in two studies published since, neither Banca *et al.* (2016) nor Caswell *et al.* (2016) found any differences on this task, Banca *et al.* comparing bingers and non-bingers and Caswell *et al.* comparing heavy and light drinkers. Interestingly, though, in the same study, Banca *et al.* (2016) found bingers to be more impulsive on the beads task, relative to non-bingers.

As the above illustrates, there is a lack of clarity around which forms of/the extent to which impulsivity are/is elevated in non-dependent drinkers: thus, the impulsivity *profile* of such individuals is unclear. An important issue in this field is that relatively few studies appear to have assessed impulsivity *across multiple domains in a single sample*, many studies administering just one or two measures (often self-report, given the relative ease of administration and scoring). The problem with this is that conflicting findings across studies in the various impulsivity measures may relate to variance associated with different samples (e.g., sample-size, age-range, gender-ratio, levels of drinking in the respective light and heavy groups, etc.), rather than relating

‘purely’ to impulsivity *per se*. Sample-sizes, for example, have varied greatly between studies: whereas Smith and Mattick (Smith & Mattick, 2013) and Papachristou *et al.* (Papachristou *et al.*, 2012) recruited 30 and 42 participants, respectively, Franken and Muris (Franken & Muris, 2006) and Pardo *et al.* (Pardo *et al.*, 2007) respectively recruited 276 and 144 participants. Such large differences make comparison between studies difficult. It is thus preferable that studies index the various forms of impulsivity within a (large enough) single sample, so as to hold such sample variances constant (at least within the context of any given study). This should facilitate greater clarity around the nature of elevated impulsivity in non-dependent drinkers.

I.VIII) THE PRESENT STUDY

Since impulsivity is reliably elevated in alcohol dependent individuals, it may be a psychological risk factor for the initial development and maintenance of non-dependent forms of alcohol misuse. The aim of this study was thus to review whether impulsivity is also elevated in groups of non-dependent alcohol misusers (e.g., heavy/hazardous drinkers, binge drinkers, etc.), relative to healthy drinking comparison groups.

The studies reviewed were restricted to those using cross-sectional designs, to gain a ‘snapshot’ of impulsivity in non-dependent alcohol misusers. Such studies are unable to disentangle cause-and-effect. If, however, impulsivity is indeed elevated in such groups, this would suggest its preceding (and possibly contributing to) the onset of dependence, rather than being merely symptomatic. Furthermore, it would also be a focus for future intervention(s). Overall, given the substantial social costs of alcohol misuse, the potential benefits of intervening in such drinking are substantial.

Given impulsivity’s comprising multiple sub-domains, the review focused on studies comparing groups on impulsivity multi-dimensionally – defined here as *via more than one index*. Within this two-measure-minimum, at least one had to be self-report and at least one behavioural. This was due to poor correlations between self-report and behavioural impulsivity measures (e.g., Dom *et al.*, 2006a) and the attendant possibility that they may each measure separate constructs – and consequently that they may share different relationships with alcohol use/misuse.

Since executive functions (of which impulsivity is one) undergo significant change (i.e. maturation) between the ages of around 18 to 25 years (e.g., Caspi, Roberts &

Shiner, 2005, Donnellan *et al.*, 2007, Blonigen *et al.*, 2008), one could argue that those within this age-range represent a neurodevelopmentally distinct subgroup. Accordingly, it is becoming increasingly common for empirical studies of impulsivity in young adults to restrict their samples to those aged 18-25. For these reasons, the present search was also limited to studies including participants within this age-range. An informal search of the literature revealed no systematic reviews to have examined impulsivity in young adults, although Stautz and Cooper (Stautz & Cooper, 2013) have reviewed self-report indices of impulsivity in adolescent drinkers.

II. METHODS

II.1) IDENTIFICATION OF STUDIES/SEARCH STRATEGY

This review was based on a systematic search of peer-reviewed papers published up to and including the beginning of the second week of January 2017. The search was conducted in line with PRISMA (preferred reporting items for systematic reviews and meta-analyses) guidelines.

The databases searched were Embase (1974-2017, Week 2), Medline (1946-January, Week 2, 2017) and PsycINFO (1806-January, Week 2, 2017). Three categories of search terms were used in combination. Terms related to: 1) impulsivity; 2) alcohol use, and; 3) type of sample. The respective verbatim strategies used to search each of the databases in Phase 1 are shown in Table A3 in Appendix 2. The use of the thesaurus in each database allowed for keywords and terms to be exploded, thereby ensuring that all relevant terms were included in the search. The aim of the search strategy was to return the maximum number of original empirical studies that have examined the relationship between levels of alcohol consumption and multiple dimensions of impulsivity within samples of non-dependent drinkers. To this end, the search strategy included terms from across the spectrum of non-dependent drinking (e.g., from ‘social drinkers’ through to ‘harmful drinking’). Since much of this literature has been carried out in university students, terms such as ‘college students’ and ‘student drinkers’ were included in the search strategy. The search was limited to studies conducted with humans and those published in English language peer-reviewed journals, with non-English language publications being excluded to avoid translation bias. The search was also limited to those including participants aged 18-25 years.

Following the online search, a backwards ancestry search was conducted. Thus, the titles and abstracts of all papers included in the references sections of all journal articles deemed to meet inclusion criteria in the qualitative synthesis were screened, in order to identify further articles to be considered for inclusion. The titles and abstracts of articles in the references sections of papers deemed eligible via this method were in turn screened for eligibility, and so on. This process of ‘going backwards through the generations’ continued until no further eligible articles were identified. Grey literature was not included.

II.II) INCLUSION CRITERIA FOR RETURNS

Articles retained for analysis: 1) were publications in peer-reviewed journals, thereby excluding unpublished dissertations and conference papers; 2) were empirical research studies; 3) were cross-sectional, thus excluding longitudinal and prospective follow-up studies; 4) included non-clinical samples of participants; 5) compared two or more groups of drinkers; 6) assessed impulsivity multi-dimensionally, defined here as *via at least one self-report measure together with at least one behavioural measure*; 7) measured alcohol use via typical consumption or problematic use, thus excluding studies that examined variables such as alcohol expectancies or craving/desire to consume alcohol during the experimental session (e.g., as part of a ‘bogus taste-test’), and; 8) included participants aged between 18 and 25 years. For more specific, operational definitions of these criteria, see Appendix 3. Overall, in cases where it was unclear whether a paper met the inclusion criteria, the benefit of the doubt was given and full-texts downloaded for further screening.

II.III) EXCLUSION CRITERIA FOR RETURNS

Studies that included individuals identified as currently or formerly alcohol-dependent participants/patients as part of their ‘heavy/heavier drinkers’ were excluded, as were studies that included participants identified as currently or formerly abusing or being dependent on any other psychoactive drugs (with the exceptions of caffeine and nicotine). However, in cases where a light-drinking/control group was compared to separate groups of heavy/heavier drinkers/alcohol abusers and other drug users/abusers (e.g., cannabis), these articles were considered eligible for full-text download.

Studies that had recruited participants identified either as having self-reported difficulties/problems with alcohol and/or wanting to cut-down/quit and/or control their drinking were excluded. Also excluded were studies with participants divided into groups based on their being either family history positive (FHP) or family history negative (FHN) for alcohol use disorders. In addition, studies that included participants with any other comorbid DSM Axis 1 and/or 2 diagnoses (e.g., those with an anxiety and/or mood disorder, attention-deficit/hyperactivity disorder and/or personality disorders) were also excluded, as were studies that examined specific, 'non-representative' groups of individuals, such as perpetrators of violent crime, street homeless individuals, etc. Also excluded were studies including individuals who had sustained any brain injury.

No inclusion or exclusion criterion was given any primacy over others as all were considered equally important. This had the result that, at the point of reading full-texts, each paper was capable of violating more than one inclusion and/or exclusion criterion.

II.IV) STUDY SELECTION

Following the initial search, the returns from the three databases were collated, resulting in a total of 3,080 results. Some 1,303 duplicates were identified and removed, leaving 1,777 returns. This was done electronically using Endnote, Version X7 (Thomson Reuters) and then verified by hand. After this, the titles and abstracts of each of the resulting papers were read in order to determine eligibility, using the inclusion and exclusion criteria outlined above. This resulted in 36 papers being identified that potentially met the inclusion criteria. Their full-texts were downloaded online via the King's College London journal subscription. These papers were reviewed in order to, firstly, determine whether they did indeed meet the inclusion criteria, and secondly, to formally assess their quality. Twenty-five full-texts did not meet the inclusion criteria and were discarded from further analysis. The authors of three articles that met all other inclusion criteria, but where the ages of participants were unclear (but which could plausibly have been between 18-25 years), were contacted for clarification but did not reply. This therefore left eight articles identified via the database route.

The backwards ancestry search was then conducted, via screening of the 435 references contained in the reference sections of the eight articles identified via the databases. After removal of duplicates (in relation to both the original database search and amongst the references of these 8 papers), 359 articles were screened for eligibility. Of these, 353 were excluded, leaving 6 as potentially eligible, for which the full-texts were downloaded. None of these six were considered eligible for inclusion, and so the backwards ancestry search ended at this point, after 1 'generation'. Figure 1 displays the PRISMA flow diagram for the selection process.

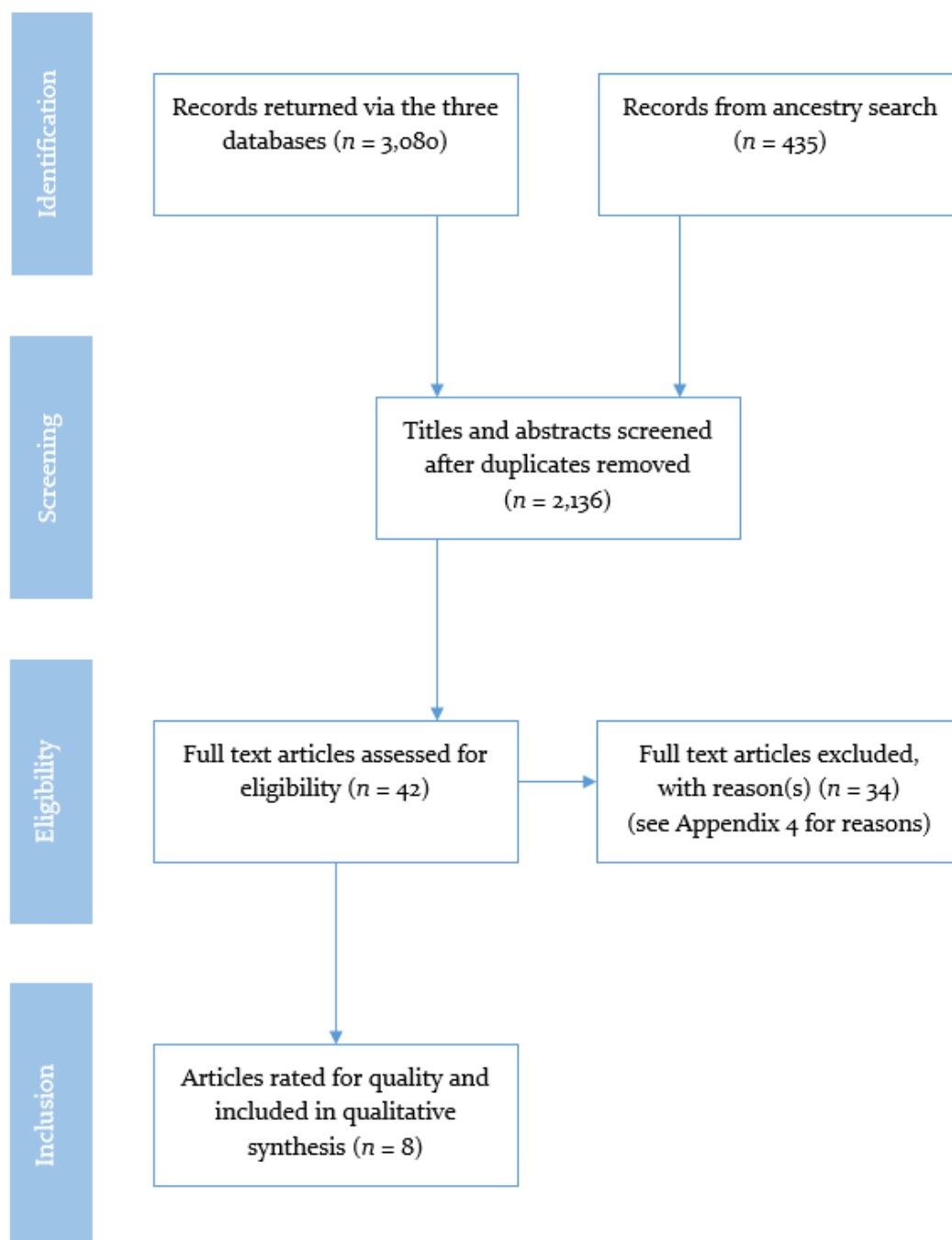


Figure 1: PRISMA flow-chart of the literature search screening and inclusion and exclusion process

Table 1 presents the reasons that downloaded full-texts were excluded from the final qualitative review, and the numbers of full-texts excluded for each reason.

Table 1: Reasons that downloaded full-texts were excluded and the numbers of full-texts excluded for each reason*

Reason (alphabetised)	Numbers of full-texts excluded (<i>N</i> = 34)
<i>Authors did not respond to request for participant ages</i>	3
<i>No behavioural impulsivity measure(s) given</i>	4
<i>No self-report impulsivity measure(s) given</i>	13
<i>Neither behavioural nor self-report measures given</i>	1
<i>Participants' ages outside of 18-25 range</i>	22*
<i>Participants met or possibly met criteria for alcohol dependence</i>	4
<i>Sample included those who had sought help to cut-down/quit</i>	1

* Sum total of full-texts exceeds the total of 34, as many violated more than one inclusion/exclusion criterion.

** This figure may have in fact been greater, as many studies did not report the age-range of their sample. Thus, the author(s) of such articles were not contacted for clarification in cases whereby their study had nevertheless violated one or more of the other inclusion/exclusion criteria.

II.V) DATA EXTRACTION

For each study included in the review, the location (by country) of data-collection was extracted, as well as the population(s) targeted for recruitment (e.g., university students), details of subgroups (e.g., light drinkers and heavy drinkers), the sample-size, mean (standard deviation [SD]) ages for the sample (and sub-groups) and the age-range. Given the importance of measuring (and potentially controlling for) socioeconomic status and IQ, data were also collected on whether these variables

were measured and, if so, respective scores. Estimated mean weekly alcohol consumption was recorded in up to two forms: (i) in the form originally reported by the authors and (ii) if not already provided as part of (i) (e.g., was not conducted in the UK, in the equivalent amount of UK units of alcohol (1 unit = 8 grams of pure alcohol). Estimated mean UK units were considered important, in order that studies could be meaningfully compared and contrasted as part of the qualitative synthesis. Details of the self-report (the scales and subscales reported) and behavioural impulsivity measures (and the specific outcomes reported) were recorded, together with the analyses performed and relevant findings.

II.VI) QUALITY ASSESSMENT

The quality of retrieved articles was assessed using the National Institutes of Health (NIH) Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (United States National Institutes of Health, 2014). This instrument is used in systematic literature reviews to consider the potential for bias and confound in the conduct and results of a study. It was based on quality assessment tools developed by researchers in the Agency for Healthcare Research and Quality (AHRQ), the Cochrane Collaboration, the Scottish Intercollegiate Guidelines Network and the National Health Service Centre for Reviews and Dissemination, among others. To this end, it assesses studies via 14 questions, to which responses can be 'yes', 'no' or 'other (cannot determine (CD), not applicable (NA) or not reported (NR))' (see note accompanying Table 2 for the specific questions). Aspects of the study assessed via the measure are: (i) the research question (Item 1); (ii) the study population (Items 2 and 3); (iii) whether groups were recruited from the same population and eligibility criteria (Item 4); (iv) whether there was a sample-size justification (Item 5); (v) whether exposures were assessed prior to measurement (Item 6); (vi) whether there was a sufficient time-frame to see an effect (Item 7); (vii) whether there were different levels of the exposure of interest (Item 8); (viii) the exposure measures and assessment (Item 9); (ix) whether there was repeated exposure assessment (Item 10); (x) the outcome measures (Item 11); (xi) whether outcome assessors were blinded (Item 12); (xii) the follow-up rate (Item 13), and; (xiii) the statistical analyses (Item 14). The extent to which a study's results are considered to reflect a genuine effect, and not to flaws in its design or conduct, leads to the study being assigned an overall quality rating of 'good', 'fair' or 'poor'. In order that the rating tool was specifically

relevant for the studies included in the present review, items were considered in terms of systematic criteria (these are detailed in Appendix 4). All included studies were assessed by two independent raters using the tool, with concordance for individual items and overall quality ratings examined using Kohen's kappa (1960). Points of difference for ratings of overall quality were discussed and resolved.

III. RESULTS

III.1) CHARACTERISTICS OF INCLUDED STUDIES

A variety of measures were used by the final eight studies to index self-reported and behavioural impulsivity across. Table A1 in Appendix 1 describes the various self-report measures used to assess impulsivity across these studies, whilst Table A2 displays the various behavioural laboratory tasks used to assess impulsivity.

Table 2 summarises the characteristics of papers included in the final synthesis, including details regarding samples, typical weekly alcohol intake, impulsivity measures administered and analyses and relevant findings.

Table 2 summarises the characteristics of papers included in the final synthesis, including details regarding samples, typical weekly alcohol intake, impulsivity measures administered and analyses and relevant findings.

Table 2: Summary of the principal characteristics of studies included in qualitative synthesis

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample- size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered		Analyses and relevant findings ³
			Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	
Ahmadi <i>et al.</i> (2013) (United States) Heavy drinkers = 18.97 (0.45) Light drinkers' = 18.80 (0.97) Range = 18-20	91 first-year university students 35 heavy drinkers (34.2% male) 56 light drinkers (55.3% male) SES not measured IQ not measured	<u>SCID number of US standard drinks per day⁴, past 6 months:</u> Heavy drinkers = 10.27 (6.60) Light drinkers = 2.85 (4.04) <u>Estimated weekly consumption in UK units:</u> Heavy drinkers = 125.81 Light drinkers = 34.91	1. BIS-11 (total score) 2. BAS Scales 3. SSS	1. BART (average pumps adjusted) 2. GNG (number of correct rejections, number of false alarms, error proportion, RT, go hit RT and no-go RT: false alarms)	<u>t-tests:</u> Heavy drinkers greater on BAS scales, BIS-11 and SSS. GNG RT, go hit RT and no-go RT: false alarms all greater in heavy drinkers. No group differences for GNG number of correct rejections, number of false alarms or error proportion. No group difference on the BART.
Banca <i>et al.</i> (2016) (United Kingdom) Binge drinkers = 22.2 (3.35) Healthy volunteers =	60 members of the community and university students 30 binge drinkers (17 males and 13 females) 30 healthy volunteers	Binge drinkers = 13.20 (4.85) units per week Healthy volunteers =4.78 (2.41) units per week	1. UPPS-P (negative urgency, premeditation, perseveration, sensation seeking and positive urgency subscales)	1. Beads task (number of beads selected) 2. IST (number of boxes opened) 3. MCQ (k)	<u>t-tests:</u> Binge drinkers greater on UPPS-P negative urgency, premeditation and positive urgency; no group differences for perseveration or

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Table 2 continued

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample- size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered		Analyses and relevant findings ³
			Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	
21.85 (3.26) Range = 20-25	(17 males and 13 females) SES not measured IQ of binge drinkers = 116.61 (5.26) IQ of healthy volunteers = 116.72 (6.19) (IQ measure not stated)				sensation seeking. Binge drinkers selected fewer beads than healthy volunteers on beads task; no group differences on IST or MCQ.
Caswell <i>et al.</i> (2016) (United Kingdom) Low drinkers = 20.34 (1.74) Excessive drinkers = 19.79 (1.45) Range = 18-25	151 university students 87 low drinkers 52 excessive drinkers Overall, 78 females and 73 males (gender-ratio by group not given) SES not measured NART IQ of low drinkers = 108.19 (6.95) NART IQ of excessive	Low drinkers = 8.13 (4.87) units per week Excessive drinkers = 30.95 (12.78) units per week	1. BIS-11 (attentional, motor and non- planning impulsiveness subscales)	1. IST (Pcorrect) 2. MCQ (k) 3. SST (SSRT)	<u>t-tests:</u> Excessive drinkers greater on BIS- 11 motor and non- planning impulsiveness; no group difference on attentional impulsiveness. No group differences on IST, MCQ or SST. <u>Hierarchical regression:</u> BIS-11 only significant positive predictor of

Table 2 continues over the page

Table 2 continued

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample- size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	Analyses and relevant findings ³
	drinkers = 107.37 (6.76)				AUQ units per week.
Henges & Marczinski (2012)	109 Undergraduate university students	<u>TLFB total number of US standard drinks⁴ in past 30 days:</u>	1. BIS-11 (total score)	1. GNG (proportion of inhibition failures following invalid go cue, proportion of inhibition failures following valid go cue, mean RT following invalid no-go cue, mean RT following valid go cue	<u>ANOVAs:</u> No group differences on any measure.
(United States)	40 binge drinkers (20 males and 20 females)	Male binge drinkers = 60.25 (49.22)			<u>Multiple regressions:</u>
Male binge drinkers = 19.30 (0.92)	69 non-binge drinkers (26 males and 43 females)	Female binge drinkers = 23.10 (23.66)			With TLFB total number of drinks as criterion, BIS-11 total and GNG proportion of inhibition failures significant predictors (GNG mean RT not).
Female binge-drinkers = 19.30 (0.92)	SES not measured	Male non-binge drinkers = 22.69 (30.06)			With TLFB number of heavy drinking days as criterion, BIS-11 total and GNG proportion of inhibition failures significant predictors. (GNG mean RT not).
Male non-binge drinkers = 20.04 (1.04)	IQ not measured	Female non-binge drinkers = 10.70 (16.18)			With TLFB number of drunk days as criterion, only BIS-11 total a significant predictor;
Female non-binge drinkers = 19.35 (1.11)		<u>Estimated weekly consumption in UK units:</u>			
Range = 18-21		Male binge drinkers = 24.62			
		Female binge drinkers = 9.43			
		Male non-binge drinkers = 9.31			
		Female non-binge			

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Table 2 continued

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample- size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered		Analyses and relevant findings ³
			Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	
		drinkers = 4.41			there was a trend for GNG proportion of inhibition failures (GNG mean RT not significant). With TLFB highest number of drinks as criterion, only GNG proportion of inhibition failures was significant (BIS-11 total and mean RT were not)
Moreno <i>et al.</i> (2012) ⁵ (Spain) Binge drinkers = 19.54 (1.40) Non-drug users = 20.11 (1.75) Range = 18-24	48 university students 22 binge drinkers (10 males and 12 females) 26 non-drug users (11 males and 15 females) SES not measured IQ not measured	No data reported regarding participants' typical alcohol consumption	1. BIS-11 (total score and attentional, motor and non-planning impulsiveness subscales) 2. SSS (total score and thrill and adventure seeking, experience seeking, disinhibition and boredom susceptibility subscales)	1. GNG (false alarms and omission errors) 2. IGT 3. SST (SSRT and go RT) 4. TCT	<u>ANOVAs</u> : Binge drinkers greater on BIS-11 total score and motor and non-planning impulsiveness subscales (no group difference for attentional impulsiveness), as well as SSS total and disinhibition subscale (no difference on thrill and adventure seeking, experience seeking and

Table 2 continues over the page

Table 2 continued

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample- size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered		Analyses and relevant findings ³
			Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	
					boredom susceptibility). Binge drinkers showed a greater number of disadvantageous card choices on IGT. No group differences on GNG, SST or TCT.
Petit <i>et al.</i> (2012) (Belgium) Light drinkers = 21.55 (2.09) Heavy drinkers = 21.00 (1.87) Range = 18-25	35 university students 18 light drinkers (10 male) 17 heavy drinkers (8 male) SES not measured IQ not measured	<u>Number of alcohol doses⁶ per week:</u> Light drinkers = 5.78 (7.90) Heavy drinkers = 20.92 (11.25) <u>Estimated weekly consumption in UK units:</u> Light drinkers = 7.23 Heavy drinkers = 26.15	1. UPPS (total score)	1. GNG (RT, omission errors and commission errors)	<u>Form(s) of analyses not specified:</u> No group difference for UPPS total score. No group differences on any GNG index.
Rose & Grunsell (2008) ⁷ (United Kingdom)	20 university students 10 bingers (5 males and 5 females) 10 non-bingers (5 males)	Bingers = 60.8 (10.7) units per week Non-bingers = 21.3 (0.7) units per week	1. BIS-11 (attentional, motor and non- planning impulsiveness)	1. TCIP (proportions of immediate and delayed choices)	<u>ANOVAs:</u> No group differences on any BIS- 11 subscale. No group differences on TCIP.

Table 2 continues over the page

Table 2 continued

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample- size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered		Analyses and relevant findings ³
			Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	
Mean (SD) age only given for overall sample = 21.5 (0.4) Range = 18-25	and 5 females) SES not measured IQ not measured				
Sanchez-Roige <i>et al.</i> (2014) ⁷ (United Kingdom) Non-bingers = 22.14 (1.83) Bingers = 20.23 (1.44) (Bingers significantly younger than non- bingers at $p < 0.00$) Range = 18-25	44 university students 22 non-bingers (11 males and 11 females) 22 bingers (11 males and 11 females) SES not measured NART IQ of non- bingers = 114.53 (9.91) NART IQ of bingers = 112.0 (8.17)	Bingers = 25.22 (13.23) Non-bingers = 10.10 (8.34)	1. BIS-11 (total score and attentional, motor and non-planning impulsiveness subscales)	1. Sx-5CSRTT ⁸ (accuracy, percentage omissions and percentage premature responding) 2. MCQ ⁹ (k and AUC) 3. SST (Go RT and SSRT) 4. TCIP (proportion of immediate choices and maximum number of consecutive delayed choices)	Binge drinkers greater on BIS-11 motor and non-planning impulsiveness (ANOVAs); no group difference on BIS-11 attentional impulsiveness or BIS-11 total (ANOVA). <u>ANOVAs:</u> In the 5CSRTT, binge drinkers showed greater levels of premature responding in fITI condition; no other group differences on other indices. In TCIP, binge drinkers chose delayed options

Table 2 continues over the page

Table 2 continued

Author(s)/study (country), participants' mean ages (SD) and age-range(s) (years)	Sample details: sample-size and population of participants (gender breakdown), SES and IQ	Mean (SD) estimated weekly alcohol consumption (UK units) ^{1, 2}	Impulsivity measures administered Self-report measure(s) and scales/subscales reported	Behavioural measure(s) and outcomes reported	Analyses and relevant findings ³
					less frequently, and a trend towards more immediate choices. No group differences for MCQ or SST indices.

¹ 1 UK unit = 8 grams of pure alcohol.

² If author(s) originally reported typical alcohol consumption in values other than UK units (e.g., if study was non-UK-based), the originally-reported values are first given, followed by their estimated equivalent(s) in UK units of alcohol.

³ Significant findings denote a p -value < 0.05.

⁴ 1 US standard drink = 14 grams of pure alcohol.

⁵ The sample in Moreno *et al.* (2012) also included a separate group of 20 cannabis users, though data pertaining to this group are not included here.

⁶ 1 Belgian alcohol dose = 10 grams of pure alcohol.

⁷ Although the authors included a further behavioural measure, the time estimation task (TET), which they identified as measuring impulsivity, time estimation is not traditionally recognised as an aspect of impulsivity in the literature and so these data were not included here.

⁸ The authors had participants perform four variants of the task: (i) a fixed inter-trial interval (fITI) and (ii) a variable inter-trial interval (vITI) session under simple task conditions, and; in order to increase attentional load, (iii) a fITI and (iv) a vITI session in combination with a dual task in which the participant is also required to respond to a 659 Hz tone by pressing a button with their non-dominant hand. Due to the potentially confounding effects of working memory on performance in the latter two variants, only data pertaining to the two variants under simple task conditions were extracted here.

