CLARIFYING THE SUBTYPES OF IMPULSIVITY AND THEIR COGNITIVE AND BEHAVIOURAL UNDERPINNINGS

Amy J. Caswell

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School of Psychology, University of Sussex

Declaration

I hereby declare that this thesis has not been and will not be, submitted in whole or in part to another University for the award of any other degree.

Amy J. Caswell

Date: / /

Preface

Data from this thesis has been published in the following articles:

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UNIVERSITY OF SUSSEX

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SUMMARY

Investigators have suggested impulsivity consists of several behavioural subtypes including 'reflection'- (decision-making without evaluation of information), 'temporal'- (failure to delay gratification) and 'motor'- (failure to inhibit a motor response) impulsivity. These facets of impulsivity are thought to be dissociable, but to share some common underlying processes.

The current studies investigated such processes. Study 1 investigated speed and accuracy biases, using instructions and cognitive priming to challenge impulsivity. Study 2 & 3 challenged inhibitory control resources, via a dual task and alcohol challenge, to investigate the effect on impulsivity. Study 3 also investigated the effect of alcohol outcome expectancies on impulsivity.

The factor structure of impulsivity was also investigated using exploratory factor analysis (study 4), to establish whether the primary measures of the proposed subtypes can indeed be categorised into these three factors. Study 4 also investigated the relationship of participant demographics to impulsivity.

The studies support the suggestion of a distinct subtype of reflection-impulsivity. Inhibitory control processes do not appear to underlie performance, however biases in speed/accuracy trade-offs have implications for this subtype.

Behavioural inhibitory control was found to be the primary process underlying motor-impulsivity whilst biases for speed/accuracy have implications for Go-responses. The factor analysis provided preliminary evidence that there may be two distinct facets of motor-impulsivity: action cancellation and action restraint.

Inhibitory control processes were not found to underlie temporal-impulsivity on an experiential task. Biases for speed/accuracy were found to contribute to performance on pen-and-paper measures. However, subsequent factor analysis provided evidence that experiential tasks may actually be more closely related to a form of cognitive control, instead of temporal-impulsivity.

In conclusion, the studies found that the three proposed factors of impulsivity differentially rely on inhibitory control processes and biases for speed/accuracy. However, factor analysis indicated that additional factors may be required to fully characterise impulsivity.

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1 General Introduction

In everyday life people can behave 'impulsively'; they make premature decisions, prefer immediate gratification and have difficulties inhibiting fast motor responses. Impulsivity functions as a dimension of normal behaviour, and it is thought that it can be adaptive in certain situations (Dalley, Everitt, & Robbins, 2011); indeed, the conservation of such traits and responses indicates an evolutionary advantage of impulsivity (Winstanley, Olausson, Taylor, & Jentsch, 2010). However, it is also well established that impulsivity is associated with a number of negative outcomes, including lower intelligence and academic failure (Aichert et al., 2012; Schweizer, 2002; Vigil-Colet & Morales-Vives, 2005). Impulsivity is elevated in clinical populations (de Wit, 2009) including Attention Deficit-Hyperactivity Disorder, mania and personality disorders (Winstanley, Dalley, Theobald, & Robbins, 2004; Winstanley, Eagle, & Robbins, 2006). In particular, high levels of impulsivity are related to drug use (Winstanley et al., 2004) and the enduring academic interest in impulsivity arises, in part, from this consistent association with addictive behaviours (Perales, Verdejo-Garcia, Moya, Lozano, & Perez-Garcia, 2009); for a detailed review see Verdejo-García, Lawrence & Clark (2008).

The current chapter will review aspects of impulsivity and will focus on the assessment of impulsivity in humans, through self-report questionnaires, but primarily through behavioural measures. Animal analogues of human tasks will be briefly discussed where relevant, and examples of impulsivity will be illustrated through reference to drug user populations.

1.1 The assessment of impulsivity

1.1.1 Self-report measures

The majority of research at the clinical level uses questionnaires to assess impulsivity (Winstanley et al., 2010). Such self-report assessments of impulsivity adopt a personality driven approach, aiming to identify impulsive traits within normal and clinical populations (J. L. Evenden, 1999b). Several self-report measures of impulsivity have been created, each identifying multiple aspects of impulsive behaviour (J. L. Evenden, 1999b). Dickman (1990) distinguished between functional and dysfunctional types of impulsivity, with the former referring to situations in which acting without forethought is optimal and the latter referring to when acting without forethought leads to difficulties. The I_7 (Eysenck, Pearson, Easting, & Allsopp, 1985) identifies two factors of Impulsiveness and Venturesomeness. Individuals high in impulsiveness are identified as failing to identify risks and as a consequence behave in a risky or impulsive manner. Individuals high in venturesomeness are proposed to be aware of the risk involved but to take that course of action regardless. The BIS/BAS scale (Carver & White, 1994) was initially developed to index two systems: the behavioural activation system (BAS) thought to represent impulsivity and the behavioural inhibition system (BIS) thought to represent fear sensitivity and anxiety (Carver & White, 1994); more recent research has found that both scales in fact correlate with certain measures of impulsivity (e.g. Poythress, Skeem, Weir, Lilienfeld, Douglas, Edens & Kennealy, 2008). The UPPS Impulsive Behaviour Scale (Cyders et al., 2007; Whiteside & Lynam, 2001, 2003) measures impulsivity across dimensions of the Five Factor Model of personality, including five subscales of positive urgency, negative urgency, lack of premediation, lack of perseverance, and sensation-seeking.

The foremost self-report measure of impulsivity is the Barratt Impulsiveness Scale (BIS-11, Patton, Stanford, & Barratt, 1995). The scale recognises multiple types of impulsivity, and identifies individuals unable to focus and concentrate on tasks are identified as being high in attentional impulsivity; individuals high in motor impulsivity have a tendency to act on the spur of the moment; nonplanning impulsivity assesses careful thinking and planning, enjoyment of challenging cognitive tasks and lack of regard for the future (Patton et al., 1995; Stanford et al., 2009). Research has consistently found that alcohol and drug user populations identify themselves as being impulsive, recording above average scores on the Barratt Impulsiveness Scale (Stanford et al., 2009).

Alcohol dependent individuals self-report elevated impulsivity scores (Bjork, Hommer, Grant, & Danube, 2004; Lawrence, Luty, Bogdan, Sahakian, & Clark, 2009a, 2009b), with early-onset individuals being more impulsive compared to late-onset alcohol dependent individuals (Dom, D'Haene, Hulstijn, & Sabbe, 2006; Dom, Hulstijn, & Sabbe, 2006; Joos et al., 2012). Cocaine dependent adults also report high impulsivity (S. D. Lane, Moeller, Steinberg, Buzby, & Kosten, 2007 628; Moeller et al., 2001). Ecstasy users score higher on the Barratt Scale than non-users (Bond, Verheyden, Wingrove, & Curran, 2004). Current amphetamine users also have increased impulsivity compared to drug-naïve controls, as do current opiate users (Clark, Robbins, Ersche, & Sahakian, 2006). The Barratt Impulsiveness Scale is not only sensitive to current drug use, but also previous drug use; ex- amphetamine and opiate users also record elevated impulsivity scores (Clark et al., 2006).

It is also known that questionnaire measures of impulsivity are sensitive to certain patterns of alcohol and drug use. In social drinkers, Balodis and colleagues (2009) found that high scores on the Barratt Impulsiveness Scale are related to a greater number of drinks consumed per drinking occasion, and also with longer drinking occasions; however the researchers found no group differences in impulsivity scores when comparing binge (according to US national guidelines) and non-binge drinkers. Additional research has found that motor impulsivity, but no other Barratt impulsiveness score, is related to number of binge drinking (US guidelines) occasions in the past 12 months (Carlson, Johnson, & Jacobs, 2010). Fossati and colleagues (2001) found that the Barratt Impulsiveness Scale shows significant correlations with alcohol intake and also with getting drunk to cope with emotional problems. In addition, the investigators found that participants who reported high frequency of alcohol intake had significantly higher Barratt impulsiveness total scores compared to subjects who reported a low frequency of alcohol intake; participants reporting a high frequency of getting drunk to cope with emotional problems also had significantly higher Barratt impulsiveness total scores compared to the low frequency group (Fossati et al., 2001). Self-report impulsivity scores are also predictive of frequency of cigarette smoking in undergraduate students (Fossati et al., 2001). Total, attentional and motor scores are predictive of crack/cocaine use in a sample of male and female treatment-seeking drug users (Lejuez, Bornovalova, Reynolds, Daughters, & Curtin, 2007).

Not only is there evidence finding that self-report measures of impulsivity are sensitive to drug use behaviours, there is also research suggesting that impulsivity has implications for treatment outcomes; research has found that cocaine dependent individuals reporting high impulsivity stay in treatment for a significantly shorter period than do individuals with low impulsivity (Moeller et al., 2001).

1.1.2 Behavioural Impulsivity

It is clear that self-report measures of impulsivity are highly sensitive to drug use behaviours, and that impulsivity may have implications for treatment outcomes. It has been suggested that impulsivity may promote drug use through two processes; trait impulsivity may predispose individuals to drug use, which in turn may lead to further impairments to impulsivity that are manifested as failure to control intake (Balodis et al., 2009).

However, there are issues with self-report measures that affect their interpretation. Questionnaires are constrained by a reliance on self-awareness and introspection (J. L. Evenden, 1999b; Helmers, Young, & Pihl, 1995). Furthermore, they encompass broad personality traits and may not inform us of state impulsivity behaviours and processes (Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012); when interested in the role of impulsivity as both a cause and consequence of drug use, such questionnaires can give no insight into whether impulsive characteristics preceded, or were a consequence, of drug use.

To circumvent such issues, recent research has begun to investigate whether ‘impulsive’ populations, according to self-report measures, also display impulsive behaviour. Laboratory research has developed experimental paradigms to index state impulsive behaviour and processes.

Mirroring the proposal that self-report impulsivity can be categorised into separate motor and cognitive facets (Patton et al., 1995), behavioural research makes the same distinction and has focused on impulsivity occurring at the point of decision making (cognitive impulsivity), and also at the point of response execution (motor impulsivity) (Ainslie, 1975; Aron, Robbins, & Poldrack, 2004; M. Field, Schoenmakers, & Wiers, 2008; Frijda, 2010).

For the purpose of the present review we will focus on three broad classes of impulsivity: (i) tendency to delay gratification (‘temporal’- impulsivity) (ii) response inhibition (‘motor’-impulsivity) (ii) tendency to make decisions under ambiguous circumstances (‘reflection’- impulsivity).

1.1.2.1 Impulsivity at the point of decision making - ‘Temporal- Impulsivity’

In everyday life, people are faced with decisions between different outcomes at different time points. Such outcomes may be rewards, and when two rewards differ in only one dimension, for example value or delay, choice of the larger, or sooner, option is relatively predictable (Green & Myerson, 2004). However, choice becomes more complex when the rewards differ on multiple dimensions. A more difficult choice may be between a smaller sooner reward, or a larger later reward (Green & Myerson, 2004). For instance, an individual may have a choice between buying a new item of clothing now, or waiting and buying a holiday in six months' time; another individual may not eat chocolate today, so that in one month they will be healthier and slimmer. Investigators have suggested that impulsive individuals prefer immediate rewards rather than delaying gratification (Ainslie, 1975; Crean, de Wit, & Richards, 2000). The tendency to delay gratification can be termed 'temporal'- impulsivity.

The founding laboratory research into delay of gratification was conducted in the lab of Walter Mischel (e.g. W. Mischel, Ebbesen, & Zeiss, 1972; W. Mischel, Shoda, & Rodriguez, 1989). Mischel and colleagues completed a series of studies, in which young children (typically aged 4) were provided with a choice between a small reward, available immediately, or a larger, more delayed, reward. Rewards were food based, including marshmallows, cookies and pretzels; both rewards were present during the choice phase and the child was instructed that if they wished they could eat the smaller, less desirable, reward, but if they waited until the experimenter returned they would be allowed to eat the larger, more desirable, reward (e.g. W. Mischel et al., 1972; W. Mischel et al., 1989). Longitudinal data from these studies indicated that the ability to delay gratification (i.e. the choice to wait for a larger reward in preference to eating the smaller reward) is associated with a number of positive lifetime outcomes, including better health, academic and social functioning and more positive inter-personal relationships. Such positive outcomes are evident ten, and even thirty, years later (e.g. W. Mischel, Shoda, & Peake, 1988; W. Mischel et al., 1989; Schlam, Wilson, Shoda, Mischel, & Ayduk, 2013).

These seminal studies presented very young children with physically available food rewards, requiring them to choose between two options. Paradigms assessing delay of gratification in adulthood utilise the same choice between a smaller sooner, and larger later reward. Such measures are typically pen-and-paper based, but experiential tasks have also been developed. Pen-and-paper measure, for example the monetary choice questionnaire (Kirby, Petry, & Bickel, 1999), present a series of choices between two rewards at different delay intervals; participants must select on each of the choices which option they would prefer. Rewards are typically monetary, and are usually hypothetical, but can also be drug rewards when investigating drug user populations (e.g. Coffey, Gudleski, Saladin, & Brady, 2003; Madden, Bickel, & Jacobs, 1999; Odum, Madden, Badger, & Bickel, 2000).

Such pen-and-paper measures utilise hypothetical rewards and delays that the participant does not experience in the laboratory. To address this, 'experiential' tasks have been designed where the participant experiences the reward and delay in the laboratory, including the Single Key- and the Two Choice- Impulsivity Paradigm (Dougherty, Mathias, Marsh, & Jagar, 2005). In the Two Choice Paradigm, the participant is presented with two shapes on a screen. One shape is associated with a smaller point reward available after a short delay, and the other with a larger point reward after a larger delay; rewards and delays are fixed throughout the task (Dougherty et al., 2005). Participants choose between the shapes, receiving their points after the delay. The Single Key Impulsivity Paradigm is a free-operant procedure. Participants are presented with a blank screen and are instructed to click a mouse in return for points. The number of points they receive per click is directly proportional to the period of time they wait between consecutive clicks; a longer delay between clicks indicates preference for a larger (delayed) reward (Dougherty et al., 2005).

Delay of gratification paradigms have been developed in animals, however none are exact analogues of the procedures used in humans (Winstanley, 2011).

Clinical populations show deficits in temporal impulsivity, preferring more immediate gratification on pen-and-paper measures, compared to normal populations. Research has generally found that alcohol dependent individuals (both those currently using and currently abstinent) prefer immediate rewards compared to controls on pen-and-paper tasks (Bjork et al., 2004); this is the case for both hypothetical alcohol (150 bottles and 15 bottles of alcohol) and monetary (£1000 and £100) rewards (Petry, 2001). Further research has found that currently using individuals prefer immediate gratification more than abstinent alcohol dependent individuals do when given a choice between immediate and delayed hypothetical alcohol and monetary rewards (Petry, 2001). There is evidence indicating that both early- and late- onset alcohol dependent individuals prefer more immediate gratification when choosing between hypothetical monetary rewards compared to healthy controls (Joos et al., 2012), other work suggests this is only the case for early- onset alcohol dependent individuals (Dom, D'Haene et al., 2006). The potential differences between early- and late- onset alcohol dependent individuals are a possible reason why some research does not find deficits in non-differentiated dependent subjects (e.g. Kirby & Petry, 2004).

Deficits in temporal impulsivity are also seen in opioid addicts; compared to control participants heroin addicts prefer more immediate rewards when choosing between two hypothetical monetary rewards (Kirby & Petry, 2004; Kirby et al., 1999; Madden, Petry, Badger, & Bickel, 1997). Such deficits are also seen in cocaine abusing populations, when they are presented with hypothetical immediate and delayed monetary rewards (Coffey et al., 2003; Kirby & Petry, 2004; Moeller et al., 2002). Drug using populations have been found to discount relevant delayed drug rewards more rapidly than they do monetary rewards (Coffey et al., 2003; Madden et al., 1999; Odum et al., 2000).

1.1.2.1.1 Processes underlying temporal- impulsivity

The tendency to delay gratification has been discussed from two main viewpoints: a ‘delay discounting’ perspective (Bickel & Marsch, 2001), and a self-regulatory or inhibitory control, perspective (Baumeister & Heatherton, 1996).

‘Delay discounting’ refers to the suggestion that rewards are perceived to lose value as a function of delay. This perspective, grounded in behavioural economics, proposes that the longer the delay, the greater the reduction in its value: an individual, who discounts delayed rewards more steeply, perceives a greater loss on the value of a delayed reward and prefers immediate gratification (Frederick, Loewenstein, & O'Donoghue, 2002; Kirby et al., 1999). Research has found that larger rewards are discounted less rapidly compared to smaller rewards (Petry, 2001). Procedures to assess delay discounting involve the identification of indifference values between the two choices; the indifference point is the point at which the two choices are of equal value to the individual (Reynolds, 2004); delay discounting is best described by a hyperbolic function viewing the devaluation of rewards as proportional to their delay (Bickel & Marsch, 2001; Green & Myerson, 2004). However, there are a number of criticisms of the delay discounting perspective. For example, it is known that monetary rewards associated with delays are also associated with uncertainty; as delay increases, the subjective probability of receiving it is likely to diminish. As a result, it is impossible to differentiate between the role of time, and the role of uncertainty in the discounting of delayed rewards. It is also not possible to account for participants expectations and experiences of inflation, and this confound creates an upward bias in estimates of the discount rate. Predicted income and means in the future could also affect the perceived value of a future reward; a reward may be perceived to be more valuable now because of expected increases in earnings in the future, rather than delay discounting. It has been suggested that purely 'discounting' models of inter-temporal choices should be treated with caution (Frederick et al., 2002).

An alternative explanation is that the desire for immediate reward is innate (an 'impulse') and that self-regulatory processes ('impulse control') must be engaged to resist such an inborn behavioural bias to delay gratification (Baumeister & Heatherton, 1996; Diekhof & Gruber, 2010; Hofmann, Friese, & Roefs, 2009). Whereas the delay discounting literature explains preference for immediate rewards as resulting from a perceived loss in the value of a delayed reward, this body of research suggests that to successfully delay gratification, self-control mechanisms must be exerted to resist desire for immediate reward (Baumeister & Heatherton, 1996; Walter Mischel et al., 2011). It is suggested that individual state and trait differences in self-regulatory strength affect the ability to delay gratification (Baumeister & Heatherton, 1996) and failure to delay gratification represents an inability to wait for reward, i.e. a failure of 'action restraint' (Dalley et al., 2011). Research has found that requiring participants to resist immediate gratification (for example, resist eating available cookies when hungry) depletes subsequent self-control on complex tasks (for example, problem solving tasks), providing support for the suggestion that resisting immediate gratification depletes self-control (Baumeister, Bratslavsky, Muraven, & Tice, 1998).

In addition to individual differences in strength of self-control resources, it has also been suggested that individual differences in reward sensitivity may play a role in the ability to delay gratification (Guerrieri, Nederkoorn, & Jansen, 2008; Guerrieri et al., 2007). Researchers have proposed that individuals make 'maladaptive' decisions because of heightened sensitivity to reward, and that abnormal reward sensitivity may bias towards immediate rewards (Martin & Potts, 2009). Tentative support for this suggestion can be found in the discovery that anhedonic individuals choose large, delayed, rewards over smaller immediate rewards, perhaps due to a reduced sensitivity to immediate rewards (Lempert & Pizzagalli, 2010).

As described, the tendency to delay gratification can be assessed both via pen-and-paper and experiential tasks. It has not yet been fully established whether the same processes are responsible for tendency to delay gratification on different task-types, or whether the tasks correspond to different situations and processes. However, it is known that asking an individual to imagine which of two options they would prefer is different from having them choose and experience the delay and reward (Odum, 2011).

Pen-and-paper measures of temporal- impulsivity typically employ hypothetical monetary rewards (for non-clinical populations); in contrast, experiential tasks use point rewards, which despite not being ‘real’ rewards, are received in the laboratory. There is research suggesting that different reward- types have implications for impulsive responding. Research has found that when real rewards are used on questionnaire measures of delay of gratification, participants show less impulsive responding compared to when hypothetical rewards are used (Hinvest & Anderson, 2009; Madden et al., 1999). Research has also found less consistent responding on questionnaire measures when payoff is subject to chance, for example paradigms where participants would receive one of their choices, compared to when rewards were entirely hypothetical or real (Shamosh et al., 2008). There is also evidence that experiential tasks result in higher levels of impulsive responding (Winstanley, 2011), which may be explained by differences in the delay values. Pen-and-paper measures require participants to make a series of choices between rewards, with delays ranging from days to years. In comparison, experiential tasks use much shorter delays, as the participant experiences them within the laboratory. It is known that more remote outcomes, i.e. rewards at longer delays, are perceived to be less desirable (Odum, 2011).

1.1.2.1.2 Brain regions and neurotransmitters associated with temporal-impulsivity

There is some evidence for a role for serotonin in tolerance to delay of reward in rats (Bizot, Le Bihan, Puech, Hamon, & Thiebot, 1999) and research in humans has recorded an increased preference for immediate gratification under conditions of tryptophan depletion, a means of reducing serotonin function (Schweighofer et al., 2008). However, research does not consistently find evidence of this relationship between serotonin and delay of gratification (Winstanley et al., 2004).

Functional magnetic imaging studies, employing measures of delay of gratification have implicated a series of brain structures including the limbic system and ventral striatum (including the nucleus accumbens), involved in reward and motivation, and the prefrontal cortex, implicated in executive functioning and planning. There is empirical evidence that the greater the negative function interaction between the two systems, the greater the success at delaying gratification (Diekhof & Gruber, 2010; McClure, Laibson, Loewenstein, & Cohen, 2004). Activation in ventral anterior striatum and insula is observed during the choice between immediate and delayed reward options; insula activation is observed at the point of receiving the reward, and greater striatal activation is observed during choice of the immediate option (and also at the point of receiving the reward after waiting through the delay) (Wittmann, Lovero, Lane, & Paulus, 2010).

1.1.2.2 Impulsivity at the point of response execution - 'Motor- Impulsivity'

Not all impulsivity arises during choices between two options. It is also known that there are individual differences in the ability to inhibit a motor response, when that action is not appropriate. In contrast to impulsivity at the point of decision-making, this form of impulsivity ('motor-impulsivity') occurs at the point of response execution, and impulsive individuals are less able to inhibit such a behavioural response (Chamberlain et al., 2007; Chamberlain & Sahakian, 2007; Ramaekers & Kuypers, 2006; Strakowski et al., 2009; Winstanley et al., 2006).

Various behavioural tasks have been developed to measure motor impulsivity in humans, including the Stop Signal (Logan, 1994, 2011; Logan, Schachar, & Tannock, 1997), Go/NoGo and Continuous Performance Task (Broos et al., 2012). These measures involve a Go task, with a secondary Stop task running in parallel; participants must selectively respond to Go stimuli and withhold responses when Stop stimuli are presented. Individuals displaying slow or inaccurate responding to stop signals are labelled as impulsive (Eagle, Baunez et al., 2008). Animal analogues of the Go/NoGo, Continuous Performance Task and Stop Signal tasks have also been developed (Eagle, Bari, & Robbins, 2008; Winstanley et al., 2010).

Alcohol dependant individuals have been found to be impaired on measures of motor impulsivity, exhibiting slow Go reaction times and failing to adjust their reaction times after commission errors on the Stop Signal task (Lawrence et al., 2009a). Both early- and late- onset alcohol dependant individuals have poor inhibitory control on the Stop Signal Task compared to healthy controls, with no difference between late- and early-onset alcoholics (Joos et al., 2012). Detoxified alcohol-dependent adults also show increased commission errors to catch trials on the 'Immediate Memory Task', a version of the Continuous Performance Task, with no increases in omission errors (Bjork et al., 2004).

Cigarette smokers show impaired responding to Stop signals, but no deficits in Go responses on the Go/NoGo task (Luijten, Littel, & Franken, 2011). Crack-cocaine users (with an average use of 3.2 days in the past week, and 14.8 days in the past week) show impairments in inhibitory control on the Stop Signal Task (Mark T. Fillmore & Rush, 2002), however it has been suggested that such impairment may be a by-product of impaired performance monitoring (Li, Milivojevic, Kemp, Hong, & Sinha, 2006). Chronic cocaine users show impaired Stopping on the Go/NoGo task (Hester & Garavan, 2004; Kaufman, Ross, Stein, & Garavan, 2003; Verdejo-Garcia, Perales, & Perez-Garcia, 2007). Methamphetamine abusers exhibit poor inhibitory control on the Stop Signal Task, without any impairment to Go responses (J. R. Monterosso, Aron, Cordova, Xu, & London, 2005). Opiate dependent individuals show slow reaction times to Go stimuli on the Go/NoGo (Fu et al., 2008), current users more so than ex-users when compared to control participants (Constantinou et al., 2010).

1.1.2.2.1 Processes underlying motor- impulsivity

There are two main processes thought to underlie motor impulsivity: action cancellation and action restraint (Dalley et al., 2011; Schachar et al., 2007; Winstanley, 2011; Winstanley et al., 2010). This distinction can be identified from, and indexed by, methodological differences in measures of motor impulsivity.

On each trial Stop Signal tasks present participants with a Go stimulus, to which they must make a quick Go response. On 25% of trials participants are subsequently presented with a Stop stimulus, at a variable delay, to which they must withhold the Go response. Inhibitory control on the task is described as a (horse-) race between independent Go and Stop responses, each activated by their respective Go and Stop stimuli; if the Stop process completes before Go process, then the participant successfully stops; if the Go process finishes first then the participant fails to inhibit their response (Logan, 1994, 2011; Logan et al., 1997). On the task participants must initiate responding to the Go stimulus, but subsequently inhibit the response if the Stop signal is presented. To stop successfully participants must withhold the already activated Go response: only if the Stop process completes before the Go process does the participant successfully inhibit the Go response (Verbruggen & Logan, 2008). This inhibition of an already activated and initiated behaviour, can be termed 'action cancellation', and is an index of ability to 'stop' (Dalley et al., 2011; Winstanley, 2011).

Go/NoGo tasks, and the Immediate Memory Task (a version of the continuous performance task), also present participants with Go and Stop stimuli, however on each trial only one stimulus (either Go *or* Stop) is presented. Participants must respond accordingly to the stimuli.

On the Go/NoGo task, participants are presented with simply Go and Stop stimuli; Go stimuli are more frequently presented, thus priming the Go response. On this task participants must refrain from responding until the Go stimulus is presented; the Go response is not initiated and then cancelled as is the case on the Stop Signal Task. This form of inhibition can be labelled 'action restraint' and is an index of ability to 'wait'; participants must simply refrain from responding until they see the Go signal (Dalley et al., 2011; Winstanley, 2011).