⁹ Although the authors refer to this as the delay discounting questionnaire (DDQ), this is in fact the MCQ (see below).

Note. Sx-5CSRTT = Sussex 5-choice serial reaction time task; ANOVA = analysis of variance; AUC = area under the curve for delay discounting; BART = balloon analogue risk task; BIS-11 = Barratt impulsiveness scale, version 11; BAS Scales = behavioural activation scales; GNG = go/no-go task; IGT = Iowa gambling task; IST = information sampling task; k = discounting parameter (MCQ); MCQ = monetary choice questionnaire; NART = national adult reading test; RT = reaction time; $P_{correct}$ = probability of being correct at the point of decision-making (IST); SD = standard deviation; SES = socioeconomic status; SSRT = stop signal

reaction time; SSS = sensation seeking scale; SST = stop signal task; TCIP = two choice impulsivity paradigm; TCT = two choice task; TLFB = time-line follow back questionnaire; UPPS-P = urgency, (lack of) premeditation, (lack of) perseverance and sensation seeking impulsive behaviour scales.

The systematic search of three scientific databases, and subsequent ancestry search of the references of eligible papers from the databases, returned eight studies, a clear majority of seven (87.5%) having been published within the last five years (i.e. since 2012). Half (4/8) were conducted in the UK, two in the US and one each in Belgium and Spain.

III.II) SAMPLE CHARACTERISTICS

All studies provided information on the age and gender of their participants. Given that ages between 18-25 years was an inclusion criterion, ranges were necessarily restricted thus. In general across studies, there were approximately equal proportions of males and females. Notably, however, the heavy drinkers in Ahmadi *et al.* (Ahmadi *et al.*, 2013) were 65.8% female and of the non-bingers in Henges and Marczinski (Henges & Marczinski, 2012), 26 were male and 43 female. Regarding other potential confounders, only three studies (37.5%) measured participants' IQ and no single study collected data on socioeconomic status. Consistent with the predominantly university student samples, participant IQs were generally above-average (i.e. > 109).

In terms of the drinking status of samples, three studies compared groups of heavy drinkers with lighter drinkers, whilst five studies compared binge drinkers with non-bingers. This issue is considered in the Discussion section. No studies included more than two groups of participants (e.g., light drinkers, moderate drinkers and heavy drinkers). In terms of the populations from which participants were drawn, seven (87.5%) studies recruited university students exclusively, whilst the remaining one (Banca *et al.*, 2016) comprised both university students and members of the community.

One study (Moreno *et al.*, 2012) did not report data pertaining to typical levels of alcohol consumption. By far the greatest mean number of units consumed amongst the (quasi-)experimental groups was the heavy drinkers in Ahmadi *et al.* (Ahmadi *et al.*, 2013), who reported consuming the equivalent of 125.81 units of alcohol per week – that is, the equivalent of approximately 17 units per day (i.e. the equivalent of over 1.5 bottles of wine each day). The lowest number of mean units consumed by an experimental group was by the binge drinkers in Banca *et al.* (Banca *et al.*, 2016), who reported consuming 13.20 units per week – that is, below the UK recommended weekly limits (i.e. 14 units per week for men and women). In general, levels of

consumption amongst the remaining five studies varied, although there was a tendency for heavy and binge drinking groups to be drinking above the UK weekly guidelines and for comparison groups to be below.

III.III) IMPULSIVITY MEASURES ADMINISTERED

In terms of self-report measures, the most widely-administered was the BIS-11, given to participants in 6/8 (75%) studies (this was the most-administered measure across both self-report and behavioural indices). The SSS-V and the UPPS-P (and its earlier incarnation, the UPPS) were each given in 2/8 (25%) studies and the BAS scales were administered in one (12.5%).

There was relatively more variation in the behavioural measures administered across studies, with no single index being given in a majority of cases. In terms of inhibitory control, the SST was given in three of the eight (37.5%) studies, the GNG used in four (50%) and the Sx-5CSRTT in one (12.5%). Regarding delay discounting, the authors of two studies (25%) gave the MCQ, whilst the DDQ, TCT, TCP and TCIP were administered in one study each. In terms of risk-taking, the BART and IGT were each administered in 1/8 (12.5%) studies. Regarding reflection impulsivity, the IST was administered in two (25%) studies and the beads task was given in one (9%).

In terms of assessing superordinate impulsivity factors behaviourally, rash impulsivity was assessed in a majority of six (75%) studies, reward-drive in five (62.5%), risk-taking in two (25%) and reflection impulsivity in two. Importantly, no single study measured all four of these superordinate indices. To recapitulate, current self-report measures tap only rash impulsivity and reward-drive. All eight studies included some measure of the former, whilst self-reported reward-drive was assessed in just one. None of the studies collected data on all superordinate impulsivity facets (i.e. a complete impulsivity profile) via available self-report and behavioural measures. Indeed, three of the eight (37.5%) studies administered just two indices – one self-report and one behavioural (i.e. the minimum for inclusion in the review).

III.IV) STUDY FINDINGS

III.IV.I) SELF-REPORT MEASURES

The BAS scales: The one study to have administered the BAS scales (Ahmadi *et al.*, 2013) reported greater scores in heavy, relative to light, drinkers – for the total scale.

The BIS-11: Of the six studies that administered the BIS-11, four reported data pertaining to the three subscales and two reported only the total scale. In terms of the former, there was a clear pattern of findings: greater motor and non planning impulsiveness in heavy and bingeing groups, with no difference between groups in terms of attentional impulsiveness (although Rose & Grunsell, 2008 reported no differences on any subscale, Moreno *et al.*, 2012, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016). Of those studies reporting only the total scale, one found greater scores in heavy drinkers (Ahmadi *et al.*, 2013) and one found no difference between bingers and non-bingers (Henges & Marczinski, 2012).

The SSS: Both of the studies to have given the SSS reported greater total scores in heavy and bingeing groups, relative to their control groups (Moreno *et al.*, 2012, Ahmadi *et al.*, 2013). Moreno *et al.* (Moreno *et al.*, 2012) (2012; but not Ahmadi) reported data for the individual subscales, finding only the disinhibition subscale to be elevated in bingers (and not the thrill and adventure seeking, experience seeking or boredom susceptibility subscales).

The UPPS-P: Of the two studies that administered the UPPS-P, Banca *et al.* (Banca *et al.*, 2016) reported bingers to be greater for negative urgency, premeditation and positive urgency, with no group differences for perseverance or sensation seeking. Petit *et al.* (Petit *et al.*, 2012), reporting only the total scale, reported no group differences.

III.IV.II) BEHAVIOURAL MEASURES

III.IV.II.I) RESPONSE-INITIATION

The 5CSRTT: Interestingly, in the single study to have administered a measure of response-initiation, Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) reported bingers to show greater impulsivity on the 5CSRTT than non-bingers.

III.IV.II.II) RESPONSE-INHIBITION

The SST: None of the three studies that gave the SST reported group differences, in samples including light versus heavy drinkers and non-binge versus bingeing groups (Moreno *et al.*, 2012, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016).

The GNG: Of the four studies to have given the GNG (Henges & Marczinski, 2012, Moreno *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013), none of them reported any differences between groups in false-alarm rates, across both light versus heavy drinker and non-binge and binger comparisons. In a series of multiple regressions, however, Henges and Marczinski (Henges & Marczinski, 2012) reported that GNG inhibition failures (presumably calculated as the mean of inhibition failures following no-go cues and inhibition failures following go cues, although this is unclear) were significantly associated with number of drinks, number of heavy drinking days, number of drunk days and highest number of drinks.

III.IV.II.III) DELAY DISCOUNTING

Of the three studies that used the MCQ (Sanchez-Roige *et al.*, 2014, Banca *et al.*, 2016, Caswell *et al.*, 2016), none reported group differences, across both light versus heavy drinker and non-binge and binger comparisons. In terms of the other delay discounting measures, no differences between groups were reported for the primary outcome measures of the TCIP or TCT in Moreno *et al.* (Moreno *et al.*, 2012) or Rose and Grunsell (Rose & Grunsell, 2008). Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) did, however, report bingers to make fewer delayed choices than non-bingers on the TCIP.

III.IV.II.IV) RISK-TAKING

The BART: The one study to have administered the BART (Ahmadi *et al.*, 2013) reported no difference between light and heavy drinkers.

The IGT: Moreno *et al.* (Moreno *et al.*, 2012) reported more impulsive performance in binge drinkers, relative to non-bingers.

III.IV.II.V) REFLECTION IMPULSIVITY

The IST: Neither of the two studies to have administered the IST reported group differences, across comparisons of both light versus heavy drinkers and non-bingers and bingers (Banca *et al.*, 2016, Caswell *et al.*, 2016).

The beads task: The one study to have given the beads task reported more impulsive performance in bingers, relative to non-bingers (Banca *et al.*, 2016).

III.V) QUALITY RATINGS

Each study's ratings, for each item of the NIH, as well as its overall quality rating, are presented in Table 3.

Table 3: Study quality ratings (by the primary researcher) for each item of the NIH Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies (Health, 2014)

Paper	Item														QR*
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	
Ahmadi <i>et al.</i> (2013)	Yes	Yes	NR	Yes	No	No	NA	No	Yes	NA	Yes	No	NA	No	Fair**
Banca <i>et al.</i> (2016)	Yes	Yes	NR	Yes	No	No	NA	No	Yes	NA	Yes	No	NA	No	Fair**
Caswell <i>et al.</i> (2016)	Yes	Yes	NR	Yes	Yes	No	NA	Yes	Yes	NA	Yes	No	NA	No	Fair**
Henges & Marczinski (2012)	Yes	Yes	NR	Yes	Yes	No	NA	Yes	Yes	NA	Yes	No	NA	No	Fair**
Moreno <i>et al.</i> (2012)	Yes	Yes	NR	Yes	No	No	NA	No	No	NA	Yes	No	NA	No	Poor**
Petit <i>et al.</i> (2012)	Yes	Yes	NR	Yes	Yes	No	NA	No	Yes	NA	Yes	No	NA	No	Fair**
Rose & Grunsell (2008)	Yes	Yes	NR	Yes	Yes*	No	NA	No	Yes	NA	Yes	No	NA	No	Fair**
Sanchez-Roige <i>et al.</i> (2014)	Yes	Yes	NR	Yes	No	No	NA	No	Yes	NA	Yes	No	NA	No	Poor***

Table 3 continues over the page

Table 3 continued

Note. Key to items: 1 = Was the research question or objective in this paper clearly defined?; 2 = Was the study population clearly specified and defined?; 3 = Was the participation rate of eligible persons at least 50%?; 4 = Were all the subjects selected or recruited from the same or similar populations (including the same time-period)? Were inclusion and exclusion criteria for being in the study pre-specified and applied uniformly to all participants?; 5 = Was a sample-size justification, power description or variance and effect estimates provided?; 6 = For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?; 7 = Was the time-frame sufficient so that one could reasonably expect to see an association between exposure and outcome, if it existed?; 8 = For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as a continuous variable)?; 9 = Were the exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants?; 10 = Was the exposure(s) assessed more than once over time?; 11 = Were the outcome measures (dependent variables) clearly defined, valid, reliable and implemented consistently across all study participants?; 12 = Were the outcome assessors blinded to the exposure status of participants?; 13 = Was loss to follow-up after baseline 20% or less? and; 14 = Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)? Each item rated either 'Yes', 'No' or 'Other', the latter having the following three sub-options: CD = cannot determine, NA = not applicable or NR = not reported.

*QR = Overall Quality Rating of paper, rated either 'Good', 'Fair' or 'Poor'.

* Although there were no significant between-groups differences for any impulsivity measure, effect-sizes were reported by the authors in relation to non-impulsivity-related variables (which are thus not relevant here) between groups. Thus, it was assumed that, if there had been significant differences, the authors would have reported effect-sizes, and so, on this assumption, the study was rated 'yes'.

** Indicates initial agreement between the two independent raters.

*** Indicates initial disagreement between the two independent raters.

The overall quality of each of the papers was initially (i.e. prior to inter-rater discussion) rated independently by both the primary researcher and their primary supervisor. As can be seen in the table, both raters assigned the same overall quality score (i.e. 'fair' or 'poor') to seven of the eight studies, resulting in a Kohen's kappa of 0.60, thereby indicating 'substantial agreement' (Landis & Koch, 1977). Of these seven, six studies were rated fair by both the first and second researcher, with one study (Moreno *et al.*, 2012) rated as poor. The reason for this poor rating was the study's failing to collect and/or report the mean levels of alcohol consumed by their bingeing and non-bingeing groups (i.e. item 9), thereby restricting the possibility for comparisons with bingeing and heavy drinking samples in other studies. One study (Sanchez-Roige *et al.*, 2014) was initially rated poor by the primary researcher and fair by the second researcher. The reason for the first researcher's poor rating was the study's finding a significant difference between groups for age (i.e. a key potential confounder) but then failing to adjust for this statistically. Following inter-rater discussion, both raters agreed upon a rating of poor for this paper.

It is notable that none of the studies received a 'good' rating. In accordance with the NIH guidelines, this was due to their failing to control for various sources of bias, to greater and lesser extents. A primary potential for bias across all studies was their failing to measure and control for *all* potentially relevant covariates (i.e. item 14 of the rating tool), leaving the results open to potential bias. Since the NIH measure states that, '... the potential for bias in a study... must be assessed based on consideration of the concepts for minimising bias', item 14 was considered particularly important to the quality rating that a paper was assigned. To recapitulate, potential confounders here were age, gender, socioeconomic status and IQ, each of which have been related to impulsivity (e.g., Eysenck *et al.*, 1985, Roberts *et al.*, 2001, 2003, de Wit *et al.*, 2007, Donnellan *et al.*, 2007, Yuan *et al.*, 2008, Raver, Blair & Willoughby, 2013, Spielberg *et al.*, 2015). Table 4 presents the degree to which each of these potential confounders were controlled for by each of the included studies.

Table 4: Potentially confounding variables measured/controlled for by each study

Paper	Age?	Gender?	Socioeconomic status?	IQ?
Ahmadi <i>et al.</i> (2013)	✓	✓	✗	✗
Banca <i>et al.</i> (2016)	✓	✓	✗	✓
Caswell <i>et al.</i> (2016)	✓	✓	✗	✓
Henges & Marczynski (2012)	✓	✓	✗	✗
Moreno <i>et al.</i> (2012)	✓	✓	✗	✗
Petit <i>et al.</i> (2012)	✓	✓	✗	✗
Rose & Grunsell (2008)	✓	✓	✗	✗
Sanchez-Roige <i>et al.</i> (2014)	✗	✓	✗	✓

Note: Papers are given a tick (✓) if they met the following conditions. Firstly, for between-groups studies, a paper received a tick if it measured the potential confounder in question and (i) found no difference between groups or (ii) found a difference between groups and controlled for this statistically. For single-group designs, a paper received a tick if it measured the potential confounder in question and controlled for this statistically.

Of the studies, Ahmadi *et al.* (Ahmadi *et al.*, 2013), Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) and Caswell *et al.* (Caswell *et al.*, 2016) made the greatest efforts to measure and control for these potential confounders, each assessing age, gender and IQ between their drinking groups. No study measured SES in their participants. Although Sanchez-Roige *et al.* found their bingers to be significantly younger than non-bingers, no statistical correction was made for this, leaving the significant differences they report for the BIS-11, 5CSRTT and TCIP open to potential bias (i.e. younger age is associated with greater impulsivity).

Another reason for no study receiving an overall good rating was that none reported outcome assessors to have been blinded to the drinking status of participants (item 12), leaving results open to potential bias via expectancy effects and demand characteristics.

None of the studies reported the participation rate of eligible individuals (item 3), leaving the question of whether those who participated in the study were

representative of the target population (i.e. this is considered so when greater than 50% of eligible individuals participate; Health, 2014).

Studies varied as to whether they included a sample-size justification, power description or variance and effect-size estimates. No single study included an *a priori* sample-size justification, meaning that, for each study, it would have been unclear at the point of data-analysis whether there were enough participants to detect a truly significant effect. However, three studies did include (Henges & Marczinski, 2012, Petit *et al.*, 2012, Caswell *et al.*, 2016) *post hoc* estimates of effect-size, meaning that the power of these studies could be calculated retrospectively, at least.

All of the studies compared only *two* drinking groups (e.g., light versus heavy drinkers); studies including three or more (e.g., light, moderate and heavy drinkers) would add greater credibility to findings, as they would allow for greater examination of dose-response relationships between alcohol and impulsivity. However, two studies (Henges & Marczinski, 2012, Caswell *et al.*, 2016) included regression analyses between alcohol use/misuse and impulsivity measures (item 8), thereby allowing for examination of such dose-response relationships.

The above limitations notwithstanding, in general, the studies had a number of strengths. Thus, in every one, the sample population was adjudged to have been clearly specified and defined (item 2). Participants in each study were recruited from the same or broadly similar populations (overwhelmingly from university students) (item 4), thereby reducing (though not eliminating) the chances that findings were related to uncontrolled-for variables; as part of this, all studies recruited participants on the basis of pre-specified inclusion and exclusion criteria (though these differed in their level of specificity). Finally, all studies administered (at least two) well-validated impulsivity measures to assess outcome (item 11).

IV. DISCUSSION

The present study is the first and only to systematically review studies that have assessed impulsivity multi-dimensionally in non-clinical drinking groups; its main findings are as follows. Firstly, a systematic search including three scientific databases, followed by an ancestry search, found only eight published studies to

have met the inclusion criteria. This, together with seven of these having been published within the last five years (i.e. since 2012), suggests that the multidimensional assessment of impulsivity in non-clinical populations of alcohol drinkers is a new and emerging area. The samples from which quasi-experimental participants were drawn varied, with two studies comparing heavy versus light drinkers and five studies comparing bingers with non-binge drinkers. The self-report and behavioural impulsivity measures administered also varied, with no two studies administering the same battery and no single study administering indices that allowed for a complete profiling of impulsivity across all sub-domains. Although study findings were somewhat mixed, overall, self-reported rash impulsivity was more consistently elevated than behavioural measures in the quasi-experimental groups. A quality assessment of each of the eight papers saw no studies being assigned a 'good' rating, due to possible bias. Six papers received a 'fair' rating, whilst two were rated as 'poor'.

IV.1) SELF-REPORT FINDINGS AND POSSIBLE IMPLICATIONS

IV.1.1) RASH IMPULSIVITY (RI) APPEARS RELIABLY ELEVATED IN QUASI-EXPERIMENTAL GROUPS

In terms of the self-report measures, there was a clear pattern of findings for the Barratt impulsiveness scale, version 11 (BIS-11), whereby quasi-experimental groups were elevated on motor and non-planning (but not attentional) impulsiveness. This was the case across three of the four studies that reported data for the individual subscales (Moreno *et al.*, 2012, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016); the study that did *not* report this pattern of findings (reporting null results across all three subscales; Rose & Grunsell, 2008) had a considerably smaller sample-size (10 bingers versus 10 non-bingers), which may have been important. Containing items such as, 'I am self-controlled', 'I buy things on impulse' and, 'I am more interested in the present than the future', the motor and non-planning subscales tap into one's ability to inhibit or modify (reward-related) behaviour (esp., in order to avoid aversive consequences; i.e. RI) (the items comprising each of the subscales of the BIS-11, SSS and UPPS-P are provided in Tables A4, A5 and A6 in Appendix 5 to aid understanding of this and the following paragraphs). As indicated by its name, the attentional subscale includes items like, 'I don't "pay attention"' and, 'I am restless at the theatre or

lectures', and thereby seems to index a somewhat different sub-construct of impulsivity. Though Ahmadi *et al.* (Ahmadi *et al.*, 2013) and Henges and Marczyński (Henges & Marczyński, 2012) also administered the BIS-11, they only reported data for the total scale and not for the three subscales – making comparisons with the above studies difficult. Overall, however, given that 22/30 of BIS-11 items relate to rash impulsivity (with only 8 for attentional impulsiveness), Ahmadi *et al.*'s finding total scores to be greater in heavy drinkers (Henges & Marczyński found no difference) means that four of the six BIS-11-administering studies produced evidence of greater self-reported RI.

The two studies that administered the sensation seeking scale (SSS) reported elevated total scores in the quasi-experimental groups, relative to their comparison groups. Whilst Ahmadi *et al.* (Ahmadi *et al.*, 2013) reported data pertaining only to the total scale, Moreno *et al.* (Moreno *et al.*, 2012) additionally reported data for each of the four subscales, finding binge drinkers were greater only on the disinhibition subscale. Thus, in Moreno *et al.* at least, the significant difference in total scores was 'driven' by the difference in the disinhibition subscale. As described by Zuckerman *et al.* (Zuckerman, Eysenck & Eysenck, 1978), the SSS-disinhibition subscale reflects 'a desire for social and sexual disinhibition, as expressed in social drinking, partying and variety in sexual partners' (p. 140). Its items seem to conceptually overlap with the form of impulsivity indexed by the BIS-11 motor and non-planning impulsiveness items – specifically in terms of a focus on shorter-term reinforcement irrespective of potential consequences (in other words, RI). For example, there seems a clear conceptual overlap between the SSS disinhibition items, 'I like wild, "uninhibited" parties', 'I enjoy the company of real "swingers"' and, 'keeping the drinks full is the key to a good party' and the BIS-11 motor and non-planning items, 'I buy things on impulse', 'I am self-controlled' and, 'I am more interested in the present than the future'. The three subscales for which there was no difference (i.e. thrill and adventure seeking, experiencing seeking and boredom susceptibility) more clearly relate to the desire(s) to engage in exciting and arguably non-traditional experiences and do not seem to tap into RI in the same type of way, or indeed at all.

Similarly, the greater urgency, (lack of) premeditation, (lack of) perseverance and sensation seeking (UPPS-P) scores in binge-drinkers reported by Banca *et al.* (Banca *et al.*, 2016) seemed also to reflect elevated RI. These authors reported greater scores for the negative urgency, premeditation and positive urgency subscales, but not for the perseverance and sensation-seeking subscales. It is notable that the items of the former three scales clearly relate to disinhibition (e.g., ‘I have trouble controlling my impulses’ (negative urgency), ‘when I am very happy, I can’t seem to stop myself from doing things’ (positive urgency), ‘I usually think carefully before doing anything (premeditation)), whilst the perseveration and sensation-seeking scales appear to tap-into conceptually separate constructs (e.g., the former includes items such as, ‘I generally like to see things through to the end’ and, ‘I tend to give-up easily’, and the latter includes, ‘I generally seek new and exciting experiences and sensations’ and, ‘I’ll try anything once’). Given their similar item-content, there seems to be some consistency in the lack of group differences for UPPS-P perseveration in Banca *et al.* and the lack of group differences in BIS-11 attentional impulsiveness in Caswell *et al.* (Caswell *et al.*, 2016), Moreno *et al.* (Moreno *et al.*, 2012) and Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014). Also, the lack of difference between groups for sensation-seeking in Banca *et al.* (Banca *et al.*, 2016) appears congruent with the lack of group differences in the more specifically sensation-seeking-related subscales (i.e. as opposed to the disinhibition subscale) of the SSS in Moreno *et al.* (Moreno *et al.*, 2012). Although Petit *et al.* (Petit *et al.*, 2012) also administered the UPPS-P, they only reported data for the total scale (for which they reported no group difference), making any interpretation difficult.

Overall, these findings suggest that elevations in self-reported/everyday RI may be associated with non-dependent patterns of alcohol misuse amongst young adults.

IV.I.II) SELF-REPORTED REWARD DRIVE (RD) REQUIRES FURTHER INVESTIGATION

Regarding RD, although Ahmadi *et al.* (Ahmadi *et al.*, 2013) reported heavy drinkers to have greater overall scores than light drinkers, the failure to report subscales restricts more detailed comment. More research is needed to confirm (or indeed to refute) this. It is thus unclear whether self-reported RD might be

associated with non-dependent alcohol misuse, though Ahmadi *et al.*'s finding is consistent with this.

IV.II) BEHAVIOURAL FINDINGS AND POSSIBLE IMPLICATIONS

IV.II.I) RESPONSE INHIBITION DOES NOT APPEAR ELEVATED IN HEAVY AND/OR BINGE DRINKERS

In terms of behavioural response inhibition (i.e. the ability to refrain from making a pre-potent response), neither Caswell *et al.* (Caswell *et al.*, 2016), Moreno *et al.* (Moreno *et al.*, 2012) nor Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) reported any differences on the SST between their quasi-experimental and comparison groups. Interestingly, each of these papers also reported elevated self-reported rash impulsivity on BIS-11 motor and non-planning impulsiveness, meaning that self-reported, but not behavioural, rash impulsivity was uniformly elevated across these samples. Similarly, none of the four studies that administered the go/no-go task found any group differences for the key index of false-alarm rate (Henges & Marczyński, 2012, Moreno *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013), indicating that elevated response inhibition is not associated with non-clinical alcohol misuse in young adults. It may thus be that poor response inhibition is more a feature of dependent-level drinking (as has been reported by, for example, Goudriaan *et al.*, 2006, Lawrence *et al.*, 2009, Schmaal *et al.*, 2013, Petit *et al.*, 2014, Zhou *et al.*, 2014).

IV.II.II) EVIDENCE FOR ELEVATED RESPONSE INITIATION IN HEAVY AND/OR BINGE DRINKERS

In the only of the studies to have administered a continuous performance task (CPT; i.e. to index response initiation), Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) found binge drinkers to respond more impulsively than non-bingers. This might therefore suggest that, though response inhibition *does not* seem to differ between groups, response initiation (the tendency to respond prior to complete information processing) *does*. Whilst interesting, further studies administering a CPT are clearly needed to explore the robustness (or not) of this finding. Nevertheless, Sanchez-Roige *et al.*'s finding indicates that the readiness with which an individual initiates an action may be elevated amongst non-dependent alcohol misusers. This may be relevant for binge drinkers' heavy consumption of

alcohol within short time periods – thus, they may have a tendency to (binge) drink prior to complete processing of the (widely publicised) potential health and other (e.g., social) consequences.

IV.II.III) DELAY DISCOUNTING DOES NOT APPEAR ELEVATED IN HEAVY AND/OR BINGE DRINKERS

Delay discounting was examined in five of the studies, with no differences between groups in four (i.e. 80%; Rose & Grunsell, 2008, Moreno *et al.*, 2012, Banca *et al.*, 2016, Caswell *et al.*, 2016). In contrast, Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) found that binge drinkers made fewer delayed choices on the two-choice impulsivity paradigm (TCIP). This measure includes very questions to those of the MCQ and TCT, so the reason(s) for Sanchez-Roige *et al.*'s positive finding is unclear, though may simply be spurious. Overall, these findings indicate that delay discounting is not elevated in non-clinical young adult drinkers.

IV.II.IV) MIXED RESULTS FOR RISK-TAKING AND REFLECTION IMPULSIVITY IN HEAVY AND/OR BINGE DRINKERS

The only two studies to have measured risk-taking reported conflicting findings. Thus, whilst Ahmadi *et al.* (Ahmadi *et al.*, 2013) found no differences between heavy and light drinkers on the balloon analogue risk task (BART), Moreno *et al.* (Moreno *et al.*, 2012) found binge drinkers to be more impulsive on the Iowa gambling task (IGT). Of course, this *may* indicate that binge drinking is associated with elevated risk-taking whilst heavy drinking is not, that the IGT is more sensitive to elevations in risk-taking in samples of heavy and binge drinkers, or some combination of these possibilities. Alternatively, one or both of these findings may simply be spurious, particularly bearing in mind that neither of them (and indeed none of the full eight studies) was rated as being of 'good' quality. Neither of the two studies to have measured reflection impulsivity (Banca *et al.*, 2016, Caswell *et al.*, 2016) via the information sampling task (IST) reported differences between quasi-experimental and comparison groups. Banca *et al.* (Banca *et al.*, 2016), however, reported greater impulsivity on the beads task in binge drinkers. Similar to the risk-taking findings, several explanations seem possible. For example, the IST might not be sensitive enough to detect potentially

elevated reflection impulsivity in such groups, whereas the beads task is. Alternatively, binge-drinkers may genuinely be greater in reflection impulsivity as assessed by the beads task. Given the scant data at present, more research is needed to draw any conclusions here.