When completing the Go/NoGo task participants refrain from responding until a Go signal is detected, at which point they can simply 'reset' the Go response into a Stop response (Winstanley, 2011). The Immediate Memory Task (Dougherty, Marsh, & Mathias, 2002) is a version of the Continuous Performance task, that also measures 'action restraint' but that requires more complex processing compared to the Go/NoGo. The task is primarily a test of attention, which also taps components of motor-impulsivity (Winstanley et al., 2010). Participants are presented with a series of number strings (each 5 digits long) and must make a Go response whenever a string is identical to the preceding string. The task contains: 'target' trials, where the number string is identical to that in the preceding trial; 'filler' trials, where the number does not match; 'catch' trials, where the number string is almost identical to the preceding trial but differs by one digit. On the Immediate Memory Task commission errors occur when a participant makes a Go response to a catch trial; on these trials it is assumed that the participant has responded prematurely, before fully processing the sequence. The Immediate Memory Task therefore also requires ‘action restraint’, but, compared to the Go/NoGo, participants must process the trial and cannot simply ‘reset’ to a Stop response (Winstanley, 2011). The animal analogue of the Immediate Memory Task is the 5-Choice Serial Reaction Time Task (5-CSRTT). The 5-choice also indexes premature responding; on the task animals are required to respond to a stimulus that can occur in one of five locations, (premature) responding before the stimulus appears is identified as impulsivity (Winstanley et al., 2010).

In addition to stopping and waiting processes, it is known that the speed/accuracy considerations also have implications for motor- impulsivity. Measures of inhibitory control require a trade-off between fast responding to Go stimuli, with stopping response to a small number of Stop trials running in parallel (Logan, 1994). Successful responding to Go stimuli (fast responding) is thought to imply failure on the stop task (failed inhibition to a Stop stimulus); successful Stopping implies failure on the go task (slow responding) (Verbruggen & Logan, 2009b).

1.1.2.2.2 Brain regions and neurotransmitters associated with motor-impulsivity

Different neurotransmitters have been found to contribute to action restraint and action cancellation processes. It is thought that serotonin may play an important role in action restraint, whereas noradrenaline may be important in action cancellation (Eagle, Bari et al., 2008; Winstanley et al., 2010). Studies of the effect of tryptophan depletion in humans, as a means of reducing serotonin function, support the suggestion that serotonin is not a central neurotransmitter in Stop Signal responding (Clark et al., 2005).

While research has implicated different neurotransmitters in action restraint and cancellation, functional magnetic imaging studies, employing the Stop Signal, as a measure of action cancellation, and Go/NoGo, as action restraint, have suggested a series of networks common to both tasks. The networks include prefrontal cortical regions (within the inferior frontal cortex and dorsolateral prefrontal cortex), the basal ganglia and the premotor cortex (the supplementary motor area and pre-supplementary motor area) (Aron, 2007; Aron, Behrens, Smith, Frank, & Poldrack, 2007; Chambers, Garavan, & Bellgrove, 2009; Li, Huang, Constable, & Sinha, 2006; Eagle, Bari et al., 2008).

1.1.2.3 Impulsivity at the point of decision-making - 'Reflection- Impulsivity'

Current understanding of impulsivity differentiates between motor impulsivity at the point of response execution, and impulsivity at the point of decision-making (cognitive-impulsivity) (Congdon & Canli, 2008; M. Field et al., 2008; Fineberg et al., 2010; Pattij & Vanderschuren, 2008; Winstanley et al., 2010).

Failures in delaying gratification are typically discussed as impulsive decision-making and it is known that impulsive individuals prefer smaller, more immediate rewards (J. M. Mitchell, Fields, D'Esposito, & Boettiger, 2005). However, there is some suggestion of an additional facet of impulsivity at the point of decision- making, encompassing risk- and uncertainty- based decisions (Winstanley et al., 2010).

There is a large body of research investigating decisions between a conservative option and a more risky option; such decisions can be investigated via gambling tasks (Bechara, Damasio, Damasio, & Anderson, 1994; Verdejo-García et al., 2008; Winstanley et al., 2010).

One of the most widely used gambling tasks is the Iowa Gambling Task (Bechara et al., 1994)**.** On this task participants are presented with four decks of cards. They are instructed that they have a £2000 loan, and that they must make a series of selections from the decks of cards in front of them to maximise profit on this loan. For each card selected the participant receives money, on some trials they also receive a penalty. The value of the money won and lost is only revealed once a deck has been selected. Choice of a card from deck A and deck B yields a reward of £100; choice of deck C or D yields £50. However, the ultimate future yield is greater for decks C and D; despite these being the ostensibly lower-paying decks, the penalty amounts are higher for decks A and B, thus incurring an overall net loss if the participant consistently chooses them.

Gambling Tasks have been proposed to measure decision-making under conditions of risk and are also thought to reflect decision-making under initially ambiguous conditions (Dannon, Shoenfeld, Rosenberg, Kertzman, & Kotler, 2010). However, the tasks are complex, requiring multiple cognitive processes including learning to sacrifice immediate rewards in favour of long-term gain (participants must choose the ostensibly 'smaller' reward, rather than the 'larger' reward if they are to avoid a net loss on the task) (Dannon et al., 2010) It is thought that insensitivity to punishment and future consequences, as well as increased sensitivity to reward may play a role in performance on gambling tasks (Bechara et al., 1994).

It is unclear whether performance deficits on gambling tasks necessarily indicate impulsivity (Verdejo-García et al., 2008). However the tasks do include components of decision-making under (initially) ambiguous circumstances; decisions under these circumstances can be directly indexed by measures of 'reflection'- impulsivity.

Not all impulsive decisions are based on a choice between two outcomes at different time points; in everyday life we also encounter situations where a decision is required, but where there are several possible alternative solutions and there is some uncertainty as to which is correct (J. Kagan, 1965a, 1965b; J. Kagan, Rosman, Day, Albert, & Phillips, 1964). In these situations there is a choice between spending less time gathering and evaluating information, resulting in fast but inaccurate responding, or opting to wait and gather more information, thus delaying the decision process (J. Kagan et al., 1964; C. Mitchell & Ault, 1979).

Research has found that individuals differ in this tendency to gather and evaluate information before making a decision in such situations, and can be classified as impulsive or reflective based on this disposition ('reflection-impulsivity'). It is known that impulsive individuals fail to reflect, or acquire enough information, before deciding on a solution. When first introduced, reflection- impulsivity was one of the most intensively studied constructs in developmental literature (Laine, 1982), however in adult psychopathology, it has received comparatively limited attention (Clark et al., 2006). Research has found that impulsive children perform poorly at school, have poor reading ability, and are more likely to be diagnosed with behavioural and psychological issues compared to reflective children (Messer, 1976).

The Matching Familiar Figures Task (J. Kagan et al., 1964) and the Information Sampling Task (Clark et al., 2006; Clark et al., 2003; Clark, Roiser, Robbins, & Sahakian, 2009) are the two main measures of reflection impulsivity. Both tasks require participants to answer a problem, allowing them to acquire as much or as little information as they wish before deciding on a solution. One animal analogue of the task has been developed, to investigate this subtype in rats, although it is unlikely the task is entirely analogous to human models. The animal is trained that a light signal indicates the availability of food if one of two levers is pressed. The task then presents the animal with a light that has a 50% likelihood of indicating the correct lever, if the animal waits to respond the likelihood of the light predicting the correct lever increases to 100%. On the task quick responding is associated with more errors (J. L. Evenden, 1999a).

Clinical populations display a tendency to make premature decisions. Alcohol dependant individuals show increased impulsivity on the Information Sampling Task, sampling less information before making a decision and tolerating more uncertainty (Lawrence et al., 2009a, 2009b). Further research has found that late- (but not early-) onset alcohol dependant individuals show increased reflection impulsivity on the task, compared to healthy controls, with no significant difference between early- and late-onset alcoholics (Joos et al., 2012).

Recreational drug users of cannabis (using at least twice/month for 6-12 months) show increased reflection impulsivity, on the Information Sampling Task, compared to control participants and alcohol users (Solowij et al., 2012); research has also found elevated impulsivity in cannabis users on the task (Clark et al., 2009). Ecstasy users (current and ex users) have higher impulsivity scores on the Matching Familiar Figures compared to those of drug-naïve controls and poly-drug controls (Morgan, Impallomeni, Pirona, & Rogers, 2006; Morgan, McFie, Fleetwood, & Robinson, 2002) but do not show impairment on the Information Sampling Task (Clark et al., 2009). Current amphetamine user, opiate users and ex-users of both drugs are more impulsive on the fixed win condition of the Information Sampling Task compared to drug-naïve controls (Clark et al., 2006).

1.1.2.3.1 Processes underlying reflection- impulsivity

Reflection- impulsivity refers to the tendency to reflect upon alternative-solution possibilities. It is suggested that impulsive individuals fail to gather and evaluate on enough, systematic, information (Messer, 1976; Zelniker & Jeffrey, 1976). However, the Matching Familiar figures and Information Sampling Tasks quantify this by different means and thus the two measures have subtly different underlying processes.

The Matching Familiar Figures indexes tendency to reflect on information by measuring latency from initial presentation of the problem to making an initial decision. Time to making a response is considered a measure of the quantity of information gathered and evaluated; shorter latencies are related to more errors (J. Kagan, 1965b). Specifically the combination of fast/inaccurate responding is identified as impulsive and slow/accurate responding is identified as reflective (J. Kagan, 1965b). The validity of the Matching Familiar Figures Task rests on the assumption that longer latencies are indicative of using that time to evaluate the available information (J. Kagan, 1965b).

However, the task is known to be dependent on multiple, potentially confounding, processes including field dependence/independence, i.e. tbe ability to separate a relevant item from its surrounding context (C. Evans, Richardson, & Waring, 2013), working memory, attention, and visual search (Clark et al., 2006; Messer, 1976; Zelniker & Jeffrey, 1976). Research has not been able to establish whether longer latencies are related to increased evaluation of the information provided; early research suggesting that reflective children devote more time to scanning the available information on the Matching Familiar Figures (Siegelman, 1969) has not been replicated (e.g. Ault, Crawford, & Jeffrey, 1972; Drake, 1970; Zelniker, Jeffrey, Ault, & Parsons, 1972). It has also been noted that the Matching Familiar Figures has considerable overlap with information processing styles (Southgate, Tchanturia, & Treasure, 2008), and that reflective and impulsive individuals differ in the extent to which they analyse complex visual stimuli; research has found that reflectives pay more attention to tasks requiring detail, compared to impulsives who focus on global information (Zelniker et al., 1972). The outcome is that it is difficult to identify whether impulsive behaviour on the Matching Familiar Figures represents a lack of reflection, or, for example, simply an ineffective processing style.

In an effort to circumvent these issues, the Information Sampling Task is designed to provide a *primary* index of information sampling, measuring the tendency to acquire information before making a decision (Clark et al., 2006). The task takes an index of the actual volume of information the individual acquires, thus circumventing the need to infer this from the latency to making a response. The task requires participants to make a decision as to which of two colours is in the majority in a screen of 25 grey boxes. Participants can acquire as much information as they wish by opening the boxes, and revealing the colour underneath, until they are ready to make a decision. The task provides information about the number of boxes the participant opens. However, depending on the configuration of the colours underneath, opening the same number of boxes can give varying levels of information; for example, opening ten boxes could reveal five of each colour, or ten of one colour – the latter would provide considerably more information on which colour is in the majority. Therefore, in addition to recording the number of boxes opened, the task also gives a measure of the probability of being correct that the participant will tolerate before making a decision; a higher tolerance for uncertainty indicates impulsivity. The task clearly displays the sampled information on-screen until a decision is made, thus removing demands on working memory (Clark et al., 2006; Huddy et al., 2013). The information provided for the decision is visually simple, removing demands on complex processing and evaluation of material.

It is known that speed/accuracy trade-offs are related to reflection- impulsivity on the Matching Familiar Figures Task as fast (and inaccurate) responding is indicative of impulsivity (J. Kagan, 1965b). However, it is unclear whether bias to fast (rather than accurate) responding is a cause or consequence of impaired reflection. In the case of the latter - fast responding as an artefact of reduced reflection - then a fast response is made because the individual does not reflect before making a decision. However, in the case of the former, an individual fails to reflect because they prioritise fast responding (for example, because of strategic concerns such as wishing to terminate the task quickly). The Information Sampling Task is designed with an inter-trial interval so that each trial lasts at least 30 seconds, if the participant makes an early decision they must wait until the commencement of the next trials. This circumvents some of the overt issues arising in the Matching Familiar Figures: participants cannot rush through the task, thus potentially avoiding strategic fast responding as a cause of reduced reflection.

Despite differences in the confounding processes related to performance on the two tasks, it is proposed that both tasks measure the same fundamental underlying process. The association between the volume of information sampled, and errors made, is a key criteria of ‘reflection- impulsivity’, and on both tasks the number of errors made is related to the volume of information sampled: less information sampling results in increased errors (Clark et al., 2006). However, it is also evident that the measure of information sampled differs between the tasks: latency on the Matching Familiar Figures and tolerance of uncertainty on the Information Sampling.

1.1.2.3.2 Brain regions and neurotransmitters associated with reflection-impulsivity

There is only very limited research employing measures of reflection- impulsivity to explore associated brain regions and neurotransmitters. There is some suggestion that serotonin may play a role in tendency to reflect (J. L. Evenden, 1999a), however the neural pathways have not been fully established (Pattij & Vanderschuren, 2008).

1.2 Issues with current understanding of impulsivity

It is apparent that impulsive populations display a failure to gather and evaluate adequate information, prefer immediate gratification and are impaired in their ability to inhibit motor responses. Each of these phenomena can be labelled as types of impulsivity: ‘motor’- impulsivity as an inability to inhibit a behavioural response; ‘reflection’- impulsivity as a tendency to make decisions without gathering or evaluating necessary information; ‘temporal’- impulsivity as a failure to delay gratification. Reflection- and temporal- impulsivity occur at the point of decision making, and can collectively be referred to as ‘cognitive impulsivity’, compared to motor impulsivity occurring at the point of response execution (M. Field et al., 2008; Fineberg et al., 2010).

However, it is clear that this range of behaviours and processes is very diverse and the term ‘impulsivity’ refers to three very different behavioural outputs according to the motor-, temporal- and reflection- perspectives. There is growing evidence that the factors of impulsivity have differing individual, as well as combined, effects on drug initiation, escalation and dependence, highlighting the importance of understanding and measuring different types of impulsivity. For example, temporal- impulsivity (on a hypothetical monetary reward questionnaire), but not motor- impulsivity on the Stop Signal Task, has been found to predict both alcohol use and alcohol pathology in a sample of (self-identified) problem drinkers, using structural equation modelling (Courtney et al., 2012).

It has been suggested that the different types of impulsivity are mediated by dissociable, but converging, underlying processes (P. G. Enticott & Ogloff, 2006; J. Monterosso & Ainslie, 1999; Winstanley et al., 2004). However, there is some disagreement as to whether they are sub-facets of one construct or unique constructs in their own right.

It is clear that if we are to merit all of these behaviours with the label 'impulsivity', we must establish whether they are fundamentally sub-facets of one construct. Within behavioural research, the means to establishing this are twofold:

First the points of convergence in the underlying processes must be determined across subtypes; it should be established whether there are individual processes responsible for deficits across *all* subtypes of impulsivity, or whether the underlying processes are discreet between subtypes. Further from this, it can be identified whether there are stable dispositional and demographic factors that contribute to different types of impulsivity.

In addition, the factor structure of impulsivity must be explored, using factor analysis protocols, to identify whether the different subtypes are ultimately one facet of behaviour, or whether multiple facets are identifiable. Factor analysis can also confirm whether multiple measures of different types of impulsivity (for example, questionnaire and experiential measures of temporal- impulsivity) do index the same underlying processes.

1.3 Establishing the points of convergence between subtypes

There are two potential points of convergence between subtypes in the processes discussed thus far: (i) impairments in speed/accuracy biases, relevant for reflection- (J. Kagan, 1965a) and motor- (Verbruggen & Logan, 2009b) (ii) impairments in inhibitory control of behaviour, relevant for motor- (Logan et al., 1997) and temporal- impulsivity (Diekhof & Gruber, 2010). It is important to note that this is not an exhaustive list of the processes underlying impulsivity; additional processes including, for example, allocation of attentional resources (de Wit, 2009; Scott J Dickman, 1993; Ortner, MacDonald, & Olmstead, 2003) and deficits in time perception (Wittmann & Paulus, 2008) have also been suggested.

1.3.1 Imbalances in speed/accuracy trade-offs

Early opinion on impulsivity took the viewpoint that impulsivity reflects an imbalance in speed-accuracy trade-offs, with a persistent bias to making a quick response, to the detriment of accuracy (S. J. Dickman & Meyer, 1988). It is known that a trade-off between speed and accuracy is adaptive when individuals are able to adjust responding based on individual circumstances: favouring speed over accuracy can be useful in contexts where quick responses have more value than errors, and vice versa (Mulder et al., 2010), however persistent bias to fast response is considered maladaptive.

The speed/accuracy trade-off has implications for motor- impulsivity. The Stop Signal Task, the primary measure of motor impulsivity, has been conceptualised as a trade-off between speed of responding, and caution to ensure successful inhibition of response (Bissett & Logan, 2011; Leotti & Wager, 2010). The task requires a trade-off between fast responding to Go stimuli, with stopping to a small number of Stop trials running in parallel (Logan, 1994); successful responding to Go stimuli (fast responding) implies failure on the stop task (failed inhibition to a Stop stimulus); successful Stopping implies failure on the go task (slow responding) (Verbruggen & Logan, 2009b). It has been found that instructions to respond quickly to Go stimuli on the Stop Signal task induce more inhibition errors to Stop signals, more Go errors and faster Go responses, compared to instructions for correct inhibition of Stop responses (A. Jones, Cole, Goudie, & Field, 2011; A. Jones, Guerrieri et al., 2011). In addition participants following instructions for speed on the Stop Signal Task display disinhibited behaviours post-task, seen in increased alcohol and food intake (Guerrieri, Nederkoorn, Schrooten, Martijn, & Jansen, 2009; A. Jones, Cole et al., 2011; A. Jones, Guerrieri et al., 2011).

The trade-off between speed and accuracy also has implications for reflection-impulsivity. The Matching Familiar Figures Task (J. Kagan, 1965a) categorises participants as impulsive based on the tendency to prioritise speed over accuracy (S. J. Dickman & Meyer, 1988). However, it is unclear whether the Information Sampling Task is also dependent on the trade-off as the task is designed to provide a primary index of information sampling, rather than a composite speed-accuracy score (Clark et al., 2006; Clark et al., 2003; Clark et al., 2009).

It is evident that the speed-accuracy trade-off has implications for motor- and reflection-impulsivity; however it is less clear whether speed/accuracy imbalances also have implications for delay of gratification.

1.3.2 Inhibitory control

A major topic of discussion is whether impulsivity can be attributed to decreased top-down processing, or increased bottom-up activation (Perales et al., 2009). It has been hypothesized that motor- and temporal- impulsivity results from reduced inhibitory control (Peter G. Enticott, Ogloff, & Bradshaw, 2006; Perales et al., 2009).

When investigating the relationship between impulsivity and inhibitory control, it is evident that the concept of motor impulsivity and behavioural inhibition are antipodes (opposite to one-another), sharing definitional features (Bickel et al., 2012). Failures in behavioural inhibition result in motor impulsivity, and the Stop Signal Task and Go/NoGo tasks are employed both as a measure of inhibitory control, and as a measure of motor impulsivity (Logan, 1994; Miyake et al., 2000; Ray Li, Yan, Sinha, & Lee, 2008).

It has been popularly suggested that a form of 'self'- control is also necessary to successfully delay gratification, that to resist an immediate reward self-regulatory processes must be engaged (Baumeister & Heatherton, 1996; Diekhof & Gruber, 2010). Experimental examples of this relationship are, for the most part, tenuous. Research finding that requiring participants to resist immediate gratification (for example, resist eating available cookies when hungry) depletes subsequent perseverance on complex tasks (for example, problem solving tasks), has been interpreted as providing support for the suggestion that resisting immediate gratification depletes self-control capacities (Baumeister et al., 1998).

The 'self-control' challenged in such studies is largely undefined, and so is difficult to manipulate experimentally and systematically; therefore, a working definition of inhibitory control is required. As with 'impulsivity', there are multiple ways of conceiving and defining inhibitory control (e.g. see Harnishfeger, 1995; Nigg, 2000). Behavioural inhibition refers to three interrelated processes: (i) inhibition of a pre-potent response to an event (ii) stopping of an on-going response, thus permitting a delay in the decision to respond, and (iii) the protection of this period of delay from interference by competing events and responses ('interference control') (Barkley, 1997). Behavioural inhibition and interference control can be categorised as types of 'Executive inhibition' (Nigg, 2000). As discussed, behavioural inhibition has implications for motor- impulsivity (Logan, 1994; Miyake et al., 2000; Ray Li et al., 2008) and it has also been suggested that this form of inhibitory control may have implications for temporal- impulsivity. It has been suggested that inhibition of an initial response, provides a necessary delay in the decision process, allowing successful self-regulation and controlled responding (Barkley, 1997), i.e. that inhibitory control allows the suppression of rapid responses and reflexes to allow slower cognitive mechanisms to guide behaviour (Taylor & Jentsch, 1999).

The few studies that have tested the reliance of cognitive impulsivity on inhibitory control have found mixed results. Petry (2001) has suggested that successful delayed discounting (temporal impulsivity) requires engagement of executive functions, including inhibition, in order to prevent impulsive responding. Another study found that a high working memory load, which challenges inhibition, increased temporal impulsivity, resulting in greater discounting of delayed rewards (Hinson & Whitney, 2006). However, a more recent study has suggested that challenging executive functions does not necessarily increase temporal- impulsivity, instead simply increases the number of inconsistent choices (Franco-Watkins, Rickard, & Pashler, 2010).

The relationship between inhibitory control and reflection impulsivity, as a second form of cognitive- impulsivity, remains unexplored.

1.4 Impulsivity and stable demographic and dispositional factors

While inhibitory control mechanisms and speed/accuracy biases can be affected transiently, research has also found that stable demographic and dispositional factors, including age and IQ, affect certain types of behavioural impulsivity.

1.4.1 Impulsivity and intelligence

There is evidence that intelligence has implications for cognitive-impulsivity (S.D. Lane, Cherek, Rhoades, Pietras, & Tcheremissine, 2003) however there is no empirical evidence of a relationship between intelligence and motor-impulsivity (Friedman et al., 2006; Logan, 1994).

Intelligence is associated with ability to delay gratification (temporal- impulsivity); individuals with higher intelligence display a reduced preference for smaller immediate rewards, over larger delayed rewards. However, there is evidence that the nature of testing the tendency to delay gratification has implications for this relationship; the relationship between IQ and delay of gratification is reduced in studies where the payoff is subject to chance, for example paradigms where participants would receive one of their choices, compared to when rewards were entirely hypothetical or real (Shamosh et al., 2008).

Research finding a relationship of intelligence to reflection- impulsivity is inconsistent. On the Matching Familiar Figures Task, decision time (latency to the first response made on each trial) and number of errors are recorded. While it was originally suggested that decision time is unrelated to intelligence (J. Kagan et al., 1964), there is evidence that high IQs are related to longer decision times on the task (e.g. Eska & Black, 1971) and the strength of this relationship between Matching Familiar Figures latency and IQ has been found to vary between studies (Block, Block, & Harrington, 1974). There is a consistent negative relationship between errors on the task and IQ (Block et al., 1974). In children, errors correlate with performance IQ (as measured by the Wechsler Intelligence Scale for Children) (Plomin & Buss, 1973) and mental abilities (Eska & Black, 1971). However, there is some additional research suggesting that IQ does not correlate with performance on the Matching Familiar Figures (Helmers et al., 1995; Larsen, 1982) and it has been suggested that different types of intelligence may be associated with performance on the task; IQ tests focusing on *verbal* skills are less correlated with Matching Familiar Figures than those indexing nonverbal skills (Eska & Black, 1971).

Despite evidence of a relationship between temporal- impulsivity and intelligence, and some evidence of such a relationship with reflection- impulsivity, motor- impulsivity, as indexed by the Stop Signal Task, does not seem to be related to general intelligence (Logan, 1994).

1.4.2 Impulsivity and age

Investigators have found that motor- impulsivity changes throughout the life span (Logan, 1994). On the Stop Signal task, inhibitory control improves through childhood, and then slightly diminishes through adulthood; responding to Go stimuli also becomes faster throughout childhood, and then slows through adulthood (B. R. Williams, Ponesse, Schachar, Logan, & Tannock, 1999). It is known that young children are less accurate on the Stop Signal Task, requiring action cancellation, compared to the Go/NoGo (Johnstone et al., 2007). On the Go/NoGo there are no age related improvements in inhibitory control (Johnstone et al., 2007).

In young children reflection- impulsivity, according to the Matching Familiar Figures Task, decreases with age (J. Kagan et al., 1964), however in older adults, aged 60-79, there are no age-related changes (Larsen, 1982).

Findings on the effects of age on temporal- impulsivity are less consistent. It has been found that preference for small immediate rewards reduces through the life-span (Green, Fry, & Myerson, 1994) but also that there are no age related differences in delay of gratification in adults (Green, Myerson, Lichtman, Rosen, & Fry, 1996). It appears that income plays a deciding role; when income is held constant, discounting rates decrease with age (Green et al., 1996).

1.5 The factor structure of impulsivity

In addition to exploring the converging processes underlying impulsive behaviour, the relationships between measures and types of impulsivity need to be established. Correlational and factor-analytical studies provide insight into whether the different types of impulsivity should be treated as distinct constructs, or whether there are significant relationships between subtypes.

Correlational research can explore the relationships between subtypes. It is important to establish whether individuals self-reporting high levels of impulsivity also show increased impulsivity on behavioural tasks, and also whether high impulsivity in one subtype is consistently related to high levels of impulsivity on another. A lack of correlations between subtypes suggests that the facets of impulsivity may be distinct from one another.

Factor analysis studies can establish whether tasks measuring different facets of impulsivity load onto one factor, or whether multiple factors of impulsivity emerge. The data analysis method can also confirm the validity of using multiple measures to investigate the same underlying construct. As introduced, several measures have been designed to index each type of impulsivity, and the validity of using these multiple tasks needs to be investigated. For example, it is known that the Matching Familiar Figures is subject to additional, confounding, processes when compared to the Information Sampling Task (Clark et al., 2006) and it should be confirmed that these two index the same primary process.