IV.III) SUMMARY OF FINDINGS ACROSS THE INCLUDED STUDIES: SEEMINGLY RELIABLE ELEVATIONS IN SELF-REPORTED RI AMONGST OTHERWISE MIXED RESULTS

To summarise: self-reported RI appears reliably elevated in non-clinical heavy and binge drinking young adults. There is also evidence that self-reported RD (indexed via the BAS scales) and behavioural response initiation (i.e. the CPT) are elevated in these groups, though each of these have only been administered in one study and further research is needed. In contrast, the evidence indicates that response inhibition and delay discounting are *not* elevated in non-dependent alcohol misusing young adults. Data are currently scant and mixed regarding risk-taking and reflection impulsivity, thereby restricting the ability to draw conclusions. Overall, though, the findings are consistent with (i) the notion of impulsivity's comprising a number of sub-domains (de Wit & Richards, 2004) and (ii) these sub-domains' sharing different relationships with impulsivity.

The reliably elevated self-report RI in the alcohol misusing groups may indicate that self-report measures are more sensitive to the type of everyday impulsive behaviour not captured by behavioural laboratory measures. Alternatively, the pattern of findings may relate to inherent differences in self-report and behavioural indices, correlations between which often being weak or non-existent (e.g., Dom *et al.*, 2006a, Cyders & Coskunpinar, 2011). One possible reason for this is that self-report scales seem insensitive to possible short-term changes in impulsivity, since they ask about general propensities (e.g., 'I plan tasks carefully' and, 'I am restless at the theatre or lectures'), with response options referring to overall frequency ('rarely/never', 'occasionally', 'often' and 'almost always/always') (Mayhew & Powell, 2014). Such questions encourage the respondent to average over an extended period of time, rather than focus on the 'here and now'. Behavioural measures, by contrast, record the individual's 'actual' responses at a precise moment and are likely to be sensitive to state fluctuations. All other things being equal, self-report measures thus provide more 'opportunities' for

differences between groups to emerge, whereas with behavioural tasks, impulsivity is measured at that exact moment only. Regardless, the apparently conflicting findings between self-report and behavioural measures indicate that the decision to include here only studies that had administered at least one of each, on the basis that they may index separate constructs, appears justified.

IV.IV) POSSIBLE THEORETICAL AND CLINICAL IMPLICATIONS

The present review is intended primarily as a summary and evaluation of the current evidence, as opposed to a thorough consideration of the possible theoretical and clinical implications of findings in this area; these issues are thus considered in more detail in the Discussion of the main empirical project of this thesis (pp. 78-84), which also examines impulsivity multi-dimensionally in non-dependent alcohol misuse. Briefly, then, Robinson and Berridge (Robinson & Berridge, 1993, 2000) contend that subjective craving and attentional biases to alcohol and associated stimuli, along with impaired executive control – and specifically, elevated impulsivity (e.g., Jentsch & Taylor, 1999) – can together account for the central phenomena observed in dependence: compulsive drug-seeking and ingestion despite profoundly adverse consequences. The findings of the studies reviewed here indicate that the key impulsivity sub-domain(s) elevated in groups of non-dependent alcohol abusers is everyday RI (and possibly everyday RD and behavioural response initiation). Importantly, elevations in these impulsivity sub-domains therefore seem to be not merely the *result* of dependence, but can be present prior to dependence and may thus be involved in the maintenance non-dependent alcohol misuse. Thus it may be that targeting and successfully reducing impulsivity in these specific facets may accordingly reduce consumption, as well as potentially reducing the attendant economic, social and medical costs of alcohol misuse (Smith *et al.*, 1999, Gmel & Rehm, 2003, Rehm *et al.*, 2003, Unit, 2003, Lister *et al.*, 2008, Balakrishnan *et al.*, 2009, Gronbaek, 2009, Lee & Forsythe, 2011, Navarro *et al.*, 2011).

These possibilities notwithstanding, a number of methodological limitations across the reviewed studies (some of which being serious) must be taken into account (see Section IV.VI below).

IV.V) SOME IMPORTANT ISSUES: HEAVY VERSUS BINGE DRINKERS AND NUMBERS OF GROUPS COMPARED

For each study, the quasi-experimental groups were identified as either heavy drinkers or binge drinkers; groups thus differed according to their overall *quantity* or their *pattern* of alcohol consumption. Interestingly, patterns of findings across studies appeared similar, regardless. To illustrate: (i) for the BIS-11, the pattern of greater motor and non-planning impulsiveness in quasi-experimental relative to comparison groups (but no differences in attentional impulsiveness) was observed across heavy versus light drinkers (Caswell *et al.*, 2016) and bingers versus non-bingers (Moreno *et al.*, 2012, Sanchez-Roige *et al.*, 2014); (ii) both the heavy drinkers in Ahmadi *et al.* (Ahmadi *et al.*, 2013) and the binge drinkers in Moreno *et al.* (Moreno *et al.*, 2012) scored greater on the SSS total scale; (iii) there were no differences between groups of heavy versus light drinkers and bingers versus non-bingers on the GNG, IST or SST (Henges & Marczyński, 2012, Moreno *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014, Banca *et al.*, 2016, Caswell *et al.*, 2016). These similarities notwithstanding, there nevertheless remains a question around whether different relationships might exist between individuals' alcohol consumption depending on the outright quantity they consume compared to the pattern in which they consume it. Future studies should therefore seek to explore this issue.

As stated above, none of the studies recruited more than two groups of drinkers. It would have been interesting, however, for studies to have examined three groups – to have compared, for example, light-, moderate- and heavy-drinkers. This would have allowed for a greater exploration of the 'dose-response'⁸ relationship(s) between alcohol intake and impulsivity – specifically, to explore the question of the level of non-dependent alcohol consumption at which elevated impulsivity might start to 'come online'. Caswell *et al.* (Caswell *et al.*, 2016) and Henges and Marczyński (Henges & Marczyński, 2012) performed hierarchical regressions between indices of alcohol use and impulsivity, thereby allowing for some examination of the dose-response by estimating the *overall* relationship (i.e. taking into account all data-points between the lowest and

⁸ The term 'dose-response' is used here in the knowledge that, in fact, current evidence seems to indicate a bidirectional association between alcohol use and impulsivity.

highest values across each variable in the equation). However, hierarchical regression alone does not provide information as to the specific point (if indeed such a point exists) at which alcohol use and impulsivity might start to become more closely ‘entwined’.

IV.VI) METHODOLOGICAL LIMITATIONS OF THE INCLUDED STUDIES CONSTRAIN THEIR FINDINGS/CONCLUSIONS

IV.VI.I) LIMITATIONS AS ASSESSED BY THE NATIONAL INSTITUTES FOR HEALTH (NIH) QUALITY RATING TOOL

The above conclusions notwithstanding, the findings of the eight studies were, in general, constrained by a number of methodological limitations (as assessed by the NIH quality ratings). Thus, the primary researcher rated six of the eight papers as ‘fair’, with two being rated ‘poor’ and none receiving a ‘good’ rating⁹. The inter-rater reliability between the two raters was considered ‘substantial’, thereby lending validity both to the notion that the ‘true’ quality of the studies was generally only fair, as well as that of the quality assessment tool used here.

Using the NIH quality assessment tool for observational cohort and cross-sectional studies, the three key socio-demographic variables of age, gender and socioeconomic status (SES), as well as IQ, were considered to be key potential confounders; each of these variables has been statistically related to impulsivity (Eysenck *et al.*, 1985, Roberts *et al.*, 2001, 2003, de Wit *et al.*, 2007, Donnellan *et al.*, 2007, Yuan *et al.*, 2008, Raver *et al.*, 2013, Spielberg *et al.*, 2015). A study was adjudged to have adequately controlled for these variables if it: (i) measured each and found no difference between the groups, or: (ii) measured each and, finding a difference between the groups, used appropriate means to statistically control for this when exploring potential impulsivity differences. Virtually every study measured and controlled for age and gender. Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014), Caswell *et al.* (Caswell *et al.*, 2016) and Banca *et al.* (Banca *et al.*, 2016) measured additionally measured IQ, though no study measured/controlled for socio-economic status (SES). Surprisingly, though Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) found their binge drinkers to be younger than their non-bingers, they did not control for this difference when examining impulsivity

⁹ The second researcher rated seven papers ‘fair’ and one as ‘poor’.

differences between their groups. Spielberg *et al.* (Spielberg *et al.*, 2015), for example, found that lower SES was associated with worse behavioural inhibition in females, which the authors related to less efficient processing within the dorsolateral prefrontal cortex (see also Raver *et al.*, 2013). This of course leaves results open to potential bias from these sources, over half of them (5/8) to IQ and all of them to SES. Given that SES has been specifically related to poorer inhibitory control, the failure to control for it may have implications for the validity of findings relating to elevated BIS-11 motor and non-planning impulsiveness, and poorer SST and GNG performances, in quasi-experimental groups, relative to their comparison groups. On the other hand, given the almost exclusive recruitment of undergraduate students as participants across these studies, it might be expected that SES was relatively constant and thus might not have required tight measurement and control. This notwithstanding, SES will almost certainly not have been uniformly distributed, even in such samples. It is therefore important that future studies adequately control for all of these potential confounders.

It is notable that none of the studies reviewed here provided an *a priori* sample-size calculation (although Henges & Marczinski, 2012, Petit *et al.*, 2012 each provided effect-sizes, meaning that power could potentially be estimated retrospectively from these data, Caswell *et al.*, 2016). Indeed, some of the conflicting findings may partly relate to sample-sizes being relatively small across the studies. For example, Banca *et al.* (Banca *et al.*, 2016)'s study comprised 30 binge drinkers, Moreno *et al.* (Moreno *et al.*, 2012) 22 binge drinkers, Petit *et al.* (Petit *et al.*, 2012) 18 light drinkers, Rose and Grunsell (Rose & Grunsell, 2008) 10 bingers, with 22 individuals comprising the binge drinkers in Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) (though it is true that the samples in Henges & Marczinski, 2012, Caswell *et al.*, 2016 were somewhat larger). Relatively small sample-sizes are an issue in this literature in general (as are conflicting findings). For example, Kambouropoulos and Staiger (Kambouropoulos & Staiger, 2001) recruited 18 light and 20 heavy drinkers, Papachristou *et al.* (Papachristou *et al.*, 2012) recruited 29 light and 13 heavy drinkers, Smith and Mattick (Smith & Mattick, 2013) 13 heavy drinkers and 17 light drinkers and Xiao *et al.* (Xiao *et al.*, 2013) 14 binge drinkers and 14 never-drinkers. It may be that here, as well as in

general, studies are often insufficiently powered to reliably detect any genuine differences.

That none of the studies seem to have been double-blinded also leaves findings open to bias via expectancy effects and demand characteristics. For example, when giving instructions to participants for a behavioural measure (e.g., the stop-signal task), unblinded assessors may (consciously or otherwise) give more detailed verbal instructions to lighter drinkers (possibly resulting in better performance) and less detailed instructions to heavier drinkers (possibly resulting in poorer performance). Such effects may have had a greater potential to influence findings in between-groups designs (e.g., between light and heavy drinkers), though could also have done so in single-group designs (e.g., individuals drinking a greater amount might be expected to behave more impulsively on behavioural measures).

Although it is relatively uncommon for empirical psychology papers to report recruitment rates (and in this sense these eight papers are typical), the failure of any of the studies to report this nevertheless leaves results open to possible bias. Thus it is possible, if admittedly unlikely, that unrepresentative samples of participants (i.e. fewer than 50% of those eligible; ref.) were tested in these studies. That is, samples recruited may have systematically differed, on one or more unidentified variables, from those who were eligible but who did not participate.

Overall, it seems reasonable to state that the various sources of confound assessed by the NIH tool may have unduly influenced the findings of the included studies, and may also be at least partly accountable for some of their conflicting results. There were also several other issues, not assessed by the rating tool, which should be held in mind.

IV.VI.II) ADDITIONAL LIMITATIONS (NOT ASSESSED AS PART OF THE NIH RATING TOOL)

IV.VI.II.I) DIFFERENT STUDIES REPORT DIFFERENT INDICES FOR THE SAME MEASURE

Firstly, there was a notable tendency for studies to report different indices in relation to the same measure. For example, whereas four of the six studies that administered the BIS-11 reported data for the three subscales, two reported only the overall BIS-11 scores. The former is the generally recognised approach, given the well-established semi-independence of the three factors, meaning it is unclear why only total scores would be reported. Similarly, of the two studies that administered the UPPS/UPPS-P (Petit *et al.*, 2012, Banca *et al.*, 2016), one reported data for the subscales and the other reported only the total scale. As per the BIS-11, the rationale for reporting the total scores is unclear. Perhaps most starkly, the four studies to have administered the Go/No-Go task all reported different sets of indices: whereas Petit *et al.* (Petit *et al.*, 2012) reported a relatively restrained trio of reaction times, omission errors and commission errors, Ahmadi *et al.* (Ahmadi *et al.*, 2013) reported an exhaustive set, including the number of correct rejections, the number of false alarms, the error proportion, reaction time, go hit reaction time and false-alarm reaction time. Given that the principal aim of this task is to measure inhibitory control, surely false-alarm rate is the outcome of primary concern. Comparing groups on such a liberal assortment of outcomes increases the likelihood for a Type-I error, with the variability in reported indices across studies also reducing the chances for comparison. For these reasons, it would be preferable for future studies to compare groups only on (the same) key indices for which there is a clear rationale.

IV.VI.II.II) POSSIBLE RECRUITMENT OF DEPENDENT DRINKERS

Although the quasi-experimental groups included in the current review were ‘non-clinical’ (defined here as not being identified as alcohol-dependent or seeking/in treatment for reducing/quitting their alcohol consumption), it was nevertheless possible that, across each study, some participants may have in fact been alcohol-dependent. For example, the heavy drinkers in Ahmadi *et al.* (Ahmadi *et al.*, 2013) were consuming the equivalent of around 125 units per week

on average (i.e. a mean of around 17 units per day), the binge drinkers in Banca *et al.* (Banca *et al.*, 2016) and Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) and the heavy drinkers in Petit *et al.* (Petit *et al.*, 2012) all had AUDIT scores suggesting that some participants were above threshold for ‘possible dependence’. As described on page nine of the Introduction, the term ‘heavy drinker’ refers to individuals drinking above the current UK guidelines of a maximum of 14 alcohol units per week, for both males and females (Officers, 2016), and who have not as yet experienced alcohol-related harm, but who are at increased risk for harm in the future (Drummond *et al.*, 2011). Clearly, if some of the participants of these studies were alcohol-dependent, they would already be experiencing alcohol-related harm. It may thus appear questionable to refer to the participants in these studies as ‘heavy drinkers’ (or as ‘binge drinkers’). The present review refers to these participants as such since this was how they were identified ‘at source’, by their respective authors, whilst at the same time being mindful of their possible inclusion of dependent drinkers. At the same time, it is also worth bearing the following in mind. Firstly, the included studies *possibly* – not *definitely* – included (some) alcohol-dependent individuals. Secondly, these are likely to have been a *minority* of the sample in each case, not the *entirety* of the sample.

That said, as part of the exclusion criteria of our search, we specified that studies describing currently or formerly alcohol-dependent participants/patients as part of their ‘heavy/heavier drinkers’ were excluded; and that studies that had recruited participants identified either as having self-reported difficulties/problems with alcohol and/or wanting to cut-down/quit and/or control their drinking were also excluded. On reflection, this nevertheless made possible the inclusion of studies in which participants were possibly dependent but who had not presented for treatment of their alcohol intake (that is, so-called ‘functioning’ alcoholics). It is notable that had ‘possible recruitment of dependent drinkers’ been an exclusion criterion here, none of the eight papers would have made it through the full-text eligibility screen¹⁰. Nevertheless, the possible inclusion of dependent drinkers in such studies is a key finding of the present

¹⁰ The one possible exception to this is Rose and Grunsell (Rose & Grunsell, 2008), who reported that ‘participants must not have suffered from any form of drug dependence’ as an exclusion criterion. Their ambiguous wording, however, makes it unclear whether they incorporated dependence on alcohol as part of ‘drug dependence’, or whether they were referring only to recreational drugs. The means via which they assessed for drug dependence was also unclear.

review, and highlights the importance of more stringent exclusion criteria for future studies in this area.

Overall, however, the possible inclusion of dependent drinkers is problematic in the interpretation of our quantitative findings, as it is possible that positive results (i.e. where a quasi-experimental group was found to have elevated impulsivity relative to the comparison group) may have been unduly influenced by a subgroup of dependent individuals. The key implication of finding elevated impulsivity in an apparently non-dependent (and never-dependent) sample is that impulsivity can occur in the absence of physical dependence. The potential inclusion of dependent drinkers in these samples therefore seriously undermines this conclusion and surely cannot be viewed as anything less than a critical limitation of these studies. It is therefore crucially important that future studies do everything possible to exclude alcohol-dependent individuals from their samples.

IV.VI.II.III) EXTERNAL VALIDITY OF FINDINGS

The quality rating measure is designed explicitly to evaluate the internal validity of studies, with little/no mention of external/ecological validity. Yet the external validity does appear also to be an issue with the studies reviewed here, consisting as they do almost exclusively of undergraduate university students. As a result, the potential generalisability of their findings to other, non-graduate groups is questionable and requires further exploration. Then again, this is an issue with psychological research in general and is hardly confined to the studies discussed here. Relatedly, generalisability of these studies' findings is also limited by the fact that a criterion for inclusion in the current review was participants aged between 18-25 years. As already stated, this was put in place so as to partially control for developmental differences in impulsivity, related to the maturation of the frontal lobes that takes place primarily within this period (Blakemore & Choudhury, 2006), and was thus considered an important criterion for inclusion.

IV.VII) LIMITATIONS OF THE PRESENT REVIEW

The present review may be accused of having been somewhat overly selective and specific with regards to the inclusion and exclusion criteria applied to the search results. To reiterate, these included studies that were cross-sectional, which had included non-clinical samples of participants, that had compared two or more drinking groups, that had assessed impulsivity multi-dimensionally (via at least one self-report *and* one behavioural measure) and which had included participants aged 18-25 years. The reasons for these criteria have already been explained (see pages 23-24) and are not re-stated here. Nevertheless, it is true that such specific criteria, by definition, reduced the pool of studies considered eligible for inclusion, thereby resulting in just the eight studies being included here. Consequently, it is possible that the results of the present review may not be fully representative of the pattern of findings of similar studies within the wider literature (i.e. that pertaining to impulsivity in non-dependent groups of alcohol drinkers). For example, those studies that assessed impulsivity using only self-report measures were not included here, meaning that their findings were not synthesised with those of the studies included in the present review. Then again, and as considered in Section I.IV.II of the Introduction (pp. 19-21), studies within the wider literature seem also to be characterised by conflicting findings. To that extent, then, the results of the present review may in fact be relatively representative of this wider literature.

IV.VIII) CONCLUSION

In conclusion, few (just eight) studies have assessed impulsivity multi-dimensionally in groups of young adult (i.e. 18-25) non-clinical heavy and/or binge drinkers (relative to comparison groups). Of those that *have*, self-reported RI appears reliably elevated, whilst response inhibition and delay discounting, as assessed via behavioural measures, do *not*. Few studies have measured risk-taking and reflection impulsivity as part of a multi-dimensional assessment, and so the question of whether they may be elevated is at present unclear. The quality of the eight studies included in the final review were generally rated 'fair', with none rated 'good', due to a range of potential sources of confound. The potential inclusion of dependent drinkers across these studies represents a serious limitation that raises questions concerning their findings/conclusions and,

consequently, concerning the present review's summary and conclusions. Overall, more studies are needed to examine the question of elevated impulsivity (across all impulsivity dimensions) in non-dependent alcohol misusers; these future studies must adequately control against potential confound.

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APPENDIX 1: DESCRIPTIONS OF INSTRUMENTS USED TO MEASURE IMPULSIVITY
ACROSS STUDIES INCLUDED IN THE QUALITATIVE SYNTHESIS

Table A1 presents descriptions of each of the self-report impulsivity measures administered by the studies included in the qualitative synthesis.

Table A1: Self-report measures of impulsivity administered by studies included in the qualitative synthesis

Measure	Description and outcomes
Barratt Impulsiveness Scale, version 11 (BIS-11; Patton <i>et al.</i>, 1995)	The BIS-11 is a widely used 30-item measure which yields three subscales: attentional impulsiveness (which measures the respondent's capacity for concentration), motor impulsiveness (which measures the propensity for acting without first considering the consequences) and non-planning impulsiveness (which measures the propensity for focusing on present events without considering possible future events). As per the BIS-10, responses are scored on a 4-point Likert scale ('rarely/never', 'occasionally', 'often' or 'almost always/always'). Total scores range from 30 to 120 and, as with the BIS-10, greater scores indicate greater impulsiveness. Patton <i>et al.</i> (1995) have reported alpha coefficients from .79 to .83.
Behavioural activation scales (BAS scales; Carver & White, 1994)	The BAS scales assess individual differences in the sensitivity of the behavioural approach system (related to the motivational predisposition to approach appetitive stimuli). The scale has 13 items, each with four response options (1 = 'very true for me', 2 = 'somewhat true for me', 3 = 'somewhat false for me' and 4 = 'very false for me'). The BAS is made up of three subscales: 1) BAS drive (4 items; range = 4-16); 2) BAS fun seeking (4 items; range = 4-16) and; 3) BAS reward

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Measure	Description and outcomes
Behavioural activation scales (BAS scales; Carver & White, 1994)	responsiveness (5 items; range = 5-20). Carver and White (1994) report internal reliability coefficients ranging from .66 to .76.
Sensation seeking scale (SSS; Kolin <i>et al.</i>, 1964)	The 40-item SSS measures the need for new, varied and complex sensations and experiences, as well as the willingness to take risks to have such experiences. Each item consists of two complimentary statements, with respondents required to endorse one. The SSS is divided into four subscales, each containing ten items: 1) thrill and adventure seeking; 2) pursuit of excitement; 3) disinhibition, and; 4) boredom susceptibility. Zuckerman <i>et al.</i> (1978, 1979) report alpha coefficients ranging from .83 to .86.
Urgency, (lack of) premeditation, (lack of) perseverance and sensation seeking scale (UPPS-P; Lynam <i>et al.</i>, 2006)	The UPPS-P is a well validated and increasingly used 59-item measure that assesses five distinct domains of impulsivity via five subscales. As in the UPPS, the domains of (lack of) premeditation, (lack of) perseverance and sensation seeking are measured. In addition, the UPPS-P has two urgency subscales, rather than the one contained in the UPPS: 1) negative urgency (a tendency to act impulsively when experiencing negative affect) and; 2) positive urgency (a tendency to act impulsively when experiencing positive affect). As in the UPPS, each item is rated from 1 ('agree strongly') to 4 ('disagree strongly'). Amlung <i>et al.</i> (2013) have reported internal reliability coefficients from .82 to .88.

Table A2 presents descriptions of each of the behavioural laboratory measures of impulsivity administered by the studies included in the qualitative synthesis.

Table A2: Behavioural laboratory measures of impulsivity administered by studies included in the qualitative synthesis

Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Balloon analogue risk task (BART; Lejuez <i>et al.</i>, 2002) – risk-taking	Participants click a mouse button to pump-up each of 30 simulated balloons (i.e. 30 trials), which are presented one after another on the screen. With each pump, the balloon becomes slightly larger and the participant earns a small amount of money (e.g., £0.05). The amount of money so far accrued on any given balloon is held in a temporary bank (the hypothetical reward), displayed on the screen. Participants are informed that different balloons have different points at which they burst: whereas some burst after just one or two pumps, others can be pumped until they fill the whole screen. The number of inflations ranges between 0-128 pumps, with a mean explosion-point of 64 ($SD = 32$). Participants are also informed that, at any time, they can transfer the hypothetical money from their temporary bank to a permanent bank (also displayed on the screen) by clicking on a button labelled ‘Collect \$\$\$’. However, if a balloon bursts, the participant loses the hypothetical money in the temporary bank. Thus, each trial ends either when the participant transfers the hypothetical money to the permanent bank or the balloon explodes (at which point the next balloon is presented and the temporary bank returns to £0). The principal DV tend to be the ‘adjusted average pumps’ – that is, the average number of pumps for unexploded balloons,

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Table A2 continued

Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Balloon analogue risk task (BART; Lejuez <i>et al.</i>, 2002) – risk-taking	with higher scores indicating greater risk-taking propensity (Bornovalova <i>et al.</i> , 2005).
Beads task (Phillips & Edwards, 1966) – reflection impulsivity	Participants are presented with a representation of two jars, via a computer screen, each jar containing complimentary ratios of red (R) and blue (B) beads (Jar A: $P = 0.80$ R, $P = 0.20$ B; Jar B: $P = 0.80$ B, $P = 0.20$ R). Participants are informed of the bead-ratio and told that beads from one of the jars will be drawn at random one at a time. Their task is to infer from which jar the beads are being drawn. Often, participants are allowed to draw up to 20 beads before they must make a decision (although the number of permitted beads varies between studies). Participants are told that, if they feel they know which jar it is before they have drawn 20 beads, they can decide sooner. The principal dependent variable is the mean number of beads drawn prior to making a decision (independent of whether the decision was correct or not). Post-decision confidence is also sometimes recorded. More impulsive individuals tend to draw fewer beads and are also more confident post-decision.
Sussex five-choice serial reaction time task (Sx-5CSRTT; Sanchez-Roige <i>et al.</i>, 2014) – response initiation (rash impulsivity)	The Sx-5CSRTT is an adaptation (for use with human participants) of the 5-choice serial reaction time task (5CSRTT; used in rodent impulsivity studies) used by Pena-Oliver <i>et al.</i> (2012), itself considered to be a pre-clinical analogue of the human continuous performance task (CPT). In the original 5CSRTT, a rodent is presented with a feeding apparatus in which there are five holes, each containing a light. On each

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Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Sussex five-choice serial reaction time task (Sx-5CSRTT; Sanchez-Roige <i>et al.</i>, 2014) – response initiation (rash impulsivity)	trial, one of the holes is illuminated for a short time, with the animal required to nose-poke within a certain period of time in order to obtain a condensed milk solution (available for ten seconds). There are short inter-trial intervals (it is). Principal DVs are accuracy (correct to incorrect responses), omission errors (when the animal fails to respond to any of the holes during a trial) and ‘premature responses’ (nose-pokes into a hole during ITIs). In the Sx-5CSRTT, the participant must detect and respond to the brief highlighting (0.5 sec) of one of five moving visual stimuli. Following practice trials, in which the stimulus is presented every five seconds (i.e. ITI 5-s), participants perform four variants of the task: (i) a fixed inter-trial interval (fITI) and (ii) a variable inter-trial interval (vITI) session under simple task conditions, and; in order to increase attentional load, (iii) a fITI and (iv) a vITI session in combination with a dual task in which the participant is also required to respond to a 659 Hz tone by pressing a button with their non-dominant hand. The principal outcome measures are accuracy, percentage of omissions and percentage of premature responses (i.e. responding before the stimulus had been presented).
Go/no-go (GNG) task – response inhibition (rash impulsivity)	Participants are presented with ‘go’ and ‘no-go’ stimuli, typically in a ratio of around 75:25 or 80:20. They must respond to the former (usually via a button-press, for example) and not respond to the latter (e.g., by not pressing the button). The GNG described by Ahmadi <i>et al.</i> (Ahmadi <i>et al.</i> , 2013) is relatively typical. Thus, in

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Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Go/no-go (GNG) task – response inhibition (rash impulsivity)	their procedure, participants were instructed to respond, by pressing a button, as accurately and quickly as possible to go stimuli (an 'X', which was presented 85% of the time) and to withhold responding to no-go stimuli (a 'K', which was presented 15% of the time). Go and no-go stimuli were each presented for 50 msec, with an inter-stimulus interval of 750, 1750 or 2750 msec. The presentation of go and no-go stimuli was randomised, with intervals of 10-15 seconds between no-go stimuli. A 'commission error' is said to occur when the participant responds to a no-go stimulus. The principal outcome measure is typically either the absolute number of commission errors or the proportion of correct responses to commission errors. Some authors also report response-speed, either for go and no-go stimuli separately or collapsed across all stimuli.
Information sampling task (IST; Clark <i>et al.</i>, 2006) – reflection impulsivity	Participants are presented with a series of 5 x 5 arrays of grey boxes on a computer screen. When clicked on, each box opens to reveal one of two colours, shown as panels below the matrix. In each trial, the participant's aim is to decide which of the two colours is more numerous in the matrix, by opening a sufficient number of boxes so as to be able to make a decision. They can open as many boxes as they wish, at their own rate. Participants complete ten trials. The primary outcome measure is the number of boxes opened prior to making a decision – that is, the probability of being correct that the participant tolerates at the point of decision-making ($P_{correct}$). Those who tolerate more

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Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Information sampling task (IST; Clark <i>et al.</i>, 2006) – reflection impulsivity	uncertainty at the point of making a decision (i.e. those who open fewer boxes) are considered more impulsive.
Iowa gambling task (IGT; Bechara <i>et al.</i>, 1997) – risk-taking	The task involves 100 card selections from four separate decks (A, B, C and D), presented via a computer monitor. Each selection results in either winning or losing money. Decks A and B usually yield moderate immediate wins (e.g., \$110, \$130) but occasional heavy losses (e.g., \$1250, \$1500) and lead to a net loss over repeated selections. They are therefore termed ‘high-risk’ decks. Decks C and D typically generate smaller wins (e.g., \$40, \$55) but also occasional smaller penalties (e.g., \$50); over time they result in an overall net profit and are therefore termed ‘low-risk’ or ‘advantageous’ decks. The principal DV, net score, is calculated by subtracting the number of choices from the risky decks (A and B) from the number of choices from the safe decks (C and D). Greater net scores therefore indicate lower risk-taking / better decision-making.
Monetary choice questionnaire (MCQ; Kirby, Petry & Bickel, 1999) – delay discounting (reward drive)	The MCQ presents participants with 27 hypothetical choices, each one between a smaller amount of money that they could hypothetically receive immediately (SI) and a larger, delayed amount of money (LD) that they could receive at a certain point in the future, with delays ranging from 7 to 186 days. Participants are asked to try to respond in the same way as they would with real money. Each of the 27 items is grouped into one of three categories, based on the approximate

Table A2 continues over the page

Table A2 continued

Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Monetary choice questionnaire (MCQ; Kirby <i>et al.</i>, 1999) – delay discounting (reward drive)	magnitudes of the delayed rewards: (i) small (ranging from \$25 to \$35); (ii) medium (\$50-\$60) and; (iii) large (\$75-\$85). The participant's pattern of responding is used to determine an estimate of their discounting rate parameter (k), for each item, using the formula: $((LD - SI) - 1)/\text{delay}$. Means are then calculated both overall, across all 27 items, and at each of the three orders of magnitude (k small, k medium and k large). Greater k values reflect a higher proportion of choices for the smaller but immediate monetary amounts (i.e. greater delay discounting).
Stop signal task (SST; Logan, 1994) – response inhibition (rash impulsivity)	Participants are presented with a series of arrows, pointing either left or right, which appear one after another in the centre of the screen. They are instructed to respond as quickly as possible to each of these 'go' stimuli: to press one button when an arrow points left and another button when it points to the right. However, on 25% of the trials, a 'stop-signal' (a 'beep') is presented, which indicates that the participant should withhold responding to that trial and await the next arrow. The initial stop-signal is presented after a fixed delay (e.g., 50 msec), with its onset thereafter adjusted via a 'staircase' procedure: thus, if/when the participant successfully stops to a stop-signal, the subsequent stop-signal onset reduces by 50 msec, and if/when they fail to successfully stop, the stop-signal onset increases by 50 msec, and so on. The main DV is the stop-signal reaction time (SSRT). The SSRT estimates the mean latency of the stopping process across stop-signal trials: those with good

Table A2 continues over the page

Table A2 continued

Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Stop signal task (SST; Logan, 1994) – response inhibition (rash impulsivity)	inhibitory control have shorter SSRTs, whereas more impulsive individuals have longer SSRTs (as it is by definition more difficult for them to engage inhibitory control processes). It is not uncommon to additionally extract data pertaining to the ‘go’ process via go reaction-times (go RTs); for example, mean go RTs for trials immediately following failed stop trials (i.e. stop trials in which the participant was unable to inhibit the go response); such trials are important indicators of whether and the extent to which the participant adjusts their responding following failed stops.
Two-choice impulsivity paradigm (TCIP; Dougherty <i>et al.</i>, 2005) – delay discounting (reward drive)	The TCIP is used to measure tolerance to delayed reward. The paradigm is a forced-choice, reward-directed task in which the participant must choose between a smaller reward given after a shorter delay (immediate reward) and a larger reward given after a longer delay (delayed reward). In each trial, an immediate and delayed reward stimulus (stimuli are usually counterbalanced) are presented via a computer screen. The participant selects the desired reward stimulus, at which point the unchosen stimulus immediately disappears and the chosen stimulus gradually fades until the delay has elapsed. A feedback screen informs the participant of how many points they have won after each given trial. Impulsivity is defined as a preference for smaller-sooner over larger-later rewards. The delay-reward contingencies can be manipulated by the experimenter, such that they may either be fixed or variable. In the former, the length of the delay and size of the reward remain constant

Table A2 continues over the page

Table A2 continued

Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Two-choice impulsivity paradigm (TCIP; Dougherty <i>et al.</i>, 2005) – delay discounting (reward drive)	across the procedure (e.g., 5 points after 5 seconds for the immediate reward and 15 points after 15 seconds for the delayed reward, as in Rose and Grunsell (2008). In the variable procedure, the length of the delay and/or the size of the reward are changed throughout the procedure on the basis of the participant's ongoing responses. For example, the length of delay for the smaller-sooner reward can be progressively increased following each smaller-sooner choice, making it increasingly less attractive over successive trials. This allows for an examination of (i) how long a delay the participant chooses to endure for a particular reward (i.e. a 'break-point') and/or (ii) how large a reward is necessary for the short and the long delay choices to be equally preferred (i.e. 50% responding for each choice, the 'point of indifference'). Several dependent variables can be used as indicators of impulsive responding. When the fixed delay-reward contingencies are used, the total number of smaller-sooner reward choices is the primary dependent variable. In addition, the longest uninterrupted series of non-impulsive choices can also be extracted. When the variable delay-reward contingencies are used, mean delay latency and reward-size are the primary indicators of impulsivity, with impulsivity being indicated by either relatively shorter mean delays or smaller mean rewards.

Table A2 continues over the page

Table A2 continued

Task and impulsivity sub-domain measured	Description of procedure and key dependent variables (DVs)
Two-choice task (TCT; Cherek & Lane, 1999) – delay discounting (reward drive)	A delay discounting task similar to the TCIP, in the TCT described by Cherek and Lane (1999), the participant is presented with the letters 'A' and 'B' via a computer screen at the beginning of each trial. The participant selects one of the two letters by pressing the corresponding button on a response panel. The selected letter then remains on the screen, whilst the unchosen letter disappears. Selecting 'A' results in a five-cent reward after a fixed delay of five seconds (the impulsive response option), whilst selecting 'B' results in a 15-cent reward after a delay which begins each procedure at 15 seconds (the self-control response option). However, the delay for B varies during the session: each time the participant selects B, the next delay for option B increases by two seconds. The delay for option A is never below seven seconds and is thus always longer than the delay for option A, which is fixed at five seconds. The primary dependent measure of impulsivity is the number of impulsive (A) choices made by the participant.

APPENDIX 2: VERBATIM SEARCH TERMS USED TO IDENTIFY STUDIES IN EACH DATABASE IN PHASE 1

Table A3 shows the verbatim search terms used in each of three databases.

Table A3: Verbatim search terms used to identify studies in each database

Database searched	Verbatim search terms used
<i>Embase (1974-2017, Week 2)</i>	1. exp impulsiveness/
	2. (impulsive behavio?r* or impulsiv*).tw.
	3. exp Alcohol Consumption/
	4. (alcohol consumption or alcohol intake or alcohol us*).tw.
	5. exp Drinking Behavior/
	6. ((((((alcohol drinking or drinking behavio?r* or drink*) adj2 habit*) or drinking) adj2 pattern*) or social drink* or non-depend?nt drink*).tw.
	7. exp Alcohol Abuse/
	8. ((alcohol adj2 abus*) or (alcohol adj2 misus*)).tw.
	9. (heavy drink* or hazardous drink* or harmful drink* or excessive drink*).tw.
	10. exp Binge Drinking/
	11. binge drink*.tw.
	12. exp College Drinking/
	13. (((alcohol drinking in college or college) adj2 drink*) or student drink* or college alcohol us*).tw.
	14. 1 or 2
	15. 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
	16. 14 and 15
	17. limit 16 to human
	18. limit 17 to english language
	19. limit 18 to adult <18 to 64 years>

Table A3 continues over the page

Table A3 continued

Database searched	Verbatim search terms used
Medline (1946-January, Week 2, 2017)	1. exp Impulsive Behavior/
	2. (impulsive behavio?r* or impulsiv*).tw.
	3. exp Alcohol Drinking/
	4. (alcohol consumption or alcohol drinking or alcohol intake or alcohol us*).tw.
	5. (social drink* or non-depend?nt drink*).tw.
	6. (((((alcohol adj2 abus*) or alcohol) adj2 misus*) or drink*) adj2 habit*).tw.
	7. (excessive drink* or harmful drink* or hazardous drink* or heavy drink*).tw.
	8. exp Binge Drinking/
	9. binge drink*.tw.
	10. exp Alcohol Drinking in College/
	11. (((alcohol drinking in college or college alcohol us* or college) adj2 drink*) or student drink*).tw.
	12. exp Drinking Behavior/
	13. (((((drinking behavio?r* or drinking) adj2 habit*) or drinking) adj2 pattern*).tw.
	14. 1 or 2
	15. 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13
	16. 14 and 15
	17. limit 16 to humans
	18. limit 17 to english language
	19. limit 18 to ("adolescent (13 to 18 years)" or "young adult (19 to 24 years)" or "adult (19 to 44 years)")

Table A3 continues over the page

Table A3 continued

Database searched	Verbatim search terms used
<i>PsycINFO (1806-January, Week 2, 2017)</i>	1. exp impulsiveness/
	2. (impulsive behavio?r* or impulsiv*).tw.
	3. exp Alcohol Drinking Patterns/
	4. (alcohol* consumption or alcohol drinking or alcohol intake or alcohol us* or (drinking adj2 pattern*)).tw.
	5. exp Drinking Behavior/
	6. drinking behavio?r*.tw.
	7. exp Social Drinking/
	8. (social drink* or non-depend?nt drink*).tw.
	9. exp Alcohol Abuse/
	10. ((alcohol adj2 abus*) or (alcohol adj2 misus*)).tw.
	11. (((heavy drink* or drink*) adj2 habit*) or harmful drink* or hazardous drink* or excessive drink*).tw.
	12. exp Binge Drinking/
	13. binge drink*.tw.
	14. (((alcohol drinking in college or college) adj2 drink*) or student drink* or college alcohol us*).tw.
	15. 1 or 2
	16. 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14
	17. 15 and 16
	18. limit 17 to human
	19. limit 18 to english language
	20. limit 19 to 320 young adulthood

APPENDIX 3: SPECIFIC INCLUSION CRITERIA FOR RETURNS

Articles retained for analysis: 1) were publications in peer-reviewed journals, thereby excluding unpublished dissertations and conference papers; 2) were empirical research studies; 3) were cross-sectional, thus excluding longitudinal and prospective follow-up studies; 4) included non-clinical samples of participants (see below for more information); 5) compared two or more groups of drinkers; 6) assessed impulsivity multi-dimensionally, defined here as *via at least one self-report measure together with at least one behavioural measure*; 7) measured alcohol use via typical consumption or problematic use, thus excluding studies that examined variables such as alcohol expectancies or craving/desire to consume alcohol during the experimental session (e.g., as part of a ‘bogus taste-test’), and; 8) included participants aged between 18 and 25 years.

Regarding point four above, participant samples were considered non-clinical here if they were recruited from non-clinical populations (e.g., college students, ‘the community’) and no formal diagnosis of alcohol-dependence was reported for participants. Nevertheless, self-reports from heavy drinking participants in included studies may indicate a level of alcohol consumption such that a diagnosis for possible or probable alcohol dependence would have been appropriate. Also, where titles and/or abstracts described participants as having an ‘alcohol use disorder’ (AUD) but where it was ambiguous as to whether these participants were identified as having difficulties/problems with alcohol and/or undergoing any treatment for alcohol consumption, these returns were considered eligible for full-text download. The reasoning for this was that the term AUD subsumes both the less severe alcohol abuse and the more severe alcohol dependence (in ICD-10), with studies including the former being considered eligible for full-text to be screened.

In terms of point six, papers in which the title and/or abstract stated that a behavioural measure of impulsivity was administered but which did not mention any self-report measures, and which met all other inclusion criteria, were included into the next round. On the other hand, papers that only mentioned the inclusion of self-report measures, and did not mention any behavioural measures, were not. The reasoning here was that studies that had included a behavioural measure may have also included a self-report measure but did not state this, due to the latter being given to participants in such studies relatively more commonly, almost as standard.

However, it was considered unlikely, given the relatively greater resource associated with behavioural measures (e.g., in terms of time, energy and possible costs in task-procurement), for a study to have administered a behavioural task but not to have this stated as part of its title and/or abstract.

In cases in which the title and/or abstract stated only that ‘impulsivity’ or ‘impulsiveness’ was measured (i.e. without any further elaboration or specification as to exactly which aspect(s)), these records were given the benefit of the doubt and their full-texts assessed for eligibility.

For the purposes of the search, delay aversion as indexed via the self-report Monetary Choice Questionnaire (MCQ; Kirby *et al.*, 1999) was considered to be a behavioural (and not self-report) measure of impulsivity. This was due to delay aversion’s being traditionally measured via behavioural tasks and conceptualised as ‘impulsive action’, a sub-category of behavioural impulsivity; the MCQ can thus be viewed as a self-report measure indexing this classically behavioural form of impulsivity.

Articles reporting on studies in which the primary focus was on participants undergoing neuroimaging whilst they performed an impulsivity task (e.g., stop-signal task), but where it was not clear from the title and/or abstract whether behavioural outcomes themselves were examined (e.g., stop-signal reaction times), were given the benefit of the doubt and their full-texts assessed for eligibility.

Concerning point eight, the titles and/or abstracts of papers that did not specifically mention the ages of participants, but which seemed likely to have included individuals aged between 18 and 25 years (e.g., those which examined the variables of interest in ‘young adults’, ‘a university sample’, ‘college drinkers’, etc.), were given the benefit of the doubt and their full-texts screened for eligibility.

Overall, in cases where it was unclear whether a paper met the inclusion criteria, the benefit of the doubt was given and full-texts downloaded for further screening.

APPENDIX 4: SPECIFIC GUIDANCE USED WHEN RATING INCLUDED STUDIES VIA THE QUALITY ASSESSMENT TOOL FOR OBSERVATIONAL COHORT AND CROSS-SECTIONAL STUDIES

If an item is not described below, this means that it was interpreted in the identical manner to the National Institutes for Health's (NIH) guidance on rating that item.

As a result of the quality assessment tool's use in assessing both cross-sectional as well as cohort studies, two items (i.e. those pertaining to cohort studies) were rated as not applicable to the quasi-experimental studies identified in the present review (i.e. Items 10 and 13).

In terms of item 2 (specifying and defining the study population), the NIH states that papers should specify (1) who, (2) where and (3) when. Since all included studies were cross-sectional, (3) was assumed to have been a year or so prior to the paper's being published and so this criterion was considered to have been implicitly met by all papers. They were thus only rated regarding (1) and (2).

In terms of Item 5 (reporting of effect-size, power, variance and effect estimates), studies differed in whether they assessed two groups of drinkers (i.e. a lighter group versus a heavier drinking group) or a single sample in which typical drinking varied from lower to greater amounts. Whereas the independent-measures design of the former studies lend themselves to between-groups comparisons (e.g., *t*-tests or ANOVAs), the latter tend to assess the extent of the relationship between alcohol intake and impulsivity via correlational and/or regression analyses. Correlations and regression coefficients are in themselves measures of effect-size, and so studies that reported these for all relevant variables were rated 'yes' for this item. When between-groups comparisons were reported, however, papers had to have *additionally* reported effect-size (e.g., partial eta-squared), power or variance and effect estimates for relevant variables in order to be rated 'yes'.

Regarding Item 6, since all studies were cross-sectional, all were accordingly rated 'no'.

In terms of Item 7, the relationship between impulsivity and alcohol misuse is believed to be bi-directional. Thus, those initially higher in impulsivity are believed to be more likely to engage in heavier alcohol consumption (Sher *et al.*, 2000, Fernie *et*

al., 2013), which, over time, is believed to (further) compromise functioning in regions associated with impulsivity (e.g., dorsolateral prefrontal cortex, anterior cingulate) (Jentsch & Taylor, 1999, Loeber *et al.*, 2009a, Loeber *et al.*, 2009b, Loeber *et al.*, 2010) leading to even greater impulsivity. Thus, given that the specific relationship between alcohol intake and impulsivity is at present unclear, for all studies, Item 7 received a rating of ‘other – NA’.

For Item 8 (levels of exposure), studies that separated participants into groups were required to have included at least three drinking groups (e.g., light drinkers, moderate drinkers and heavy drinkers) in order to receive a ‘yes’ rating. Studies in which associations between level of alcohol intake as a continuous variable and impulsivity were assessed in a single group received a ‘yes’ rating for this item, as such studies allow for dose-response-like estimates.

In terms of Item 9 (exposure measures and assessment), papers were assessed on whether they had administered a reliable and valid measure of participants’ typical levels of alcohol intake (e.g., in a typical week over the previous year, in a typical day in the last three months, etc.). The purpose of this was in order that *participants’ levels of alcohol intake could be estimated in UK units of alcohol* (i.e. 1 unit equals 8 grams of pure alcohol), for comparative purposes in the qualitative synthesis. Thus, recognised instruments such as the Alcohol Use Questionnaire (AUQ; Mehrabian & Russell, 1978) and Daily Drinking Questionnaire (DDQ; Collins, Parks & Marlatt, 1985), which give clear estimates of respondents’ typical alcohol consumption, would receive a ‘yes’. Measures such as the total score on the Alcohol Use Disorders Identification Test (AUDIT; Saunders *et al.*, 1993), however, which do not provide a clear estimate of respondents’ typical alcohol consumption *per se*, were scored ‘no’. Overall, the emphasis here was on whether studies measured typical alcohol consumption using a valid and reliable instrument.

For Item 12 (blinding of outcome assessors), it was generally considered possible for studies to have included blinded assessors, so the rating ‘other – NA’ was not considered to be a valid option when rating this item. Studies only received a ‘yes’ rating if they explicitly stated that blinding took place.

Regarding Item 14, key potentially confounding variables here were age, gender, socioeconomic status (SES) and IQ, all of which have been related to impulsivity

(Eysenck *et al.*, 1985, Roberts *et al.*, 2001, 2003, de Wit *et al.*, 2007, Donnellan *et al.*, 2007, Yuan *et al.*, 2008, Raver *et al.*, 2013, Spielberg *et al.*, 2015). Thus, only studies that measured and, if necessary (e.g., if the design utilised independent groups, with a significant difference in one or more of these variables being found), controlled for all of these variables, were rated 'yes'.

Overall, in some cases, the principal aim of a study was not to examine the relationship between alcohol intake and self-reported and behavioural measures of impulsivity, but to instead, for example, compare light and heavy drinkers on neuroimaging indices (e.g., N2 and P3 waves in EEG) whilst performing a behavioural task – with impulsivity self-reports and behavioural performances restricted to a secondary position. In such cases, the ratings for items remained broadly the same as for studies in which the alcohol intake-impulsivity association was the main question. However, for Items 5, 11 and 14, studies were considered *only in terms of the alcohol intake-impulsivity relationship* and not in terms of aspects of the study unrelated to this association, such as the measurement and effect-size of EEG indices, etc.

APPENDIX 5: THE BARRATT IMPULSIVENESS SCALE, VERSION 11 (BIS-11), SENSATION-SEEKING SCALE (SSS) AND URGENCY, PREMEDITATION, PERSEVERANCE SENSATION-SEEKING SCALES (UPPS-P), INCLUDING GUIDE FOR WHICH ITEMS COMPRISE EACH SUBSCALE

FACTOR STRUCTURE OF THE BIS-11

Table A4 presents the items comprising each of the three BIS-11 subscales.

Table A4: Items comprising each of the three subscales of the BIS-11

BIS-11 subscale	Items comprising subscale
<i>Attentional impulsivity</i>	5. I don't "pay attention."
	6. I have "racing" thoughts.
	9. I concentrate easily.
	11. I "squirm" at plays or lectures.
	20. I am a steady thinker.
	24. I change hobbies.
	26. I often have extraneous thoughts when thinking.
	28. I am restless at the theatre or lectures.
<i>Motor impulsiveness</i>	2. I do things without thinking.
	3. I make-up my mind quickly.
	4. I am happy-go-lucky.
	16. I change jobs.
	17. I act "on impulse."
	19. I act on the spur of the moment.
	21. I change residences.
	22. I buy things on impulse.
	23. I can only think about one thing at a time.
	25. I spend or charge more than I earn.
	30. I am future-oriented.

Table A4 continues over the page

Table A4 continued

BIS-11 subscale	Items comprising subscale
<i>Non planning impulsiveness</i>	1. I plan task carefully.
	7. I plan trips well ahead of time.
	8. I am self-controlled.
	10. I save regularly.
	12. I am a careful thinker.
	13. I plan for job security.
	14. I say things without thinking.
	15. I like to think about complex problems.
	18. I get easily bored when solving thought problems.
	27. I am more interested in the present than the future.
	29. I like puzzles.

FACTOR STRUCTURE OF THE SSS-V

Table A5 presents the items comprising each of the four subscales of the SSS-V

Table A5: Items comprising each of the four subscales of the SSS-V

SSS-V subscale	Items comprising subscale
<i>Thrill and adventure seeking</i>	3. I often wish I could be a mountain climber
	11. I sometimes like to do things that are a little frightening
	16. I would like to take up the sport of water skiing
	17. I would like to try surfboarding
	20. I would like to learn to fly an aeroplane
	21. I would like to go scuba diving
	23. I would like to try parachute jumping
	28. I like to dive off the high board
	38. I would like to sail a long distance in a small but seaworthy sailing craft
	40. I think I would enjoy the sensations of skiing very fast down a high mountain slope
<i>Experience seeking</i>	4. I like some of the earthy body smells
	6. I like to explore a strange city or section of town by myself, even if it means getting lost
	9. I have tried marijuana or would like to
	10. I would like to try some of the new drugs that produce hallucinations
	14. I like to try new foods that I have never tasted before

Table A5 continues over the page

Table A5 continued

SSS-V subscale	Items comprising subscale
<i>Experience seeking</i>	18. I would to take off on a trip with no pre-planned or definite routes, or timetable
	19. I would like to make friends in some of the “far out” groups like artists or “punks”
	22. I would like to meet some persons who are homosexual (men or women)
	26. I often find beauty in the “clashing” colours and irregular forms of modern paintings
	37. People should dress in individual ways even if the effects are sometimes strange
<i>Disinhibition</i>	1. I like “wild”, uninhibited parties
	12. I enjoy the company of real “swingers”
	13. I often like to get high (drinking liquor or smoking marijuana)
	25. I like to have new and exciting experiences and sensations, even if they are a little frightening, unconventional or illegal
	29. I like to date members of the opposite sex who are physically exciting
	30. Keeping the drinks full is the key to a good party
	32. A person should have considerable sexual experience before marriage
	33. I could conceive of myself seeking pleasures around the world with the “jet set”

Table A5 continues over the page

Table A5 continued

SSS-V subscale	Items comprising subscale
<i>Disinhibition</i>	35. I enjoy watching many of the “sexy” scenes in movies
	36. I feel best after taking a couple of drinks
<i>Boredom susceptibility</i>	2. I can’t stand watching a movie I’ve seen before
	5. I get bored seeing the same old faces
	7. When you can predict almost everything a person will do or say he or she must be a bore
	8. I usually don’t enjoy a movie or play where I can predict what will happen in advance
	15. Looking at someone’s home movies or travel slides bores me tremendously
	24. I prefer friends who are excitingly unpredictable
	27. I get very restless if I have to stay around home for any length of time
	31. The worst social sin is to be a bore
	34. I like people who are sharp and witty even if they do sometimes insult others
	39. I have no patience with dull or boring persons

FACTOR STRUCTURE OF THE UPPS-P

Table A6 presents the items comprising each of the four subscales of the UPPS-P

Table A6: Items comprising each of the four subscales of the UPPS-P

UPPS-P subscale	Items comprising subscale
<i>Negative urgency</i>	2. I have trouble controlling my impulses.
	7. I have trouble resisting my cravings (for food, cigarettes, etc.).
	12. I often get involved in things I later wish I could get out of.
	22. Sometimes when I feel bad, I can't seem to stop what I am doing even though it is making me feel worse.
	29. When I am upset I often act without thinking.
	34. When I feel rejected, I will often say things that I later regret.
	39. It is hard for me to resist acting on my feelings.
	44. I often make matters worse because I act without thinking when I am upset.
	50. In the heat of an argument, I will often say things that I later regret.
	53. I always keep my feelings under control.
	58. Sometimes I do impulsive things that I later regret.
<i>(Lack of) premeditation</i>	1. I have a reserved and cautious attitude toward life.
	6. My thinking is usually careful and purposeful.
	11. I am not one of those people who blurt out things without thinking.

Table A6 continues over the page

Table A6 continued

UPPS-P subscale	Items comprising subscale
<i>(Lack of) premeditation</i>	16. I like to stop and think things over before I do them.
	21. I don't like to start a project until I know exactly how to proceed.
	28. I tend to value and follow a rational, "sensible" approach to things.
	33. I usually make up my mind through careful reasoning.
	38. I am a cautious person.
	43. Before I get into a new situation I like to find out what to expect from it.
	48. I usually think carefully before doing anything.
	55. Before making up my mind, I consider all the advantages and disadvantages.
<i>(Lack of) perseverance</i>	4. I generally like to see things through to the end.
	9. I tend to give up easily.
	14. Unfinished tasks really bother me.
	19. Once I get going on something I hate to stop.
	24. I concentrate easily.
	27. I finish what I start.
	32. I am able to pace myself so as to get things done on time.
	37. I am a person who always gets the job done.
	42. I almost always finish projects that I start.

Table A6 continues over the page

Table A6 continued

UPPS-P subscale	Items comprising subscale
<i>(Lack of) perseverance</i>	47. Sometimes there are so many little things to be done that I just ignore them all.
<i>Sensation seeking</i>	3. I generally seek new and exciting experiences and sensations.
	8. I'll try anything once.
	13. I like sports and games in which you have to choose your next move very quickly.
	18. I would enjoy water skiing.
	23. I quite enjoy taking risks.
	26. I would enjoy parachute jumping.
	31. I welcome new and exciting experiences and sensations, even if they are a little frightening and unconventional.
	36. I would like to learn to fly an airplane.
	41. I sometimes like doing things that are a bit frightening.
	46. I would enjoy the sensation of skiing very fast down a high mountain slope.
	51. I would like to go scuba diving.
	56. I would enjoy fast driving.
<i>Positive urgency</i>	5. When I am very happy, I can't seem to stop myself from doing things that can have bad consequences.
	10. When I am in great mood, I tend to get into situations that could cause me problems.