1.5.1 Relationships between impulsivity measures

1.5.1.1 Relationships between self-report questionnaires and behavioural tasks

Despite the use of both self-report and behavioural tasks to index impulsivity, research suggests that these two types of measures are not homogenous (Dick et al., 2010) and there is little consistent evidence to suggest that self-report measures correlate with behavioural measures (e.g. Reynolds, Penfold, & Patak, 2008).

Investigators have found that questionnaire measures correlate with one another, both within subscales of the same instruments and between instruments (S.D. Lane et al., 2003; Reynolds, 2006; Reynolds et al., 2008). There is also some very limited evidence that questionnaire measures can correlate with behavioural tasks: self-report impulsivity has been found to correlate with motor impulsivity on the Go/NoGo task (Aichert et al., 2012; Reynolds, Ortengren, Richards, & de Wit, 2006) and Immediate Memory task (Marsh, Dougherty, Mathias, Moeller, & Hicks, 2002). Investigators have also found nonplanning impulsivity on the Barratt Impulsiveness Scale to be a significant predictor of delay discounting (de Wit, Flory, Acheson, McCloskey, & Manuck, 2007).

However, the Barratt Impulsiveness Scale does not consistently correlate with behavioural measures, including motor impulsivity tasks (the Stop Signal and Go/NoGo task), delay of gratification tasks and risk taking tasks (balloon analogue risk task) (S.D. Lane et al., 2003; Lansbergen, Schutter, & Kenemans, 2007; Reynolds, Ortengren et al., 2006; Reynolds et al., 2008).

These studies suggest a distinction between self-report and behavioural measures of impulsivity, suggesting that they perhaps index different elements of impulsivity. A number of explanations for the discrepancy between these measures have been proposed (Dougherty et al., 2005). It has been suggested that self-report and behavioural tasks may reflect trait and state impulsivity respectively. It is thought that self- report questionnaires assess stable trait individual differences, and reflect established cognitive and affective processes; compared to this behavioural tasks measure state impulsivity, i.e. relatively specific cognitive processes, and are more dependent on transient changes in, for example, inhibitory control resources (Bjork et al., 2004; Dick et al., 2010; Dougherty, Marsh-Richard, Hatzis, Nouvion, & Mathias, 2008). Other explanations suggest that confounding processes may be the cause of the discrepancy between the questionnaires and laboratory tasks; for example, an individual who perceives himself as being impulsive may attempt to compensate for this in the laboratory (Wingrove & Bond, 1997), and it is also thought that questionnaire measures are subject to bias from self-awareness (Helmers et al., 1995).

1.5.1.2 Relationships between behavioural tasks

From the above, it is evident that self-reports of high impulsivity do not necessarily correspond to increased impulsivity in the laboratory. Further research is also required to investigate whether performance on behavioural measures correlates between tasks. Studies investigating the relationships of the subtypes to one another are few. For the most part studies applying multiple measures typically find correlations between dependent variables of a task and also find relationships between tasks within a subtype (for example, multiple measures of motor- impulsivity) (e.g. Broos et al., 2012; Dougherty et al., 2009). However relationships between subtypes are not uniformly found (de Wit, 2009).

There is evidence to suggest that performance on tasks ‘within’ subtypes of impulsivity correlates. Tasks measuring motor impulsivity have been found to correlate with one another; Dougherty et al (2009) found small but significant correlations between performance on the Immediate Memory Task and the GoStop; Reynolds et al (2006) found participants with longer Stop reaction times on the Stop task made more commission errors on the Go/NoGo. Measures of temporal impulsivity (hypothetical pen-and-paper measures and an experiential task) have also been found to correlate with one another (Reynolds et al., 2008).

However, there is little evidence that tasks correlate with one another across subtypes. There is no correlation between pen-and-paper, and experiential, measures of temporal-impulsivity, and measures of motor impulsivity (Broos et al., 2012; Dougherty et al., 2009; Reynolds, Ortengren et al., 2006; Reynolds et al., 2008). There is also no correlation between the Matching Familiar Figures, as a measure of reflection impulsivity, and measures of motor impulsivity (Messer, 1976).

Together these studies provide preliminary evidence for well-defined subtypes of impulsivity that are distinct from one another. It appears that multiple measures within the different subtypes (for example measures of motor- impulsivity) are related to one another, however there is no evidence of relationships between tasks indexing different subtypes. The lack of relationship between subtypes suggests that the facets of impulsivity are well differentiated.

1.5.2 Studies attempting to identify a factor structure of impulsivity

A small number of studies have attempted to map the different subtypes of impulsivity, in healthy individuals, using factor analysis and principal component analysis (e.g. Malle & Neubauer, 1991). These studies predominantly find distinct factors of self-report and behavioural impulsivity. Within behavioural impulsivity, further support is found for the suggestion of two distinct factors of temporal- impulsivity and motor-impulsivity. It is important to note that hitherto no factor analysis studies have included measures of reflection impulsivity.

It has been suggested that self-report and behavioural impulsivity should be grouped into separate domains (Malle & Neubauer, 1991). Using principal components analysis on a sample of healthy young adults (aged 18-30), Malle and Neubauer (1991) found that self-report impulsivity and the Matching Familiar Figures load onto separate factors; these results provide support for the suggestion that reflection-impulsivity is separate from self-report impulsivity. In another sample of healthy adults (mean age 21.9 years) Havik and colleagues (2012) found self-report impulsivity, as measured by the Adaptive and Maladaptive Impulsivity Scale, to load separately from the Stop Signal Task as a measure of motor- impulsivity. In a large sample of 176 participants, including healthy individuals, individuals with a family history of alcoholism, and former and current cocaine users, Meda and colleagues (2009) found that self-report impulsivity, on the Barratt Impulsiveness Scale, and delay of gratification on a behavioural real-time task, load onto separate factors. Studies by Lane et al (2003) and Broos et al (2012) found the Barratt Impulsiveness Scale to load separately both from measures of motor-impulsivity (the Stop Signal Task and Immediate Memory Task) and temporal- impulsivity. Together these studies provide further support for the suggestion that self-report impulsivity is distinct from the impulsivity indexed by behavioural tasks.

To explore the relationships and distinctions between measures of state impulsivity, studies applying multiple behavioural measures of impulsivity are required. Such studies provide insight into whether behavioural subtypes of impulsivity are distinct from one another. Broos and colleagues (2012) applied the Immediate/Delayed Memory Task, the Stop Signal Task and a Delayed Discounting Task that employed hypothetical monetary rewards to a group of healthy young adults (mean age 21.2 years). The results indicated two separate constructs of behavioural impulsivity using principal component analysis. The first factor represented motor- impulsivity; this consisted of performance on the Immediate Memory Task/Delayed Memory Task and on the Stop Signal Task; the second factor was found to represent temporal- impulsivity on the Delay Discounting Task, and had a negative loading of the Stop Signal Task. This study supports the distinction between motor- and cognitive- impulsivity.

Lane and colleagues (2003) applied principal components analysis to five measures of impulsivity in a small sample of 32 healthy males aged 18-40. Analysis indicated one component with high positive loadings on the temporal- impulsivity tasks (self-control choice, experiential delay discounting and hypothetical delay discounting) and negative loadings on the motor-impulsivity tasks (Immediate Memory Task and the Response Inhibition task, in which participants must modify an initially fast response to a delayed response). A second component had high positive loadings on the response inhibition tasks and low loadings on the delay of gratification tasks.

Reynolds et al (2006) found behavioural tasks to load onto two components: ‘behavioural disinhibition’ (motor-impulsivity) (Stop Signal and Go/NoGo tasks) and ‘impulsive decision making’ (cognitive- impulsivity; delay discounting task and balloon analogue risk task) in a sample of healthy young adults (mean age 22.9 years).

Taken together these studies provide evidence for motor- and temporal- impulsivity as being distinct subtypes; they indicate that measures of temporal- impulsivity load separately from measures of motor- impulsivity.

However, there is also evidence that tasks thought to measure one subtype, can, in fact, load onto separate factors. For example, Dougherty and colleagues (2009) conducted a factor analysis on the Immediate Memory Task /Delayed Memory Task, the Go Stop task and the Two Choice Impulsivity Paradigm in a sample of healthy adults, and found them to load onto 3 distinct factors; each factor consisted of the dependent variables for a single task. They concluded that there are at least 3 factors of behavioural impulsivity, and did not find the Immediate Memory Task and Go Stop to load onto one ‘motor impulsivity’ factor. Reynolds and colleagues (2008) studied a sample of adolescents (mean age 15.29 years) and incorporated more measures of impulsivity to find three behavioural dimensions: "impulsive decision-making" (cognitive- impulsivity; question based delay discounting measure, question based probability discounting measure and experiential discounting task), "impulsive inattention" (experiential discounting latency to bank rewards, continuous performance task omissions and commissions) and "impulsive disinhibition" (GoStop). In this study impulsive decision making was found to load onto a distinct factor, however tasks thought to index ‘motor- impulsivity’ loaded onto two separate factors. These two studies provide preliminary evidence that further categorisations of impulsivity are required.

1.6 Conclusions

Current research views impulsivity as consisting of several dissociable subtypes of behaviour (J. L. Evenden, 1999b). Trait impulsivity can be assessed with self-report measures (Stanford et al., 2009) compared to ‘behavioural’ impulsivity (a term we use to refer to both cognitive- and motor- impulsivity) which is typically assessed via laboratory paradigms. Within the behavioural impulsivity literature, a distinction has been proposed between cognitive- impulsivity and motor- impulsivity (Bechara, Damasio, & Damasio, 2000; Congdon & Canli, 2008) and three primary subtypes of impulsivity have been suggested: motor-impulsivity, which occurs at the point of response execution, and temporal- and reflection- impulsivity, as types of cognitive-impulsivity, (Fineberg et al., 2010; Winstanley et al., 2010).

Motor- impulsivity is the inability to inhibit a response when that behaviour is no longer appropriate (Strakowski et al., 2009). ‘Temporal- impulsivity’, is the tendency to delay gratification and the preference to choose small immediate rewards over large(r) delayed rewards (Richards, Zhang, Mitchell, & de Wit, 1999). Reflection- impulsivity refers to the tendency to make premature decisions under conditions of uncertainty (J. Kagan, 1965a, 1965b). Correlational and factor analysis research suggests that these subtypes are well-defined and differentiated from one another (e.g. Broos et al., 2012). Various processes have been proposed as underlying the different subtypes; these processes include availability of behavioural inhibitory control resources, thought to have particular relevance for motor- (e.g. Logan et al., 1997) and temporal- impulsivity (e.g. Diekhof & Gruber, 2010), and biases for speed or accuracy, relevant for motor- (e.g. Bissett & Logan, 2011; Leotti & Wager, 2010) and reflection- (S. J. Dickman & Meyer, 1988) impulsivity.

Current impulsivity research is hampered by the tendency of different researchers to adopt different definitions of impulsivity (J. Evenden, 1999) and multiple measures are rarely simultaneously administered to participants (Dougherty et al., 2005). However, there is unanimous agreement that a better understanding is needed of the factor structure of impulsivity (Reynolds, Ortengren et al., 2006) to help us separate impulsivity per se, from behaviours influenced by impulsivity (J. L. Evenden, 1999b). Furthermore, it is thought that there are converging processes underlying types of impulsivity (Peter G. Enticott et al., 2006; J. L. Evenden, 1999b; Pattij & Vanderschuren, 2008; Winstanley et al., 2006), and further research is needed to explore these.

Studies investigating the relationships of the subtypes to one another are few. Those that do exist do not uniformly find relationships *between* subtypes (de Wit, 2009). However, for the most part studies applying multiple measures typically find correlations between dependent variables of a task (for example the two versions of the Immediate Memory Task (Broos et al., 2012) and there is evidence to suggest that tasks 'within' subtypes of impulsivity correlate with one another (e.g. Dougherty et al., 2009).

In addition, investigators have attempted to map the different subtypes of impulsivity using factor analysis and principal component analysis in a small number of studies (e.g. Broos et al., 2012; Meda et al., 2009) in which. These studies predominantly find distinct factors of self-report and behavioural impulsivity. Within behavioural impulsivity, temporal- impulsivity tasks typically load separately to those indexing motor- impulsivity. While these studies provide us with a tentative understanding of the distinctions and relationships between subtypes, they only implement a limited number of tasks. It is clear that larger factor analytic studies, applying additional measurements for multiple subtypes of impulsivity, are needed to better define the relationships among different impulsivity measures (S.D. Lane et al., 2003; Meda et al., 2009). Furthermore, there are currently no factor analysis studies that have implemented measures of reflection-impulsivity simultaneously with measures of temporal- and motor-impulsivity, leaving this relationship entirely unexplored.

There is currently no empirical research systematically exploring the processes underlying *multiple* subtypes of impulsivity simultaneously. Early impulsivity researchers took the view that impulsivity reflects an imbalance in trade-offs between speed and accuracy, with a persistent bias to making a quick response, to the detriment of accuracy (S. J. Dickman & Meyer, 1988). More recent research has hypothesized that impulsivity results from reduced inhibitory control (Chikazoe, 2010; Dalley et al., 2011; P. G. Enticott & Ogloff, 2006; Perales et al., 2009; Verbruggen & Logan, 2009a). It is also known that certain demographic factors including intelligence (e.g. S.D. Lane et al., 2003) and age (e.g. Logan, 1994) are also related to behavioural impulsivity.

It is evident that impulsivity, whilst a topic of great interest, is poorly understood. The processes underpinning the behaviours are largely unresearched; furthermore it has not yet been definitively clarified whether impulsivity consists of one, or multiple, constructs.

1.7 Studies

1.7.1 Aims

This thesis sets out to explore three facets of impulsivity, encompassing 'reflection'- and 'temporal'- impulsivity (both as types of cognitive- impulsivity at the point of decision-making), and 'motor'- impulsivity. Investigators have suggested these three subtypes, however there has previously been very little systematic research establishing the validity of them or the processes underlying such responding. It has been suggested that the different types of impulsivity are dissociable, but may be mediated by converging underlying processes (P. G. Enticott & Ogloff, 2006; J. Monterosso & Ainslie, 1999; Winstanley et al., 2004). The current thesis aims to investigate the three factors of reflection-, temporal- and motor- impulsivity suggested by current literature, and investigate whether these subtypes from impulsivity are distinct from one-another. These aims will be addressed in two ways, firstly the processes underlying impulsivity will be investigated, in parallel the factor structure of impulsivity will be explored. The studies will explore the three facets of impulsivity simultaneously.

A series of studies will manipulate state impulsivity, concentrating on inhibitory control processes and speed-accuracy trade-offs, on the premise that behavioural impulsivity is transient and can be affected by changes in available resources and cognitive biases. The aims of these studies are two-fold; first they will investigate the validity of inhibitory control and speed-accuracy trade-offs as processes contributing to reflection-, temporal- and motor- impulsivity; second, they will provide information on whether such processes are relevant for all subtypes of impulsivity, or unique to certain facets of impulsivity, thus providing evidence on whether subtypes of impulsivity are dissociable. It is certainly not the case that inhibitory control and speed-accuracy trade-offs are the only processes that have relevance for impulsivity (for example it is thought that reward sensitivity plays a role in the ability to delay gratification (Guerrieri et al., 2008; Guerrieri et al., 2007). However, they are the two processes that are widely discussed as having implications for multiple types of impulsivity.

These studies investigating the processes underlying impulsivity will focus on the three factors of reflection-, temporal- and motor- impulsivity, as suggested by available literature. In parallel, exploratory factor analysis will be applied using a large cohort of participants, and multiple measures of impulsivity, in order to further investigate these three factors of impulsivity. While the majority of research suggests that these subtypes are well-defined and differentiated, there is some preliminary evidence that further categorisations of impulsivity may be required and that multiple measures of one subtype may not necessarily index the same underlying processes. Factor analysis will help to establish the validity of using multiple tasks to index the subtypes of impulsivity.

The studies will incorporate a self-report measure of impulsivity. This will be included within the factor analysis study to further investigate the relationship of self-report and behavioural measures of impulsivity. Self-report impulsivity will also be included, where appropriate, within the studies exploring the processes underlying state impulsivity, to help establish whether trait impulsivity can contribute to behaviour.

It is hoped that this thesis will provide a sounder understanding of the construct of impulsivity, on which future research can be based. The studies will investigate the three factors of motor-, temporal- and reflection- impulsivity and establish whether these subtypes are dissociable from one another. First, the studies aim to systematically establish processes underlying the different subtypes, and determine where these processes converge between subtypes. In parallel, to further confirm the three subtypes of impulsivity, the underlying factor structure of impulsivity will be explored.

1.8 Studies 1-3. Manipulating state impulsivity

Studies 1 to 3 will explore the processes underlying impulsivity, by challenging speed/accuracy biases and inhibitory control processes. Current impulsivity research has been limited by the fact that different researchers adopt different definitions of impulsivity (J. Evenden, 1999) and multiple measures are rarely simultaneously administered to participants (Dougherty et al., 2005). The studies will apply multiple measures of impulsivity to explore their underlying mechanisms.

Study 1 will examine the effect of imbalances in the speed-accuracy trade-off on the subtypes of impulsivity. Study 2 will examine how the different subtypes of impulsivity are affected when inhibitory control is impaired. Study 3 will examine the effects of an acute dose of alcohol, and cognitive factors related to alcohol, on the subtypes.

1.8.1.1.1 Study 1. Manipulating state impulsivity via the speed/accuracy trade-off

Early impulsivity research focused on the finding that there is a dichotomy between individuals who prioritise speed of response and those who prioritise accuracy; it has been suggested that impulsivity reflects an imbalance in such a trade-off, with a persistent bias to making a quick response, to the detriment of accuracy (S. J. Dickman & Meyer, 1988). It is known that motivational biases, task requirements and self-regulatory strategic concerns can modify the trade-off (Forster, Higgins, & Bianco, 2003). Research suggests that imbalances in the speed-accuracy trade-off has implications for reflection-, and motor- impulsivity, however the reliance of temporal-impulsivity on the trade-off has not previously been researched.

Study 1 will investigate the susceptibility of different subtypes to imbalances in the trade-off. The studies will also explore the effect of trait impulsivity on behavioural impulsivity. Bias in the speed/accuracy trade-off will be encouraged through (i) direct instructions for speed or accuracy (ii) cognitive priming of related schema (ii) a combination of instructions and cognitive priming.

1.8.1.1.2 Study 2. Challenging inhibitory control via a dual task

It has been suggested that impulsivity results from reduced inhibitory control (Peter G. Enticott et al., 2006; Perales et al., 2009). When investigating the relationship between impulsivity and inhibitory control, the concept of motor impulsivity and behavioural inhibition are antipodes, and share definitional features (Bickel et al., 2012). Failures in behavioural inhibition are identified as motor impulsivity. However, the assumption that deficits in inhibitory control are responsible for ‘impulsivity’ also implicates cognitive impulsivity. Studies empirically testing this assumption are sparse, and the question of whether cognitive impulsivity relies on inhibitory control remains unanswered (Perales et al., 2009).

Study 2 will investigate whether taxing inhibitory control increases impulsivity on the different subtypes. The study will challenge inhibitory control via a dual random letter generation task presented during responding to impulsivity measures.

1.8.1.1.3 Study 3. Challenging inhibitory control via an acute dose of alcohol

It is well established that alcohol can act to challenge inhibitory control: it acutely impairs the ability to inhibit a pre-potent response (motor impulsivity) (de Wit, Crean,

& Richards, 2000; M. T. Fillmore & Vogel-Sprott, 1999; Loeber & Duka, 2009; Mulvihill, Skilling, & Vogel-Sprott, 1997; Ramaekers & Kuypers, 2006). However, studies investigating the effects of alcohol on cognitive impulsivity typically do not demonstrate an acute effect of alcohol. Studies have found no effect of alcohol on temporal- or reflection- impulsivity (Dougherty et al., 2008; Dougherty et al., 2005; George, Rogers, & Duka, 2005; Ortner et al., 2003; Reynolds, Richards, & de Wit, 2006; Richards et al., 1999)

It is known that non-pharmacological cognitive factors, including expectancies of alcohol's effects, affect behavioural and cognitive responses to alcohol. Alcohol outcome expectancies are beliefs about the effects of alcohol (Merrill, Wardell, & Read, 2009).

Study 3 will investigate the effect of alcohol, as a challenge to inhibitory control, and alcohol outcome expectancies, on subtypes of impulsivity.

1.8.1.2 Study 4. Exploring the contributions of demographics and dispositions to behavioural impulsivity

Investigators have found a relationship between intelligence and reflection- and temporal- impulsivity (de Wit et al., 2007; S.D. Lane et al., 2003; Shamosh et al., 2008), and have found evidence of age-related changes on measures of reflection- and motor- impulsivity (J. Kagan et al., 1964; Logan, 1994; B. R. Williams et al., 1999). There is some limited evidence of a relationship between self-report impulsivity and behavioural impulsivity (Aichert et al., 2012; Bjork et al., 2004; de Wit et al., 2007; Dick et al., 2010; Dougherty et al., 2008; Marsh et al., 2002; Reynolds, Ortengren et al., 2006), although it is clear that this association is inconsistent, and needs to be further explored. There is also some evidence that binge drinking behaviours may have implications for impulsivity (Nederkoorn, Baltus, Guerrieri, & Wiers, 2009). Study 4 will explore the relationships between age, IQ, self-report impulsivity and binge drinking behaviours and behavioural impulsivity.

1.8.1.3 Study 5. Exploring the underlying factor structure of impulsivity

Study 5 will examine the underlying factor structure of impulsivity. While a range of subtypes and measures of impulsivity have been suggested by the literature, the concept of impulsivity is currently poorly defined and research has neglected to validate measures. Current impulsivity research includes a small number of studies which have used factor analysis to explore the relationships between tasks. While these studies provide us with a tentative understanding of the distinctions and relationships between subtypes, larger factor analytic studies applying additional measurements for multiple subtypes of impulsivity, are needed (S.D. Lane et al., 2003; Meda et al., 2009).

A large number of currently used impulsivity tasks, encompassing reflection- temporal- and motor- impulsivity, will be implemented. Multiple tasks will be employed to capture each of the potential subtypes; the primary dependent variable of each task will be identified by the literature and exploratory factor analysis will be used to explore the underlying factor structure, and provide evidence for the currently accepted distinctions between behavioural impulsivity tasks. Furthermore, correlational analysis will be performed to explore the relationships between tasks, and across subtypes.

2 General Methodology

The experiments presented in this thesis use a selection of laboratory and questionnaire measures of impulsivity, and share several methodological procedures. Participants were all required to meet certain eligibility criteria, and comply with pre-testing requirements. Therefore, to avoid repetition, details of experimental questionnaires and tasks, and details of eligibility criteria and pre-testing requirements are given in this chapter. Further specific details can be found in each experimental data chapter.

2.1 General protocol

All behavioural testing was conducted in the psychopharmacology laboratory at the University of Sussex. Behavioural testing took place in small environmentally controlled testing rooms. The University of Sussex Ethics Committee approved all experimental protocols. For all studies in the debriefing session the rationale of the studies was explained to the participants, and they were reimbursed for their time. Participants were paid £5 per hour, or equivalent course credits. All participants were debriefed verbally at the end of the testing session

2.2 Eligibility criteria

Participants were recruited from the University of Sussex subject pool, and gave informed consent. Participants were required to be between 18 and 40 years of age, not suffering from any mental illness, not be a heavy smoker (< 20 per day), not taking any medication (excluding the contraceptive pill), not be pregnant or breastfeeding. Participants were all required to supply a record of weekly alcohol consumption and recreational drug use. Participants were naïve and no one was tested on more than one study.

2.3 Pre-testing requirements

Participants were instructed to abstain from the use of illicit recreational drugs for at least 1 week prior to the experiment and from the use of alcohol for at least 12 h prior to the experiments. In addition, participants were instructed to abstain from drinking coffee or tea in the morning prior to the experiment, and asked to eat a low-fat meal the evening before testing and a low-fat breakfast on the day of testing.

2.4 Data analysis

All data were analysed using Statistical Package for Social Sciences (SPSS) version 20, run on a windows computer.

2.5 Procedure

When administering a battery of tasks, tasks were completed in a random order. Research has suggested that ideally the Matching Familiar Figures Task should, perhaps, be administered first to give a reliable measure of reflection impulsivity (Plomin & Buss, 1973). However, the decision was taken to administer the tasks in a random order to avoid fatigue effects.

2.6 Materials

2.6.1 Questionnaires

***Personal Details Questionnaire (PDQ)**:* The PDQ is a brief questionnaire asking for age, date of birth, smoking status, alcohol use and current medication. See Appendix 1 for questionnaire.

Beck Depression Inventory II (BDI; Beck, Steer, & Brown, 1996): The BDI is a 21-item multiple choice checklist measuring severity of clinical depression. On each item participants select which of four statements most applies to them. The questionnaire gives a depression score ranging from “normal” to “extreme depression”. Higher scores indicate elevated depression. See Appendix 2 for questionnaire.

Alcohol Use Questionnaire (AUQ; Townshend & Duka, 2002): Participants give an estimation of alcohol drinks consumed per week, and an indication of drinking behaviour including number of times drunk in the last year, number of drinks consumed per hour.

The questionnaire gives a measure of total units per week, binge score and alcohol use score (AUQ score). The binge score gives a measure of drinking patterns and incorporates speed of drinking, number of times drunk in the past 6 months and percentage of times drunk when going out drinking; AUQ score gives a measure of quantity of alcohol consumed as well as drinking patterns, and incorporates number of drinks per week in addition to the factors included in binge score.

See Appendix 3 questionnaire.

Barratt Impulsiveness Scale, Version 11 (BIS-11; Dimoska, Johnstone, Barry, & Clarke, 2003): The Barratt Impulsiveness Scale is a 30-item checklist measuring impulsivity. Participants score on a 4 point scale how much a statement describes them.

The questionnaire gives a total impulsivity score, and three sub-scores: attentional-, motor- and nonplanning- impulsivity. See Appendix 4 for questionnaire.

Alcohol Expectancy Questionnaire (AEQ; Fromme, Stroot, & Kaplan, 1993): A 38-item questionnaire which assesses positive and negative expected effects of alcohol consumption.

The questionnaire gives a measure of alcohol outcome expectancies. There are seven expectancy factors, four positive: sociability, tension reduction, liquid courage and sexuality; and three negative: cognitive and behavioural impairments, risk and aggression, and self-perception. See Appendix 5 for questionnaire.

Alcohol Visual Analogue Scales (VAS; Duka, Stephens, Russell, & Tasker, 1998): The Alcohol VAS is a set of 90mm visual analogue scales. Participants score how much a mood state applies to them at that moment.

Dependent variables are 0-90 scores for the following adjectives: contented, lightheaded and relaxed. See Appendix 6 for questionnaire.

Multidimensional Mood State Questionnaire (MDMQ; Steyer, Schwenkmezger, Notz, & Eid, 1997): The Multidimensional Mood State Questionnaire is an English version of the German Der Mehrdimensionale Befindlichkeitsfragebogen. Participants score how much 30 mood states apply to them on a six point scale.

The questionnaire gives scores on each of the following continuums: good-bad, awake-tired, calm-nervous. See Appendix 7 for questionnaire.

Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1992): The POMS is a 72-item mood-related adjective checklist which participants are instructed to rate on a 5-point scale from “not at all” to “extremely”.

The items are then grouped into 8 factors; these are anxiety, fatigue, depression, anger, vigour, confusion, friendliness and elation. In addition, two other factors can be calculated; these are arousal=[(anxiety+vigour)−(fatigue +confusion)] and positive mood = (elation−depression). See Appendix 8 for questionnaire.

Rey Auditory-Verbal Learning Test (RAVLT; Rey, 1964): The immediate word recall task assesses short term memory. A list of 15 words are read to the participants and after a one minute delay participants are asked to verbally recall as many words as they can remember.

The task gives an immediate word recall score. See Appendix 9 for questionnaire.

2.6.2 Cognitive and behavioural tasks

National Adult Reading Task (NART; Nelson & O'Connell, 1978): The National Adult Reading Task is a list of 50 short, irregular words of increasing complexity which participants are required to read aloud. Pronunciation of irregular words in the English language cannot be deduced by relying upon the common rules of grapheme-phoneme representation. It is supposed that the ability to read irregular words reflects previous familiarity with them (an index of prior intellectual ability). There is no time limit to the task. The word card is presented and participants are to read slowly down the list, attempting every word and guessing where necessary.

Participants are not required to complete the task if they are dyslexic or 2nd language English speakers.

Number of errors in pronunciation is used as an estimate of verbal IQ. See Appendix 10 for questionnaire.

Information Sampling Task (IST; Clark et al., 2006): The Information Sampling Task assesses information sampling before decision making. On each trial, a matrix of 5x5 grey squares is presented on a computer screen. Participants are instructed to select a square by clicking with the mouse over the square, to reveal one of two colours (e.g. red and blue) until they decide which of the two colours is in the majority. Participants can open as many boxes as they wish before making a decision, and are able to open boxes at their own rate. Boxes remain open for the duration of the trial. Participants can then express their decision by selecting one of two coloured boxes at the bottom of the screen. A feedback response “You have won/lost ___ points” is then presented on the screen; see Figure 2.1 for screen display.

Participants complete one practice trial, followed by the experimental trials.

There are two conditions of experimental trials available:

(i) Fixed win condition Participants win or lose 100 points regardless of how many boxes they have opened. Participants complete 10 experimental trials.

(ii) IST reward conflict For every box opened, participants lose 10 points from a bank of 250. If a participant chooses correctly they win the remaining points in the bank, if they choose incorrectly they lose 100 points. Participants complete 10 experimental trials.

In both conditions there is an inter-trial interval of variable delay, with a minimum interval of 1 second, such that the minimum inter-trial interval between trial onsets is 30 seconds.

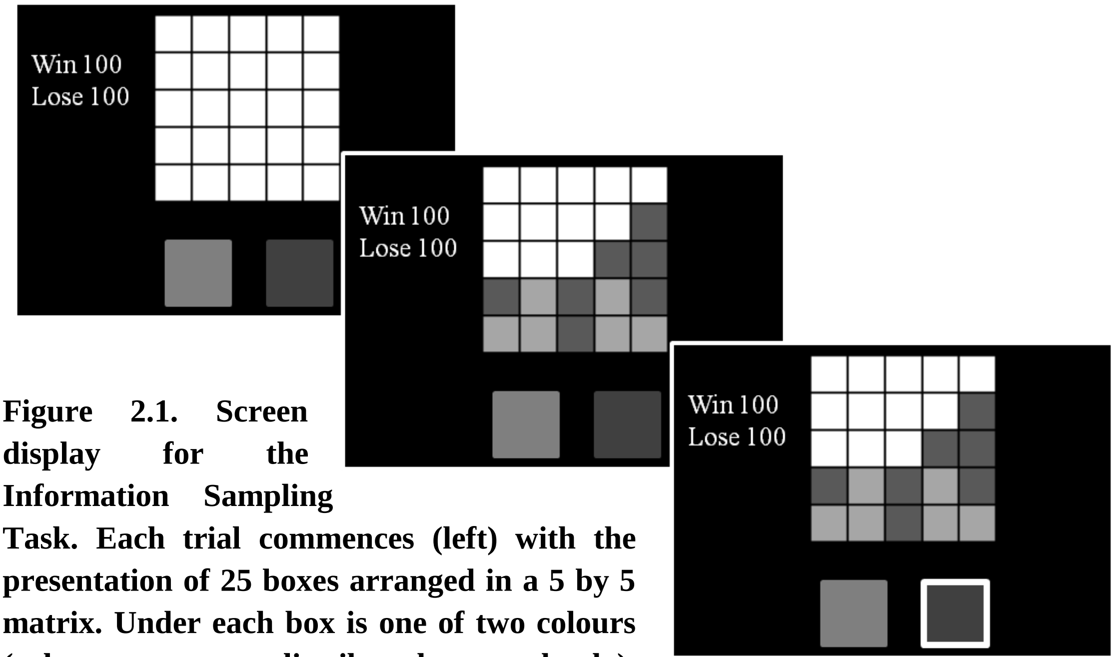

Figure 2.1. Screen display for the Information Sampling Task. Each trial commences (left) with the presentation of 25 boxes arranged in a 5 by 5 matrix. Under each box is one of two colours (colours are distributed randomly). Participants click on boxes to reveal the colour underneath. Participants must decide which of the two colours is in the majority on the board; once they have made their decision they click on the corresponding colour at the bottom of the screen (bottom right). Participants are instructed that they can open as many boxes as they wish to make their decision.

The task gives a measure of the average number of boxes opened before making a decision, the average number of errors made, and the probability of being correct that a participant will tolerate when they make a decision [P(correct)]. P(correct) values of 1 indicate that the participant acquired full information before making a decision, 0.5 indicates that the participant had only enough information to make a decision at chance;

for example, if a participant opens 20 boxes, of which 10 are red and 10 blue, P(correct)=.5, or 15 red and 5 blue, P(correct)=1.0. The formula for calculating P(correct) is:

$$\mathrm{P(correct)} = \frac{\sum_{k=A}^{z}\binom{z}{k}}{2^{z}}$$

A small number of boxes opened, large number of errors and a low P(correct) value indicates increased impulsivity.

Matching Familiar Figures Test (MFF20; Cairns & Cammock, 1978; J. Kagan et al., 1964): The Matching Familiar Figures Task measures the tendency to acquire information before decision making. On each trial an image is presented on the left of the screen with six versions presented to the right, of which one is identical to the original. Participants are required to select the identical copy. Participants can select multiple images within a trial, the trial ends when the identical image has been selected; see Figure 2.2 for screen display. Participants complete two practice and 20 experimental trials.

The task gives a measure of latency to first response, total number of errors and Impulsivity Score (I-score) and Efficiency Score (E-score).

The I-score is calculated by subtracting the standard score of the mean latency from the standard score of the total number of errors (I-score = Zerror-Ztime).

The E-score is calculated by summing the standard score of the mean latency with the standard score of number of errors, and multiplying that value by -1 (E-score = -Zerrors+Ztime).

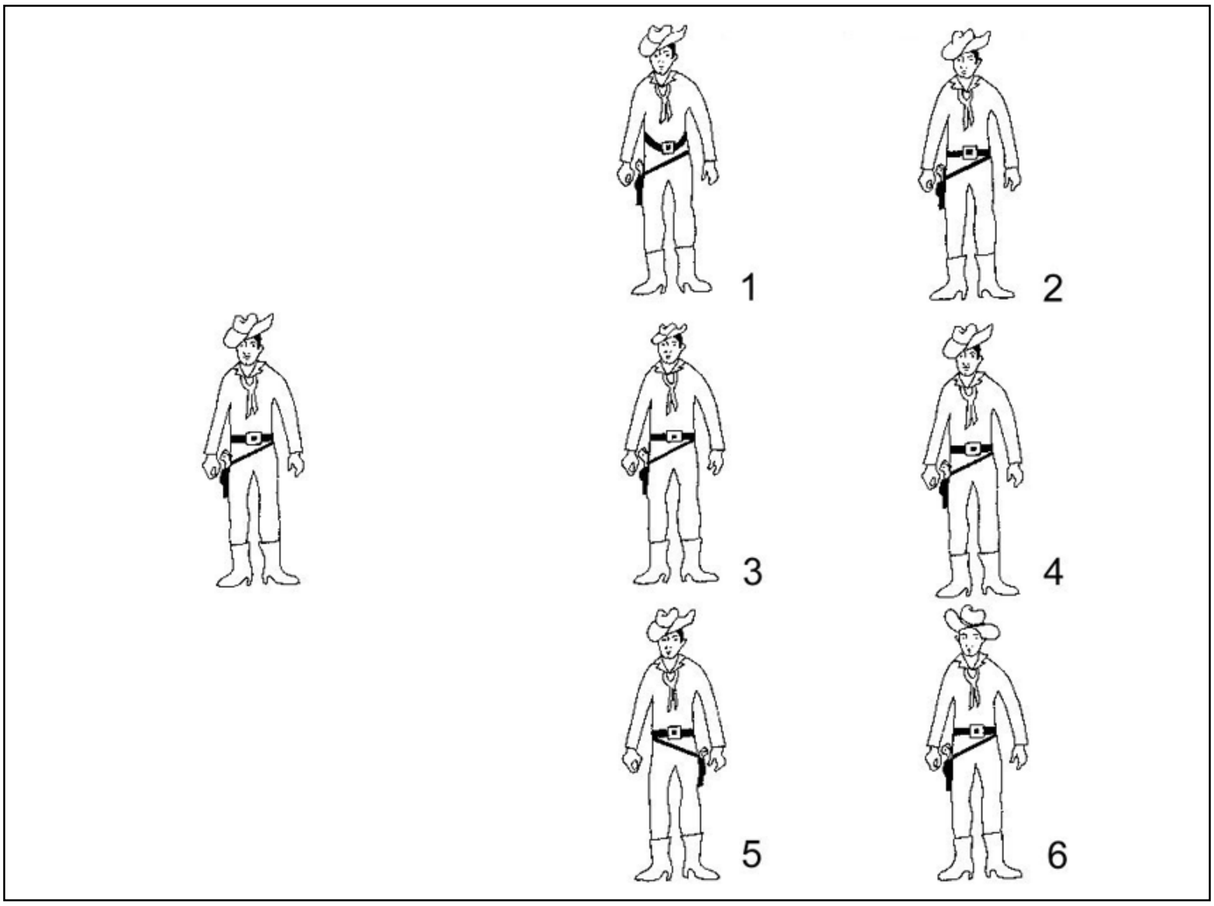

Figure 2.2. Screen display for the Matching Familiar Figures Task. Participants are presented with an image on the left and six on the right. Of the six images, one is identical to the original; participants must select the identical image. There is no time limit to the task, the next trial commences once the participant has selected the correct image.

Tower of London Task (TOL; Fimbel, Lauzon, & Rainville, 2009; Shallice, 1982): The Tower of London is a measure of planning ability. On each trial participants are required to rearrange a set of three disks to a shown configuration of three piles. Harder trials include indirect moves in which a disk must be moved to a position that is essential for solution, but that is not its final position. On each task a minimum number of moves required is calculated, but not revealed to the participant. The trial ends when the participant has successfully moved the disks to the shown configuration. Participants complete 30 trials of progressive difficulty.

The task gives a mean value of pre-planning time (time before first move), and a mean difference score between minimum moves required, and the number of moves the participant made.

Iowa Gambling Task (IGT: Bechara et al., 1994): Participants are presented with four decks of cards, equal in appearance and size, on the screen. Participants are instructed they have a £2000 loan, and are instructed to make a series of selections from the decks of cards in front of them to maximise profit on this loan. For each card selected the participant receives money, on some trials they also receive a penalty. The value of the money won and lost is only revealed once a deck has been selected. Participants are free to switch between decks.

Choice of a card from deck A and deck B yields a reward of £100; choice of deck C or D yields £50. However, the ultimate future yield is greater for decks C and D; despite these being the ostensibly lower-paying decks, the penalty amounts are higher for decks A and B, thus incurring an overall net loss if the participant consistently chooses them. A choice of 10 cards from deck A yields £1000, but contains 5 punishments, resulting in a net loss of £250. Ten choices from deck C or D results in a net win of £250 (participants win £500 and lose £250 in punishment). Decks A and B, and C and D, are equivalent in terms of net loss; in decks A and C, however, the punishment is more frequent but is of smaller magnitude (five punishments totalling £1250 or £250 for decks A and C respectively), in decks B and D the punishment is less frequent but of a larger magnitude (one punishment totalling £1250 or £250).

The task gives a measure of advantageous choices ((C+D)-(A+B)); the sum of disadvantageous choices is subtracted from the sum of the advantageous choices (Preston, Buchanan, Stansfield, & Bechara, 2007).

Stop Signal Task (SST; Logan, 1994): The Stop Signal Task assesses inhibitory control of a pre-potent motor response. Participants are instructed to respond using button presses to the direction of a visually presented green arrow (Go signal) but to withhold this response whenever the arrow changes from green to red (a Stop Signal, occurring on 25% of trials).

On each trial, a fixation cross is presented for 1200-1500 msecs. The stimulus display that followed always began with the presentation of a Go stimulus (green arrow), which either remained on screen for a total stimulus-display duration of 800msecs, or was replaced, after a variable stimulus onset asynchrony (SOA) by a Stop stimulus (red arrow). See Figure 2.3 for details.

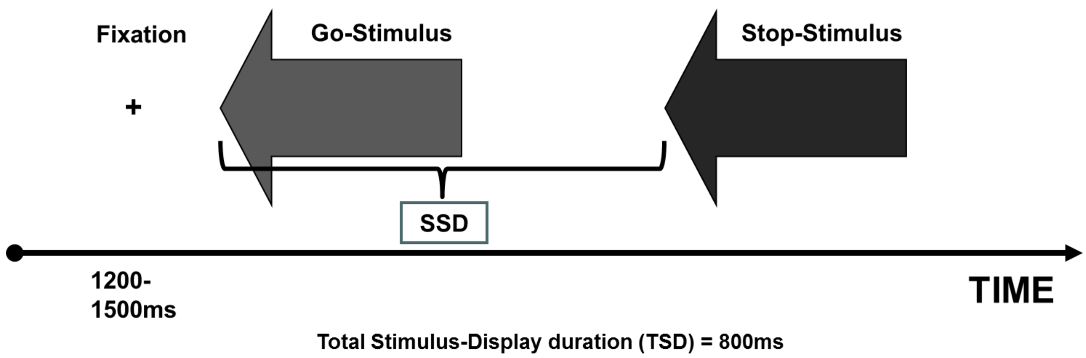

Figure 2.3. Screen display for the Stop Signal Task. Participants are presented with a fixation cross, followed by a Go stimulus (green arrow, presented here as light grey). Participants must respond to the direction of the Go stimulus using the keyboard, but withhold this response if a Stop stimulus is presented (red arrow, presented here as dark grey).

Initial Stop Signal is presented at a delay of 200 msecs (stimulus onset asynchrony, SOA). The timing of the Stop Signal is then adjusted using a staircase procedure: when the participant successfully stops to a Stop Signal the subsequent stimulus onset asynchrony is increased by 50ms; if the participant fails to stop then the subsequent stimulus onset asynchrony is reduced by 50ms. This staircase procedure resulted in an even number of successful and failed stops (Verbruggen & Logan, 2009a).

There are multiple versions of the task available:

(i) Participants complete 20 practice trials followed by 160 experimental trials. SSD is ‘capped’ at 100-500msecs; if SSD increases to 500msecs, or decreases to 100msecs it reverts to 200msecs and the staircase procedure resumes.

(ii) Participants complete 20 practice trials and 120 experimental trials. SSD is capped at 100-500 msecs; if SSD increases to 500msecs it drops to 450msecs, if SSD decreases to 100msecs it increases to 150msecs and the staircase procedure continues.

(iii) Participants complete three blocks of 120 trials (practice, baseline and experimental). SSD is capped at 100-500 msecs; if SSD increases to 500msecs it drops to 450msecs, if SSD decreases to 100msecs it increases to 150msecs and the staircase procedure continues.

From the task Go and Stop accuracy, average Go reaction time and average Stop stimulus delay (SSD) are recorded. The main dependent variables are Go accuracy and reaction times, and Stop Signal Reaction time (SSRT).

SSRT can be calculated using the mean (SSRTm) and the integration (SSRTi) method. Large SSRT values indicate poor inhibitory control, i.e. high impulsivity.

SSRTm = mean GoRT – mean SSD.

SSRTi = *nth*GoRT – meanSSD; *n* is calculated by rank ordering the GoRTs, and multiplying the number of RTs in the RT distribution by the proportional stop accuracy of the participant (e.g. .50) (Logan, 1981), then selecting the Go RT that corresponds to *n*. SSRTm is appropriate if average stop accuracy is equal to 50%, SSRTi gives reliable and unbiased estimates of stop signal reaction time if stop accuracy is different from 50% (see Verbruggen, Chambers, & Logan, in press).

Go/NoGo (adapted from Kim, Iwaki, Imashioya, Uno, & Fujita, 2007): The Go/NoGo assesses inhibitory control of a motor response. Participants are presented with a series of triangles; they are instructed to respond as quickly as possible whenever a triangle is pointing upwards (Go trials), using the space-bar, but to withhold this response if a triangle is pointing in any other direction (No Go trials).

On each trial, a fixation cross is presented for 1000msecs, followed by a black period occurring for 500msecs. Participants are then presented with a Go or No Go triangle stimulus for 1300 msecs; 60% of trials present Go stimuli, 40% present No Go trials (of which 50% are downward triangles, 25% right-facing triangles, 25% left-facing triangles). A second blank period is then presented for 500 msecs.

The task gives a measure of commission errors, occurring when a participant makes an incorrect Go response to a No Go signal. Go accuracy and average Go reaction time are also recorded.

Immediate Memory Task (IMT; Dougherty et al., 2002): The Immediate Memory Task is a variant of the Continuous Performance Task, measuring inhibitory control of a motor response.

On each trial a 5-digit number string is presented for 500 msecs, followed by a blank screen presented for 500msecs. Participants are instructed to press the mouse button if a number string is identical to that which preceded it, but to withhold this response if the number differs. The task contains three trial types: 'target' trials, where the number string is identical to that in the preceding trial, occurring 33% of trials; 'filler' trials, where the number does not match, occurring 33% of trials; 'catch' trials, where the number string is almost identical to the preceding trial but differs by one digit, occurring 34% of trials. See Figure 2.4 for screen display.

Participants completed two blocks of 180 seconds, with a 20 second rest period between blocks

The task gives a measure of commission errors. Commission errors occur when a participant makes a premature Go response to a catch trial, before they have fully processed the sequence. Participants who make more commission errors to catch stimuli are labelled more impulsive.

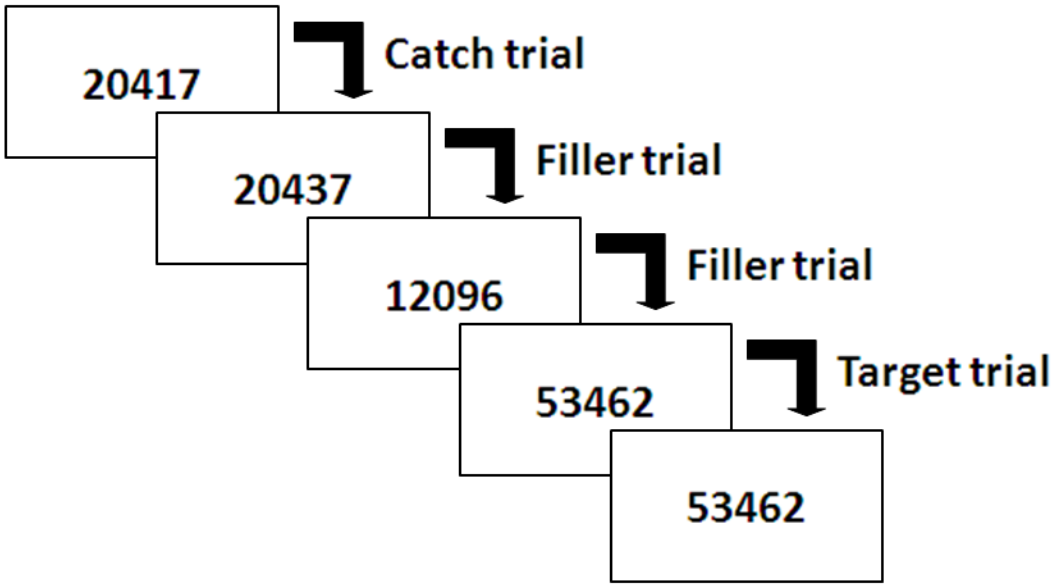

Figure 2.4. Screen display for the Immediate Memory Task. Participants are presented with a number string. The must respond using a mouse click whenever a number string is identical to that which preceded it (a 'Target' trial). Catch trials occur when a number is almost identical to the preceding trial, but differs by one number.

Single Key Impulsivity Paradigm (SKIP; Dougherty et al., 2005): The Single Key Impulsivity Paradigm assesses ability to delay gratification, using a free-operant procedure.

Participants are presented with a screen and instructed to press the mouse-button to obtain a point reward. Participants can press the mouse-button as many times as they wish for the duration of the task (determined by the experimenter). The magnitude of the point reward is dependent on the delay between consecutive responses: the relationship between delay and reward is linear.

Feedback is displayed on screen for the duration of the task: a point counter at the top of the screen displays the total points accumulated during the session, and a counter at the bottom of the screen displays the number of points earned by the most recent response. The latter point counter provides information regarding the delay–reward contingency, allowing the participant to infer that responses emitted at faster rates earn smaller rewards than responses emitted at slower rates do.

The size of the reward is directly proportional to the delay. Participants complete a five-minute trial.

The task gives a measure of average inter-response time (IRT, the average time delay between consecutive mouse clicks). Short inter-response times indicate a preference for smaller, immediate rewards (i.e. high impulsivity).

Two Choice Impulsivity Paradigm (TCIP; Dougherty et al., 2005): The Two Choice Impulsivity Paradigm measures preference for smaller, immediate rewards over larger, delayed rewards.

Participants are presented with a series of trials in which they must choose between two shapes (a circle and a square). One shape is associated with a small reward available after a short delay (3 points after a 3 second delay); the second shape corresponds to a larger, more delayed reward (9 points after a 9 second delay).

The two shapes are presented visually on screen; participants are instructed to choose between them to receive points. Participants make a selection by clicking on a shape. The un-selected shape disappears and the chosen shape remains on screen, becoming faded for the period of the pre-programmed delay (‘black-out period’). When the delay has passed the black-out period ends and participants re-click the shape to collect the pre-programmed reward. See Figure 2.5 for screen display.

Reward delay and magnitude remain constant throughout the task. Participants are not informed of the delay and magnitude of reward for the two shapes. To allow participants to infer the value and delay associated with each shape they complete training trials prior to the experimental trials, during which they are presented with one shape (circle or square) per trial. Participants complete 30 trials.

The task gives a measure of proportion of small immediate rewards over large delayed choices.

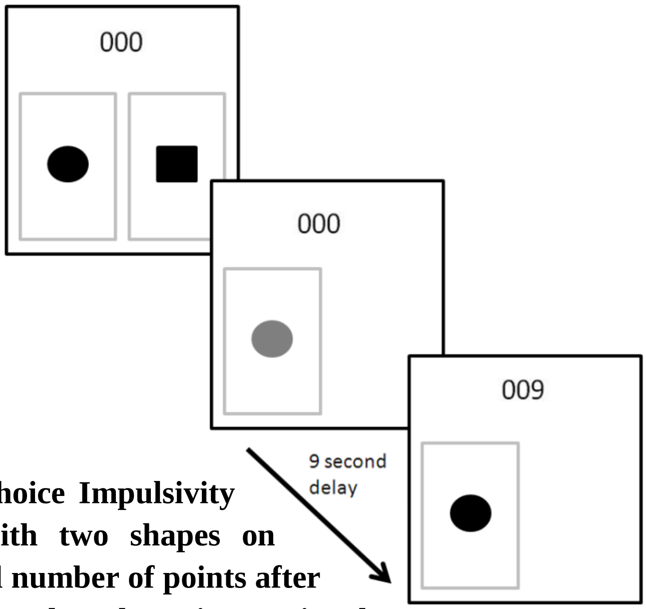

Figure 2.5. Screen display for the Two Choice Impulsivity Paradigm. Participants are presented with two shapes on screen. One shape is associated with a small number of points after a small delay (3 points after 3 seconds) the other shape is associated with a larger number of points after a longer delay (9 points after 9 seconds). Participants select their chosen shape by mouse clicking on it. The unchosen shape disappears and the chosen shape becomes faded for the pre-programmed black-out period (9 seconds for the circle). Once the black-out period ends the shape flashes and participants can click again to collect their points.

Monetary Choice Questionnaire (MCQ; Kirby et al., 1999): The Monetary Choice Questionnaire measures preference for large delayed rewards over small, more immediate rewards.

For each item, participants must choose between a large delayed reward (LDR), and a smaller more immediate reward (SIR). For example, on the first trial participants are asked “would you prefer £54 today or £55 in 117 days?”. Participants indicate the alternative by circling their preferred choice. All rewards are hypothetical.

There are three categories of delayed rewards: small (from £25 to £35; with immediate rewards ranging from £11 to £34 and delays 7-186 days), medium (from £50 to £60; with immediate rewards ranging from £20 to £54 and delays 7-160 days) and large (from £75 to £85; with immediate rewards ranging from £31 to £80 and delays 7-162 days). See table 2.1 for details of delay and reward values.