Table A6 continues over the page

Table A6 continued

UPPS-P subscale	Items comprising subscale
<i>Positive urgency</i>	15. When I am very happy, I tend to do things that may cause problems in my life.
	20. I tend to lose control when I am in a great mood.
	25. When I am really ecstatic, I tend to get out of control.
	30. Others would say I make bad choices when I am extremely happy about something.
	35. Others are shocked or worried about the things I do when I am feeling very excited.
	40. When I get really happy about something, I tend to do things that can have bad consequences.
	45. When overjoyed, I feel like I can't stop myself from going overboard.
	49. When I am really excited, I tend not to think of the consequences of my actions.
	52. I tend to act without thinking when I am really excited.
	54. When I am really happy, I often find myself in situations that I normally wouldn't be comfortable with.
	57. When I am very happy, I feel like it is ok to give in to cravings or overindulge.
	59. I am surprised at the things I do while in a great mood.

MAIN EMPIRICAL PROJECT

ARE HEAVY DRINKERS MORE IMPULSIVE THAN LIGHT
DRINKERS?

A COMPREHENSIVE MULTI-DIMENSIONAL ASSESSMENT
OF IMPULSIVITY IN NON-DEPENDENT HEAVY DRINKING
YOUNG ADULTS

SUPERVISED BY DR. TIM MEYNEN

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ABSTRACT

Background and aims: The present study set out to comprehensively assess impulsivity in non-dependent heavy drinkers, relative to lighter drinkers. Few previous studies of this nature exist, whilst the findings of those that do are constrained by important methodological limitations. The present study therefore systematically controlled for the potential confounders of age, gender, SES and IQ, as well as exclude possibly dependent drinkers, in order to estimate the ‘true’ association between non-dependent heavy drinking and impulsivity sub-domains. Profiling non-dependent heavy drinkers’ impulsivity may lead to insights into the potential mechanism(s) involved in the maintenance of heavy alcohol intake.

Methods: In a single testing session, 63 light and 53 heavy drinkers were assessed on the following impulsivity sub-domains (measures): self-reported rash impulsivity (RI; the BIS-11) and reward-drive (RD; the BAS scales), together with behavioural measures of response-initiation (the CPT), response-inhibition (the SST), delay-discounting (the MCQ), risk-taking (the BART) and reflection impulsivity (the beads task).

Results: Heavy drinkers were significantly more impulsive on the BIS-11 motor impulsiveness subscale, and they were substantially more impulsive on the CPT. However, there were no group differences *for any other impulsivity measure*. In a subsequent logistic regression in which the *a priori* covariates were controlled, CPT performance remained a (highly) significant predictor of drinking group, although BIS-11 motor impulsiveness did not.

Conclusions: Overall, the present findings suggest that, with the exception of behavioural response-initiation (i.e. CPT performance), none of the other impulsivity sub-domains are involved in non-dependent heavy drinking, at least in young adults. On the other hand, response-initiation, in tandem with other neuropsychological aspects of addiction such as cue-reactivity, may serve to maintain heavy alcohol intake.

I. INTRODUCTION

Alcohol misuse is a serious public health concern and it is thus important to improve our understanding of the factors involved. A bio-psycho-social perspective holds that certain aspects of an individual, in the context of environmental ‘triggers’, increase the risk of alcohol misuse. Elevated impulsivity, given its reliable presence in those with alcohol dependence (Jentsch & Taylor, 1999), is potentially one such important intra-individual, psychological factor. It is important to characterise non-dependent heavy drinkers’ impulsivity profile, as doing so may provide insight into the potential mechanism(s) involved in the maintenance of heavy alcohol intake. The present study thus assessed impulsivity multi-dimensionally in non-dependent heavy drinkers, via a comprehensive set of self-report and behavioural measures.

I.1) ECONOMIC, HEALTH AND OTHER COSTS ASSOCIATED WITH ALCOHOL MISUSE

As detailed in the Introduction of the systematic literature review of this volume (pp.7-8), alcohol misuse is a major public health concern. In terms of the economic impact, combined costs related to NHS expenditure (e.g., ambulance journeys and accident and emergency admissions) and other public services (e.g., social care, criminal justice and fire services), private and informal health and care, lost income due to work absenteeism, unemployment, crime and accidents and injuries have been estimated at £55.1 billion annually (Lister *et al.*, 2008). The increased physical health risks of alcohol misuse include cancers, dementias, osteoporosis, pancreatitis, heart disease, epilepsy, hypertension and liver cirrhosis, as well as fetal alcohol syndrome (FAS), stillbirths and miscarriages (Gmel & Rehm, 2003, Rehm *et al.*, 2003, Balakrishnan *et al.*, 2009, Navarro, Doran & Shakeshaft, 2011); with regards to mental health, rates of major depression, bipolar disorder, anxiety disorders and schizophrenia are all greater in heavier drinkers (Helzer & Pryzbeck, 1988, Kessler *et al.*, 1997). Consequently, alcohol has been labelled more dangerous than heroin (Lee & Forsythe, 2011). With rates of alcohol misuse in the UK increasing (Statistics, 2001, Centre, 2008), it is likely that the associated costs will accordingly worsen.

I.II) DEFINITIONS AND PREVALENCE OF ALCOHOL MISUSE

The International Classification of Diseases (ICD-10; Organization, 1992) defines the distinct AUDs of ‘harmful alcohol use’ and ‘alcohol dependence’ (for more detail, see Introduction of systematic literature review, pp. 8-10). In the former, individuals may experience damage to physical and mental health, as well as adverse social consequences, but are not physically dependent (i.e. they do not show tolerance or a withdrawal syndrome). In alcohol dependence, tolerance and withdrawal *are* present, along with a cluster of other behavioural, cognitive and physiological phenomena including craving, difficulties controlling use and continued use despite adverse consequences. Six per cent of men and two per cent of women are estimated to be alcohol dependent (Drummond *et al.*, 2004). These disorders are increasingly recognised to exist along a continuum of severity (e.g., mild, moderate and severe forms of alcohol dependence have been described Drummond *et al.*, 2011); thus, the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders DSM-V; Association (2013b) collapses these two diagnoses into a single ‘alcohol use disorder’ diagnosis, with mild, moderate and severe sub-categories.

Other forms of non-diagnosable alcohol misuse also exist. For example, those who exceed UK recommended weekly limits of 14 units for men and women (Officers, 2016) are ‘hazardous drinkers’, thought to be at increased risk for future harm (Drummond *et al.*, 2011). Research studies tend to use the alternative yet broadly synonymous ‘heavy drinkers’ to refer to such individuals; and indeed this latter term is used to refer to such drinkers from here on in. ‘Harmful’ drinking occurs when men consume more than 50 units per week and women more than 35 units (1986), whilst ‘binge’ drinking refers to men consuming more than eight units, and women more than six, in a single day (Unit, 2004). An estimated 21% of men and 15% of women are hazardous drinkers, a further 7% of men and 5% of women are harmful drinkers, whilst 21% of men and 14% of women binge drink.

Those who go on to develop alcohol dependence presumably consume alcohol at a less severe level (e.g., heavily) at an earlier point. It thus seems reasonable to believe that AUDs exist on a continuum with normality, with certain individual and environmental risk factors making a person more or less likely to drift towards the ‘clinical’ end of this continuum. Given this, together with the considerable numbers

drinking alcohol in a way that is either potentially or actually harmful (McManus *et al.*, 2009), it is vital that we increase our understanding of potential risk factors.

I.III) ALCOHOL USE DISORDERS ARE ASSOCIATED WITH DYSFUNCTIONS IN MESOCORTICOLIMBIC DOPAMINERGIC CIRCUITRY

A large and growing body of research literature documents the characteristic neuropsychological features demonstrated by people with AUDs, and especially those with alcohol dependence. For example, numerous empirical studies (e.g., see reviews by Grace, 2000, Weiss & Porrino, 2002, Diana *et al.*, 2003, Volkow, Fowler & Wang, 2004) have revealed alcohol and substance misusers to show chronic attenuation of tonic or resting activity within brain ‘reward’ circuitry, comprising dopaminergic (DAergic) projections from the ventral tegmental area (VTA) to the nucleus accumbens (NAcc), amygdala, anterior cingulate gyrus (ACG) and prefrontal cortex (PFC). The mechanisms via which a substance user’s MCL system becomes hypodopaminergic are at present unclear, though could involve a diathesis-stress relationship of both chronic alcohol intake and genetic factors (Crabbe, 2002).

Collectively termed the mesocorticolimbic (MCL) system, it is believed that these tracts have evolved to direct appropriate responses towards ‘natural’ rewards such as food or sex (Kelley & Berridge, 2002). Exposure to an appetitive stimulus phasically increases dopamine (DA) transmission in the VTA, signalling the availability of reward and influencing attention, decision-making and behaviour via DAergic projections to the NAcc, striatum, anterior cingulate cortex (ACC) and other prefrontal regions (Schultz, Dayan & Montague, 1997). Crucially, even in dependent individuals, drugs of abuse directly increase DA transmission in the VTA in the MCL circuitry with a potency, immediacy and reliability that exceed the effects of *almost every natural reward* (Hyman & Malenka, 2001). In their ‘incentive sensitisation’ theory of addiction, Robinson and Berridge (Robinson & Berridge, 1993, 2000) argue that, in susceptible individuals and under certain circumstances, the repeated administration of an abusable drug can persistently change the structure and function of brain cells and circuits involved in regulating the attribution of incentive salience to stimuli. Specifically, DAergic activity within MCL circuitry comes to be excessively geared towards the procurement of the drug, to the detriment of virtually all other natural reinforcers: drugs thereby ‘hijack’ the MCL system (Lubman, Yucel & Pantelis, 2004). One key psychological manifestation of this so-called ‘hijacking’ is the

user's enduring preoccupation with the procurement and consumption of alcohol – in other words, craving.

I.III.I) KEY CORRELATES OF DOPAMINERGIC MESOCORTICOLIMBIC DYSFUNCTION IN ALCOHOL ADDICTION I: APPETITIVE RESPONSES TO ALCOHOL AND ASSOCIATED STIMULI

‘Craving’ can be defined as ‘a subjective feeling of a strong urge to do something’ (West & Brown, 2013, p. 11), and is considered to be a fundamental element in the maintenance of AUDs (Kozlowski & Wilkinson, 1987). Compared to healthy controls, those with alcohol dependence show reliable increases in self-reported craving following exposure to alcohol-related cues, such as the sight or smell of alcohol (e.g., Pomerleau *et al.*, 1983, Cooney *et al.*, 1987, McCusker & Brown, 1995, Reid *et al.*, 2006). In addition, a number of studies have also reported alcoholics to demonstrate cue-elicited increases in indices of autonomic arousal, such as salivation (Pomerleau *et al.*, 1983), skin temperature, respiration, blood pressure, heart rate (Kaplan *et al.*, 1985, McCaul, Turkkan & Stitzer, 1989, Payne *et al.*, 1992), skin conductance¹¹ (Kaplan *et al.*, 1985, McCaul *et al.*, 1989), as well as changes in brain activity (recorded via fMRI) within and throughout dopaminergic mesocorticolimbic circuitry (e.g., see reviews by George *et al.*, 2001, Wrase *et al.*, 2002, Heinz *et al.*, 2009). Taken together, these phenomena are termed ‘cue-reactivity’. In addition, those with dependence show an excessive attentional bias towards alcohol and associated stimuli, for example on a modified alcohol Stroop task (e.g., Johnsen *et al.*, 1994, Stetter *et al.*, 1995). Franken (Franken, 2003) contends that a reciprocally excitatory relationship exists between subjective craving and attentional bias. Thus, when alcohol-related cues become the focus of attention, subjective craving increases, which in turn heightens the ‘attention-grabbing’ properties of alcohol-related stimuli, and so on. A ratchet effect thereby occurs, increasing the urge to consume alcohol.

Disruptions in DAergic activity within MCL circuitry also relate to the other key psychological characteristic of addiction (Robinson *et al.*, 2001): impaired executive control and, specifically, elevated impulsivity. According to the incentive-sensitisation theory (Robinson & Berridge, 1993, 2000), cue-reactivity and attentional

¹¹ The term ‘skin conductance’ refers to the skin’s ability to conduct weak electrical currents. This ability varies as a function of the amount of moisture on the surface of the skin, and is therefore used as an index of sweat gland activity (Drobes & Thomas, 1999).

biases, combined with the elevated impulsivity commonly observed in addicts (see below), can explain the core symptoms of addiction: compulsive drug-seeking and consumption despite profound adverse consequences and relapse. Indeed, around half (that is, five of 11) of the DSM-5 criteria (Association, 2013a) for alcohol use disorder describe phenomena related to aspects of impulsivity: ‘alcohol is often taken in larger amounts or over a longer period than was intended’ (criterion one); ‘there is a persistent desire or unsuccessful efforts to cut down or control alcohol use’ (criterion two); ‘continued alcohol use despite having persistent or recurrent social or interpersonal problems caused or exacerbated by the effects of alcohol’ (criterion six); ‘recurrent use of alcohol in situations in which it is physically hazardous’ (criterion eight), and; ‘alcohol use is continued despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by alcohol’ (criterion nine).

I.III.II) KEY CORRELATES OF DOPAMINERGIC MESOCORTICOLIMBIC DYSFUNCTION IN ALCOHOL ADDICTION II: ELEVATED IMPULSIVITY

Elevated impulsivity is implicated in virtually all contemporary neurobiological theories of addiction, accounting for difficulties resisting the urge to consume the drug despite the clear adverse consequences. Jentsch and Taylor (Jentsch & Taylor, 1999) review evidence that chronic exposure to drugs of abuse induces abnormalities in the structure and function of regions of the prefrontal cortex (PFC), in particular the orbitofrontal cortex (OFC), anterior cingulate gyrus (ACG) and dorsolateral PFC (DLPFC) (Volkow *et al.*, 1993, London *et al.*, 2000, Robinson *et al.*, 2001). Loeber *et al.* (Loeber *et al.*, 2009a, Loeber *et al.*, 2009b, Loeber *et al.*, 2010) argue that withdrawal from alcohol may produce neurotoxic lesions in the frontal lobe, citing evidence that alcohol-dependent patients with two or more detoxifications show greater dysfunction than those detoxified not more than once. Aron, Robbins and Poldrack (Aron, Robbins & Poldrack, 2004) suggest that OFC function is involved in processing the affective value of stimuli and adjusting behaviour accordingly; the ACG in the inhibition of prepotent reflexive responses; and the DLPFC in the monitoring of strategically-guided behaviour and working memory. Dysfunction in these regions is thus expected to bring about deficits in their associated processes.

The evidence of prefrontal dysfunction in those with alcohol dependence has been complemented by studies using self-report and behavioural measures, which have

demonstrated high levels of impulsivity in these individuals, relative to controls. Before detailing these findings, it is necessary to first define what is meant by the term ‘impulsivity’.

I.III.II.I) DEFINING AND MEASURING IMPULSIVITY

Although definitions differ, impulsivity is typically thought to involve a tendency to seek immediate gratification of urges/impulses, problems with response-inhibition and a propensity not to reflect prior to decision-making (Robbins, Curran & de Wit, 2012). A detailed description of the construct, as well as instruments used for its measurement, is given in the Introduction of the systematic literature review of this thesis (pp. 13-14). Briefly, then, impulsivity is a multidimensional construct (de Wit & Richards, 2004), widely considered to consist of two distinct yet related sub-dimensions (2008): (i) reward drive (RD), which refers to one’s sensitivity to signals of reward (as manifested in the tendency to engage in appetitive behaviour when exposed to incentives), and; (ii) rash impulsivity (RI), reflected in difficulties modifying or inhibiting pre-potent (reward drive-initiated) behaviour in order to avoid potentially aversive consequences.

A variety of self-report and behavioural measures are used to measure these sub-domains. Self-report measures of RD include the behavioural activation scales (BAS scales; 1994) and Torrubia *et al.*’s (2001) sensitivity to reward scale, whilst behavioural measures tend to be delay discounting tasks (Bickel & Marsch, 2001) and/or probability discounting tasks (Green, Myerson & O’Staszewski, 1999). In terms of RI, commonly administered self-report measures include the Barratt impulsiveness scale, version 11 (BIS-11; Patton, Stanford & Barratt, 1995a) and the sensation-seeking scale (SSS; Kolin, Price & Zoob, 1964). The two most widely-used behavioural indices are the stop-signal task (SST; Logan, 1994) and the go/no-go task, which each measure response-inhibition – that is, the ability to override a pre-potent ‘go’ response (e.g., a button-press) when an infrequent ‘stop’ signal (requiring withholding of the button-press) is given. In addition, the continuous performance task (CPT) assesses response *initiation*, defined as the readiness with which an individual initiates an action (e.g., a button-press). As well as RD and RI, risk-taking and ‘reflection impulsivity’ (deficient gathering and evaluation of information during decision-making’ (Solowij *et al.*, 2012)) seem to be further, distinct aspects of impulsivity (Meda *et al.*, 2009, Caswell *et al.*, 2015). Risk-taking is commonly indexed via the balloon analogue risk task (BART;

Lejuez *et al.*, 2002) or the conceptually similar Iowa gambling task (IGT; Bechara *et al.*, 1997), with reflection impulsivity often assessed via the beads task (Phillips & Edwards, 1966) or information sampling task (IST; Clark *et al.*, 2006).

I.III.II.II) IMPULSIVITY IS ELEVATED IN ALCOHOL DEPENDENCE

A wealth of studies has reported the various impulsivity sub-domains to be reliably elevated in alcohol dependent individuals (relative to healthy control, thereby complementing findings indicating dysfunction within regions of the PFC (Jentsch & Taylor, 1999). Concerning RD, Petry (2001) reported both current and formerly alcohol dependent individuals to demonstrate abnormally high discounting of delayed monetary and alcohol rewards. Similar findings have been reported by Bjork *et al.* (2004), Mitchell *et al.* (2005, 2007), Boettiger *et al.* (2007) and Bobova *et al.* (2009). Self-report measures of RD have also discriminated alcohol dependent samples from controls (e.g., Johnson, Turner & Iwata, 2003, Sprah & Novak, 2008, Lyvers *et al.*, 2014). In terms of RI, a number of studies have reported significant performance deficits (via SST and go/no-go task) in alcohol dependent groups (Goudriaan *et al.*, 2006, Lawrence *et al.*, 2009, Schmaal *et al.*, 2013, Petit *et al.*, 2014, Zhou *et al.*, 2014). In terms of self-report indices, many studies have reported greater impulsiveness in both current and former alcohol dependent and abusing individuals, relative to controls (e.g., von Knorring, Orelund & von Knorring, 1987, Hallman *et al.*, 1990, Ketzenberger & Forrest, 2000, Bjork *et al.*, 2004, Chen *et al.*, 2007, von Diemen *et al.*, 2008, Cangemi *et al.*, 2010). Similarly, in terms of risk-taking, a number of studies have found those with alcohol dependence to perform more poorly than controls on the IGT (e.g., Goudriaan *et al.*, 2005, Dom *et al.*, 2006, Noël *et al.*, 2007, Kim, Sohn & Jeong, 2011), as well as on conceptually similar gambling tasks (Fein, Klein & Finn, 2004, Lawrence *et al.*, 2009). Few studies have used either the beads task or the IST to explore potential differences in reflection impulsivity between alcohol-dependent individuals and healthy controls. In one of the only such studies, Lawrence *et al.* (2009) found these individuals to demonstrate significantly higher reflection impulsivity (via the IST).

It is important to note that elevated impulsivity may be either a determinant or a consequence (or both) of alcohol misuse. As described above, there is evidence that chronic drug abuse leads to prefrontal cortical dopaminergic hypofunction (e.g., Loeber *et al.*, 2009a, Loeber *et al.*, 2009b, Loeber *et al.*, 2010). Conversely, pre-existing

trait impulsivity has been implicated as a risk factor for subsequent problematic drug use. For example, in a sample of 457 young adults, Sher, Bartholow and Wood (2000) reported that 'behavioural disinhibition' predicted substance use disorder six years later (see also Fernie *et al.*, 2013). Interestingly, the relative importance of delay aversion and inhibitory control failures may change across the development and course of AUDs. Rubio *et al.* (2008) assessed 384 heavy drinkers and 149 healthy volunteers at baseline and four years later. Over the course of this period, 33 per cent of the heavy drinkers developed alcohol dependence. Whereas difficulty in delaying reward correlated with baseline substance use, impaired inhibitory control at baseline predicted the subsequent development of dependence.

I.IV) EVIDENCE OF DOPAMINERGIC MESOCORTICOLIMBIC DYSFUNCTION IN NON-DEPENDENT HEAVY DRINKERS

The aforementioned clinical research has focused on long-term, chronically relapsing alcohol-dependent samples. However, addiction theory (e.g., Robinson & Berridge, 1993, Jentsch & Taylor, 1999, Robinson & Berridge, 2000) conceptualises chronic patterns of addictive behaviour as the 'end-point' of a progressive development; thus, those with non-dependent but heavy patterns of consumption might also be expected to show cue-reactivity and elevated impulsivity. This view has increasingly been corroborated by research with such samples. In terms of cue-reactivity, when presented with alcohol cues, non-dependent heavy drinkers report greater desire for alcohol than light drinkers (McCusker & Brown, 1990, Walitzer & Sher, 1990, Greeley *et al.*, 1993), as well as showing elevated autonomic responses (such as increases in pulse rate, salivation, skin temperature reactivity and skin conductivity McCusker & Brown, 1990, Walitzer & Sher, 1990) and attentional bias towards alcohol cues (Cox, Yeates & Regan, 1999, Jones & Schulze, 2000). However, the evidence is less clear as to whether the other key neuropsychological characteristic of addiction – elevated impulsivity – is also present in non-dependent heavy drinkers.

I.IV.1) IS IMPULSIVITY ELEVATED IN NON-DEPENDENT HEAVY DRINKERS?

The systematic literature review of this thesis examined whether impulsivity, across all of its various sub-domains, is elevated in non-clinical¹² groups of alcohol misusers (e.g., heavy and binge drinkers), relative to healthy drinking comparison groups. Briefly, the review found that, firstly, few (only eight) empirical studies have assessed impulsivity multi-dimensionally in groups of young adult (i.e. 18-25) alcohol misusers. Furthermore, the self-report and behavioural impulsivity measures administered by these eight papers varied, with no two studies administering the same battery and no single study administering indices that allowed for a complete profiling of impulsivity across all sub-domains.

Collectively, the studies' findings suggested that self-reported rash impulsivity (and the sensation seeking scale or SSS; Zuckerman, Eysenck & Eysenck, 1978, as assessed by, e.g., the Barratt impulsiveness scale, version 11 or BIS-11; Patton, Stanford & Barratt, 1995b) is greater in the quasi-experimental groups (Moreno *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016). Interestingly, behavioural response initiation (as assessed by the continuous performance task) was elevated in the one study that had assessed this (Sanchez-Roige *et al.*, 2014), although response inhibition (e.g., stop signal and go/no-go tasks) was consistently found *not* to be (Henges & Marczinski, 2012, Moreno *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016). There also seemed not to be any group differences for behavioural RD (delay discounting; Rose & Grunsell, 2008, Moreno *et al.*, 2012, Banca *et al.*, 2016, Caswell *et al.*, 2016), though the one study that assessed RD via self-report (the BAS scales) reported elevated impulsivity in heavy drinkers (Ahmadi *et al.*, 2013). The question of whether risk-taking and reflection impulsivity might be elevated in alcohol misusers was unclear, due to insufficient data (i.e. just two studies had administered measures of each, these studies reporting mixed findings; Moreno *et al.*, 2012, Ahmadi *et al.*, 2013, Banca *et al.*, 2016, Caswell *et al.*, 2016).

The quality of the eight studies included in the final review were generally rated 'fair', none being rated 'good', due to a range of potential sources of confound. Thus, no

¹² The term 'non-clinical' is used here to refer to samples that were not undergoing any form of treatment for alcohol problems and for whom there was no formal diagnosis of alcohol dependence.

study controlled for *all* of the following variables: the three key socio-demographic variables of age, gender and socioeconomic status (SES) and IQ. Each of these variables is statistically related to impulsivity (Eysenck *et al.*, 1985, Roberts, Caspi & Moffitt, 2001, 2003, de Wit *et al.*, 2007, Donnellan, Conger & Burzette, 2007, Yuan *et al.*, 2008, Raver, Blair & Willoughby, 2013, Spielberg *et al.*, 2015) and can therefore be considered a potential source of confound. Indeed, given that SES has been specifically related to poorer inhibitory control, the failure to control for it has possible implications for the validity of findings especially relating to elevated self-reported rash impulsivity in quasi-experimental groups. Perhaps more seriously, however, it is possible that, across each study, at least some participants were alcohol dependent. For example, the heavy drinkers in Ahmadi *et al.* (Ahmadi *et al.*, 2013) had a mean alcohol intake equivalent to around 125 units per week on average (i.e. a mean of around 17 units per day) and the heavy drinkers in Petit *et al.* (Petit *et al.*, 2012) and the binge drinkers in Banca *et al.* (Banca *et al.*, 2016) and Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014) all had mean AUDIT scores consistent with some participants scoring above threshold for ‘possible dependence’ (i.e. greater than 15). This is problematic, as results (esp. group differences) may have been unduly influenced by a subgroup of dependent individuals. The key implication of finding elevated impulsivity in an apparently non-dependent (and never-dependent) sample is that impulsivity can occur in the absence of physical dependence. Clearly, this is seriously undermined if some participants were alcohol dependent.

I.V) THE PRESENT STUDY

A bio-psycho-social understanding of AUDs holds that certain aspects of an individual, combined with environmental ‘triggers’, will increase the risk of chronic alcohol misuse. Elevated impulsivity (present either prior to first drinking episode or subsequent to a period of heavy drinking, or both), given its reliable presence in alcohol-dependent individuals, is a clear candidate as a potential psychological vulnerability factor. It is therefore important to characterise non-dependent heavy drinkers’ impulsivity profile, as doing so may provide insight into the potential mechanisms involved in the initial development of heavy alcohol consumption. Cross-sectional studies cannot disentangle cause-and-effect relationships between impulsivity and non-dependent heavy alcohol use (and possible future dependent drinking). However, if certain impulsivity sub-domains are reliably elevated in such

drinkers, this would be consistent with their *preceding* the development of AUDs, rather than being merely symptomatic of them. Furthermore, it may suggest their being involved in the initial development of AUDs.

This study was thus designed to assess impulsivity multi-dimensionally in non-dependent heavy drinkers, using a comprehensive battery of self-report and behavioural measures. All of the recognised sub-domains of impulsivity were measured. Thus, participants were assessed on each of the following: self-reported (i) RD (the BAS scales) and; (ii) RI (the BIS-11); as well as behavioural: (iii) response initiation (the CPT); (iv) response inhibition (the SST); (v) delay discounting (the MCQ); (vi) risk-taking (the BART) and; (vii) reflection impulsivity (the beads task).

In order to circumvent the possible low power of prior research (i.e. none of the studies included in the systematic literature included *a priori* sample-size calculations), the present study aimed to recruit around 50 participants per group (see Methods for power calculations). The present study also sought to systematically control for the potential confounders of age, gender, SES and IQ, as well as exclude dependent drinkers, in order to estimate the ‘true’ association between non-dependent heavy drinking and impulsivity sub-domains.

Such research may pave the way for future interventions: if elevated impulsivity (in one or more sub-domains) were a reliable risk factor for heavy alcohol consumption, treatment strategies could seek to reduce the effects of impulsivity (and increase self-control). For example, successful results have been reported in terms of reducing impulsivity arising from inhibitory control failures in children with attention-deficit/hyperactivity disorder (ADHD; Re, Capodiceci & Cornoldi, 2015). Given the economic, social and health burdens of alcohol misuse, the potential benefits of intervening in non-dependent heavy drinking (e.g., preventing transition to dependence) are substantial.

In sum, the present study hypothesised that, compared to light drinkers, non-dependent heavy drinkers will show greater impulsivity, as indexed by scores on the self-report BAS scales and BIS-11 and behavioural CPT, SST, MCQ, BART and beads task.