The task gives an estimate of the participant's discounting parameter (*k*), using the pattern of choices across the 27 items. *k* values for each choice on the questionnaire can be calculated using the formula ((LDR-SIR)-1)/delay. For example, question 19 (category L), has a *k* value of 0.10; choice of the immediate reward on question 19 therefore implies a discount rate greater than 0.10. Question 4 (category L) has a *k* value of 0.25; choice of the delayed reward therefore implies a discount rate lower than 0.25. Therefore, if a participant chooses the immediate reward on Q 19 but the delayed reward on Q 4, their discount value for the L category falls between 0.10 and 0.25. See table 1 for details of *k* values for each choice.

Participants complete 27 items.

Delay Discounting Questionnaire (DDT): The Delay Discounting Task is a variation on the MCQ, measuring preference for large delayed rewards over smaller immediate rewards. The procedure is identical to the MCQ. Values of SIRs vary from a value of £1000 to £1, LDRs remain constant at £1000. There are 7 delay values (1 week, 2 weeks, 1 month, 6 months, 1 year, 5 years, 25 years). Participants complete five practice trials, followed by a series of experimental trials. There are two versions of the experimental trials available:

(i) Participants complete six blocks of 27 trials. Delay intervals are presented in blocks (one delay per block). SIRs within each block are presented in descending order, from £1000-£1.

(ii) Participants complete three blocks of 50 trials, and one block of 62. Stimuli are presented in a fixed random order.

From the data *k* values for each delay value can be calculated using the formula ((LDR-SIR)-1)/delay; procedure for calculating k is identical to the MCQ.

Time estimation task: The time estimation task gives a measure of ability to accurately estimate time. Participants are required to press and hold the space bar for a stated period of time. Participants complete one 27-second trial.

The task gives a measure of time estimation accuracy (time the participant held the space bar for – 27 seconds).

Order	SIR	LDR	Delay (days)	k at indiff.	k rank	LDR size
13	$34	$35	186	0.00016	1	S
20	$28	$30	179	0.00040	2	S
26	$22	$25	136	0.00100	3	S
22	$25	$30	80	0.00250	4	S
3	$19	$25	53	0.00600	5	S
18	$24	$35	29	0.01600	6	S
5	$14	$25	19	0.04100	7	S
7	$15	$35	13	0.10000	8	S
11	$11	$30	7	0.25000	9	S
1	$54	$55	117	0.00016	1	M
6	$47	$50	160	0.00040	2	M
24	$54	$60	111	0.00100	3	M
16	$49	$60	89	0.00250	4	M
10	$40	$55	62	0.00600	5	M
21	$34	$50	30	0.01600	6	M
14	$27	$50	21	0.04100	7	M
8	$25	$60	14	0.10000	8	M
27	$20	$55	7	0.25000	9	M
9	$78	$80	162	0.00016	1	L
17	$80	$85	157	0.00040	2	L
12	$67	$75	119	0.00100	3	L
15	$69	$85	91	0.00250	4	L
2	$55	$75	61	0.00600	5	L
25	$54	$80	30	0.01600	6	L
23	$41	$75	20	0.04100	7	L
19	$33	$80	14	0.10000	8	L
4	$31	$85	7	0.25000	9	L

Table 2.1. Table showing the reward and delay values for each item of the monetary choice questionnaire. k at indifference = the value of the discount rate are of equal value according to ((LDR-SIR)-1)/delay; k rank = k values within each delay category are ranked in ascending order; SIR= small immediate reward; LDR = large delayed reward; S, M, L = the small, medium and large delay categories grouped in ascending order.

3 Impulsivity and the speed/accuracy trade-off

3.1 Introduction

Early research on impulsivity focused on the finding that there is a dichotomy between individuals who prioritise speed of response, to the detriment of accuracy, and those who prioritise accuracy, sacrificing speed. This trade-off between speed and accuracy is known to be adaptive when individuals are able to adjust responding based on individual circumstances: favouring speed over accuracy can be useful in contexts where quick responses have more value than errors, and vice versa (Mulder et al., 2010). It has been suggested that impulsivity reflects an imbalance in such a trade-off, with a persistent bias to making a quick response (S. J. Dickman & Meyer, 1988).

The speed/accuracy trade-off has been suggested to have particular implications for both motor- (e.g. Bissett & Logan, 2011; Leotti & Wager, 2010) and reflection-impulsivity (e.g. J. Kagan, 1965b).

With regards to motor- impulsivity, the Stop Signal Task has been conceptualised as a trade-off between speed of responding, and caution to allow successful inhibition of a response (Bissett & Logan, 2011; Leotti & Wager, 2010). The task requires a trade-off between fast responding to Go stimuli, with a stopping response to a small number of Stop trials running in parallel (Logan, 1994). Successful responding to Go stimuli (fast responding) implies failure on the stop task (failed inhibition to a Stop stimulus); successful Stopping implies failure on the go task (slow responding) (Verbruggen & Logan, 2009b).

With regards to reflection- impulsivity, the subtype refers to the tendency to reflect upon alternative-solution possibilities. However, the two main tasks that measure reflection- impulsivity, the Matching Familiar figures and Information Sampling Tasks, quantify this type of impulsivity by different means and thus the two measures have subtly different underlying processes, with differing implications for the speed/accuracy trade-off.

The Matching Familiar Figures Task indexes reflection- impulsivity by measuring latency from initial presentation of the problem to making an initial decision. Time to making a response is considered a measure of the quantity of information gathered and evaluated; shorter latencies are related to more errors and fast/inaccurate responding is identified as impulsive (J. Kagan, 1965b). However, the task is known to be dependent on multiple, potentially confounding processes, and research has not been able to establish whether longer latencies are a valid index of greater evaluation of the information (e.g. Ault et al., 1972; Drake, 1970; Zelniker et al., 1972). To circumvent these issues, the Information Sampling Task is designed to provide a *primary* index of information sampling, rather than a composite speed-accuracy score; the task gives a measure of tolerance of uncertainty at the point of decision-making. In addition, the Information Sampling Task is designed with an inter-trial interval, so that each trial lasts at least 30 seconds, to prevent participants from strategically rushing through the task (Clark et al., 2006; Clark et al., 2003; Clark et al., 2009).

Thus, while both tasks are proposed to measure the same underlying process of reflection- impulsivity (Clark et al., 2006), the measurement of evaluation of information differs between the tasks: time taken to make a decision on the Matching Familiar Figures and tolerance of uncertainty at the point of decision-making on the Information Sampling. It is evident that speed/accuracy trade-offs are inherent to measurement of reflection- impulsivity on the Matching Familiar Figures Task as fast (and inaccurate) responding is identified as impulsivity (J. Kagan, 1965b). However the Information Sampling Task is designed to reduce the impact of biases for speed over accuracy.

While early literature typically viewed the trade-off between speed and accuracy as ‘built-in’ (trait) disposition, it is possible to manipulate speed/accuracy biases experimentally. It is known that our behaviour is the result of complex interactions between internally and externally generated goals and motivations (Kesek, Cunningham, Packer, & Zelazo, 2011) and recent research has suggested that several factors including self-regulatory strategic concerns, motivational biases, and task requirements can modify the trade-off between speed and accuracy (Forster et al., 2003; Leotti & Wager, 2010). Such factors can be manipulated experimentally in two ways: via conscious and non-conscious mechanisms (Bargh & Chartrand, 1999; MacDonald, 2008). Direct instructions can be used to initiate conscious and wilful strategic regulation of behaviour. Cognitive priming through exposure to similar schema or concepts can be used to activate non-conscious control of behaviour (Bargh & Chartrand, 1999; Rotenberg et al., 2005).

Both direct instructions and cognitive priming manipulations have been found to successfully induce impulsive behaviour in the laboratory. Instructions to respond quickly to Go stimuli on the Stop Signal task induce more inhibition errors to Stop signals, more Go errors and faster Go responses, compared to instructions for correct inhibition of Stop responses (A. Jones, Cole et al., 2011; A. Jones, Guerrieri et al., 2011). In addition, participants following instructions for speed display disinhibited behaviours post-task, seen in increased alcohol and food intake (Guerrieri et al., 2009; A. Jones, Cole et al., 2011; A. Jones, Guerrieri et al., 2011). Cognitive priming of impulsivity, flexibility and spontaneity schema, via a story disguised as a memory task, has been found to increase impulsivity as evidenced by increased caloric intake in a subsequent taste test (Guerrieri et al., 2009).

The three current studies are designed to investigate the reliance of different subtypes on the speed-accuracy trade-off; the studies will use direct instructions (for speed or accuracy) and cognitive priming (of speed or accuracy schema) to experimentally generate imbalances in the speed/accuracy trade-off. It is proposed that the instructions will encourage conscious, strategic, control over responding to the tasks, whereas the cognitive priming will activate non-conscious control over behaviour. In addition, the studies will explore the effects of trait impulsivity, as a 'built-in' disposition for speed or accuracy.

There is clear evidence that imbalances in the speed/accuracy trade-off have implications for motor- impulsivity, as measured by the Stop Signal Task (A. Jones, Cole et al., 2011; A. Jones, Guerrieri et al., 2011) and reflection impulsivity as measured by the Matching Familiar Figures Task (J. Kagan, 1965a). However, the reliance of temporal- impulsivity on the trade-off has not previously been investigated; the current study will include a measure of temporal- impulsivity as this is considered an important aspect of cognitive- impulsivity. The reliance of the Information Sampling Task on the trade-off has also not been fully established; the task is designed to minimise the impact of strategic fast responding, but the susceptibility of the task to non-conscious biases has not previously been explored.

Study 1a will explore the speed/accuracy trade-off through the use of instructions; participants will be instructed to respond quickly (disinhibition condition), accurately (restraint condition), or quickly and accurately (control condition). Study 1b will explore the speed/accuracy trade-off through the use of cognitive priming via an imagery script; participants will complete a priming task, disguised as a memory task, that focuses on quick, impulsive responses (disinhibition condition), slower more considered responses (restraint condition), or neither (control condition). Study 1c will combine the instructions and priming manipulations; participants will be assigned to the disinhibition, restraint or control condition, and will complete the associated priming and instructions.

To measure impulsivity we selected one or two performance based tasks for each of the three subtypes. The Stop Signal Task as the measure of motor impulsivity, and the Matching Familiar Figures Task as a measure of reflection impulsivity were selected as two tasks known to be affected by imbalances in the speed/accuracy trade-off. The Information Sampling Task as a second measure of reflection impulsivity and the Delay Discounting Questionnaire as the measure of temporal impulsivity were selected to explore the effects of speed/accuracy imbalances on temporal impulsivity, and further investigate the effects on the Information Sampling Task. In addition a questionnaire measure of trait impulsivity (the Barratt Impulsiveness Scale) was selected to explore the effects of trait impulsivity on responding to the tasks.

3.2 Study 1a – Instructions for speed or accuracy

Study 1a will explore the speed/accuracy trade-off through the use of instructions; participants will be instructed to respond quickly (disinhibition condition), accurately (restraint condition), or quickly and accurately (control condition).

3.2.1 Method

3.2.1.1 Participants

Fifty paid participants were randomly allocated to one of three conditions: disinhibition (8 f, 9 m), restraint (8 f, 9 m) and control (9 f, 8 m).

3.2.1.2 Procedure

Participants completed the questionnaire pack (see section 3.2.1.3.2 'Questionnaires'). They were then moved to the computer booth and completed the four impulsivity measures: the Matching Familiar Figures Task, the Information Sampling Task (i,ii), Stop Signal Task (ii) and Delay Discounting Task (ii). All tasks contained polarised instructions (see section 3.2.1.3.1 'Polarised instructions') according to the assigned condition, and were completed in a random order. Participants then repeated the POMS and time estimation task.

3.2.1.3 Materials

3.2.1.3.1 Polarised instructions

Participants in the disinhibition condition were instructed to complete all experimental tasks as quickly as possible; on the Stop Signal Task participants were required to prioritise fast responding to Go stimuli. Participants in the restraint condition were instructed to complete tasks as accurately as possible; on the Stop Signal Task participants were instructed to be as accurate as possible in inhibiting responding to Stop stimuli. Participants in the control condition were instructed to complete tasks both as quickly and as accurately as possible.

3.2.1.3.2 Questionnaires

Personal Details Questionnaire (PDQ): The personal details questionnaire is a brief questionnaire asking for age, date of birth, smoking status, alcohol use and current medication.

Beck Depression Inventory II (BDI-II; Beck et al., 1996; Pliszka, Liotti, & Woldorff, 2000): The Beck depression inventory measures severity of clinical depression.

Alcohol Use Questionnaire (AUQ; Townshend & Duka, 2002): The questionnaire gives a measure of total units per week, binge score and alcohol use score (AUQ score).

Barratt Impulsiveness Scale, Version 11 (BIS-11; Dimoska et al., 2003): The Barratt Impulsiveness Scale is a 30-item checklist measuring impulsivity. The questionnaire gives a Total impulsivity score, and three sub-scores: Attentional, Motor and Nonplanning impulsivity.

Drug Use Questionnaire (see Townshend & Duka, 2005): This questionnaire gives a rough guide of drug use; participants were given a score in which 0 = no drug use; 1 = occasional use of cannabis/hash or marijuana; 2 = regular use of cannabis/hash or marijuana (at least once a week); 3 = use of ecstasy and/or other drugs.

3.2.1.3.3 Cognitive and behavioural tasks

Matching Familiar Figures Task (MFF20; Cairns & Cammock, 1978; J. Kagan et al., 1964): The Matching Familiar Figures Task measures the tendency to acquire information before making a decision. Participants have to select the one of six visually presented stimuli which is identical to an original image. The task gives a composite Impulsivity score (I-score) and Efficiency score (E-score). Higher I-scores are indicative of fast and inaccurate responding, i.e. impulsivity.

Information Sampling Task (IST; Clark et al., 2006): The Information Sampling Task measures the tendency to acquire information before making a decision. Participants must open a matrix of boxes to reveal two colours underneath; participants must then select the colour which is in the majority. There are two conditions of experimental trials available: (i) Fixed win condition Participants win or lose 100 points regardless of how many boxes they have opened; participants complete 10 trials (ii) IST reward conflict For every box opened, participants lose 10 points from a bank of 250. If a participant chooses correctly they win the remaining points in the bank. Participants complete 10 trials.

The task gives a measure of number of boxes opened, number of errors when selecting the colour, and probability of being correct that the participant tolerates at the point of decision making [P(correct)]. Fewer boxes opened, more errors and a lower P(correct) value indicate impulsivity.

Stop Signal Task, version (i) (SST; Logan, 1994): The Stop Signal Task assesses motor impulsivity. Participants respond to the direction of visually presented green arrows but withhold this response whenever the arrow changes from green to red (the Stop Signal, occurs 25% of trials). Participants complete 160 trials.

The task gives a measure of Go accuracy and Go Reaction times, and Stop Signal Reaction Time (SSRTi). Large SSRTi values indicate poor inhibitory control, i.e. high impulsivity.

Delay Discounting Task, version (i) (DDT): The Delay Discounting Task is a pen-and-paper measure measuring preference for large delayed rewards over smaller immediate rewards. Participants must choose between large delayed rewards (LDR), and small immediate reward (SIR). Participants complete 162 trials.

From the data *k* values for each individual delay can be calculated using the formula ((LDR-SIR)-1)/delay. Large *k* values indicate impulsivity.

3.2.1.4 Statistical analysis.

Baseline group demographics, including age, IQ, time estimation and self-reported alcohol use and impulsivity were analysed using one-way analysis of variance (ANOVA) to check that the three groups did not differ.

A series of one-way ANOVA were performed to explore the effect of experimental condition on the impulsivity measures. Experimental condition (disinhibition, restraint, control) was included as the fixed factor. Dependent variables are as follows:

Information Sampling Task number of boxes opened, number of errors and P(correct) for the fixed win and reward conflict conditions;

Matching Familiar Figures Task I-score and E-score;

Stop Signal Task Go accuracy, Go RT and SSRTi;

Delay Discounting Task mean *k* value.

In all analyses post hoc tests were Bonferroni corrected if the assumption of equal variances was met, and Games-Howell corrected if not (accepted *p* value=.05); all tests are Bonferroni corrected unless otherwise reported. All descriptive values stated in text are (Mean±s.e.m.) unless otherwise stated.

The assumptions of normality (Shapiro-Wilk statistic), and homogeneity of variance (Levene's test) are met, unless otherwise stated. ANOVA statistics were Welch corrected if homogeneity of variance was violated. If both assumptions of normality and equal variances were violated, Kruskal Wallis test was used and bonferroni corrected Mann-Whitney tests were subsequently performed to test for pairwise differences (manually corrected, accepted *p* value=.017).

To explore the contribution of self-report impulsivity to performance on the behavioural tasks, Barratt impulsiveness scores were included as covariates in subsequent analysis of covariance (ANCOVA). If a covariate was found to have a significant relationship with an impulsivity measure then Pearson correlations (or equivalent Spearman correlations if nonparametric) were performed, to explore the direction of any relationship. For the ANCOVA the effect of experimental condition on the impulsivity measures is only reported if a previously significant effect (as reported by one-way ANOVA) is found to be no longer significant after controlling for self-reported impulsivity; or a significant effect of condition is found that was not present previously.

Mood, self-reported impulsivity and time estimation changes were analysed with a mixed ANOVA with time (pre- and post- manipulation) applied as the within subjects factor, and experimental condition as the between subjects factor. Main effects of time are reported to indicate whether mood, self-reported impulsivity and time estimation changed over the time-frame of the experiment, however this will not be focused on within the discussion.

3.2.2 Results

3.2.2.1 Group demographics

There were no group differences on any of the baseline group demographics or trait characteristics. See table 3.1 for descriptive values and *F* statistics.

	Control	Disinhibition	Restraint	*p*
Age	22.53±3.59	22.18±3.75	22.69±4.74	*F*(2,47)=.070, *p*=.933
NART, Verbal IQ	106.56±4.03	108.77±6.83	108.09±6.49	*F*(2,30)=.357, *p*=.703
Time estimation	.48±8.72	-2.07±5.23	.51±9.95	*W*(2,27.510)=.746, *p*=.483[a]
Alcohol Use Questionnaire				
Units drunk per week	14.22±12.38	16.81±10.30	20.82±13.89	*F*(2,44)=1.117, *p*=.336
Binge score	14.47±8.35	18.99±12.94	13.26±7.85	*F*(2,44)=1.441, *p*=.248
AUQ score	28.69±19.85	35.80±17.17	34.08±19.96	*F*(2,44)=.598, *p*=.554
Barratt Impulsiveness Scale				
Total score	64.24±11.67	67.24±12.00	66.69±8.71	*F*(2,47)=.361, *p*=.699
Attentional impulsivity	16.94±4.19	18.18±4.65	17.81±3.75	*F*(2,47)=.383, *p*=.684
Motor impulsivity	24.53±3.83	24.35±5.24	23.94±3.19	*F*(2,47)=.086, *p*=.918
Nonplanning impulsivity	22.76±5.18	24.71±6.18	24.94±4.52	*F*(2,47)=.833, *p*=.441

Table 3.1. Baseline group demographics, alcohol use and self-reported trait impulsivity for the control, disinhibition and restraint conditions, and ANOVA statistics. Values are presented as Mean±s.d. [a] Welch statistic reported.

3.2.2.2 Stop Signal Task

Two participants were excluded for failing to follow task instructions, and waiting for the Stop signal (average GoRT>1000msecs and stop accuracy >85%). Participants in the restraint condition were not excluded if RTs were longer than 1000msecs. For descriptive values and *F* statistics see Table 3.2.

Assumption of normality was violated for Go RT, *W*(47)=.873, *p*<.001, Levene's was also violated (*p*=.048). Normality was violated for Go accuracy, *W*(47)=.341, *p*<.001, Levene's was also violated (*p*=.022). Normality was violated for SSRTi, *W*(47)=.910, *p*<.001, Levene's was also violated (*p*=.045).

There was a significant main effect of experimental condition on GoRTs on the Stop Signal task, *H*(2)=6.816, *p*=.033. Participants in the restraint condition (Mdn=639, range=705) had longer GoRTs compared to those in the disinhibition condition (Mdn=547, range=420), this difference approached significance, *U*=66, *p*=.020. There was not a significant difference in GoRTs between participants in the control condition (Mdn=545, range=458) and the restraint condition, *U*=60, *p*=.029, or the control condition and the disinhibition condition, *U*=120, *p*=.794.

There was also a significant effect of instructions on Go accuracy, *H*(2)=7.697, *p*=.021. Participants in the restraint condition (Mdn=97, range=57) displayed reduced Go accuracy compared to those in the disinhibition condition (Mdn=98, range=4), *U*=61, *p*=.011.Participants in the control condition (Mdn=97, range=8) and the restraint condition were equally accurate, *U*=93.50, *p*=.436, as were the control and disinhibition conditions, *U*=75.50, *p*=.049. See Figure 3.1.

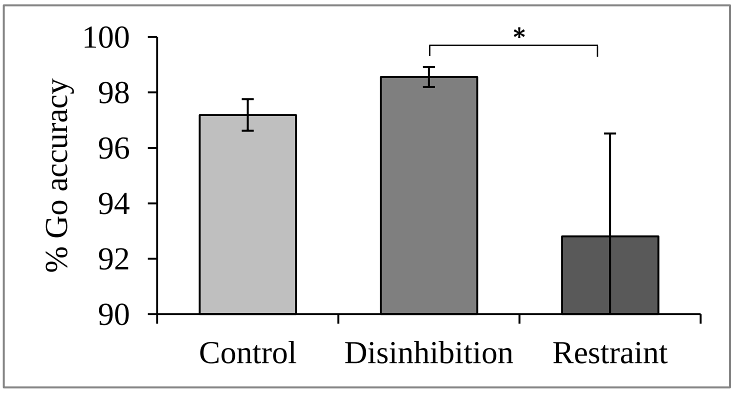

Figure 3.1. Go accuracy (%) on the Stop Signal Task for the Control, Disinhibition (instructions for speeded responses to Go signals) and Restraint (instructions for accurate responses to Stop signals) conditions, for Study 1a, with polarised instructions. Bars represent mean±sem. *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

There were no group differences in inhibitory control as indexed by SSRTi, *H*(2)=2.757, *p*=.252.

There were no effects of Barratt impulsiveness covariates on the Stop Signal Task (*Fs*<2.686, *ps*>.05).

3.2.2.3 Information Sampling Task

Assumption of normality was violated for fixed win errors, *W*(50)=.893, *p*<.001, for reward conflict P(correct), *W*(50)=.922, *p*<.001, and for reward conflict errors, *W*(50)=.946, *p*=.027. Levene's was not violated for any measure.

There were no group differences on any of the Information Sampling Task fixed win, or reward conflict outcome variables (*Fs*<1.791, *ps*>.05). For descriptive values and *F* statistics see Table 3.2.

	Control	Disinhibition	Restraint	***p***
Stop Signal Task				
N	15	17	15	
Go RT	558.82±32.89	549.62±30.30	728.31±60.60	$H(2)=6.816$, $p=.033^{b}$*
Go accuracy	97.19±.57	98.56±.36	92.81±3.71	$H(2)=7.697$, $p=.021^{b}$*
SSRTi	236.63±20.36	237.67±19.12	291.46±25.29	$H(2)=2.757$, $p=.252$
Information Sampling Task				
N	17	17	16	
Fixed Win. Number of boxes opened	12.64±1.34	16.45±1.45	14.31±1.60	$F(2,47)=1.721$, $p=.190$
Fixed Win. P(correct)	0.80±0.03	0.86±0.03	0.83±0.03	$F(2,47)=1.119$, $p=.335$
Fixed Win. Number of errors	1.76±0.30	1.35±0.19	2.00±0.39	$F(2,47)=1.179$, $p=.317$
Reward Conflict. Number of boxes opened	6.75±0.75	8.90±0.96	8.86±1.04	$F(2,47)=1.791$, $p=.178$
Reward Conflict. P(correct)	0.70±0.01	0.72±0.02	0.73±0.02	$F(2,47)=.648$, $p=.527$
Reward Conflict. Number of errors	3.29±0.41	2.53±0.45	3.06±0.39	$F(2,47)=.884$, $p=.420$
Matching Familiar Figures Task				
N	17	17	16	
I-score	-.4864±.2919	.9521±.4424	-.4948±.4561	$F(2,47)=4.342$, $p=.019$*
E-score	.1089±.1902	.0316±.3008	-.1493±.2167	$F(2,47)=.296$, $p=.746$
Delay Discounting Task				
N	10	10	8	
mean *k*	.0239±.0142	.0151±.0098	.0155±.0076	$F(2,25)=.674$, $p=.518$

Table 3.2. Key impulsivity values for the control, disinhibition and restraint conditions, and ANOVA statistics. Values are presented as Mean±sem. *indicates significant difference between groups (*$p<.05$) [b] Kruskal Wallis test

3.2.2.4 Matching Familiar Figures Task

There was a main effect of experimental condition, $F(2,47)=4.342$, $p=.019$, on impulsivity scores on the Matching Familiar Figures Task. Participants in the control condition were less impulsive, according to I-score, compared to those in the disinhibition condition, $p=.041$. Participants in the restraint condition were also less impulsive compared to the disinhibition condition, $p=.044$. There was not a significant difference between control and restraint participants, $p=.100$, see Figure 3.2.

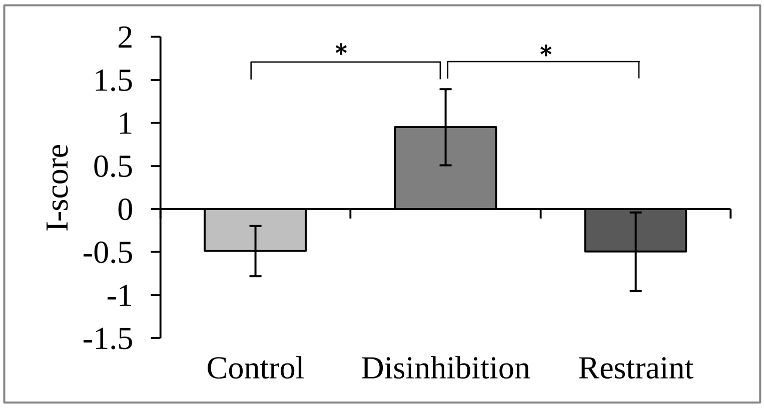

Figure 3.2. Mean I-score on the Matching Familiar Figures Task for the Control, Disinhibition (instructions for speed) and Restraint (instructions for accuracy) conditions, for Study 1a, with polarised instructions. High values indicate increased impulsivity. Bars represent mean±sem. *indicates significant difference between groups (*$p<.05$; **$p<.01$; ***$p<.001$)

There was not a significant group difference on E-score, $F(2,47)=.296$, $p=.746$. For descriptive values and F statistics see Table 3.2.