II. METHODS

II.1) DESIGN AND PROCEDURE

In this independent-measures design, 116 light and heavy drinkers were compared on a battery of self-report and behavioural impulsivity measures. Participants were tested on one occasion after: (i) overnight (12-hour) abstinence from drinking alcohol; (ii) having abstained from smoking cigarettes for at least one hour prior to their participation and; (iii) having abstained from drinking tea, coffee and/or any other highly-caffeinated drinks for at least three hours prior to their participation. Overnight abstinence from alcohol was verified via BACtrack Mobile Pro breathalyser (KHN Solutions, Inc.), with nicotine and caffeine abstinence verified by self-report. Participants were instructed to bring ID (with a photo and date of birth) to the testing session, in order to verify age between 18 and 25 years.

Table A1 in Appendix 1 provides a schematic overview of the overall study design and the order in which assessments were administered. In total, the study procedure lasted around one hour and took place in a single testing room within the Addiction Sciences Building at the Institute of Psychiatry, Psychology and Neuroscience. Participants (but not experimenters) were blinded as to their grouping as a light or heavy drinker.

In order to reduce possible order effects, measures considered to have considerable conceptual and/or procedural overlap with one another were administered in counterbalanced order. Thus, the self-report BIS-11 and BIS/BAS Scales were counterbalanced, as were the behavioural CPT and SST. Due to its possible short-term effects on self-confidence (based on anecdotal observations and participant self-reports during an earlier pilot study of the procedure), the TOPF was also counterbalanced. The various permutations resulting from the counterbalancing across measures meant that each participant was administered 1 of 32 possible orders of measure administration, with equal numbers of participants being administered each order.

In addition to the measures reported here, the test battery also included two new self-report questionnaires, respectively indexing trait and state impulsivity (the TIS and RIS), administered as part of a separate study aimed at validating these measures (these data are yet to be entered and analysed). Although the number of measures

administered may appear somewhat demanding, a pilot study established that participants did not feel fatigued/fed-up with the number of measures. Also, all behavioural measures were relatively brief, with the CPT and SST lasting around only five minutes, the beads task and MCQ typically lasting between 2-3 minutes and only the BART taking up to ten minutes.

At the end of their participation, all participants were paid a minimum of £15 for taking part, this being supplemented with the amount earned in the BART. The mean amount paid to participants was £18.51 ($SD = 0.98$; $range = £16.00-£21.49$).

Finally, participants identified as heavy drinkers were provided with information about the possible risks of heavy alcohol consumption, as well as possible sources of help, should they wish to cut-down or quit their drinking.

Each participant was tested by the primary researcher (MJM) or by a research assistant working under the supervision of MJM.

II.II) PARTICIPANTS

An opportunistic sample of 116 students and members of the wider community (73 females and 43 males) took part in the study.

Inclusion and exclusion criteria:

On the basis of their responses in the alcohol use questionnaire (AUQ; Mehrabian & Russell, 1978), participants were classified either as light drinkers or heavy drinkers, according to whether they were regularly drinking below or above the most recent UK alcohol unit guidelines of 14 units of alcohol per week for both men and women (Officers, 2016).

Potential participants were excluded if they reported being abstinent from alcohol on the AUQ, or if they were either 'possibly' or 'definitely' alcohol-dependent, as indicated by AUDIT scores of 16-18 and >19, respectively (Saunders *et al.*, 1993). Individuals were excluded if they currently or had been previously dependent on drugs other than alcohol, caffeine and/or nicotine, as indicated by a score of three or above on the drug abuse screening test (DAST-10; Skinner, 1982). Heavy smokers were also excluded from the study, with heavy smoking defined as typically smoking more

than 20 cigarettes per day during the previous year (Caswell *et al.*, 2015). Exclusion criteria were thus relatively stringent.

Participants were limited to individuals aged between 18 and 25 years. This was in order to partially control for developmental discrepancies, given findings that executive functions (of which impulsivity is one) continue to develop and mature up until around age 25 (e.g., Caspi, Roberts & Shiner, 2005, Donnellan *et al.*, 2007, Blonigen *et al.*, 2008). All participants had normal or corrected-to-normal visual acuity.

Participant recruitment:

Participants were recruited from mid-September 2016 through to early-April 2017, via the following three routes: (i) electronic advertisements as part of the fortnightly email circulars disseminating ongoing research studies at King's College London; (ii) advertisements placed on the official King's College London Facebook page and Gumtree and; (iii) poster advertisements placed in the King's College London Students Union bar at Guy's Campus, as well as in cafés, bars, pubs, libraries, gyms and swimming pools throughout South-East London. In i and ii, potential participants clicked on a link taking them to the study Information Sheet (see Appendix 2), Consent Form (see Appendix 3) and, in order to determine eligibility, reported their age and completed the AUQ and the DAST-10 (all hosted via Bristol Online Surveys). Potential participants accessed the Information Sheet, Consent Form and eligibility questions via the poster advertisements by either scanning a QR barcode using a smartphone or by typing-in the URL for the link. Those eligible for the study were invited in to participate. This process is depicted visually in Figure 1.

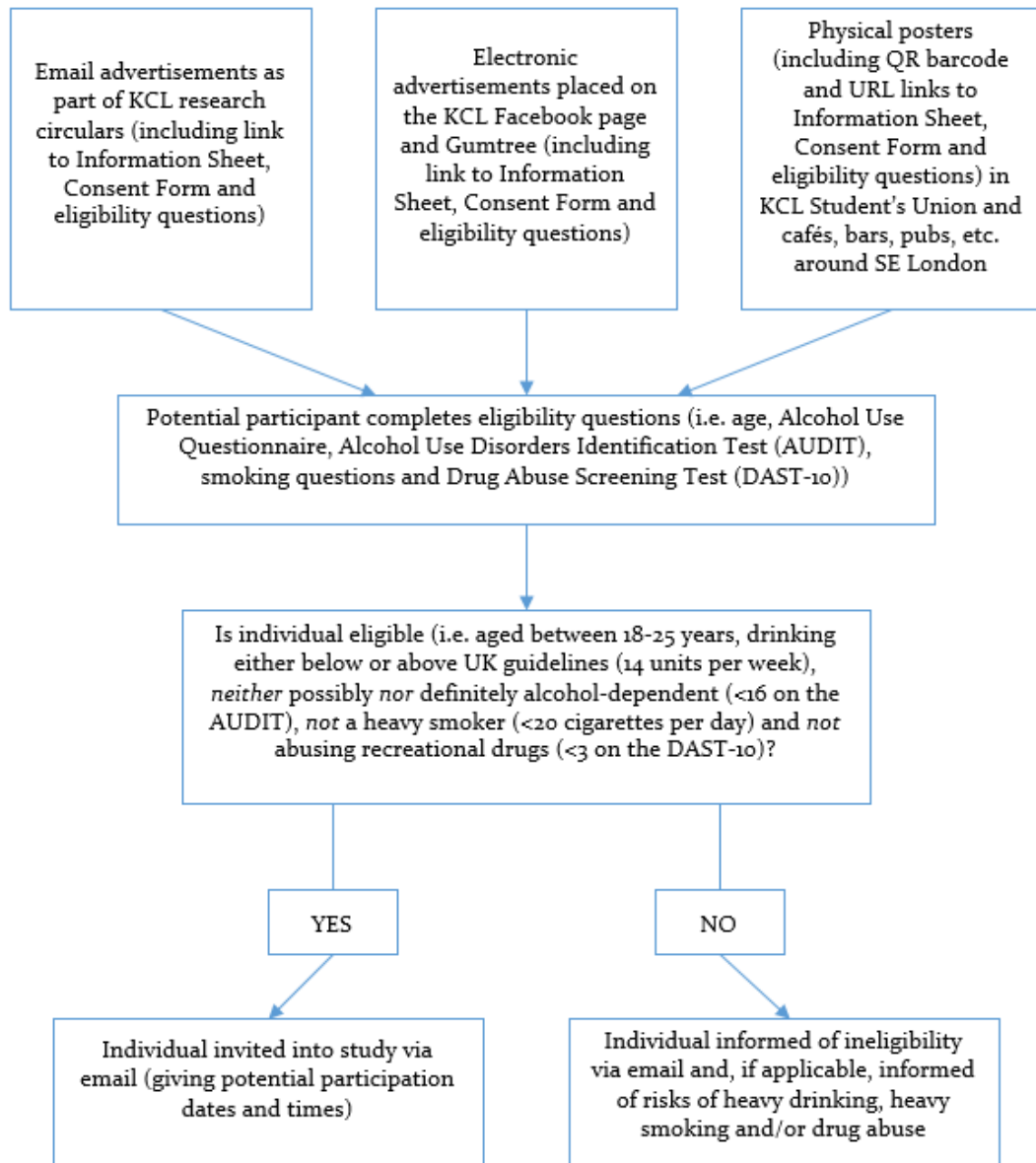


Figure 1: Flow diagram depicting the process via which participants were recruited

Ineligible individuals were informed via email and, if their ineligibility was due to possible or definite alcohol dependence, heavy smoking and/or recreational drug abuse, were given information on the potential risks of these activities, as well as advice on how to access help to cut down/quit should they wish to do so.

Ethical approval:

Ethical approval for the study was given by the Psychiatry, Nursing and Midwifery Research Ethics Sub-Committee (PNM RESC) at King's College London (review reference: HR-15/16-1992; the approval letter from the PNM RESC is presented in Appendix 4). As required by the Helsinki Declaration (Association, 2002), all

participants were assured of confidentiality and informed that they could terminate their participation at any stage and, up to April 2017, request that their data be removed from the final analyses.

Power:

An *a priori* statistical power analysis had been performed using G*Power (2009) for sample-size estimation, based on a number of recent studies reporting positive effects (in the predicted direction) between light and heavy drinkers on each of the impulsivity indices to be used in the present study. Thus, data were taken from Papachristou *et al.* (2012; the Barratt Impulsiveness Scale, Version 11), Ahmadi *et al.* (2013; the Behavioural Activation Scales), Smith and Mattick (2013; the Stop-Signal Task), Banca *et al.* (2016; the Beads task), Field *et al.* (2007a, using the Delay Discounting Task - no studies could be found reporting a significant difference between groups for the Monetary Choice Questionnaire - that is, the measure used here) and Fernie *et al.* (2010; the Balloon Analogue Risk Task) (no studies have to date examined or reported differences between groups for the Continuous Performance Task). Of the effect-sizes reported in these studies, the smallest was that pertaining to the Delay-Discounting Task (0.56; Field *et al.*, 2007a). Thus, in order to give the best opportunity for capturing potential differences between groups for measures in the present study, this effect-size was used for projected sample-size calculation. Using Cohen's (1988) criteria, the effect-size was considered to be of medium magnitude. With an $\alpha = 0.05$ and power = 0.85, the projected sample-size needed with this effect-size (Gpower 3.1.9.2; Universität Düsseldorf; Faul *et al.*, 2009) was $N = 94$ for the simplest between-groups comparison (i.e. 47 per group). The present sample-size of 116 (with 63 light and 53 heavy drinkers) was thus at power.

II.III) MEASURES

II.III.1) SOCIODEMOGRAPHIC INFORMATION

All participants provided their date of birth and gender. They also self-reported their ethnicity from the list of ethnic groupings developed by the Office for National Statistics (2015a).

Socioeconomic status (SES):

Participants were asked to provide three indices of SES. Due to participants mainly consisting of university students aged between only 18-25 years, they were asked for information pertaining to their parents. They were firstly asked to give the highest educational qualification obtained by each of their parents, from the following options: (i) no qualifications; (ii) GCSEs/CSEs/O-Levels (or equivalent); (iii) A-Levels/VCEs (or equivalent) or; (iv) degree (e.g., BA, BSc) or higher degree (e.g., MA, PhD, PGCE) (or equivalent).

Secondly, participants were asked to give the occupation of each of their parents, from a list of 31 options, ranked from lower to higher SES, developed and published by Chan and Goldthorpe (2004) (these authors ranked their 31 occupations such that 1 indicated greatest SES and 31 lowest; these ranks were reversed here, so that 31 indicated greater SES). In cases where one or both parents had retired or deceased, participants were asked to give the occupation with which their parent(s) was (or were) engaged for the longest amount of time throughout the parent's (or parents') life (or lives).

Thirdly, participants were asked to estimate the joint annual income of both of their parents, from all sources and before any deductions, with the following response-options, based closely on response-categories developed by the ONS (2015b): (i) up to £4,999; (ii) from £5,000 up to £9,999; (iii) from £10,000 up to £14,999; (iv) from £15,000 up to £19,999; (v) from £20,000 up to £24,999; (vi) from £25,000 up to £29,999; (vii) from £30,000 up to £34,999; (viii) from £35,000 up to £49,999 and; (ix) from £50,000 and above. In cases where one or both parents had retired or deceased, participants were asked to estimate the annual income earned for the longest amount of time throughout the parent's (or parents') life (or lives).

For educational attainment and occupation, participants' responses for each of their parents were mean-averaged. Based on a method previously employed by Matthews *et al.* (2000; although these authors used two SES measures – educational attainment and income), standardised measures of parental educational attainment, occupation and income were each created across all participants. These figures were then summed and divided by three to create a single, overall SES (z-)score for each participant, with greater scores reflecting greater SES.

II.III.II) INTELLIGENCE QUOTIENT (IQ)

The Test of Premorbid Functioning – UK Edition (TOPFUK; Wechsler, 2011):

The TOPF consists of a list of 70 words that have atypical grapheme to phoneme translations. The examinee must read each word from the list aloud in turn, with the words becoming increasingly phonetically irregular as one progresses further down the list. As implied by its name, this measure is used to estimate optimal intellectual and memory abilities, as the ability to identify and articulate words is thought to be relatively resistant to the effects of brain-injury and/or dementia. The test's scoring manual provides age-corrected standard scores with a mean of 100 and standard deviation (SD) of 15. The TOPF^{UK} was not administered where a participant was a non-native English speaker or had dyslexia. IQ was estimated using participants' TOPF^{UK} scores.

II.III.III) ALCOHOL AND OTHER DRUG USE AND ABUSE

The Alcohol Use Questionnaire (AUQ; Mehrabian & Russell, 1978):

This 12-item self-report scale asks the respondent about their alcohol consumption in a typical week over the preceding six months. This was adapted here to 12 months in order to ensure that differences between light and heavy drinkers were stable and long-lasting. Participants are asked to indicate, in relation to their consumption of three types of drink (wine; beer, lager and cider; spirits) the average number of days per week over the last twelve months they have consumed it, the average quantity consumed on each occasion and the average quantity consumed in a 'typical' week. Participants' number of units consumed in a typical week was the main outcome variable here (used to delineate light from heavy drinkers) and was calculated by summing responses to items 3, 6 and 9.

The Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993):

The AUDIT is a widely-used, freely available 10-item self-report instrument for detecting alcohol abuse and dependence. The respondent is asked to report how often they have engaged in behaviours or experienced situations consistent with problematic alcohol consumption. Responses are rated either on three- or five-point Likert scales, ranging respectively from 'no'/'never' (a score of 0) to 'yes'/'daily or almost daily' (a score of 4). Total scores can range from 0 to 40, with scores ≥ 8 indicating the possible presence of an alcohol use disorder. The AUDIT has sound validity and internal consistency across different samples and contexts (Reinert & Allen, 2007). In the present study, Cronbach's α was 0.63 (i.e. above the 0.50 level considered acceptable by Kline, 2013).

Smoking:

Participants were asked to select one of three response-options to describe their status in terms of smoking cigarettes: (i) have never smoked; (ii) former smoker, or; (iii) current smoker. Participants who identified themselves as current smokers were asked to state how many cigarettes they have tended to smoke in a typical day in the last 12 months. Participants who identified themselves as former smokers were asked to state (i) approximately how long ago they stopped smoking and (ii) how many cigarettes they tended to smoke in a typical day.

The Drug Abuse Screening Test (DAST-10; Skinner, 1982):

The DAST is a 10-item self-report instrument that can be used in clinical and non-clinical settings to screen for potential abuse and dependence on a variety of substances other than alcohol. The respondent answers questions (in a dichotomous 'yes'/'no' format) about their use and experiences of drugs other than alcohol, nicotine and caffeine in the previous 12 months. The respondent is informed that the term 'drug' includes recreational use of both prescription drugs and other illicit drugs such as marijuana, cocaine, LSD, ecstasy, etc. The total score can thus range from 0-10, with scores of 3 or higher indicating potential drug abuse or dependence. Cronbach's alpha for the DAST-10 has been reported at 0.69 (McCabe & Teter, 2007). In the present sample, the alpha coefficient was 0.33. Although this was below the level of acceptability suggested by Kline (2013), this value was almost certainly distorted by the fact that only individuals scoring 0-2 were eligible for the study.

II.III.IV) MULTIDIMENSIONAL IMPULSIVITY ASSESSMENT

II.III.IV.1) SELF-REPORT MEASURES

Reward drive – the behavioural inhibition and behavioural activation scales (BIS/BAS Scales; Carver & White, 1994):

The BIS/BAS Scales assess individual differences in the sensitivity of the behavioural avoidance system (related to the motivational predisposition to avoid aversive stimuli) and the behavioural approach system (related to the motivational predisposition to approach appetitive stimuli). The scale has 24 items, each with four response options (1 = 'very true for me', 2 = 'somewhat true for me', 3 = 'somewhat false for me' and 4 = 'very false for me'). Four items are filler questions that are not used to compute BIS/BAS scores. The BIS consists of a single scale (7 items; range = 7-28), whereas the BAS is made-up of three subscales: 1) BAS drive (4 items; range = 4-16); 2) BAS fun seeking (4 items; range = 4-16) and; 3) BAS reward responsiveness (5 items; range = 5-20). Carver and White (1994) reported internal reliability coefficients ranging from .66 to .76. Alpha coefficients in the present study were 0.67 for BAS drive, for BAS fun seeking and 0.62 for BAS reward responsiveness.

Rash impulsivity – the Barratt Impulsiveness Scale, Version 11 (BIS-11; Patton et al., 1995a):

The BIS-11 is a widely used 30-item measure that yields three subscales: attentional impulsiveness (which measures the respondent's capacity for concentration), motor impulsiveness (which measures the propensity for acting without first considering the consequences) and non-planning impulsiveness (which measures the propensity for focusing on present events without considering possible future events). Responses are scored on a 4-point Likert scale ('rarely/never', 'occasionally', 'often' or 'almost always/always'). Total scores range from 30 to 120, with greater scores indicating greater impulsiveness. Patton et al. (1995a) have reported alpha coefficients from .79 to .83. In the present study, α reliability was 0.76 for attentional impulsiveness, 0.58 for motor impulsiveness and 0.69 for non-planning impulsiveness.

Response initiation – the continuous performance task (CPT; Dougherty et al., 1999):

The CPT administered in the present study ran via E-Prime Version 1.2 (Psychology Software Tools, Inc.) and was the same as that used by Dawkins *et al.* (2007) in their study with smokers. Thus, participants were presented with a series of five-digit numbers, which appeared one after another in the middle of the screen, at a constant rate of two per second, for a period of 5 minutes. Participants were instructed to respond, by pressing the left mouse button, whenever a five-digit number was identical to the preceding one ('target' stimuli), and *not* to respond (i.e. to withhold from pressing the button) to either 'novel' stimuli (in which all 5 digits were different from those in the preceding stimulus) or 'catch' stimuli (in which 4 of the 5 digits were identical to the preceding stimulus). Each presentation of a target, novel or catch stimulus was separated from the next by three consecutive presentations of the fixed 'filler' sequence '12345', to which participants were told *not* to respond. Participants completed a 20-item practice trial, before completing 75 experimental trials. One fixed sequence was used here. Button-presses to consecutive identical stimuli were categorised as 'correct hits', whereas responses to catch stimuli were classified as 'commission errors' or 'false alarms'.

The rate of impulsive incorrect responses to catch stimuli has been found to correlate positively with impulsive personality traits (Dougherty *et al.*, 1999). However, the probability of a commission error is influenced both by the participant's ability to discriminate between target and catch stimuli, as well as by response-bias. Based on signal detection theory (Swets, Tanner Jr & Birdsall, 1961), the preferred dependent variable (DV) – and thus the one used here – is a net score (correct hits minus commission errors) that takes into account the range for both components, by calculating the relative proportion of hits minus false alarms, named *d* prime (*d'*). *d'* is calculated from the hit-rate and false-alarm-rate (FA) using the formula $d' = Z_{\text{Hit}} - Z_{\text{FA}}$, where *Z* represents a transformation of the two distributions, allowing for comparison of measures with different ranges of absolute values (Macmillan & Creelman, 2004, Haatveit *et al.*, 2010).

Response inhibition – the stop signal task (SST; Logan, 1994):

The present study administered the SST procedure developed by Verbruggen *et al.* (2013) via Inquisit Laboratory Version 5 (Inquisit Lab 5; Millisecond Software, LLC). Participants are presented with a series of arrows, pointing either left or right, which appear one after another in the centre of the screen. They are instructed to respond as quickly as possible to each of these ‘go’ stimuli: to press the ‘D’ button on the keyboard when an arrow points left and the ‘K’ button when it points to the right. However, on one third of the trials, a ‘stop signal’ (a ‘beep’) is presented, which indicates that the participant should withhold responding to that trial and await the next arrow. The delay between the presentation of the arrow and the stop-signal begins at 250 msec, with its onset thereafter adjusted up or down (i.e. a ‘staircase’ procedure) by 50 msec as a function of performance: thus, the delay becomes longer (up to a potential maximum of 1150 msec) if the previous signal stop was successful and shorter if the previous signal stop was unsuccessful (down to a potential minimum of 50 msec). The stimulus onset asynchrony between the start of each trial (the onset of the fixation cross) is 2000 msec. Participants can respond up until the next trial begins. Participants completed one practice block of 32 trials (24 no-signal trials and 8 stop-signal trials), followed by three blocks of 64 experimental trials (each block consisting of 48 no-signal trials and 16 stop-signal trials).

As per convention, the main outcome variable used here was the stop-signal reaction time (SSRT). The SSRT estimates the mean latency of the stopping process across stop-signal trials: individuals with good inhibitory control have shorter SSRTs, whereas more impulsive individuals have longer SSRTs. SSRT was calculated using the integration (SSRTi) method (Verbruggen *et al.*, 2013).

Both the CPT and the SST were administered here as, though they each broadly index behavioural rash impulsivity, the indices they measure are subtly different and can be conceptualised as occurring at ‘different ends’ of the ‘action sequence’: the CPT specifically measures the readiness with which an individual *begins* an action (i.e. at the ‘start’ of the sequence), whereas the SST specifically measures the individual’s ability to successfully *inhibit* a prepotent action (i.e. at the ‘end’ of the sequence).

Reflection impulsivity – the beads task (Garety, Hemsley & Wessely, 1991):

The beads task used here was administered via Inquisit Lab 5 and employed the same procedure as that described by Banca *et al.* (2016), in their study with binge-drinkers. Participants were presented with two jars on the computer screen, containing complimentary ratios of red (R) and blue (B) beads (Jar A: $P = 0.80$ R, $P = 0.20$ B; Jar B: $P = 0.80$ B, $P = 0.20$ R). Participants were informed of the bead-ratio and told that beads from one of the jars would be drawn at random one at a time and presented in the centre of the screen. They were told that the aim was for them to infer from which jar the beads were being drawn. Participants were informed that they could draw up to 20 beads before they would *have* to make a decision, but that, if they felt they knew which jar it was *before* they had drawn 20 beads, they could decide sooner. The participant drew a bead by clicking the left mouse button. The task controlled for differences in short-term memory by showing the beads drawn so far across the bottom of the screen. Participants were informed that the task was not a test of speed, and that they should make their decision when they felt they had enough information to make a decision. There were three trials, with the same bead-orders used by Banca *et al.* (2016) and Moutoussis *et al.* (2011) (that is, in Trial 1, beads were presented in the order: R, B, R, R, R, R, B, R, R, R, B, R, B, B, B, B, R, B, B, B; in Trial 2, the order was: R, B, R, R, R, B, R, R, B, R, B, R, R, R, R, B, B, R, R, B, and; in Trial 3, the order was: B, R, B, B, B, B, R, B, B, B, R, B, R, R, R, R, B, R, R, R).

The outcome variable was the mean number of beads drawn prior to making a decision across the three trials (regardless of whether the decision was correct or not), with more impulsive individuals selecting fewer beads prior to making a decision.

Delay-discounting – the monetary choice questionnaire (MCQ; Kirby, Petry & Bickel, 1999):

The MCQ presents participants with 27 hypothetical choices between a smaller amount of money that they could receive immediately (SI) and a larger, delayed amount of money (LD) that they could receive at a certain point in the future, with delays ranging from 7 to 186 days. Participants are asked to try to respond in the same way as they would with real money. The MCQ was modified in the present task so that the reference currency was British pound sterling (£), rather than US dollars (\$).

The MCQ was administered in the form of an A4 bound booklet, with each item presented on a different page (to encourage participants to consider each item individually, rather than in the context of their responses to other items).

The participant's pattern of responding is used to determine an estimate of their discounting rate parameter (k), for each item, using the formula: $((LD - SI) - 1)/\text{delay}$, with their mean for these choices then calculated. Greater k values reflect a higher proportion of choices for the smaller but immediate monetary amounts (i.e. greater delay discounting).

Risk-taking – the balloon analogue risk task (BART; Lejuez et al., 2002):

The BART models real-world risk-taking behaviour via the conceptual frame of balancing the potential reward versus the potential for loss. In this task, which was administered here via Inquisit Lab 5, participants click a mouse button to pump-up each of 30 simulated balloons (i.e. 30 trials). Each balloon is presented one after another on the screen and, with each pump, the balloon becomes slightly larger and the participant earns £0.005. The amount of money so far accrued on any given balloon is held in a temporary bank (the 'potential earnings' in the figure), displayed on the screen. Participants are informed that different balloons have different points at which they burst: whereas some burst after just one or two pumps, others can be pumped until they fill the whole screen. Participants are informed that, at any time, they can transfer their potential earnings to a permanent bank (also displayed on the screen as 'total winnings') by clicking on a box labelled 'Collect \$\$\$'. However, if a balloon bursts, the participant loses the potential earnings in the temporary bank. Thus, each trial ends either when the participant transfers the hypothetical money to the permanent bank or the balloon explodes (at which point the next balloon is presented and their potential earnings returns to £0). The balloons were set to explode on a variable ratio, with a mean explosion-point of 64 pumps (for more information, see Lejuez et al., 2003).

On the basis of previous research (e.g., Lejuez et al., 2002), the outcome variable used here was the 'adjusted average pumps' – that is, the average number of pumps for unexploded balloons, with higher scores indicating greater risk-taking propensity (Bornovalova et al., 2005). The BART has strong split-half reliability ($r = 0.82$; Lejuez et al., 2002) and test-retest reliability ($r = 0.62$ - 0.82 across 3 administrations on the

same day; Lejuez *et al.*, 2003, $r = 0.77$ across a 2-week interval; White, Lejuez & de Wit, 2008).

II.IV) ANALYSES

All analyses were performed using SPSS Version 24.0 (IBM, Armonk, NY). Descriptive analyses were used to examine all variables of interest and determine whether they were appropriate for parametric analyses.

Independent-samples *t*-tests were initially used to compare the light and heavy drinkers on the *a priori* potential confounders of age, gender, SES and IQ, as well as units per week and problematic alcohol use (i.e. AUDIT scores). Prior to comparisons, the data were screened for univariate outliers (z-scores in excess of ± 3.29) within each drinking group separately. Univariate outliers were replaced with a value either one unit greater or smaller (as appropriate) than the next-most-extreme value. Given that *N* was above 100 and variables had light-tailed distributions (i.e. those with few outliers), the normality of variables was considered robust enough, owing to the central limit theorem (Field, 2013).

Independent-measures *t*-tests were then performed to explore any potential differences between the groups in terms of the self-report measures of impulsivity (i.e. the BIS-11 and BAS drive, fun seeking and reward responsiveness) and the DVs for each of the behavioural tasks (i.e. CPT *d'*, SST SSRT, mean number of beads selected prior to decision on the beads task, MCQ *k* and BART adjusted average pumps), with *p*-values ≤ 0.05 interpreted as being statistically-significant throughout. Multiple comparisons were not corrected for here (e.g., using the Bonferroni correction) as, although this would have reduced the likelihood for Type-I errors, it would also have increased the likelihood for Type-II errors (i.e. false negatives). This was important, as the measures administered were semi-independent; thus, though they all fell under the rubric of 'impulsivity', they each indexed statistically separable sub-domains of the construct (e.g., Caswell *et al.*, 2015) and were therefore not equivalent. Furthermore, adjusting for multiple tests is not standard procedure within the literature and a number of published studies performing multiple (and similar numbers of) impulsivity measures have done so without applying adjustments (e.g., Rose & Grunsell, 2008, Moreno *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014, Banca *et al.*, 2016, Caswell *et al.*, 2016). Effect-sizes were

reported as Cohen's d , with values of 0.2 considered 'small', those of 0.5 considered 'medium' and values of 0.8 being 'large' (1988).

A hierarchical logistic regression (with two stages) was then performed to test whether, after controlling for the *a priori* covariates, significant group differences in self-report and/or behavioural indices of impulsivity remained significant predictors of drinking status (i.e. light versus heavy drinkers). Age, gender, SES and IQ were entered in the first level of the model. Self-report and/or behavioural impulsivity outcomes *that had been significantly different between light and heavy drinkers* in the t -tests were entered in the second level. Collinearity diagnostics and residual plots were examined to assess for model violations (e.g., multicollinearity, non-linearity and heteroscedasticity). Throughout the regression analyses, p -values ≤ 0.05 were interpreted as statistically significant.

III. RESULTS

III.1) MISSING DATA AND MULTIPLE IMPUTATION

Thirty participants were either non-native English speakers and/or were dyslexic and thus were not administered the TOPF^{UK}, resulting in missing data for these participants. Since these data were not collected simply due to these reasons, as well as there being no difference in SES between participants with and without TOPF^{UK} data ($t(102) = 0.98$; $p = 0.33$), it was considered reasonable to assume that these data were missing completely at random (MCAR). Similarly, 39 participants had missing data on the beads task, due to this task not having been available until after that point; consequently, these data were also considered to be MCAR. Relative to the TOPF^{UK} and the beads task, several other variables had smaller amounts of missing data (see Table A2 in Appendix 5). Little's MCAR test (2014) was used to examine these missing data for randomness (excluding data pertaining to the TOPF^{UK} and the beads task) and was found to be non-significant ($\chi^2(88) = 90.59$; $p = 0.40$), indicating that these data were also MCAR.

In order to generate a full dataset, multiple imputation (a form of regression analysis), with five imputations and using a fully conditional specification method, was used to estimate values for all missing data (see Appendix 13 for more details). Prior to multiple imputation, the data were screened for univariate outliers (z-scores in excess of ± 3.29) within each drinking group separately. Univariate outliers were

replaced with a value either one unit greater or smaller than the next-most-extreme value. The pooled data across the five imputations were used for all of the analyses below, so as to include variation across the imputations, thereby reducing the chances of a Type-I error.

III.II) COMPARING NON-DEPENDENT LIGHT AND HEAVY DRINKERS

III.II.I) PARTICIPANT CHARACTERISTICS

Table 1 displays the socio-demographic and alcohol-related characteristics of participants in the two groups.

Table 1: Socio-demographic and alcohol-related characteristics of participants

Variable	Light drinkers (<i>n</i> = 63)	Heavy drinkers (<i>n</i> = 53)	Light drinkers vs. heavy drinkers <i>t</i> or χ^2 <i>p</i> -value	
Age (years)	21.63 (1.95)	21.28 (2.05)	0.95	0.35
Gender (female : male)	44 : 19	29 : 24	2.82	0.09
Ethnicity^{ab}:				
White: English / Welsh / Scottish / Northern Irish / British	25 (39.70)	30 (56.60)	-	-
White: Irish	0 (0.00)	1 (1.90)	-	-
White: Any other White background	16 (25.40)	7 (13.20)	-	-
Mixed / Multiple Ethnic Groups: White and Black Caribbean	1 (1.60)	0 (0.00)	-	-
Mixed / Multiple Ethnic Groups: White and Black African	1 (1.60)	0 (0.00)	-	-
Mixed / Multiple Ethnic Groups: White and Asian	1 (1.60)	2 (3.80)	-	-
Mixed / Multiple Ethnic Groups: Any other Mixed / Multiple Ethnic background	3 (4.80)	2 (3.80)	-	-
Asian / Asian British: Indian	3 (4.80)	2 (3.80)	-	-
Asian / Asian British: Bangladeshi	0 (0.00)	1 (1.90)	-	-
Asian / Asian British: Chinese	5 (7.90)	5 (9.40)	-	-
Asian / Asian British: Any other Asian background	3 (4.80)	1 (1.90)	-	-

Table 1 continues over the page

Table 1 continued

Variable	Light drinkers (<i>n</i> = 63)	Heavy drinkers (<i>n</i> = 53)	Light drinkers vs. heavy drinkers <i>t</i> or χ^2 <i>p</i> -value	
<i>Black / African / Caribbean / Black British: African</i>	4 (6.30)	2 (3.80)	-	-
<i>Other Ethnic group: Any other Ethnic group</i>	1 (1.60)	0 (0.00)	-	-
<i>Socioeconomic status^{cd}</i>	0.03	0.00	0.14	0.89
<i>TOPF^{UK} estimated IQ^{ce}</i>	103.93	103.18	0.45	0.65
<i>AUQ units per week^f</i>	7.02 (4.28)	23.14 (7.24)	-14.26	<0.00
<i>AUDIT total^f</i>	6.54 (3.32)	9.45 (2.89)	-4.99	<0.00

Values represent mean ($\pm$ SD), except for the categorical variables of gender, ethnicity and smoking status, where absolute numbers of participants for each level of the variable are given.

^a Light and heavy drinking groups were not compared in terms of ethnicity.

^b Values represent the absolute number (and percentage) of participants from each ethnic group per drinking group.

^c Indicates variable had missing data and so at least some data were imputed. Data presented are the pooled estimates across the five imputations (i.e. to include variability and minimise chances of a Type-I error).

^d In the original dataset, the total *n* for light drinkers = 55; for heavy drinkers, *n* = 49.

^e In the original dataset, the total *n* for light drinkers = 48; for heavy drinkers, *n* = 38.

^f The assumption of equal variances was violated and so equal variances were not assumed.

Note: AUDIT = Alcohol Use Disorders Identification Test; AUQ = Alcohol Use Questionnaire; TOPF^{UK} = Test of Premorbid Functioning – UK Edition.

There were no differences between light and heavy drinkers on age, gender ratio, socioeconomic status or estimated IQ. The groups were thus well matched across a range of socio-demographic and intra-individual variables. The groups were not compared for relative ratios of ethnic groups, although it can be seen that a clear majority of participants were White (79/116). As expected, the greater number of alcohol units consumed by heavy relative to light drinkers, as well as problematic alcohol use by heavy compared to light drinkers (i.e. AUDIT scores), were both highly-significant.

III.II.II) COMPARING IMPULSIVITY IN NON-DEPENDENT LIGHT AND HEAVY DRINKERS

Table 2 presents the comparisons between light and heavy drinkers on measures of impulsivity.

Table 2: Summary statistics comparing light and heavy drinkers across the impulsivity measures

Variable	Light drinkers (<i>n</i> = 63)	Heavy drinkers (<i>n</i> = 53)	<i>t</i> - value	<i>p</i> - value	Cohen's <i>d</i>
<i>BIS-11 subscales:</i>					
<i>BIS-11 attentional impulsiveness</i>	16.14 (4.14)	16.94 (3.86)	-1.07	0.28	0.20
<i>BIS-11 motor impulsiveness</i>	20.89 (3.64)	22.51 (4.04)	-2.27	0.03	0.42
<i>BIS-11 non- planning impulsiveness^{ab}</i>	21.46 (3.98)	23.04 (5.28)	-1.83	0.07	0.34
<i>BAS scales:</i>					
<i>BAS drive</i>	11.00 (2.14)	11.64 (1.87)	-1.70	0.09	0.32
<i>BAS fun seeking^c</i>	11.52 (2.01)	11.75 (2.68)	-0.52	0.61	0.10
<i>BAS reward responsiveness</i>	17.37 (1.74)	17.45 (1.95)	-0.26	0.80	0.04
<i>CPT d^{ad}</i>	0.43 (1.41)	-0.51 (1.50)	3.51	<0.00	0.65
<i>SST SSRT^{ae}</i>	231.68 (32.63)	242.55 (32.29)	-1.71	0.09	0.33
<i>Number of beads selected in Beads task^{af}</i>	11.07 (4.74)	10.10 (4.23)	0.78	0.08	0.22
<i>MCQ k^{acg}</i>	0.01 (0.12)	0.01 (0.02)	-1.71	0.09	0.10
<i>BART adjusted average number of pumps^{ah}</i>	35.34 (13.03)	37.75 (15.24)	-0.92	0.36	0.17

Table 2 continues over the page

Table 2 continued

Values represent mean ($\pm$ SD).

^a Indicates variable had missing data and so at least some data were imputed. Data presented are the pooled estimates across the five imputations (i.e. to include variability and minimise chances of a Type-I error).

^b In the original dataset, the total n for light drinkers = 63; for heavy drinkers, n = 52.

^c Levene's test was significant and thus equal variances were not assumed.

^d In the original dataset, the total n for light drinkers = 63; for heavy drinkers, n = 52.

^e In the original dataset, the total n for light drinkers = 57; for heavy drinkers, n = 52.

^f In the original dataset, the total n for light drinkers = 33; for heavy drinkers, n = 44.

^g In the original dataset, the total n for light drinkers = 62; for heavy drinkers, n = 52.

^h In the original dataset, the total n for light drinkers = 62; for heavy drinkers, n = 53.

Note: BART = balloon analogue risk task; BAS scales = behavioural activation scales; BIS-11 = Barratt impulsiveness scale, version 11; CPT d' = continuous performance task d' -prime (i.e. z -score for number of false alarms subtracted from z -score for number of correct hits); MCQ k = monetary choice questionnaire, where k represents: ((larger, later choices – smaller, immediate choices) – 1)/delay; SST = stop signal task; SSRT = stop signal reaction time.

From the table, it can be seen that heavy drinkers had significantly greater scores on the BIS-11 motor impulsiveness subscale, for which there was a small effect-size, using Cohen's criteria (Cohen, 1988). Heavy drinkers also performed significantly poorer on the CPT, for which there was a moderate effect-size. It is notable that both of these indices are measures of rash impulsivity. No differences were observed for any other impulsivity measures.

III.II.III) EXAMINING ASSOCIATIONS BETWEEN IMPULSIVITY AND DRINKING STATUS AFTER CONTROLLING FOR A *PRIORI* COVARIATES

A sequential logistic regression was then performed to assess the prediction of drinking status (light versus heavy drinker), first on the basis of the four socio-demographic and intra-individual factors, and secondly, after addition of BIS motor impulsiveness and CPT d' -prime. The four socio-demographic and intra-individual factors were age, gender, socioeconomic status and estimated IQ.

Table 4 shows no inordinately large parameter estimates or standard errors. There was thus no reason to suspect a problem with too many empty cells or with outcome groups perfectly predicted by any variable. No violation of linearity in the logit was observed (i.e. none of the interaction terms between continuous predictors and their log-transformations significantly predicted drinking status). There was no evidence of any multicollinearity (i.e. no tolerance values below 0.1 and no VIF values above 10; Menard, 1995; Myers, 1990).

There was *not* a good model fit (discrimination among groups) on the basis of the four socio-demographic and intra-individual variables alone (i.e. Step 1). Thus, across all five imputations, χ^2 (4, $N = 116$) = 3.33-4.95, in all cases $p > 0.05$. At Step 2, following the addition of BIS-11 motor impulsiveness and CPT d-prime, χ^2 (9, $N = 116$) = 22.38-23.32, in all cases $p < 0.05$. Comparison of χ^2 values for models with and without the impulsivity indices showed statistically-significant improvement with the addition of BIS-11 motor impulsiveness and CPT d-prime, χ^2 (2, $N = 116$) = 17.77-19.60, in all cases $p < 0.05$.

On the basis of the four socio-demographic and intra-individual factors alone, correct classification rates were between 71.4%-76.2% for light drinkers across the five imputations and between 35.8%-45.3% for heavy drinkers; overall correct classification rates were between 56.9%-58.6%. Correct classification rates rose noticeably following the addition of the two impulsivity variables, to between 76.2%-81.0% for light drinkers, 60.4%-64.2% for heavy drinkers and 69.0%-72.4% overall.

Table 3 displays the unstandardized regression coefficients (B), the standard errors of B , p -values and odds-ratios (with 95% confidence intervals) for the constant and all six IVs, as well as χ^2 values, at each of the two steps in constructing the model.

Table 3: Logistic regression analysis of drinking status (light drinkers versus heavy drinkers) as a function of socio-demographic and impulsivity variables

	95% confidence interval for odds-ratio					
	<i>B</i>	<i>SE B</i>	<i>p</i> -value	Odds-ratio	Lower	Upper
Step 1						
Constant	2.22	3.64	0.54	9.23	0.01	12363.77
<i>Sociodemographic and intra-individual variables:</i>						
Age	-0.07	0.10	0.48	0.93	0.77	1.13
Gender	-0.65	0.40	0.10	0.52	0.24	1.15
SES	-0.03	0.25	0.90	0.97	0.60	1.58
TOPF IQ	-0.02	0.03	0.54	0.98	0.93	1.04
Model χ^2 s (<i>dfs</i> = 4) = 3.33-4.95						
Step 2						
Constant	-1.95	4.05	0.63	0.14	<0.00	404.26
<i>Sociodemographic and intra-individual variables:</i>						
Age	-0.11	0.11	0.32	0.90	0.73	1.11
Gender	0.96	0.46	0.04	2.61	1.06	6.39
SES	0.01	0.27	0.99	1.01	0.59	1.73
TOPF IQ	0.01	0.03	0.82	1.01	0.95	1.07
<i>Impulsivity variables:</i>						
BIS-11 motor impulsiveness	0.09	0.06	0.10	1.10	0.98	1.23
CPT <i>d'</i>	-0.57	0.16	<0.00	0.57	0.41	0.78
Model χ^2 s (<i>dfs</i> = 6) = 22.38-23.32						

After Step 2, with all six predictors in the final model, only gender and CPT d' were significant predictors of drinking status. Regarding gender, being male increases the odds of being a heavy drinker by 61 per cent. In terms of CPT performance, the negative beta-value and odds-ratio of 0.57 indicates that, with a one standard deviation reduction in CPT performance (i.e. with greater proportions of false alarms relative to correct hits), the odds of being a heavy drinker increase by 43 per cent. Thus, after controlling for all *a priori* covariates, only a behavioural measure of response-initiation remained a significant impulsivity predictor of drinking status (i.e. the self-reported BIS-11 motor impulsiveness subscale did not).

IV. DISCUSSION

To reiterate the aims of the present study: elevated impulsivity is characteristic of alcohol (and other drug) dependence (Jentsch & Taylor, 1999, Crews & Boettiger, 2009, Potenza & de Wit, 2010). It is important to establish whether elevated impulsivity is also present in non-dependent heavy drinkers: if so, this would be consistent with impulsivity's being a risk factor for the maintenance of heavy drinking, as well as for possible escalation to dependent drinking. Given that impulsivity comprises several related but distinct sub-domains (e.g., Caswell *et al.*, 2015), it is possible that these various sub-domains share different relationships with heavy alcohol use. Previous studies of this issue have not measured all impulsivity sub-domains.

The present study is the most comprehensive to have examined impulsivity in non-dependent heavy drinkers. For example, it measured a broader sweep of impulsivity sub-domains than any previous study, incorporating indices of self-reported rash impulsivity (RI; the BIS-11) and reward drive (RD; the BAS scales), together with behavioural measures of response initiation (the CPT), response inhibition (the SST), delay-discounting (the MCQ), risk-taking (the BART) and reflection impulsivity (the beads task). The present study is also the most well-controlled, accounting for the potential influences of age, gender, SES and IQ; each of these variables have been related to impulsivity (Eysenck *et al.*, 1985, Caspi *et al.*, 2005, de Wit *et al.*, 2007, Donnellan *et al.*, 2007, Yuan *et al.*, 2008, Raver *et al.*, 2013, Spielberg *et al.*, 2015), yet no prior study has systematically controlled for all of them. The present study is also the first to examine impulsivity in light and heavy drinkers using the new UK

recommended weekly limits of 14 units per week for both men and women (Officers, 2016).

The main findings were as follows. Firstly, in a set of independent-measures *t*-tests, heavy drinkers scored significantly more impulsively on the BIS-11 motor impulsiveness subscale, and they were substantially more impulsive on the CPT (i.e. heavy drinkers made a greater proportion of false alarms relative to correct hits). There were no group differences *for any other impulsivity measure*. Secondly, in a subsequent logistic regression, whereby the potentially confounding influences of the *a priori* covariates (i.e. age, gender, SES and IQ) were controlled, BIS-11 motor impulsiveness did not remain a significant predictor of drinking group (i.e. light versus heavy drinkers), owing to the effect of (male) gender. CPT performance, however, remained a (highly) significant predictor of drinking group, even after controlling for the *a priori* covariates. Thus, from the battery of self-report and behavioural impulsivity measures administered here, only a behavioural index of response-initiation was greater in non-dependent heavy drinkers.

IV.1) SELF-REPORT FINDINGS AND POSSIBLE IMPLICATIONS

IV.1.1) RASH IMPULSIVITY (RI): THE BARRATT IMPULSIVENESS SCALE (BIS-11)

Interestingly, findings pertaining to the BIS-11 were largely consistent with previous studies. Thus, motor impulsiveness was significantly greater in heavy drinkers and there was an indication of a trend ($p = 0.07$) for greater non-planning impulsiveness, with no group difference for attentional impulsiveness. Moreno *et al.* (2012), Sanchez-Roige *et al.* (2014) and Caswell *et al.* (2016) all reported greater motor and non-planning impulsiveness in their quasi-experimental groups (i.e. heavy or binge drinkers), relative to their respective comparison groups, with no difference for attentional impulsiveness. *Prima facie*, this seems to suggest that motor impulsiveness (and possibly non-planning impulsiveness) is reliably greater in heavy and binge drinking groups, and that attentional impulsiveness is *not*. However, the logistic regression performed in the present study showed that, after all socio-demographic variables had been controlled for, the association between motor impulsiveness and drinking status ‘disappeared’ (specifically, due to the significant effect of male gender). Thus, even though gender-ratio did not differ between the groups, males were more likely to be heavy drinkers, and with this variance

controlled for, the motor impulsiveness effect was ‘wiped-out’. This was also reported by Caswell *et al.* (2016). Though their groups had equal gender-ratios, neither Moreno *et al.* nor Sanchez-Roige *et al.* statistically controlled for the effects of these potential confounders and it is therefore possible that the apparently greater motor impulsiveness of their quasi-experimental groups was an artefact of potentially greater male relative to female scores. Overall, the findings of the present study indicate that self-reported/everyday RI is *not* associated with heavy drinking in non-dependent young adults (those aged 18-25). Together with the greater BIS-11 scores reliably observed in dependent drinkers (von Knorring *et al.*, 1987, Hallman *et al.*, 1990, Ketzenberger & Forrest, 2000, Bjork *et al.*, 2004, Chen *et al.*, 2007, von Diemen *et al.*, 2008, Cangemi *et al.*, 2010), the present findings suggest that elevated self-reported RI is more associated with longer-term, more chronic alcohol abuse.

IV.I.II) REWARD-DRIVE (RD): THE BEHAVIOURAL ACTIVATION SCALES (BAS SCALES)

No differences were observed between the groups in terms of the BAS scales, indicating that self-reported reward-drive (RD) was *not* greater in non-dependent heavy drinking young adults. These findings contrast with those of Ahmadi *et al.* (Ahmadi *et al.*, 2013), who reported a greater total BAS score in their heavy drinkers, relative to their light drinkers. However, Ahmadi *et al.*’s heavy drinkers reported consuming the equivalent of around 125 UK units of alcohol per week, with the authors also reporting 45.71 per cent of their heavy drinkers to have been ‘alcohol-dependent’ (although it is unclear how this was specifically assessed). In contrast, the present study was careful to exclude any ‘possibly’ or ‘definitely’ alcohol-dependent participants (on the basis of AUDIT scores), with heavy drinkers reporting a mean weekly unit-intake of 23.14. The conflicting findings may thus relate to the dependent-level-drinking of some of the heavy drinkers in Ahmadi *et al.* In other studies of non-clinical drinkers, both Murphy, Murphy and Garavan (2013) and Hamilton, Sinha and Potenza (2012) reported greater BAS scores in groups of problem and hazardous drinkers, respectively, relative to comparison groups. Consistent with Ahmadi *et al.*, the quasi-experimental groups in each of these studies also included possibly- and definitely-dependent individuals. Thus, similar to self-reported RI, elevations in self-reported RD might be associated with more chronic alcohol consumption.

IV.II) BEHAVIOURAL FINDINGS AND POSSIBLE IMPLICATIONS

IV.II.I) POORER PERFORMANCE IN THE CONTINUOUS PERFORMANCE TASK (CPT) BY HEAVY DRINKERS: EVIDENCE FOR ELEVATED RESPONSE-INITIATION

The heavy drinkers' significantly poorer performance on the CPT was the only impulsivity index on which the groups differed (after controlling for all *a priori* covariates). The present study is one of only two (the other being Sanchez-Roige *et al.*, 2014) to have compared non-clinical light and heavy drinking young adults on the CPT, with both reporting an elevation in the quasi-experimental groups. If we consider the task requirements in the CPT, the participant must decide whether each successively presented string of five-digit numbers (e.g., 46782) matches the digit-string presented immediately before (by pressing a button). Thus, the form of impulsivity that leads to poorer CPT performance (i.e. response initiation) involves a 'go' response in the absence of full processing of all necessary aspects of stimuli (i.e. checking that all digits from both the digit-strings match). The readiness with which an individual initiates behaviour thus appears elevated in non-dependent heavy drinkers and may serve to maintain heavy drinking patterns. Elevated laboratory response-initiation may underlie heavy drinkers' consumption of large quantities of alcohol without their fully processing the potential health and other (e.g., social) consequences. That said, it is true that the potential significance of performance on neuropsychological tests for real-world behaviour is a controversial issue (Chaytor & Schmitter-Edgecombe, 2003). Although the effect-size of the CPT performance difference was in the moderate range, this nevertheless suggests that other, non-impulsivity-related factors must also play an important role in heavy drinking.

Regarding other potentially important factors: in their incentive-sensitisation theory, Robinson and Berridge (Robinson & Berridge, 1993, 2000) argue that subjective craving and attentional bias to alcohol and associated stimuli, when combined with the impaired executive control (e.g., impulsivity) commonly observed in addicts (e.g., Jentsch & Taylor, 1999), can explain the core symptoms of addiction: compulsive drug-seeking and consumption despite profound adverse consequences. A range of studies has documented attentional bias and craving in non-dependent heavy drinkers (McCusker & Brown, 1990, Walitzer & Sher, 1990, Greeley *et al.*, 1993, Bauer & Cox, 1998, Cox *et al.*, 1999, Sharma, Albery & Cook, 2001, Ryan, 2002).

At least part of the myriad economic, social and medical costs associated with alcohol misuse (Smith, Branas & Miller, 1999, Gmel & Rehm, 2003, Rehm *et al.*, 2003, Unit, 2003, Lister *et al.*, 2008, Balakrishnan *et al.*, 2009, Gronbaek, 2009, Lee & Forsythe, 2011, Navarro *et al.*, 2011) are attributable to the estimated 18 per cent of males and 13 per cent of females in the UK drinking heavily (i.e. those drinking above current UK guidelines of 14 alcohol units per week for both males and females; Health and Social Care Information Centre, 2013). These costs would likely increase further if a proportion of heavy drinkers were to escalate their drinking to dependent levels. For these reasons, it is important to intervene in and try to modify the potentially significant factors involved in heavy drinking. To this end, given the attentional bias toward alcohol-related stimuli (and associated craving) in heavy drinkers, Field and others have sought to train such individuals to direct their attention *away* from such stimuli – though results have so far been mixed (Field *et al.*, 2007b, Schoenmakers *et al.*, 2007, Fadardi & Cox, 2009). The present findings suggest that the efficacy of such efforts may be augmented by also trying to reduce response-initiation. This may involve, for example, helping heavy drinkers to become more aware of their potential tendency to respond quickly and impulsively to alcohol urges and to encourage them to think more carefully (e.g., about the pros and cons) before they decide to have a drink.¹³

Whilst potentially exciting and informative, the (much) poorer CPT performance shown by heavy drinkers might be interpreted cautiously, as it is not an *unequivocal* index of impulsivity. Whilst the CPT does seem to self-evidently measure a tendency to respond in the absence of full information processing, it would also appear to measure aspects of sustained attention and working memory, and indeed is often used as an index of such (e.g., Rutschmann, Cornblatt & Erlenmeyer-Kimling, 1977, Cornblatt *et al.*, 1988). Whilst this makes interpretation of the present findings somewhat tricky, virtually every neuropsychological measure is to some extent an index of two or more cognitive processes, rather than being a ‘pure’ measure of any one process in particular (Lezak, 2004). Clearly, this is a reflection of cognitive processes in themselves seeming to consist of a number of inter-related sub-processes. Nevertheless, it remains possible that the heavy drinkers in the present study were poorer in aspects of attention than light drinkers, rather than having

¹³ This approach could be contrasted with one in which, were heavy drinkers to have shown elevated delay discounting, for example, they would be encouraged to specifically try to focus more on larger, longer-term rewards, as opposed to smaller, shorter-term ones.

greater response-initiation. For this reason, it is important to consider collateral information from other measures in order to aid interpretation. The consistent lack of difference between non-clinical light and heavy drinkers in BIS-11 attentional impulsiveness (in this and other studies) may be evidence against the involvement of attentional deficits in the poorer CPT performance of heavy drinkers seen here. Nevertheless, in order to try to more conclusively rule out possible attention effects, future studies should also administer specific tasks of sustained attention and working memory, such as the sustained attention to response task (SART; Robertson *et al.*, 1997) and tests of digit-span (such as those administered as part of the WAIS-IV; Wechsler, 2008). Few studies seem to have systematically examined this, although both Stephens and Duka (2008) and George *et al.* (2012) reported working memory deficits in binge drinkers (although cf. with Montgomery *et al.*, 2012, who reported no differences in working memory between light and heavy drinkers).

IV.II.II) FAILURE TO FIND GROUP DIFFERENCES ON ANY OTHER IMPULSIVITY TASK OR SUB-DOMAIN

The present study found no group difference for stop signal reaction time (SSRT), thereby indicating no difference in behavioural response inhibition. This is consistent with a number of studies of non-clinical young adult heavy and binge drinkers to have reported null SSRT findings (Moreno *et al.*, 2012, Sanchez-Roige *et al.*, 2014, Caswell *et al.*, 2016). Furthermore, and as discussed in the previous chapter, a number of studies in these types of samples have also reported null findings on the conceptually similar go/no-go task (Henges & Marczinski, 2012, Moreno *et al.*, 2012, Petit *et al.*, 2012, Ahmadi *et al.*, 2013), all of which appears to indicate that behavioural response inhibition is *not* elevated in these groups. Behavioural response inhibition *does*, however, appear elevated in dependent samples (Goudriaan *et al.*, 2006, Lawrence *et al.*, 2009, Schmaal *et al.*, 2013, Petit *et al.*, 2014, Zhou *et al.*, 2014), and it may be that this form of impulsivity is associated with more chronic levels of alcohol consumption. This would be consistent with Loeber *et al.*'s (2009a, 2009b, 2010) findings of greater prefrontal dysfunction following greater numbers of alcoholic detoxifications, suggesting that poorer inhibitory control develops over time with increasingly chronic intake. The present study's null findings for SSRT are consistent with the null findings (after having controlled for *a priori* covariates) of the BIS-11, a self-report measure of RI in everyday life. Thus, the non-dependent drinkers of the

present study were elevated in neither self-report nor behavioural response inhibition.