There was no effect of any Barratt impulsiveness covariate scores on I-score or E-score ($Fs<2.314$, $ps>.05$).

3.2.2.5 Delay Discounting Task

Data were log transformed to correct non normality of data (pre-transformation, $W(32)=.575$, $p<.001$; post-transformation, $W(32)=.942$, $p=.121$).

Data were missing from 18 participants due to a technical issue. Data were excluded from a further 4 participants because they failed to meet inclusion criteria (see Johnson & Bickel, 2008).

There were no group differences on mean *k* values, $F(2,25)=.674$, $p=.518$. For descriptive values and *F* statistics see Table 3.2. There was no effect of any Barratt impulsiveness covariate on any of the outcome variables (*Fs*<2.686, *ps*>.05).

3.2.2.6 Time estimation

There was no effect of time, $F(2,46)=.226$, $p=.636$, or condition, $F(1,24)=.595$, $p=.556$, on time estimation [control, time1 27.48±2.18, time2 25.76±1.99; restraint, time1 27.51±2.49, time2 24.89±1.72; disinhibition, time1 27.51±2.49, time2 28.31±2.47]. There was also no time by condition interaction, $F(2,46)=1.196$, $p=.312$.

3.2.2.7 Mood changes

There were no effects of time (*Fs*<3.203, *ps*>.05) experimental condition (*Fs*<1.046, *ps*>.05) or time by condition interactions (*Fs*<1.384, *ps*>.05). See table 3.3 for descriptive values.

3.2.2.8 Barratt impulsiveness changes

Barratt impulsiveness changes are not reported as the measure was not taken at time 2.

	Control		**Disinhibition**		**Restraint**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Profile of Mood States						
N	17	17	17	17	16	16
Anxiety	.73±.09	.67±.10	.82±.09	.83±.14	.73±.09	.62±.14
Depression	.73±.10	.70±.12	.69±.06	.64±.09	.76±.07	.67±.08
Anger	.79±.09	.71±.10	.75±.07	.75±.08	.77±.11	.63±.11
Vigour	.70±.10	.73±.15	.91±.14	.78±.13	.73±.11	.59±.13
Fatigue	.73±.10	.68±.12	.82±.12	.61±.13	.85±.10	.83±.12
Confusion	.82±.14	.66±.16	.73±.14	.69±.14	.78±.09	.78±.14
Friendliness	.87±.18	.72±.17	.77±.09	.80±.16	.71±.12	.70±.13
Elation	.89±.12	.77±.18	.72±.12	.60±.14	.77±.18	.83±.21
Arousal	-.12±.26	.06±.27	.16±.30	.31±.29	-.18±.16	-.39±.33
Positive mood	.16±.20	.07±.25	.02±.14	-.04±.15	.01±.19	.16±.21

Table 3.3. Profile of Mood States questionnaire scores for the three experimental groups pre- and post- instructions and cognitive tasks. Values are presented as Mean±sem

3.2.3 Brief discussion of study 1a

Study 1a found that inhibitory control, as measured by the Stop Signal Task, was not affected by task instructions; however, the instructions did affect Go responses (both reaction times and accuracy) on the task. Participants in the restraint condition had longer reaction times compared to the disinhibition condition and displayed poorer Go accuracy. Self-reported impulsivity did not contribute to performance on the Stop Signal Task.

Reflection impulsivity as measured by the Matching Familiar Figures Task, but not the Information Sampling Task, was affected by the instructions for speed or accuracy. Participants in the disinhibition condition were more impulsive on the Matching Familiar Figures (according to I-score) compared to participants in the restraint and control conditions; there was not a significant difference between participants in the restraint and control conditions. There was no effect of instructions on E-score. Self-reported impulsivity did not contribute to performance on the Matching Familiar Figures.

Neither reflection impulsivity according to the Information Sampling Task, nor temporal impulsivity on the Delay Discounting Task were affected by the instructions or self-reported impulsivity.

3.3 Study 1b – cognitive priming

Study 1b will explore the speed/accuracy trade-off through the use of cognitive priming via an imagery script; participants will complete a priming task, disguised as a memory task that focuses on quick, impulsive, responses (disinhibition condition), slower more considered responses (restraint condition), or neither (control condition).

3.3.1 Method

3.3.1.1 Participants

49 paid participants (24 male, 25 female) were randomly allocated to one of three conditions: disinhibition (8 m, 9 f), restraint (8 m, 8 f) and control (8 m, 8 f).

3.3.1.2 Procedure

Participants completed the questionnaire pack and were informed that they were going to complete four computerised tasks. Before they would complete the task they were instructed that they would first complete a 'memory task' (see 3.3.1.3.1 'priming task').

Participants completed the priming task, according to their assigned condition, and then completed the four impulsivity measures: the Matching Familiar Figures Task, the Information Sampling Task (i,ii), Stop Signal Task (ii) and Delay Discounting Task (ii). All tasks were completed in a random order.

Participants then re-completed the Barratt Impulsiveness Scale, Profile of Mood States Questionnaire and time estimation task, recorded as many details as they could recall from the story, and scored how much they were able to relate to the main character.

3.3.1.3 Materials

3.3.1.3.1 Priming task.

The priming task was presented in the form of a memory task. The three groups read a story describing the life of an individual. Participants were instructed that they had five minutes to remember as many details as they could from the story, and that they would be required to recall the details of the story at the end of the experiment. Participants were told that it would help their memory if they imagined they were the main character in the story, even if he/she behaved in a manner unlike the participant. Stories were tailored to the participant's gender. Participants in the speed condition read a story in which the character was described as a very successful individual who could attribute their success to the fact that they were impulsive and tended to make snap judgments. The character in the accuracy condition attributed their success to being conscientious and slow to make judgments. The control condition gave no mention of speed or accuracy traits. See appendix 11 for copies of the priming stories.

3.3.1.3.2 Questionnaires

see Study 1a for details of questionnaires (see section 3.2.1.3.2. 'Questionnaires').

3.3.1.3.3 Cognitive and behavioural tasks

see Study 1a for details of tasks (see section 3.2.1.3.3. 'Cognitive and behavioural tasks').

3.3.1.4 Statistical analysis.

See Study 1a 'Statistical analysis' for details (see section 3.2.1.4. 'Statistical analysis').

3.3.2 Results

3.3.2.1 Group demographics

There were no group differences on any of the baseline group demographics or trait characteristics. See Table 3.4 for descriptive values and *F* statistics.

	Control	**Disinhibition**	**Restraint**	***p***
Age	19.88±1.36	19.59±1.12	21.88±5.39	$F(2,46)=2.396, p=.102$
NART, estimated verbal IQ	106.13±9.46	107.81±7.72	110.09±6.12	$F(2,46)=.769, p=.470$
Beck depression score	8.19±5.74	6.18±5.98	4.13±4.33	$F(2,46)=2.252, p=.117$
Time estimation	-2.84±5.48	1.09±7.58	-.88±5.64	$F(2,46)=1.589, p=.215$
Alcohol Use Questionnaire				
Units drunk per week	15.32±10.63	22.81±12.29	17.66±28.11	$F(2,46)=.701, p=.501$
Binge score	31.88±22.54	36.88±17.02	23.08±25.45	$F(2,46)=1.677, p=.198$
Alcohol use score	47.20±31.10	59.69±25.76	40.73±48.95	$F(2,46)=1.160, p=.322$
Barratt Impulsivity Scale				
Total score	68.67±11.09	66.71±10.35	65.31±9.10	$F(2,45)=.421, p=.659$
Attentional impulsivity	19.00±4.07	16.94±3.51	17.31±4.30	$F(2,45)=1.196, p=.312$
Motor impulsivity	23.80±5.28	24.12±3.22	24.31±3.59	$F(2,45)=.062, p=.940$
Nonplanning impulsivity	25.87±4.66	25.65±5.22	23.69±4.41	$F(2,45)=.999, p=.376$

Table 3.4. Baseline group demographics, alcohol use and self-reported trait impulsivity for the control, disinhibition and restraint conditions, and ANOVA statistics. Values are presented as Mean±s.d.

3.3.2.2 Stop Signal Task

Six participants were excluded from analysis. Three participants displayed go reaction times >1000 msecs and >90% stop accuracy (2 speed, 1 control; participants in the accuracy condition displaying RTs>1000msecs were not excluded from the analysis). One participant displayed 60% Go accuracy, one participant failed to stop to any stop signals, one participant had 75% Go accuracy, and 80% stop accuracy.

Normality was violated for GoRT, $W(43)=.869$, $p<.001$, for Go accuracy, $W(43)=.661$, $p<.001$, and for SSRTi, $W(43)=.944$, $p=.037$. Levene's was violated for GoRT ($p=.003$) and Go accuracy ($p<.001$) but not violated for SSRTi ($p=.179$).

There were no group differences on Go accuracy, $H(2)=4.047$, $p=.132$, or GoRTs, $H(2)=3.394$, $p=.183$, on the Stop Signal Task. There were no significant differences in inhibitory control as indexed by SSRTi, $F(2,40)=1.386$, $p=.262$. See table 3.5 for descriptive values.

When included as covariates, there was a significant effect of Barratt impulsiveness total score, $F(1,38)=4.732$, $p=.036$, and of non-planning impulsivity, $F(1,38)=4.267$, $p=.046$, on average GoRTs. There was an effect of motor impulsivity that approached significance, $F(1,38)=3.828$, $p=.058$, however there was no effect of attentional impulsivity, $F(1,38)=1.044$, $p>.05$. Participants recording greater self-report impulsivity displayed longer Go reaction times, $r_s(42)=.327$, $p=.035$, see Figure 3.3; there was also a relationship between nonplanning impulsivity and Go RT that approached significance, $r_s(42)=.296$, $p=.057$.

There was no effect of Barratt impulsiveness covariates on Go accuracy ($Fs<2.961$, $ps<.05$) or SSRTi ($Fs<3.031$, $ps<.05$).

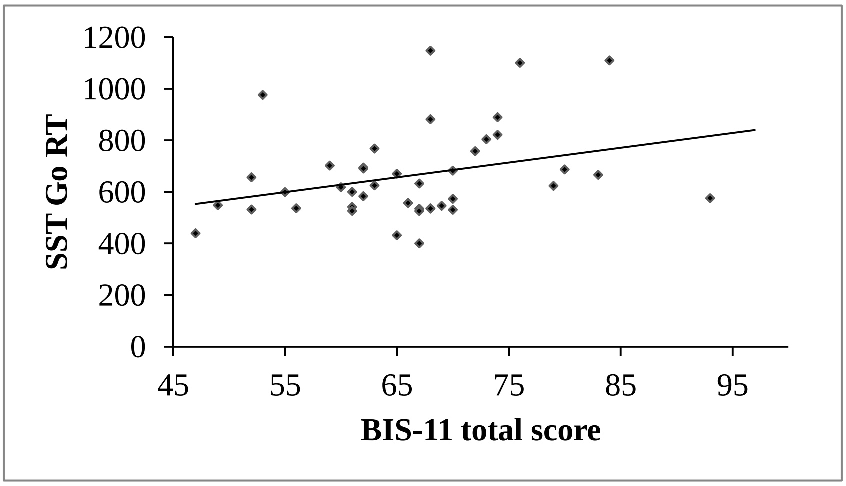

Figure 3.3. Scatterplot showing Go Reaction times on the Stop Signal Task (msecs) and self-report Barratt impulsiveness total score, for Study 1b, with the cognitive priming manipulation. High values indicate increased self-report impulsivity and longer Go reaction times.

3.3.2.3 Information Sampling Task

Assumption of normality was violated for fixed win errors, $W(49)=.875$, $p<.001$, and for reward conflict errors, $W(49)=.868$, $p<.001$. Levene's was not violated for any variable.

There was not a significant effect of cognitive priming on the Information Sampling Task; there were no group differences on any of the dependant variables ($Fs<1.914$, $ps>.05$). See table 3.5 for descriptive values and individual ANOVA statistics.

There was an effect of Barratt motor impulsivity covariate, on the number of boxes opened, $F(1,44)=4.402$, $p=.042$, in the fixed win condition of the task; participants recording higher impulsivity scores opened fewer boxes on the task, $r(48)=-.284$, $p=.051$

There were no other effects of any Barratt impulsiveness scores on the IST ($Fs<3.794$, $ps>.05$) or any effects of experimental condition ($Fs< 2.207$, $ps>.05$).

3.3.2.4 Matching Familiar Figures Task

There was no effect of cognitive priming on the Matching Familiar Figures Task, there were no group differences on I-score, $F(2,46)=.595, p=.556$, or E-score, $F(2,46)=.103, p=.903$; see table 3.5 for descriptive values.

There was no effect of any of the Barratt impulsiveness covariates on I-score (*Fs*<1.854, *ps*>.05).

There was an effect of Barratt impulsiveness total score, *F*(1,44)=4.341, *p*=.043, and nonplanning scores, *F*(1,44)=6.522, *p*=.014, on E-score; participants reporting high total impulsivity were less efficient on the task, *r*(49)=-.308, *p*=.033, as were those reporting high nonplanning scores, *r*(49)=-.356, *p*=.013; see Figure 3.4.

There was no effect of attentional impulsivity, *F*(1,44)=.631, *p*=.431, or motor impulsivity covariates, *F*(1,44)=2.067, *p*=.158, on E-scores.

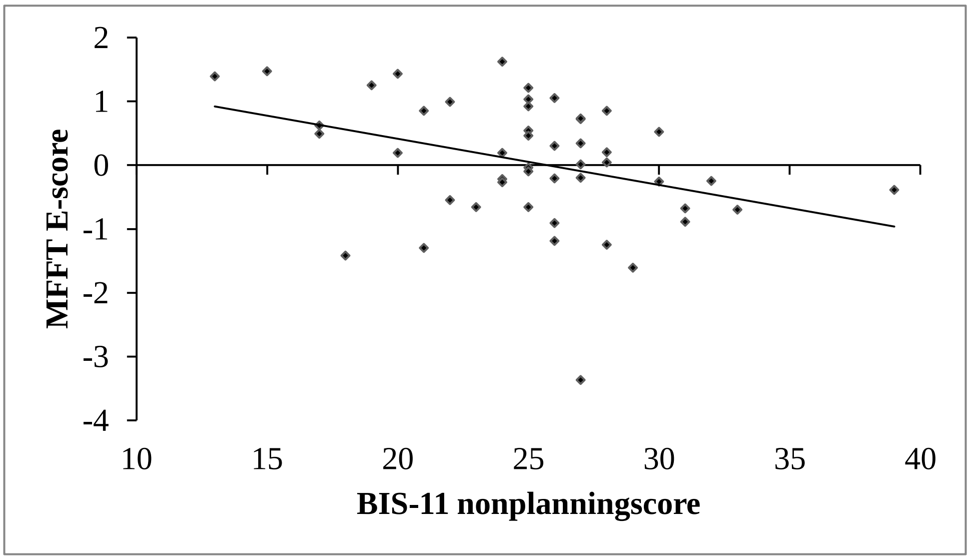

Figure 3.4. Scatterplot showing Efficiency scores on the Matching Familiar Figures Task and self-report Barratt impulsiveness nonplanning score, for Study 1b, with the cognitive priming manipulation. High values indicate increased self-report impulsivity and more efficient responding on the Matching Familiar Figures Task.

3.3.2.5 Delay Discounting Task

Three Participants were excluded for failing to meet inclusion criteria (see Johnson & Bickel, 2008). Normality of data was violated *W*(45)=.367, *p*<.001; homogeneity of variance was not violated (*p*=.130).

There were no group differences on mean *k* values, *F*(2,42)=.430,*p*=.654. There was no effect of Barratt impulsiveness scores (*Fs*<2.463, *ps*>.05); see table 3.5 for descriptive values.

	Control	Disinhibition	Restraint	***p***
Stop Signal Task				
N	13	15	15	
Go RT	678.37±28.52	600.42±32.14	699.87±61.51	$H(2)=3.394$, $p=.183$ [b]
Go Accuracy	96.58±1.25	98.41±.34	92.71±2.20	$H(2)=4.047$, $p=.132$ [b]
SSRTi	292.03±16.27	252.98±19.79	298.87±24.33	$F(2,40)=1.386, p=.262$
Information Sampling Task				
N	16	17	16	
Fixed Win, boxes opened	15.225±1.279	17.076±1.241	17.688±1.279	$F(2,46)=1.008, p=.373$
Fixed Win, P(correct)	.835±.024	.879±.023	.873±.024	$F(2,46)=1.028, p=.366$
Fixed Win, errors	1.500±.255	1.294±.248	.813±.255	$F(2,46)=1.914, p=.159$
Reward Conflict, boxes opened	9.738±1.030	10.700±.999	10.456±1.030	$F(2,46)=.241, p=.787$
Reward Conflict, P(correct)	.739±.020	.749±.019	.758±.020	$F(2,46)=.234, p=.793$
Reward Conflict, errors	2.063±.401	1.471±.389	1.688±.401	$F(2,46)=.570, p=.569$
Matching Familiar Figures Task				
N	16	17	16	
I-score	-.111±.424	-.190±.411	.072±.424	$F(2,46)=.595, p=.556$
E-score	-.177±.245	.187±.238	.078±.245	$F(2,46)=.103, p=.903$
Delay Discounting Task				
N	14	15	16	
Mean K value	.0059±.0079	.0084±.0077	.01557±.0075	$F(2,42)=.430, p=.654$

Table 3.5. Key impulsivity values for the control, disinhibition and restraint conditions, and ANOVA statistics. Values are presented as Mean±sem. [b]Kruskal Wallis test

3.3.2.6 Time estimation

There was a significant effect of time, $F(1,46)=4.475, p=.040$; participants gave longer estimates at time 2 (27282±826 msecs) compared to at time 1 (26122±905 msecs). There was a significant effect of condition, $F(2,46)=3.495, p=.039$; participants in the control condition (24111±1438 msecs) gave shorter estimates compared to those in the disinhibition condition (29403±1395 msecs), $p<.05$; there was not a significant difference between disinhibition and restraint (26592±1438 msecs), or restraint and control conditions ($p> .05$). There was not a significant time by condition interaction, $F(2,46)=2.115, p=.132$.

3.3.2.7 Mood changes

There were no significant effects of condition [*Fs*>3.036, *ps*>.05] no time by condition interactions [*Fs*>.858, *ps*>.05]. There was a significant effect of time on depression scores [$F(1,46)=4.830, p=.033$]; scores at time 1 (0.56± 0.10) were significantly greater than at time 2 (0.46±.010). There was a significant effect of time on vigour scores, $F(1,46)=6.973, p=.011$; scores at time 1 (1.66± 0.12) were significantly higher than time 2 (1.52±.013). There was a significant effect of time on friendliness scores, $F(1,46)=5.675, p=.021$; scores at time 1 (2.47±0.11) were greater than time 2 (2.32±0.12). There was a significant effect of time on elation scores, $F(1,46)=4.799, p=.034$; scores at time 1 (1.73±0.12) were greater than time 2 (1.60±0.13). There were no effects of time on anger, fatigue, confusion, positive mood or arousal scores (*Fs*<2.776, *ps*>.05). See Table 3.6 for descriptive values.

3.3.2.8 Barratt impulsiveness changes

There were no significant group differences (*Fs*<1.443, *ps*>.05) or effects of time (*Fs*<3.466, *ps*>.05) on self-reported impulsivity scores. There were no time by condition interactions [*Fs*<.534, *ps*>.05]. See Table 3.6 for descriptive values.

	Control		Disinhibition		Restraint	
	Pre	Post	Pre	Post	Pre	Post
Barratt Impulsivity Scale						
Total score	68.67±2.86	68.38±2.36	66.71±2.51	66.50±2.69	65.31±2.28	65.67±2.61
Attentional subtype	19.00±1.05	18.44±1.02	16.94±0.85	16.50±0.84	17.31±1.08	16.73±1.07
Motor subtype	23.80±1.36	23.81±1.05	24.12±0.78	23.94±0.93	24.31±0.90	24.60±0.83
Nonplanning subtype	25.87±1.20	26.13±1.14	25.65±1.27	26.06±1.31	23.69±1.10	24.33±1.56
Profile of Mood States						
Anxiety	0.94±0.19	0.88±0.14	0.52±0.10	0.44±0.08	0.92±0.17	0.84±0.17
Depression	0.85±0.21	0.67±0.21	0.35±0.12	0.26±0.11	0.51±0.17	0.48±0.18
Anger	0.57±0.16	0.48±0.21	0.23±0.08	0.12±0.05	0.58±0.17	0.57±0.17
Vigour	1.34±0.19	1.20±0.20	1.63±0.21	1.43±0.22	2.03±0.22	1.93±0.23
Fatigue	1.11±0.16	1.11±0.21	0.87±0.14	0.76±0.11	0.94±0.78	0.88±0.19
Confusion	1.27±0.17	1.10±0.17	0.97±0.15	0.92±0.14	1.00±0.18	0.94±0.18
Friendliness	2.28±0.22	2.03±0.21	2.44±0.17	2.36±0.21	2.68±0.18	2.56±0.19
Elation	1.44±0.21	1.30±0.20	1.70±0.21	1.56±0.21	2.05±0.21	1.95±0.23
Arousal	-0.09±0.27	-0.13±0.36	0.31±0.32	0.20±0.34	1.00±0.35	0.96±0.31
Positive mood	0.46±0.38	0.64±0.38	1.35±0.28	1.30±0.26	1.54±0.24	1.47±0.27

Table 3.6. Profile of Mood States questionnaire scores and Barratt impulsiveness Scores for the three experimental groups pre- and post- cognitive priming. Values are presented as Mean±sem

3.3.3 Brief discussion of study 1b

There was no effect of the cognitive priming manipulation on inhibitory control on the Stop Signal Task. There was an effect of self-reported impulsivity on Go reaction times. Higher Barratt impulsiveness total and nonplanning scores indicated longer Go reaction times. Stop signal inhibition was not affected by either the cognitive priming or self-reported impulsivity.

There was no effect of cognitive priming on either measure of reflection impulsivity. On the Information Sampling Task there was an effect of motor impulsivity on boxes opened in the fixed win condition, higher impulsivity scores indicated less information sampling, i.e. greater reflection impulsivity. There were no other effects of self-report impulsivity on the Information Sampling Task. For the Matching Familiar Figures Task, there was an effect of Barratt impulsiveness total score and nonplanning impulsivity on E-score, but no effects on I-score. Higher impulsivity scores were related to low efficiency scores on the task.

There was no effect of cognitive priming or Barratt impulsiveness scores on the Delay Discounting Task.

3.4 Study 1c – combined instructions and cognitive priming

Study 1c combines the instructions and priming manipulations; participants will be assigned to the disinhibition, restraint or control condition, and will complete the associated priming and instructions.

3.4.1 Method

3.4.1.1 Participants

49 paid participants (25 male, 24 female) were randomly allocated to one of three conditions: disinhibition (9 m, 8 f), restraint (8 m, 8 f) and control (8 m, 8 f); participants received their condition-appropriate tasks and instructions from Studies 1a and b.

3.4.1.2 Procedure

Participants completed the questionnaire pack and were informed that they were going to complete a memory task, followed by four computerised tasks. On each computerised task they were asked to make their responses as quickly/ accurately/ quickly and accurately as possible, according to their assigned condition.

Participants completed the priming task (see Study 1b 'priming task') and then completed the four impulsivity measures: the Matching Familiar Figures Task, the Information Sampling Task (i,ii), Stop Signal Task (i) and Delayed Discounting Task (i). All tasks contained polarised instructions (see Study 1a 'polarised instructions') according to the assigned condition, and were completed in a random order.

Participants then repeated the Barratt Impulsiveness Scale, Profile of Mood States Questionnaire and time estimation task.

3.4.1.3 Materials

3.4.1.3.1 Priming task and polarised instructions

see Study 1a and 1b for details of polarised instructions (see section 3.2.1.3.1. 'Polarised instructions') and priming tasks (see section 3.3.1.3.1. 'Priming task').

3.4.1.3.2 Questionnaires

see Study 1a for details of tasks (see section 3.2.1.3.2 'Questionnaires').

3.4.1.3.3 Cognitive and behavioural tasks

see Study 1a for details of tasks (see section 3.2.1.3.3 ‘Cognitive and behavioural tasks’).

3.4.1.4 Statistical analysis.

See Study 1a ‘Statistical analysis’ for details (see section 3.2.1.4 ‘Statistical analysis’).

3.4.2 Results

3.4.2.1 Group demographics

There was a significant difference between groups in baseline Barratt impulsiveness non-planning scores, $F(2,46)=3.730$, $p=.032$. Participants in the disinhibition condition reported significantly higher baseline non-planning impulsivity (27.88±1.16) compared to the control condition (23.56±1.13), $p=.043$; there were no significant differences between control and restraint, or restraint and impulsivity conditions ($ps>.05$).

There were no other significant differences in participant demographics ($Fs<1.253$, $ps>.05$), see table 3.7 for descriptive values and ANOVA statistics.

	Control	**Disinhibition**	**Restraint**	***p***
Age	22.31±4.77	22,29±4.40	20.56±2.34	$F(2,46)=1.025$, $p=.367$
NART, Verbal IQ	108.82±9.00	112.46±5.78	110.40±4.17	$F(2,46)=.996$, $p=.379$
Beck depression score	7.44±7.92	6.00±5.51	4.25±5.53	$F(2,46)=.994$, $p=.378$
Time estimation	2.80±5.07	3.71±6.38	3.43±9.64	$F(2,40)=.056$, $p=.946$
Alcohol Use Questionnaire				
Units drunk per week	23.41±18.26	32.52±25.53	23.94±14.54	$F(2,46)=1.078$, $p=.349$
Binge score	22.34±15.83	27.24±18.07	33.06±33.31	$F(2,46)=.828$, $p=.443$
Alcohol use score	45.74±24.68	59.76±38.81	57.00±43.43	$F(2,46)=.671$, $p=.516$
Barratt Impulsiveness Scale				
Total score	65.00±11.17	70.29±9.20	65.75±10.91	$F(2,46)=1.253$, $p=.295$
Attentional impulsivity	17.56±4.10	17.35±4.23	16.81±4.00	$F(2,46)=.142$, $p=.868$
Motor impulsivity	23.88±4.76	25.00±3.34	24.63±4.05	$F(2,46)=.324$, $p=.725$
Nonplanning impulsivity	23.56±4.50	27.88±4.77	24.31±5.33	$F(2,46)=3.730$, $p=.032$*

Table 3.7. **Baseline group demographics, alcohol use and self-reported trait impulsivity for the control, disinhibition and restraint conditions, and ANOVA statistics. Values are presented as Mean±s.d. *indicates significant difference between groups (*$p<.05$)**

3.4.2.2 Stop Signal Task

One participant was excluded (from the control condition) for failing to follow task instructions, and waiting for the stop signal (average GoRT>1000ms). Data were missing for 1 participant. Assumption of normality was violated for Go accuracy, *W*(47)=.719, *p*<.001, and for SSRTi, *W*(47)=.852, *p*<.001; levene's was also violated for both Go accuracy (*p*=.047) and SSRTi (*p*<.001).

There was a significant difference in GoRT on the Stop Signal Task between groups, , *F*(2,44)=25.984, *p*<.001. Participants in the disinhibition condition displayed faster GoRTs compared to those in the control condition, who in turn were faster than those in the restraint conditions (*ps*<.005).See Figure 3.5.

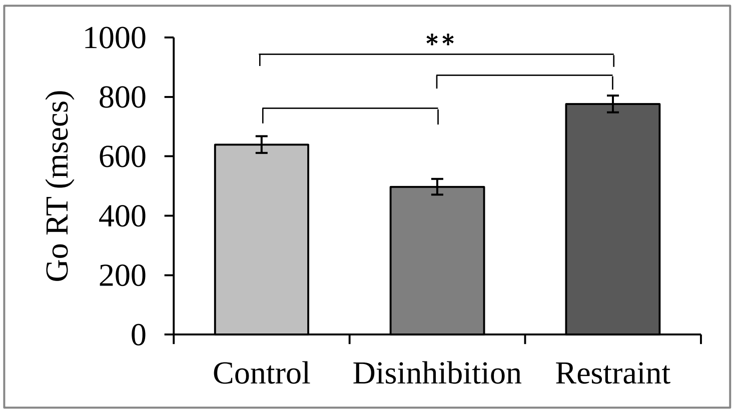

Figure 3.5. Go reaction times (msecs) on the Stop Signal Task for the Control, Disinhibition and Restraint conditions, for Study 1c, with combined polarised instructions and cognitive priming. Bars represent mean±sem. *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

There was a significant effect of condition on Go accuracy, *H*(2)=11.668, *p*=.003. Participants in the restraint condition (Mdn=96.67, range=14.17) had significantly lower Go accuracy compared to control participants (Mdn=98.33, range=5.83), *U*=48.50, *p*=.007, and disinhibition participants (Mdn=98.33, range=4.17), *U*=45, *p*=.001; there was not a significant difference between the control and disinhibition conditions, *U*=126, *p*=.953, see Figure 3.6.

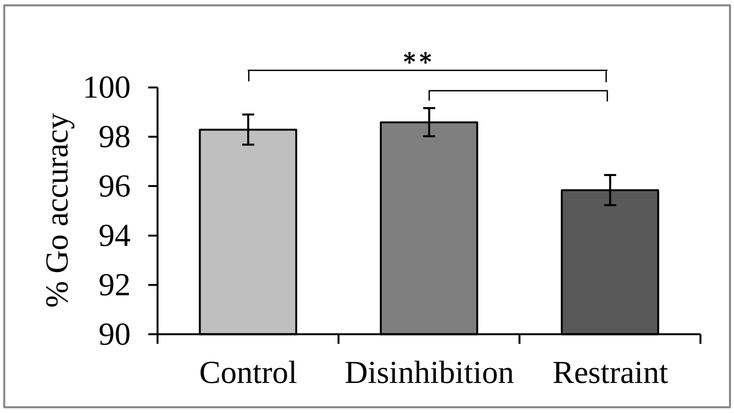

Figure 3.6. Go accuracy (%) on the Stop Signal Task for the Control, Disinhibition and Restraint conditions, for Study 1c, with combined polarised instructions and cognitive priming. Bars represent mean±sem. *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

SSRTi data are not presented as the large group differences in Go reaction times mean the SSRTs are not directly comparable between groups (A. Jones, Cole et al., 2011).

See Table 3.8 for descriptive values.

There was no effect of any Barratt impulsiveness covariate on Go RT or Go accuracy (*Fs*<.332, *p*s>.05).

3.4.2.3 Information Sampling Task

Data were missing for two participants.

Assumption of normality was violated for fixed win boxes opened, *W*(47)=.917, *p*=.003, and fixed win P(correct), *W*(47)=.862, *p*<.001, and fixed win errors, *W*(47)=.825, *p*<.001. Normality was also violated for reward conflict errors, *W*(47)=.873, *p*<.001. Homogeneity of variance was violated for reward conflict errors (*p*=.002).

Fixed win condition.

There was a significant effect of condition on the number of boxes opened in he fixed win condition of the Information Sampling Task, *F*(2,44)=13.947, *p*<.001. Participants in the control condition opened more boxes than those in the disinhibition condition (*p*=.002), as did participants in the restraint condition (*p*<.001). There was not a difference between control and restraint conditions (*p*=.512).

	Control	Disinhibition	Restraint	*p*
Stop Signal Task				
N	15	17	15	
Go RT	639.41±28.23	497.26±26.51	776.13±28.23	*F*(2,44=25.984, *p*<.001***
Go accuracy	98.28±0.61	98.58±0.57	95.83±0.61	*H*(2=11.668, *p*=.003**
Information Sampling Task				
N	15	17	15	
Fixed Win. boxes opened	19.11±1.63	12.65±1.17	21.65±0.89	*F*(2,44=13.947, *p*<.001***
Fixed Win. P(correct)	0.92±0.03	0.79±0.02	0.95±0.02	*F*(2,44=12.347, *p*<.001***
Fixed Win. Number of errors	1.07±0.32	2.12±0.32	0.53±0.24	*F*(2,44=7.635, *p*=.001***
Reward Conflict. boxes opened	10.96±1.12	7.93±0.80	14.20±0.80	*F*(2,44=12.075, *p*<.001***
Reward Conflict. P(correct)	0.77±0.03	0.70±0.02	0.83±0.02	*F*(2,44=10.098, *p*<.001***
Reward Conflict. Number of errors	1.87±0.45	2.53±0.31	0.87±0.19	*H*(2=10.762, *p*=.005**
Matching Familiar Figures Task				
N	14	17	15	
I-score	-.78±.35	1.81±.32	-1.27±.25	*F*(2,44=29.231, *p*<.001***
E-score	.29±0.23	-0.05±0.20	0.03±0.16	*F*(2,44=.061, *p*=.941
Delay Discounting Task				
N	13	14	14	
Mean *k*	0.0038±0.0017	0.0130±0.0043	0.0026±0.0008	*F*(2,38=3.757, *p*=.032*

Table 3.8. Key impulsivity values for the control, disinhibition and restraint conditions, and ANOVA statistics. Values are presented as Mean±sem. *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

There was a significant group difference in the probability of being correct that the groups tolerated at the point of decision-making [P(correct)], $F(2,44)=12.347$, $p<.001$. Participants in the control condition tolerated less uncertainty compared to the disinhibition condition ($p=.002$) as did the restraint condition ($p<.001$); there was not a difference between control and restraint conditions ($p=1.000$). See Figure 3.7.

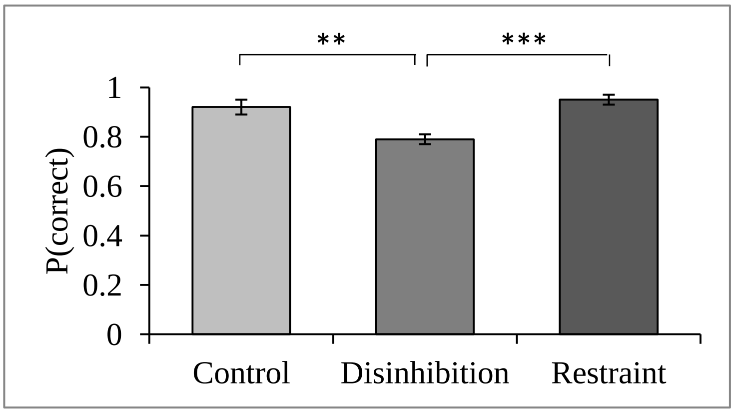

Figure 3.7. The probability of being correct at the point of decision making [P(correct)] on the fixed win version of the Information Sampling Task (i) for the Control, Disinhibition and Restraint conditions for Study 1c, with combined polarised instructions and cognitive priming. Small values indicate increased impulsivity, and more uncertainty tolerated at the point of decision making. Bars represent mean±sem. *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

There was a significant effect of condition on the number of errors made on the task, $F(2,44)=7.635$, $p=.001$. Participants in the disinhibition condition made more errors compared to those in the control ($p=.045$) and restraint ($p<.001$) conditions.There was not a difference between control and restraint conditions ($p=.658$). See Table 3.8 for descriptive values.

There was no effect of any Barratt impulsiveness covariate on boxes opened (*Fs*<.906, *ps*>.05), on P(correct) (*Fs*<1.125, *ps*>.05), or on number of errors (*Fs*<.766, *ps*>.05).

Reward conflict condition.

There was a significant group difference in the number of boxes opened on the task, $F(2,44)=12.075$, $p<.001$. Participants in the disinhibition condition opened fewer boxes compared to those in the restraint condition ($p<.001$), however there was not a significant difference between control and disinhibition conditions, or control and restraint conditions (p = .066 and .053 respectively).

There was also a significant effect of condition on tolerance of uncertainty at the point of decision making, $F(2,44)=10.098$, $p<.001$. Participants in the disinhibition condition tolerated more uncertainty compared to those in the restraint condition ($p<.001$). There was not a significant difference between control and disinhibition or control and restraint conditions ($p = .085$; $p = .110$), see Figure 3.8.

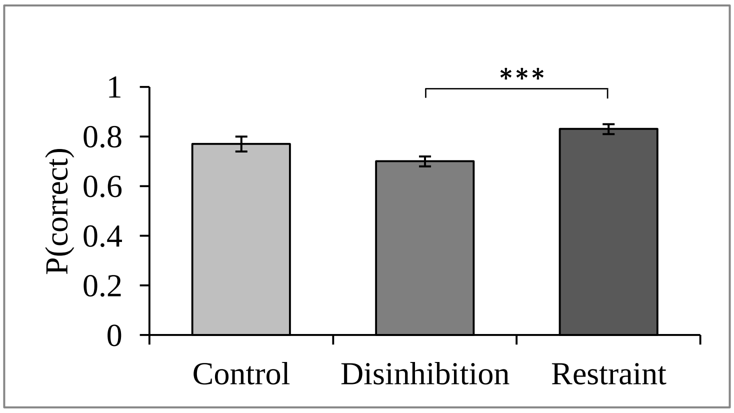

Figure 3.8. The probability of being correct at the point of decision making [P(correct)] on the reward conflict version of the Information Sampling Task (ii) for the Control, Disinhibition and Restraint conditions for Study 1c, with combined polarised instructions and cognitive priming. Small values indicate increased impulsivity, and more uncertainty tolerated at the point of decision making. Bars represent mean±sem. *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

There was a significant difference between groups in the number of errors made on the task, $H(2)=10.762$, $p=.005$. Participants in the disinhibition condition (Mdn=3, range=3) made more errors in comparison to those in the control restraint condition (Mdn=1, range=2), $U=92$, $p=.164$. See Table 3.8.

There was no effect of any Barratt impulsiveness covariate on boxes opened ($Fs<.578$, $ps>.05$), P(correct) ($Fs<.612$, $ps>.05$) or number of errors ($Fs<.670$, $ps>.05$).

3.4.2.4 Matching Familiar Figures Task

Data were missing for two participants. Normality was violated for E-score, $W(47)=.906$, $p=.002$; homogeneity of variance was not violated.

There was a significant effect of condition on I-score, $F(2,44)=29.231$, $p<.001$. Participants in the disinhibition condition were more impulsive, according to I-score than those in the control and restraint conditions ($ps<.001$). There was not a significant difference between control and restraint conditions ($p=.860$), see Figure 3.9.

There was no group difference on E-score, $F(2,44)=.061$, $p=.941$.

See table 3.8 for descriptive values.

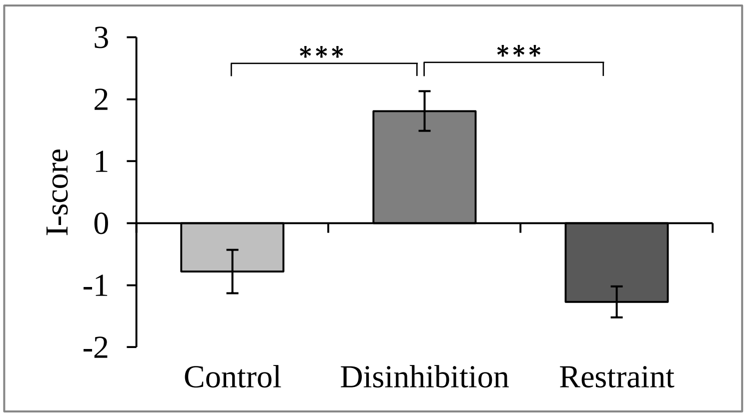

Figure 3.9. Mean I-score on the Matching Familiar Figures Task for the Control, Disinhibition and Restraint conditions, for Study 1c, with combined polarised instructions and cognitive priming. High values indicate increased impulsivity. Bars represent mean±sem. *indicates significant difference between groups (*$p<.05$; **$p<.01$; ***$p<.001$)

There was no effect of any covariate on I-score or E-score ($Fs<1.726$, $ps>.05$).

3.4.2.5 Delay Discounting Task

Data were missing for four participants; a further four participants were excluded for failing to meet inclusion criteria (see Johnson & Bickel, 2008).

Data were log transformed to help correct non-normal distribution, all subsequent analysis was performed on the log transformed data; all descriptive values are original data. [pre-transformation, $W(41)=.602$, $p<.001$; post-transformation, $W(41)=.969$, $p=.322$]; levene's was not violated ($p=.636$).

There was a significant effect of condition on the mean *k* value [$F(2,38) = 3.757$, $p=.032$]; Participants in the disinhibition condition had higher mean *k* values, indicating an increased preference for immediate rewards, compared to the restraint condition ($p=.041$); there were no other differences between groups. See Table 3.8 for descriptive values.

There was no effect of any Barratt impulsiveness covariate ($Fs<.196$, $ps>.05$). After controlling for Barratt impulsiveness scores, there was not an effect of condition on mean *k* values, $F(2,34)=3.017$, $p=.062$.

3.4.2.6 Mood changes

Data were missing from one participant in the pre- experimental manipulation mood ratings, and another in the post- manipulation mood ratings.

There was a significant effect of condition on vigour ratings, F(2,44=3.544, $p=.037$. Post hoc tests found a significant difference between disinhibition (1.43±.20) and restraint (2.17±.20) conditions ($p=.037$), there was not a significant difference between control (1.66±.20) and disinhibition or restraint conditions ($p>.05$). There was a significant effect of condition on elation ratings, $F(2,44)=3.788$, $p=.030$; post hoc tests did not find a difference between any of the experimental conditions ($p>.05$). There was a significant effect of time on depression ratings, $F(1,44)=12.082$, $p=.001$. Post manipulation mood ratings (.35±.08) were significantly lower than pre manipulation ratings (.53±.09). There was also a significant effect of time on confusion ratings, $F(1,44)=4.953$, $p=.031$. Post manipulation mood ratings (.99±.10) were significantly lower than pre manipulation ratings (1.03±.10).

There were no other effects of experimental condition, or time, on any mood ratings ($p>.05$). There were no time by condition interactions ($p>.05$).

See table 3.9 for descriptive values.

3.4.2.7 Barratt impulsiveness changes

There was a significant effect of time on Barratt impulsiveness attentional scores, $F(1,46)=7.876$,$p=.007$; pre manipulation scores (17.24±.59) were significant higher than scores post manipulation (16.55±.60).

There was a significant effect of condition on nonplanning impulsivity scores, *F*(2,46)=4.485,*p*=.017, post hoc tests indicated a significant difference between control (23.97±1.15) and disinhibition (28.21±1.11) conditions and between restraint (24.22±1.15) and disinhibition conditions (*p*=.033, .048 respectively); there was not a significant difference between control and restraint conditions (*p*=1.000).

There were no other effects of time, condition, or any time by condition interactions (*Fs*<1.708, *p*s>.05).

See table 3.9 for descriptive values.

	Control		**Disinhibition**		**Restraint**	
	Pre	Post	Pre	Post	Pre	Post
Profile of Mood States						
N	16	16	16	17	16	15
Anxiety	0.88±0.14	0.83±0.20	0.58±0.11	0.53±0.09	0.79±0.20*	0.57±0.16
Depression	0.57±0.13	0.43±0.15	0.50±0.14	0.31±0.08	0.49±0.20	0.32±0.17
Anger	0.43±0.09**	0.22±0.07	0.29±0.09*	0.17±0.04	0.63±0.23	0.56±0.24
Vigour	1.75±0.24	1.56±0.21	1.52±0.19	1.41±0.16	2.15±0.21	2.18±0.23
Fatigue	1.06±0.24	1.04±0.27	0.80±0.11	0.76±0.12	0.94±0.23	0.83±0.22
Confusion	0.96±0.10	0.91±0.15	1.17±0.19	0.99±0.18	0.95±0.20*	0.74±0.17
Friendliness	2.42±0.19	2.28±0.23	2.64±0.14	2.50±0.20	2.88±0.20	2.87±0.20
Elation	1.60±0.23	1.50±0.22	1.64±0.20	1.49±0.18	2.24±0.23	2.28±0.19
Arousal	0.61±0.42	0.67±0.45	0.12±0.34	0.20±0.27	1.05±0.34	1.17±0.36
Positive mood	1.03±0.31	1.10±0.29	1.14±0.32	1.18±0.26	1.75±0.34	1.96±0.27
Barratt Impulsiveness Scale						
N	16	16	17	17	16	16
Total score	65.00±2.79	63.88±2.75	70.29±2.23	70.53±2.37	65.75±2.73	64.63±2.45
Attentional Impulsivity	17.56±1.02*	16.75±1.14	17.35±1.03*	16.71±0.97	16.81±1.00	16.19±1.01
Motor impulsivity	23.88±1.19	23.38±1.31	25.00±0.81	25.29±0.85	24.63±1.01	24.31±0.71
Nonplanning impulsivity	23.56±1.1	24.38±0.88	27.88±1.16	28.53±1.22	24.31±1.33	24.13±1.28

Table 3.9. Profile of Mood States questionnaire scores and Barratt impulsiveness Scores for the three experimental groups pre- and post- instructions and cognitive priming. Values are presented as Mean±sem * Indicates a significant change between pre- and post- manipulation ratings (*<.05, **<.01)

3.4.2.8 Time estimation changes

There was no effect of time, *F*(1,40)=1.105, *p*=.299, or condition, *F*(2,40)=.051, *p*=.950, on time estimation. There was not a time by condition interaction, *F*(1,40)=.392, *p*=.678.

3.4.3 Brief discussion of study 1c

Go responding on the Stop Signal Task was affected by the manipulation. Participants in the disinhibition condition had faster reaction times compared to the control group, who in turn had shorter times compared to the restraint condition. Go accuracy was also affected; participants in the restraint condition showed poor Go accuracy compared to those in the disinhibition group.

Reflection impulsivity according to the Information Sampling Task was affected by the manipulation; there was an effect of condition on boxes opened, P(correct) and errors in both the fixed win and reward conflict condition. In the fixed win condition participants in the disinhibition condition were more impulsive (they opened fewer boxes, tolerated more uncertainty and made more errors) than the control and restraint participants. In the reward conflict condition participants in the disinhibition condition were more impulsive compared to the restraint condition, but not the control condition (there was not a significant difference between control and restraint conditions).

Reflection impulsivity according to the Matching Familiar Figures was also affected: participants in the disinhibition condition were more impulsive than the control and restraint conditions. There was no effect of the manipulation on E-score.

The manipulation increased temporal impulsivity on the Delay Discounting Task; participants in the disinhibition condition were more impulsive than the restraint participants.

There were no effects of self-report impulsivity according to the Barratt Impulsiveness Scale.

3.5 Baseline differences between studies 1a, b & c

To allow us to make comparisons between the three studies, baseline differences in age, IQ, depression, alcohol use, mood ratings and self-report impulsivity were compared between the studies.

3.5.1 Statistical analysis.

One-way ANOVA were run to establish any baseline group differences between studies. Study (1a, b and c) was included as the fixed factor. Age, verbal IQ, Beck depression score, alcohol use, mood ratings and self-reported impulsivity ratings were included as the dependent variables. Post hoc tests were Bonferroni corrected if assumption of equal variances was met, and Games-Howell if not (assume Bonferroni unless otherwise stated). Welch statistic was run if assumptions of normality and equal variance were violated.

3.5.2 Baseline differences

There were no baseline differences in self-reported impulsivity, verbal IQ, Beck depression score or anxiety, depression or fatigue mood ratings [$Fs<2.765$, $ps>.05$]

There was a difference in age between studies, $F(2,145)=3.667$, $p=.028$. Participants were older in study 1a (M 22.46, SD 3.97) compared to 1b (M 20.43, SD 3.34), $p=.019$, Games-Howell corrected. See Table 3.10 for descriptive values.

There was a difference in self-repotred alcohol use between studies, $F(2,142)=4.204$, $p=.017$. Participants drank a greater number of units of alcohol per week in study 1c compared to 1a, $p=.017$, Games-Howell corrected. Participants recorded higher binge scores in study 1b and 1c compared to 1a, $ps<.05$, Games-Howell corrected; significant main effect, $F(2,82.90)=12.264$, $p<.001$. Participants recorded higher alcohol use scores in study 1b and 1c compared to 1a, $ps<.01$, Games-Howell corrected; significant main effect, $F(2,86.32)=8.619$, $p<.001$. See Table 3.10 for descriptive values.

	Study 1a	Study 1b	Study 1c	*p*
N	50	49	49	
Age	22.46±3.97	20.43±3.34	21.73±3.99	*F*(2,145=3.667, *p*=.028*
Verbal IQ	107.67±6.12	107.81±7.99	110.64±6.35	*F*(2,111=2.233, *p*=.112
Beck depression score	7.64±6.60	6.16±5.55	5.90±6.40	*F*(2,145=1.136, *p*=.324
Alcohol Use Questionnaire				
Units per week	17.26±12.23	18.68±18.51	26.74±20.14	*F*(2,142=4.204, *p*=.017*
Binge score	15.72±10.23	30.74±22.16	27.54±23.52	*F*(2,82.90=12.264, *p*<.001 [a]**
Alcohol use score	32.98±18.79	49.42±36.56	54.28±36.32	*F*(2,86.32=8.619, *p*<.001 [a]**
Barratt Impulsiveness Scale				
Total score	66.04±10.79	66.85±10.07	67.08±10.49	*F*(2,144=.136, *p*=.873
Attentional impulsivity	17.64±4.17	17.71±3.98	17.24±4.04	*F*(2,144=.185, *p*=.831
Motor impulsivity	24.28±4.12	24.08±4.00	24.51±4.02	*F*(2,144=.135, *p*=.873
Nonplanning impulsivity	24.12±5.34	25.06±4.79	25.31±5.14	*F*(2,144=.748, *p*=.475

Table 3.10. Group characteristics (age, verbal IQ, beck depression score, alcohol use) mood ratings and trait measurements (self-reported impulsivity ratings) at baseline for study 1a (Instructions) study 1b (Cognitive priming) and study 1c (Instructions and priming). Values are expressed as mean±s.d. *indicates a significant difference between studies. (*p<.05, **p<.001)

3.5.3 Alcohol use and age correlations.

To address these baseline differences, alcohol use and age were correlated with the impulsivity measure variables using Pearson's correlation coefficient.

There were no correlations between age, alcohol use and any of the impulsivity measures in Study 1a or Study 1c.

In Study 1b there were no significant relationships between age or alcohol use and the Stop Signal Task or Delay Discounting Task. There were significant relationships between age and reflection impulsivity. Older participants were less efficient on the Matching Familiar Figures Task, *r*(49)=-.468, *p*=.001; older participants also opened fewer boxes on the Information Sampling Task reward conflict condition, *r*(49)=-.393, *p*=.005, tolerated more uncertainty at the point of decision making, *r*(49)=-.365, *p*=.010. There were no correlations between alcohol use and reflection impulsivity.

	SST			IST						MFFT		DDT
				Fixed win			Reward conflict					
	SSRT	**Go%**	**GoRT**	**Boxes opened**	**P(correct)**	**Errors**	**Boxes opened**	**P(correct)**	**Errors**	**I-score**	**E-score**	**Mean *k***
Study1a												
Instructions	—	Yes	Yes	—	—	—	—	—	—	Yes	—	—
BIS-11	—	—	—	—	—	—	—	—	—	—	—	—
Study1b												
Priming	—	—	—	—	—	—	—	—	—	—	—	—
BIS-11	—	—	Yes	Yes	Trend	—	—	—	—	—	Yes	—
Study1c												
Combination	N/a	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	—	Yes
BIS-11	N/a	—	—	—	—	—	—	—	—	—	—	—

Table 3.11. Summary of results for the three studies. Study 1a= polarised instructions; Study 1b=cognitive priming; Study 1c=combination manipulation of polarised instructions and cognitive priming. — indicates no significant result was found. N/a indicates these data were not analysed. SST= Stop Signal Task; IST= Information Sampling Task; MFFT= Matching Familiar Figures Task; DDT= Delay Discounting Task

3.6 General discussion

The current research suggests that all three of the subtypes of impulsivity are affected, to an extent, by imbalances in the speed/accuracy trade-off. The data show that the combination of instructions and cognitive priming was most successful at modifying the trade-off. The instructions-only manipulation modified performance only on the Matching Familiar Figures and the Stop Signal Task. The cognitive priming-only manipulation did not affect any impulsivity measure in itself, but instead trait impulsivity was related to behaviour. See table 3.11 for a summary of the results.

Interestingly, the combination of instructions and cognitive priming (study 1c) affected all four impulsivity measures. Go reaction times and Go accuracy were affected on the Stop Signal. Reflection impulsivity was affected on both the Information Sampling Task and Matching Familiar Figures Task. The manipulation also increased temporal impulsivity on the Delay Discounting Task; participants in the disinhibition condition were more impulsive than those in the restraint condition. It is clear that experimentally encouraging conscious and non-conscious control of behaviour, through direct instructions and cognitive priming, was most effective at creating an imbalance in the trade-off: the cognitive priming appears to have potentiated the effect of the instructions.