Similarly, there were no differences between the groups on the balloon analogue risk task (BART). This is consistent with Ahmadi *et al.* (2013), who also reported no difference between their young adult light and heavy drinkers on this task. As per findings regarding behavioural response inhibition, risk-taking appears reliably elevated in dependent drinkers (Fein *et al.*, 2004, Goudriaan *et al.*, 2005, Dom *et al.*, 2006, Noël *et al.*, 2007, Lawrence *et al.*, 2009, Kim *et al.*, 2011). It is notable that the positive findings shown by the ‘hazardous drinkers’ reported in Claus and Hutchison (2012) may be attributable to the sample’s including individuals whose ‘alcohol use ranged from probable abuse to severe dependence’ (p. 933). On the other hand, Moreno *et al.* (2012) reported elevated risk-taking in young adult binge drinkers using the Iowa gambling task (IGT), and Xiao *et al.* (2013) found adolescent binge drinkers to also perform more impulsively (than non-bingers) on the IGT. Thus it may be that either the BART is not sensitive enough to detect potentially elevated risk-taking in young adult heavy drinkers (and that the IGT is) or that elevated risk-taking is a feature of binge drinking but not of greater alcohol consumption overall, or some combination. Regardless, the present findings indicate that risk-taking as measured via the BART is not elevated in non-dependent heavy drinkers.

The present study also found no differences between groups on the beads task. To reiterate, this measure indexes reflection impulsivity – that is, deficits in the gathering and evaluation of information during the decision-making process (Solowij *et al.*, 2012). This conflicts with Banca *et al.*’s (2016) binge drinkers being more impulsive than non-bingers on this task (i.e. choosing fewer beads prior to decision-making). Then again, that Banca *et al.* compared groups on drinking *pattern*, relative to the present study’s comparing groups on *overall intake*, may be significant. Perhaps more importantly, however, the mean and standard deviation for the AUDIT score ($M = 15.48$; $SD = 5.45$) of Banca *et al.*’s binge drinkers indicate that some of their participants may have been alcohol-dependent (i.e. scores above 15 on the AUDIT), whereas possible dependence was an exclusion criterion in the present study. Thus, similar to Ahmadi *et al.*’s (Ahmadi *et al.*, 2013) BAS findings, Banca *et al.*’s finding here may have been brought about by a sub-sample of individuals drinking at dependent levels (at which impulsivity seems more reliably elevated). Banca *et al.* also

administered another index of reflection impulsivity, the Information Sampling Task (IST), as did Caswell *et al.* (Caswell *et al.*, 2016), neither of whom reporting group differences. Overall, and considering the present study's exclusion of dependent drinkers, the evidence seems to indicate that reflection impulsivity is *not* elevated in non-dependent heavy drinkers.

The present study's finding no group difference on the monetary choice questionnaire (MCQ) is in-line with findings reported by Caswell *et al.* (Caswell *et al.*, 2016), Banca *et al.* (Banca *et al.*, 2016) and Sanchez-Roige *et al.* (Sanchez-Roige *et al.*, 2014), none of whom reported differences between their groups of light versus heavy drinkers or non-bingers versus bingers. Similarly, using the two-choice impulsivity paradigm (TCIP) and two-choice task (TCT), Moreno *et al.* (Moreno *et al.*, 2012) and Rose and Grunsell (Rose & Grunsell, 2008) also reported no differences between groups. Taken together, these findings suggest that delayed reward discounting is *not* elevated in young adult (i.e. 18-25) heavy and/or binge drinkers, relative to comparison groups.

In summary, of the various sub-domains of impulsivity assessed here, only behavioural response-initiation (indexed by CPT performance) was significantly greater in the non-dependent heavy drinkers. Thus, none of the following seem related to non-dependent heavy drinking: self-report measures of: (i) rash impulsivity (BIS-11); (ii) reward drive (the BAS scales), and behavioural measures of: (iii) response-inhibition (SSRT); (iv) delay-discounting (MCQ *k*); (v) reflection impulsivity (beads task), or; (vi) risk-taking (BART). These findings provide further support for the notion of impulsivity as a multi-faceted construct (de Wit & Richards, 2004), since its different sub-domains seem to share different relationships with heavy drinking. Overall, the present findings indicate that the key – indeed, the only – impulsivity sub-domain elevated in non-dependent heavy drinkers (at least amongst those aged 18-25) is response-initiation.

Those with alcohol dependence, on the other hand, show reliable elevations across *all* impulsivity sub-domains (von Knorring *et al.*, 1987, Hallman *et al.*, 1990, Ketzenberger & Forrest, 2000, Petry, 2001, Johnson *et al.*, 2003, Bjork *et al.*, 2004, Fein *et al.*, 2004, Goudriaan *et al.*, 2005, Mitchell *et al.*, 2005, Dom *et al.*, 2006, Goudriaan *et al.*, 2006, Chen *et al.*, 2007, Mitchell *et al.*, 2007, Noël *et al.*, 2007, Sprah & Novak, 2008, von Diemen *et al.*, 2008, Bobova *et al.*, 2009, Lawrence *et al.*, 2009, Cangemi *et al.*, 2010,

Kim *et al.*, 2011, Schmaal *et al.*, 2013, Petit *et al.*, 2014, Zhou *et al.*, 2014). It is intriguing to speculate on whether elevated response-initiation in heavy drinkers, together with attentional biases and urges to drink, might be involved in the initial development and maintenance of heavy drinking; and whether these levels of consumption, sustained over time, might eventually bring about (e.g., as a result of changes to the MCL dopamine system) more widespread impulsivity elevations. It may be that, once this more general impulsivity is 'online', increasingly more chronic levels of consumption are observed. As already stated, however, these are speculations and are made here somewhat tentatively; longitudinal studies are therefore needed in order to explore these possibilities.

IV.III) EVALUATION OF THE PRESENT STUDY

IV.III.I) STRENGTHS

An important strength of the present study was that the heavy drinkers were neither 'possibly' nor 'definitely' alcohol-dependent, on the basis of their scores on the Alcohol Use Disorders Identification Test (AUDIT) (i.e. all scores were equal to or below 15). This is important, since it allows us to rule-out any findings (specifically, greater impulsivity on the CPT) possibly being attributable to a sub-sample of highly impulsive dependent drinkers. Few previous studies in this area (e.g., none of those studies included in the systematic literature review in this thesis) have taken steps to exclude the recruitment of dependent drinkers. The possibility that previous studies might have (inadvertently) recruited (at least some) dependent drinkers in their samples is a fundamental limitation. Thus, when they have reported finding elevated impulsivity in a sample of apparently non-dependent heavy drinkers, this ostensibly raises the intriguing possibility that impulsivity is not merely a consequence of dependent drinking, but can be present prior to dependence. Furthermore, it even raises the possibility that such elevated impulsivity may serve as a risk factor for the initial development of chronic drinking. The possible inclusion of dependent drinkers in such data, however, represents a crucial flaw and undermines such conclusions. Indeed, the present study's finding heavy drinkers to be elevated on just one impulsivity index may be the result of its very exclusion of possibly and definitely dependent drinkers. That a sample-size calculation was performed prior to participant recruitment meant that the study should have had enough power to detect any genuinely significant group differences. It is typically assumed that non-

dependent heavy drinkers are generally more impulsive (i.e. across a number of sub-domains) than light drinkers; consistent with Caswell *et al.* (Caswell *et al.*, 2016), the present results challenge this assumption.

IV.III.II) LIMITATIONS

As the results of a cross-sectional study, the present findings are limited in that the possible cause and effect relationship(s) between impulsivity and heavy drinking cannot be disentangled. For example, it is possible that, due to the sample's being non-alcohol-dependent and relatively young, the greater response-initiation shown by heavy drinkers here is a long-standing personality characteristic that has prospectively contributed to their hazardous drinking. This would be consistent with the findings of Sher *et al.* (2000) and Rubio *et al.* (2008), each of whom reported that adolescents with greater impulsivity at baseline were more likely to go on to become substance abusers and/or develop alcohol use disorders some years later. However, it is *also* possible that the heavy alcohol consumption in which the sample has already engaged has brought about or exacerbated their response-initiation, possibly as a result of damage to prefrontal cortical regions (e.g., Loeber *et al.*, 2009a, Loeber *et al.*, 2009b, Loeber *et al.*, 2010). That all participants were aged 18-25 years, and thus in the 'late adolescent' period of prefrontal neurodevelopment, would presumably make them more vulnerable to such potentially neurotoxic effects of alcohol. It is possible that heavy drinking commencing after this potentially 'sensitive period' may have less neurotoxic effect(s). In order to fully address such questions, further longitudinal research is needed, in which the relationships between alcohol (and other drug) consumption and a comprehensive profile of impulsivity is explored from early adolescence (i.e. prior to exposure to alcohol and other drugs) through to early adulthood (and beyond).

In order to comprehensively profile impulsivity in non-dependent young adults, the present study required participants to complete a number of self-report and behavioural measures. One might suggest the largely null findings to have resulted from fatigue and possible failure to apply full effort. However, in a pilot study, in which the feasibility and acceptability of the procedure was specifically evaluated, participants reported no concerns about the duration and/or demands of the procedure. Furthermore, the entire procedure lasted around an hour, each of the five behavioural tasks generally taking no more than five minutes to complete.

After the present study, the second most comprehensive and well-controlled study of this nature seems to be that recently reported by Caswell *et al.* (2016). These authors administered one self-report measure (the BIS-11) and three behavioural tasks (the SST, the MCQ and the IST). After controlling for the *a priori* covariates of age, gender and estimated IQ, the only index to remain a significant predictor of heavy drinking was BIS-11 non-planning impulsiveness. That is, of six key indices (i.e. three for the BIS-11 and one each for the SST, MCQ and SST), just *one* came-out as significantly differing between the groups – a ‘hit-rate’ of around 17 per cent. In the present study, one index (CPT *d'*) out of eight (13%) came-out as significant.¹⁴ Due partly to the statistical independence of the various impulsivity sub-domains (Caswell *et al.*, 2015), neither study controlled for the multiple comparisons undertaken in their analyses. It is true that applying the Bonferroni correction, for example, in either study would have reduced the chances of finding any genuinely significant effects almost to zero (i.e. possible effects would have had to have been highly, highly significant). On the other hand, it is possible that the each of the two significant effects were merely Type-I errors. It is perhaps notable in this respect that the two indices reported significant by each study were different. Then again, and as already discussed, it is entirely plausible that only certain impulsivity sub-domains are elevated in non-clinical young adult heavy drinkers; and that the significant index in each study falls under the rubric of rash impulsivity might be construed as consistent with these indeed being genuine effects. Overall, the possibility of Type-I errors notwithstanding, it seems preferable to administer a comprehensive battery of measures in a single (ideally well-powered, large) sample, as doing so means that group differences are held constant. Thus, such studies allow one to state that a group of heavy drinkers are elevated on *X* but that no group differences exist for *Y* or *Z*. Attempts to collate findings across studies, on the other hand, are often hampered by differences in the samples.

The present study was specifically aimed at examining impulsivity in a sample of 18-25-year-olds. Furthermore, the majority of participants were undergraduate students in London. Overall, the present sample was relatively specific, meaning that the present findings may not be directly generalisable to other populations. Then again,

¹⁴ Various other studies have also included relatively large numbers of impulsivity indices (e.g., Henges & Marcinski, 2012, Moreno *et al.*, 2012, Ahmadi *et al.*, 2013, Sanchez-Roige *et al.*, 2014).

whether or not this can be considered a limitation is debatable, since the specific aim of the study was to examine impulsivity within the 18-25-year age-range.

The misuse of alcohol is a complex phenomenon and incorporates not just the amount of alcohol consumed (e.g., in the form of hazardous or dependent drinking), but also the pattern (e.g., binge drinking). In line with previous studies, the present study included just two groups – light and heavy drinkers, distinguished on the basis of current UK recommended limits for men and women of 14 units per week. The relative effect(s) of quantity versus pattern (i.e. a binge pattern) of alcohol consumption thus remains unclear: it is impossible to say whether heavy drinkers' greater response-initiation was attributable to quantity or pattern, or to some combination. Ideally, a third group consisting of binge drinkers would have been included, but for time and cost reasons, this was unfortunately not possible. This is an issue that future studies should seek to address. Relatedly, studies in this area often tend to divide groups based either on quantity or pattern of alcohol intake, which is reasonable enough. However, numerous other alcohol-related variables may also be important in examining young adults' drinking, such as individuals' motivations to drink – for which there is a considerable literature. Clearly, a complete and thorough understanding of alcohol misuse can only be achieved via consideration of all potentially relevant factors.

IV.IV) CONCLUSION

The present study found that, across a comprehensive battery of impulsivity measures, and after having controlled for *a priori* covariates, non-dependent heavy drinkers were more impulsive than light drinkers only in terms of response-initiation. This study was the first to demarcate drinkers on the basis of the new UK recommended maximum drinking guidelines of 14 alcohol units per week for both men and women. This was arguably the most comprehensive and well-controlled study of this type so far conducted and its findings suggest that, across most measures, there are no differences between non-dependent light and heavy drinkers. Although the apparently greater response-initiation of heavy drinkers is a potentially exciting and informative finding, it is also possible that the poorer CPT performance of heavy drinkers may be related to aspects of attention and/or working memory – though this needs further investigation. Overall, it seems that more broadly elevated impulsivity (i.e. across multiple sub-domains) is a feature of more chronic levels of

alcohol consumption (e.g., dependence), rather than the non-dependent heavy drinking levels of the present study.

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APPENDIX 1: SCHEMATIC OVERVIEW OF DESIGN AND ORDER OF ASSESSMENTS

Table A1 provides a schematic overview of the overall study design and the order in which assessments were administered.

Table A1: Schematic overview of design and order of assessments

Stage of assessment and time taken	Actions/order of assessments administered
Start of session (duration: approximately 5 minutes)	<i>Verbal overview of procedure given</i>
	<i>Expired breath alcohol measured</i>
	<i>Nicotine and caffeinated drinks self-report</i>
	<i>Age verified via ID</i>
First set of questionnaires administered (duration: approximately 10 minutes)	<i>Socio-demographic questions</i>
	<i>AUDIT</i>
	<u>Impulsivity self-report measures:</u>
	Either: BIS-11 and BIS/BAS Scales (counterbalanced) Or: RIS and TIS (counterbalanced)*
Behavioural impulsivity tasks administered (duration: approximately 30 minutes)	<i>TOPF (counterbalanced)†</i>
	<i>CPT or SST (counterbalanced)</i>
	<i>Beads task</i>
	<i>MCQ</i>
	<i>BART</i>
	<i>SST or CPT (counterbalanced)</i> <i>TOPF (counterbalanced)†</i>
Second set of questionnaires administered (duration: approximately 5-10 minutes)	<u>Impulsivity self-report measures (i.e. whichever were not given as part of the first set of questionnaires):</u>
	Either: BIS-11 and BIS/BAS Scales (counterbalanced) Or: RIS and TIS (counterbalanced)*
	<i>Payment given; receipt of payment form signed and dated</i>
End of session (duration: approximately 5 minutes)	<i>Verbal debrief given</i>
	<i>Information about possible risks of drinking given‡</i>

Note: Italicised items denote those administered in fixed order.

† TOPF given either before or after administration of behavioural impulsivity tasks.

‡ For participants drinking above UK recommended weekly limits for alcohol consumption.

Abbreviations: AUDIT = alcohol use disorders identification test; BIS-11 = Barratt impulsiveness scale, version 11; BIS/BAS Scales = behavioural inhibition and behavioural activation scales; RIS = recent impulsivity scale; TIS = trait impulsivity scale; TOPF = test of premorbid functioning; CPT = continuous performance task; SST = stop signal task; MCQ = monetary choice questionnaire; BART = balloon analogue risk task.

* Measures administered as part of another study.

INFORMATION SHEET FOR PARTICIPANTS

REC Reference Number: RESCMR-16/17-1992



YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Examining Aspects of Personality and Alcohol Consumption

I would like you to participate in this study, which forms a part of my research dissertation in my Doctorate in Clinical Psychology (DClinPsy) programme. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. If there is anything that you do not understand or would like more information on, please feel free to contact the lead researcher, Dr. Matthew J. Mayhew, at Matthew.J.Mayhew@kcl.ac.uk.

What is the purpose of the study?

The aim of this study is to examine how aspects of personality relate to people's consumption of alcohol. I am exploring this via both self-report questionnaires and computerised tasks. This will involve your completing some questionnaires and computerised tasks on one occasion.

Why have I been invited to take part?

I am inviting any native English speakers, aged between 18 and 25, who regularly drink alcohol. I am looking for people drinking across all levels of alcohol consumption. It is important for participants to be native English speakers as one of the tests requires participants to have English as their mother tongue.

Do I have to take part?

Participation is voluntary. You do not have to take part. You should read this Information Sheet and if you have any questions, you should email the lead

researcher. You should not agree to take part in this research until you have had all your questions answered satisfactorily.

What will happen to me if I take part?

If you are deemed eligible for the study and you decide to take part, you will be invited to come to the Institute of Psychiatry, Psychology and Neuroscience (IoPPN), King's College London. Once there, we would ask you to complete some questionnaires and then to complete some computerised tasks. The questionnaires will ask you about your thoughts, feelings and behaviour, and the computerised measures will be looking at the way you respond in the tasks. Overall, both the questionnaires and the tasks are looking at aspects of your personality. In total, the study will last around 1 hour; this will include a short break, around half-way through.

You will be asked to abstain from alcohol for 24 hours prior to participating, as well as smoking cigarettes and drinking tea, coffee or any other highly-caffeinated drinks (e.g., coke) for 3 hours prior to participation.

Even if you have decided to take part, you are still free to cease your participation at any time and to have research data/information relating to you withdrawn without giving any reason up to the point of data analysis in March 2017.

Incentives (where relevant)

If you are deemed eligible and you decide to take part, you will receive between £15 and £20 as recompense for your time. The exact amount you receive as recompense is dependent on your performance in one of the tasks you will be asked to complete.

What are the possible risks of taking part?

There are no foreseeable risks in participating in the study. The main disadvantage to taking part in the study is that you will be giving around 1 hour of your time to take part. It is possible that you may not wish to answer all the questions and withdraw your participation; this is unlikely but if it were to occur, your participation could be terminated at any time by simply informing me that you no longer wish to participate.

What are the possible benefits of taking part?

There are no direct benefits of taking part. However, the information I get from the study will help to increase the knowledge base concerning aspects of personality and how they relate to the consumption of alcohol and other drugs. Consequently, the findings from this study may contribute to the development of future prevention and treatment strategies aimed at managing and cutting-down/quitting alcohol and other drug consumption. Furthermore, I will provide you with a summary of a final report describing the main findings.

Will my taking part be kept confidential?

Your taking part, as well as the answers to the questions on the questionnaires and your performance on the computerised measures, will be regarded as strictly confidential and will be held securely until the research is finished. Your participation is entirely voluntary. If you change your mind, you are free to stop your participation and to have your data withdrawn, without giving any reason, up to the point of data analysis in March 2017. If you ask me to withdraw your data at any time up to and including 28th February 2017, I will remove all traces of them from the records. All data used for analysis will be anonymised. In reporting on the research findings, I will not reveal the names of any participants. At all times there will be no possibility of you as an individual being linked with the data.

The UK Data Protection Act 1998 will apply to all information gathered within the interviews and held on password-locked computer files within King's College London. No data will be accessed by anyone other than myself or other members of the research team. No data will be able to be linked back to any individual taking part in the completion of the questionnaires or the computerised measures.

How is the project being funded?

The Research Fund, allocated to all trainees on the Doctorate in Clinical Psychology programme at King's College London, will fund the study. The study has been approved by the King's College London Research Ethics Committee. The project is also being funded by the Psychiatry Research Trust at the Institute of Psychiatry, Psychology and Neuroscience (IoPPN).

What will happen to the results of the study?

I will produce a final report summarising the main findings, which will be sent to you. The study and its findings will be written-up as part of my final research dissertation, for the qualification of Doctorate in Clinical Psychology (DClinPsy). I also plan to disseminate the research findings via peer-review publications and conferences.

What if something goes wrong?

If this study has harmed you in any way or you wish to make a complaint about the conduct of the study, you can contact my supervisor using the following contact details:

Dr. Tim Meynen

Institute of Psychiatry, Psychology and Neuroscience (IoPPN)

King's College London

Addiction Sciences Building

4 Windsor Walk

London SE5 8AF

Email: Tim.Meynen@kcl.ac.uk

Tel: +44 (0)20 7848 0501

Can I access help to cut-down or quit my alcohol consumption via the study?

This is a research study only – we are *not* part of any treatment programmes for alcohol/drug issues or indeed any other mental health problems.

If you wish to know more about safe and unsafe levels of alcohol consumption, the potential physical and psychological effects of drinking above NHS-recommended guidelines and/or suggestions for how to cut-down or quit drinking, there is some useful information on the NHS Choices website (<http://www.nhs.uk/conditions/Alcohol-misuse/Pages/Introduction.aspx>). This also has some contact details for people or organisations you can speak to if you are concerned about your drinking and would like to get professional help or advice to cut-down or quit. At it says, one option is to speak to your GP – they will be able to tell you about services and treatments available. You can also call Drinkline, which is a national 24-hour support service (on 0300 123 1110; open Monday-Friday, 9 AM-8PM, weekends 11 AM-4 PM).

Thank you for reading this information sheet and for considering taking part in this research.

CONSENT FORM FOR PARTICIPANTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Examining Aspects of Personality and Alcohol Consumption



King's College Research Ethics Committee Ref: RESCMR-16/17-1992

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Please tick or initial

I confirm that I understand that by ticking/initialling each box I am consenting to this element of the study. I understand that it will be assumed that unticked/initialled boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element I may be deemed ineligible for the study.

☐

Please tick or initial

1. *I confirm that I have read and understood the Information Sheet dated 23/11/2014 (Version 1) for the above study. I have had the opportunity to consider the information and/or have asked questions which have been answered satisfactorily.
2. *I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. Furthermore, I understand that I will be able to withdraw my data up to 28th February 2017.
3. *I consent to the processing of my personal information for the purposes explained to me. I understand that such information will be handled in accordance with the terms of the UK Data Protection Act 1998.

☐☐☐

4. *I understand that my information may be subject to review by responsible individuals from the College for monitoring and audit purposes. ☐
5. I understand that confidentiality and anonymity will be maintained and it will not be possible to identify me in any publications ☐
6. I understand that this is a research study only and is not part of any treatment programmes to cut-down or quit alcohol intake, or indeed any other mental health issues ☐

Name of Participant

Date

Signature

APPENDIX 4: ETHICAL APPROVAL LETTER

Research Ethics
Office

Franklin Wilkins Building
5.9 Waterloo Bridge Wing
Waterloo Road
London SE1 9NH
Telephone 020 7848 4020/4070/4077
reo@kcl.ac.uk



Matthew Mayhew

1 July 2016

Dear Matthew,

Study Title: Profiling Impulsivity in 'At Risk' Non-Dependent Heavy Drinkers

Study Reference: HR-15/16-1992

I am pleased to inform you that full approval for your project has been granted by the PNM Research Ethics Subcommittee

Please ensure that you follow all relevant guidance as laid out in the King's College London Guidelines on Good Practice in Academic Research (<http://www.kcl.ac.uk/college/policyzone/index.php?id=247>).

For your information, ethical approval has been granted for 3 years from 1 July 2016. If you need approval beyond this point, you will need to apply for an extension at least two weeks before this. You will be required to explain the reasons for the extension. However, you will not need to submit a full re-application unless the protocol has changed. If you have been granted approval for only 12 months, you will not be sent a reminder when it is due to lapse.

Ethical approval is required to cover the data-collection phase of the study. This will be until the date specified in this letter. However, you do not need ethical approval to cover subsequent data analysis or publication of the results.

For secondary data-analysis, ethical approval is applicable to the data that is sensitive or identifies participants.

Approval is applicable to period in which such data is accessed or evaluated.

Please note you are required to adhere to all research data/records management and storage procedures agreed to as part of your application. This will be expected even after the completion of the study.

If you do not start the project within three months of this letter, please contact the Research Ethics Office.

Please note that you will be required to obtain approval to modify the study. This also encompasses extensions to periods of approval. Please refer to the URL below for further guidance about the process:

<http://www.kcl.ac.uk/innovation/research/support/ethics/applications/modifications.aspx>

Please would you also note that we may, for the purposes of audit, contact you from time to time to ascertain the status of your research.

If you have any query about any aspect of this ethical approval, please contact the Research Ethics Office:

(<http://www.kcl.ac.uk/innovation/research/support/ethics/contact.aspx>)

We wish you every success with this work.

Yours sincerely,

James Patteron - Senior Research Ethics Officer

For and on behalf of

Dr Jane Petty, Chair of the PNM Research Ethics Subcommittee

Cc: Tim Meynen

APPENDIX 5: DATA-SCREENING AND ACTIONS

Missing data: Table A2 presents the amounts of missing data on variables other than the TOPF^{UK} and beads task.

Table A2: Missing data for variables other than the TOPF^{UK} and beads task ($N = 116$)

Variable	Number of missing values	Percentage of missing values
<i>Age</i>	0	0.00
<i>Gender</i>	0	0.00
<i>Ethnicity</i>	0	0.00
<i>Socioeconomic status</i>	12	10.30
<i>AUQ units per week</i>	0	0.00
<i>AUDIT total score</i>	0	0.00
<i>BIS-11 attentional impulsiveness</i>	0	0.00
<i>BIS-11 motor impulsiveness</i>	0	0.00
<i>BIS-11 non-planning impulsiveness</i>	1	0.90
<i>BAS drive</i>	0	0.00
<i>BAS fun seeking</i>	0	0.00
<i>BAS reward responsiveness</i>	0	0.00
<i>CPT d'</i>	1	0.90
<i>SST SSRT</i>	7	6.00
<i>MCQ k</i>	2	1.70
<i>BART adjusted number of pumps</i>	1	0.90

Note: AUDIT = alcohol use disorders identification test; AUQ = alcohol use questionnaire; BART = balloon analogue risk task; BAS scales = behavioural activation scales; BIS-11 = Barratt impulsiveness scale, version 11; CPT d' = continuous performance task d-prime (i.e. z-score for number of false alarms subtracted from z-score for number of correct hits); MCQ k = monetary choice questionnaire, where k represents: ((larger, later choices – smaller, immediate choices) – 1)/delay); SST = stop signal task; SSRT = stop signal reaction time.

Prior to multiple imputation, the data were screened for univariate outliers (z-scores in excess of ± 3.29) within each drinking group separately. One heavy drinking participant was a univariate outlier for AUQ number of alcohol units consumed per week (with a z-score of 3.66). Following Tabachnik and Fidell (2007), the outlier was re-assigned a value one unit greater than the next-most-extreme score. There were several outliers across the impulsivity variables: (i) one heavy drinker on BIS-11 attentional impulsiveness (z-score = 3.46); (ii) one light drinker on BIS-11 motor impulsiveness (z-score = 3.37); (iii) one heavy drinker on BAS reward-responsiveness (z-score = -4.03); (iv) one heavy drinker on CPT *d*-prime (z-score = -3.36); (v) one light drinker on SST SSRT (z-score = -4.51) and; (vi) one heavy drinker on MCQ *k* (z-score = 4.66). In each case, these outliers were remedied by replacement with a value one unit greater than the non-outlying next-most-extreme value. One light drinking outlier on MCQ *k* (z-score = 4.17) remained an outlier following this method (z-score = 3.37); their outlying value was thus replaced with the non-outlying next-most-extreme value. There were no univariate outliers on any other variables.