Compared to this, the instructions only manipulation, as a means of encouraging strategic conscious control of behaviour, had a limited effect on behavioural impulsivity. Direct instructions for speed or accuracy, were found to be effective at increasing reflection impulsivity, as measured by the Matching Familiar Figures Task, but did not affect performance on the Information Sampling Task, Delay Discounting Task, or inhibitory control on the Stop Signal. It can be hypothesised that the direct instructions, without the additional cognitive priming, might create a conflict between the attempted conscious control needed to follow direct instructions, and internally generated, automatic, responding. With the combination of externally generated conscious and non-conscious motivation, such a conflict is resolved.

The Matching Familiar Figures and the Stop Signal Task, as suggested by the literature, were the two tasks consistently affected by the instruction manipulations in Studies 1a and c. The Stop Signal Task, the primary measure of motor impulsivity, requires a trade-off between fast responding to Go stimuli, with stopping response to a small number of Stop trials running in parallel (Logan, 1994). It has been hypothesised that successful responding to Go stimuli (fast responding) implies failure on the Stop task (failed inhibition to a Stop stimulus); successful Stopping implies failure on the go task (slow responding) (Verbruggen & Logan, 2009b). In the current studies Go responses on the Stop Signal Task were consistently affected by the instructions. This partially supports research suggesting that the Stop Signal Task involves a trade-off between speed of responding and inhibitory control (Bissett & Logan, 2011; Leotti & Wager, 2010). However, interestingly the studies did not find an effect of instructions on inhibitory control on the task (Study 1a), suggesting that fast Go responding does not necessarily imply poor inhibitory control to the Stop trials. It appears that whilst the Go responses are dependent on a trade-off, inhibitory control on the task may not be so readily affected.

The Matching Familiar Figures Task (J. Kagan, 1965a) categorises participants as impulsive based on the tendency to prioritise speed over accuracy (S. J. Dickman & Meyer, 1988), and was affected by both the instructions-only and combination manipulation. Compared to this, the Information Sampling Task, the second measure of reflection impulsivity, was only affected by the combination manipulation of instructions and priming. It is evident that the two tasks, despite both having been created as measures of reflection- impulsivity differ in terms of their susceptibility to speed/accuracy trade-off instructions.

It is known that the Matching Familiar Figures Task requires additional processes to the Information Sampling Task, and places high demand on working memory and visual search (Clark et al., 2006). The latter was designed as a primary index of information sampling, i.e. tendency to gather information before making a decision, rather than the composite speed-accuracy score calculated from the Matching Familiar Figures (Clark et al., 2006). The Information Sampling Task has an in-built inter-trial interval of 30 seconds to avoid conscious delay-averse responding (Clark et al., 2006), and the current studies support the suggestion that the task is not susceptible to imbalances in the trade-off caused by conscious strategic control over behaviour. It can be interpreted that only the Matching Familiar Figures is sensitive to imbalances in the speed/accuracy trade-off resulting from direct strategic control of responding. However, the combination manipulation, of conscious and non-conscious control of behaviour, did affect responding to the Information Sampling Task, suggesting that the task is partly susceptible to imbalances in the trade-off.

Cognitive priming of speed or accuracy schema (study 1b) did not affect any impulsivity measure. This supports previous research that has found no effect of cognitive priming via a scrambled sentences task on impulsive behaviour (Guerrieri et al., 2007). However the current research does not support findings that cognitive priming can increase impulsive responding associated with increased caloric intake (Guerrieri et al., 2009). Interestingly, whilst the current study indicated that cognitive priming did not affect responding per se, trait impulsivity was related to impulsivity on the tasks under conditions of the priming. It is thought that trait impulsivity reflects 'built-in' patterns of behaviour. High self-reported impulsivity was associated with increased impulsivity on the Information Sampling Task and on the Matching Familiar Figures. However, unexpectedly, high self-reported impulsivity was actually related to longer Go reaction times on the Stop Signal Task, a finding that should be explored further. Interestingly, where direct instructions were employed (studies 1a and c), there were no effects of trait impulsivity. This suggests that whilst the instructions-only manipulation (study 1a) did not encourage behavioural impulsivity on all four tasks, the instructions over-rode the effects of trait impulsivity on behaviour.

It is a limitation of the current studies that there were baseline differences in age and alcohol use between studies. Subsequent exploration of the effects of age and alcohol use found that, in study 1b, age was related to reflection impulsivity: older participants were less efficient on the Matching Familiar Figures, and opened fewer boxes and tolerated more uncertainty in the reward conflict version of the Information Sampling task. The relationship between age and reflection impulsivity was not present on the fixed win condition of the Information Sampling Task, suggesting that the reward conflict aspect was important (older participants opened fewer boxes only when the value of the potential reward dropped per box opened, thus decreasing the chance of winning but increasing the potential reward). It is important to note that we cannot know whether these relationships are present because of the cognitive priming manipulation, or whether they are unique to this particular group of participants; this relationship between age and impulsivity was not found in either study 1a or c.

In conclusion, the current studies found evidence that the speed/accuracy trade-off has implications for the three subtypes of impulsivity: motor, temporal and reflection. The combination of externally generating both conscious and non-conscious control of behaviour, through direct instructions and cognitive priming, was most successful at modifying the trade-off, with all four impulsivity measures affected. The instructions-only manipulation was partially successful at manipulating impulsivity, with the Matching Familiar Figures and Go responses on the Stop Signal Task affected. Cognitive priming did not affect any impulsivity measure however trait impulsivity modified behaviour. It can be concluded that the speed/accuracy trade-off has implications for the subtypes of impulsivity, and that both the Matching Familiar Figures and Stop Signal Task are susceptible to strategic conscious control over responding. Performance on the Delay Discounting and Information Sampling Task are less vulnerable to strategic responding, however when externally generated conscious motivation is combined with externally generated non-conscious motivation, impulsivity on these tasks is affected.

4 Impulsivity and inhibitory control – challenging inhibitory control via a dual task

Data from this chapter has been published in the following article:

Caswell, A.J., Morgan, M.J., & Duka, T. (2013). Inhibitory control contributes to “motor”- but not “cognitive”- impulsivity. *Exp Psychol*, 1-11.

4.1 Introduction

Further from the early ideas of impulsivity arising from a bias to speed over accuracy (S. J. Dickman & Meyer, 1988), more recent research has focused on the suggestion that impulsivity is a consequence of impaired inhibitory control (e.g. Lawrence et al., 2009a; Perales et al., 2009).

It is known that the mechanisms underlying impulsivity are yet to be fully established (Peter G. Enticott et al., 2006) and research has not explained whether impulsivity can be attributed to decreased top-down processing, or increased bottom-up activation (Perales et al., 2009). It has been hypothesized that impulsivity results from reduced inhibitory control (Peter G. Enticott et al., 2006; Perales et al., 2009), a suggestion that may have particular relevance for drug addiction. Research finds marked increases in temporal-impulsivity (Bjork et al., 2004; Coffey et al., 2003; Petry, 2001), reflection-impulsivity (Clark et al., 2009; Morgan et al., 2006) and motor-impulsivity (Mark T. Fillmore & Rush, 2002; Lawrence et al., 2009a; J. R. Monterosso et al., 2005) in drug users. It has been suggested that frontal cortical brain regions associated with inhibitory control are directly affected by long-term exposure to drugs of abuse (Duka et al., 2011; Goldstein & Volkow, 2011; Taylor & Jentsch, 1999). Frontal cortical cognitive dysfunction may lead to an inability to inhibit inappropriate responses and facilitate relapse during abstinence. It is generally accepted that drug-seeking behavior results from an increase in the incentive motivational properties of a drug, combined with an impaired ability to resist the impulse, arising from impaired inhibitory control (Taylor & Jentsch, 1999).

As with impulsivity, there are multiple ways of conceiving and defining inhibitory control (e.g. see Harnishfeger, 1995; Nigg, 2000), but in the context of the current study the term refers to the deliberate, controlled suppression of an explicit motor response, something that can be termed ‘behavioural inhibition’ (Peter G. Enticott et al., 2006;

Miyake et al., 2000). Behavioural inhibition refers to three interrelated processes: (i) inhibition of a pre-potent response to an event; (ii) stopping of an on-going response, thus permitting a delay in the decision to respond; and (iii) the protection of this period of delay from interference by competing events and responses (‘interference control’) (Barkley, 1997). Behavioural inhibition can be categorised as a type of ‘executive inhibition’ (Nigg, 2000).

It is evident that motor impulsivity and behavioural inhibition are antipodes, sharing definitional features (Bickel et al., 2012). Failures in the behavioural inhibition of a pre-potent (inappropriate) response are categorised as motor impulsivity. Indeed, the Stop Signal Task is employed both as a measure of inhibitory control in the executive function field, and as a measure of motor impulsivity (Logan, 1994; Miyake et al., 2000; Ray Li et al., 2008).

However, the assumption that deficits in inhibitory control are responsible for impulsivity also implicates cognitive- impulsivity (encompassing reflection- and temporal- impulsivity). It has been popularly suggested that a form of ‘self’- control is necessary to successfully delay gratification, that to resist an immediate reward self-regulatory processes must be engaged (Baumeister & Heatherton, 1996; Diekhof & Gruber, 2010). While this type of ‘self’- control is largely undefined, it has been suggested that ‘behavioural inhibition’ may have implications for cognitive- impulsivity. It has been suggested that behavioural inhibition of an initial response provides a necessary delay in the decision process, allowing successful self-regulation and controlled responding (Barkley, 1997), i.e. that inhibitory control allows the suppression of rapid responses and reflexes to allow slower cognitive mechanisms to guide behaviour (Taylor & Jentsch, 1999). Studies empirically testing this assumption are few, and the question of whether cognitive, impulsive, decision-making relies on behavioural inhibitory control is not yet answered (Perales et al., 2009).

The few studies that have tested the reliance of cognitive- impulsivity on inhibitory control have found mixed results. There is some evidence of inhibitory control mechanisms being necessary to prevent temporal- impulsivity. Research has found that a high working memory load, which challenges inhibition, increases temporal-impulsivity on a questionnaire measure (Hinson & Whitney, 2006). However, a more recent study has suggested that challenging executive functions does not necessarily increase temporal- impulsivity, instead it simply increases the number of inconsistent choices (Franco-Watkins et al., 2010). The relationship between inhibitory control and reflection- impulsivity is currently unexplored. It is clear that the assumption that inhibitory control underlies impulsivity as a whole needs further exploration. Indeed current research has failed to establish where and even if, the underlying mechanisms converge between subtypes.

The current study aims to investigate whether cognitive- impulsivity (encompassing reflection- and temporal- subtypes), as well as motor impulsivity, is reliant on inhibitory control. It is hypothesised that if successful inhibitory control is necessary to prevent cognitive- impulsivity, challenging such control via a competing dual task should increase impulsivity. The studies will explore whether motor- and cognitive- types of impulsivity are dissociable; if motor impulsivity and cognitive impulsivity subtypes are indeed distinct from one another, and rely differentially on inhibitory control, then challenging such control should affect the subtypes of impulsivity to different degrees. It was predicted that motor impulsivity, as measured by the stop signal task, should increase when inhibitory control is challenged.

To measure motor-, reflection- and temporal- impulsivity we selected a behavioural task for each of the three subtypes: the Stop Signal Task (Logan, 1994), the Information Sampling Task (Clark et al., 2006), and the Single Key Impulsivity Paradigm (Dougherty et al., 2005) respectively. The Stop Signal Task was selected as the most widely used measure of motor- impulsivity. The Matching Familiar Figures Task was not selected as a measure of reflection- impulsivity, as the task is known to be dependent on multiple, potentially confounding, processes including field dependence/independence, working memory, attention and visual search (Clark et al., 2006; Messer, 1976; Zelniker & Jeffrey, 1976) which may be disrupted by an inhibitory control challenge. Instead the Information Sampling Task was selected as the sole measure of reflection- impulsivity. The Single Key Impulsivity Paradigm was selected as a measure of temporal- impulsivity, instead of the Delay Discounting Questionnaire used in chapter 3, as it is not clear whether pen-and-paper measures under conditions of a dual task would be comparable to performance on experiential tasks, and there is research suggesting that dual tasks increase the number of inconsistent choices on pen-and-paper tasks (Franco-Watkins et al., 2010). The Two-Choice Impulsivity Paradigm was not selected as the experiential measure of temporal- impulsivity, as participants' responding dictates the duration of the task and we wanted to avoid discrepancies between participants who completed the task more quickly than others.

Inhibitory control was challenged, during performance on the tasks, using a Random Letter Generation task (Franco-Watkins et al., 2010). Random generation requires engagement of multiple executive functions, including inhibitory control mechanisms and updating (Fisk & Sharp, 2004; Miyake et al., 2000). "Updating" refers to the dynamic process of updating and monitoring working memory (Miyake et al., 2000). We have assumed that, although updating is a necessary function to monitor responses and check randomness, inhibitory control processes dominate as the most challenging component of the task is to prevent the pre-potent responses to name the letters sequentially (Miyake et al., 2000; Swanson & Sachse-Lee, 2001; Wiegersma, 1982). To control for any group differences on inhibitory control, baseline measures of inhibitory control on the Stop Signal task were recorded, along with IQ and memory capacity.

4.2 Method

4.2.1 Participants

Thirty three (16 female, 17 male) healthy participants were randomly assigned to either the executive function challenging condition (experimental condition, 8 f, 9 m), or the control condition (8 f, 8 m). Both conditions involved a dual task running in parallel to the performance in the impulsivity tasks.

4.2.2 Procedure

Participants completed the questionnaire pack. They were then moved to the computer booth where they completed the National Adult Reading Task, the Rey Auditory-Verbal Learning Test and the Stop Signal Task at baseline. Participants were given the dual task instructions, according to their assigned condition and were informed that they were to complete this task alongside three computerised tasks. They then completed the Information Sampling Task, Stop Signal Task and Single Key Impulsivity Paradigm, alongside the dual task. The three tasks were completed in a random order.

4.2.3 Materials

4.2.3.1 Dual task.

Participants in the experimental condition were required to complete a random letter generation task whilst performing the impulsivity tasks. Participants were required to generate random letters in response to a tone, every second (Franco-Watkins et al., 2010).

In the control condition participants were required to produce a single syllable ('ba') in response to a tone, every second.

The task gives a measure of errors made during random generation (failing to give a response) and the random number generation (RNG) score (F. J. Evans, 1978). The RNG score gives a measure of departure from randomness. It has a range from 0 to 1, where 0 indicates perfect equality of digram distribution, and 1 indicates complete predictability of responses. The RNG score was calculated using RgCalc (Towse & Neil, 1998).

4.2.3.2 Questionnaires

Personal Details Questionnaire (PDQ): The personal details questionnaire is a brief questionnaire asking for age, date of birth, smoking status, alcohol use and current medication.

Beck Depression Inventory II (BDI-II; Pliszka et al., 2000): The Beck depression inventory measures severity of clinical depression.

Alcohol Use Questionnaire (AUQ; Rubia et al., 2001): The questionnaire gives a measure of total units per week, binge score and alcohol use score.

Barratt Impulsiveness Scale, Version 11 (BIS-11, Patton et al., 1995): The Barratt Impulsiveness Scale is a 30-item checklist measuring impulsivity. The questionnaire gives a total impulsivity score, and three sub-scores: attentional, motor and non-planning impulsivity.

Multidimensional Mood State Questionnaire (MDMQ; Steyer et al., 1997): The questionnaire gives scores on each of the following mood continuums: good-bad, awake-tired, calm-nervous.

4.2.3.3 Cognitive and behavioural tasks.

National Adult Reading Task (NART; Nelson & O'Connell, 1978): The National Adult Reading Task gives an estimate measure of verbal IQ.

Rey Auditory-Verbal Learning Test (RAVLT; Rey, 1964): The Rey Auditory-Verbal Learning test assesses short term memory.

*Information Sampling Task, version (i) (IST; Clark et al., 2006):*The Information Sampling Task measures the tendency to acquire information before making a decision. Participants must open a matrix of boxes to reveal two colours underneath; participants must then select the colour which is in the majority. Participants win/lose 100 points if they choose correctly/incorrectly. Participants completed 10 trials.

The task gives a measure of number of boxes opened and probability of being correct that the participant tolerates at the point of decision making [P(correct)]. Fewer boxes opened and a low P(correct) value indicate increased impulsivity.

Single Key Impulsivity Paradigm (SKIP; Dougherty et al., 2005): The Single Key Impulsivity Paradigm assesses ability to delay gratification. Participants are instructed to press the mouse-button to obtain a point reward. The magnitude of the point reward is dependent on the delay between consecutive responses. Participants completed one four minute trial.

The task gives a measure of average inter-response time (the average time delay between consecutive mouse clicks). Short IRTs indicate increased impulsivity.

Stop Signal Task, version (iii) (SST; Logan, 1994): The Stop Signal Task assesses motor impulsivity. Participants respond to the direction of visually presented green arrows but withhold this response whenever the arrow changes from green to red (the Stop Signal, occurs 25% of trials). Participants completed 120 practice trials, 120 trials at baseline and 120 trials under conditions of the dual task.

The task gives a measure of Go accuracy and Go reaction times (GoRT), and Stop Signal Reaction Time (SSRTm/SSRTi). For details of how to calculate SSRTm and SSRTi, see section 2.6.2 ‘Stop Signal Task’. Large SSRT values indicate poor inhibitory control, i.e. high impulsivity.

4.2.4 Statistical analysis

Baseline group demographics, including age, baseline inhibitory control according to the Stop Signal Task (SSRTm, SSRTi), IQ and memory scores, self-reported alcohol use and impulsivity were analysed using one-way ANOVA to check that the two groups did not differ.

Data from the Stop Signal Task, Information Sampling Task and Single Key Impulsivity Paradigm were analysed using one-way ANOVA. Condition (control vs experimental) was applied as the fixed factor, with dependent variables from each of the three measures; dependent variables are as follows:

Stop Signal Task SSRTm, SSRTi, Go accuracy, GoRT and Stop accuracy;

Information Sampling Task (number of) boxes opened, P(correct);

Single Key Impulsivity Paradigm average IRT.

All descriptive values stated in text are (Mean±s.e.m.) unless otherwise stated. The assumptions of normality (Shapiro-Wilk statistic), and homogeneity of variance (Levene's test) are met, unless otherwise stated.

Random Generation Task data were analysed to check for differences in random generation between impulsivity tasks using repeated measures ANOVA. Impulsivity task (Information Sampling Task, Stop Signal Task and Single Key Impulsivity Paradigm) was included as the repeated measures factor, with percentage of errors and RNG score as the dependent variables. If the assumption of sphericity was not met, the ANOVA was corrected using Greenhouse-Geisser ($\varepsilon < .75$) or Huynh-Feldt ($\varepsilon > .75$). Percentage of errors and RNG score were also correlated with performance on the corresponding impulsivity measure, using Pearson's correlation coefficient, to check for relationships between performance on the RGT and impulsive responding.

To examine the relationship between state and trait impulsivity, correlations between the Barratt impulsiveness total and subscale scores and the different task variables were also performed using Pearson's correlation coefficient.

4.3 Results

4.3.1 Group differences at baseline

There were no significant group differences on any baseline measure, see Table 4.1 for descriptive values.

	Experimental	**Control**	***p***
N	17	16	
Age	21.06±2.68	20.13±1.26	.214
RAVLT, words recalled (memory)	7.76±1.95	8.25±2.35	.523
NART, estimated verbal IQ	110.94±5.83	110.08±7.42	.723
Barratt Impulsiveness Scale			
Total score	65.88±10.89	69.50±7.96	.287
Attentional impulsivity	17.47±3.45	18.38±3.70	.473
Motor impulsivity	23.94±4.39	25.25±3.44	.350
Nonplanning impulsivity	24.47±4.84	25.88±4.26	.384
Multidimensional Mood State Questionnaire			
Good/bad subscale	43.25±8.41	41.73±7.30	.597
Awake/tired subscale	36.56±11.25	38.73±7.32	.532
Calm/nervous subscale	43.50±8.17	41.00±6.79	.364
Alcohol Use Questionnaire			
Units drunk per week	21.13±18.07	14.29±13.01	.239
Binge score	22.75±15.02	26.52±26.19	.624
AUQ score	46.53±32.62	40.81±36.13	.646
Stop Signal Task (inhibitory control at baseline)			
SSRTm	231.02±41.56	252.91±83.49	.347
SSRTi	235.21±45.78	265.60±80.05	.191

Table 4.1. Group characteristics (age, memory, verbal IQ, current mood, alcohol use, inhibitory control) and trait demographics (self-reported impulsivity) for the control and experimental groups. Values are expressed as mean±s.d.

4.3.2 Stop Signal Task

One participant was excluded from the control condition for failing to follow task instructions, seen in a mean GoRT>1000ms.

Participants in the experimental group had poor inhibitory control, according to SSRTm, compared to those in the control condition, $F(1,30)=5.503$, $p=.026$, see Figure 4.1.

There was not a significant difference between the two groups according to SSRTi (control: 270.09±17.18; experimental 315.06±17.63), $F(1,30)= 3.299$, $p=.079$. There were no significant differences between groups in Go or Stop accuracy, or Go RT ($Fs<2.220$, $ps>.05$); see Table 4.2 for descriptive values.

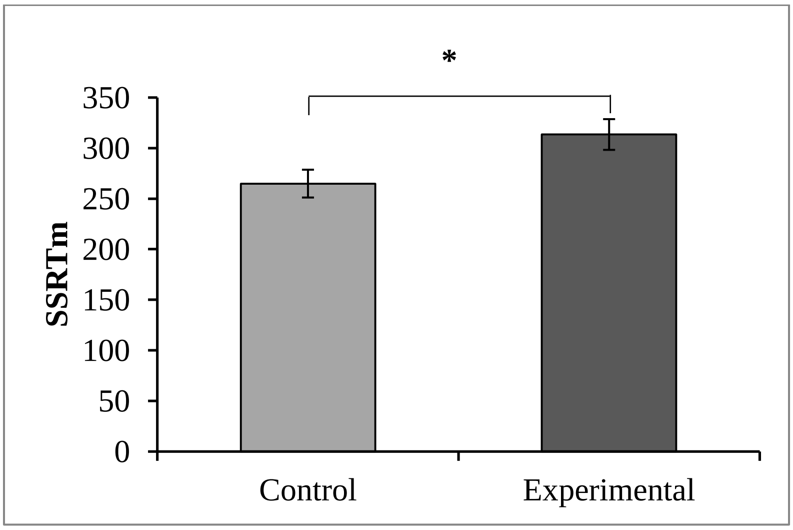

Figure 4.1. Stop Signal Reaction Times (SSRTm; msecs), as calculated using the mean method on the Stop Signal Task for the control and experimental group. A higher SSRT indicates greater motor impulsivity. Bars represent Mean±s.e.m *indicates significant difference between groups (*p<.05; **p<.01; ***p<.001)

4.3.3 Information Sampling Task

There were no significant differences between groups on number of boxes opened or P(correct) (*Fs*<.018, *ps*>.05); see Table 4.3 for descriptive values.

4.3.4 Single Key Impulsivity Task

There were no significant differences between groups on average IRT, $F(1,31)=.025$, $p=.875$; see Table 4.3 for descriptive values.

4.3.5 Random Generation Task

Data were missing from 3 participants.

There was no effect of the impulsivity task on number of errors made on the Random Generation Task, $F(1.203, 15.635)=2.237$, $p=.153$. However, there was an effect of task type on RNG score, $F(1.721, 20.156)=7.090$, $p=.006$; participants displayed less random responding during performance on the Stop Signal Task compared to the Single Key Impulsivity Paradigm ($p=.001$); there was not a significant difference between the Stop Signal Task and Information Sampling Task, or the Information Sampling Task and Single Key Paradigm (*ps*>.05); see Table 4.4 for descriptive values.

There were no significant correlations between errors or RNG scores on the Random Generation Task and performance on the corresponding impulsivity measures (*ps*>.05).

	Control				Experimental				p
	Mean	median	s.e.m	range	Mean	median	s.e.m	range	
GoRT	596.27	587.88	30.55	434.40-862.54	617.61	626.24	17.62	451.95-730.78	$F(1,30)=.388$, $p=.538$
Go%	93.85	97.78	2.50	61.11-100.00	89.54	91.11	1.59	72.22-100.00	$F(1,30)=2.220$, $p=.147$
Stop%	55.11	53.33	1.25	50.00-63.33	54.51	53.33	1.07	50.00-63.33	$F(1,30)=.135$, $p=.716$
SSRTm	264.93	247.31	13.76	172.15-391.49	313.53	303.00	15.20	215.29-459.15	$F(1,30)=5.503$, $p=.026$
SSRTi	270.09	257.24	17.18	207.33-466.01	315.06	303.50	17.63	188.53-452.83	$F(1,30)= 3.299$, $p=.079$

Table 4.2. Stop Signal Task key values for the control and experimental groups. Go% = GoAccuracy; Stop% = Stop Accuracy

	Experimental	Control	p
N	16	17	
Single Key Impulsivity Paradigm			
Total number of responses	239.12±81.24	256.25±70.66	$F(1,31)=.025$, $p=.875$
Information Sampling Task			
Number of boxes opened	18.02±1.12	17.82±1.05	$F(1,31)=.018$, $p=.895$
P(correct)	.8811±.0215	.8838±.0202	$F(1,31)=.008$, $p=.928$

Table 4.3. Single Key Impulsivity Paradigm and Information Sampling Task key values for the control and experimental groups. Values are expressed as Mean±s.e.m.

	SST	IST	SKIP	p
Random Generation Task				
Errors	5.500±2.284	10.286±2.756	11.071±3.697	$F(1.203,15.635)=2.237$, $p=.153$
RNG	.206±.009	.193±.015	.174±.009	$F(1.721,20.156)=7.090$, $p=.006$

Table 4.4. Random generation during performance on the Stop Signal Task, Information Sampling Task and the Single Key Impulsivity Paradigm. Values are expressed as Mean±sem.

4.3.6 Correlational analysis

There were no significant correlations between the Barratt Impulsiveness Scales and any impulsivity tasks (*ps*>.05).

4.4 Discussion

The current study provides evidence that motor impulsivity is dependent on behavioural inhibitory control. Challenging inhibitory control processes did not increase cognitive-impulsivity on either the temporal or reflection subtypes. These findings support the suggestion that impulsivity is not a unitary construct, and should be conceived as consisting of dissociable subtypes: motor impulsivity appears to be, at least partly, distinct from cognitive reflection- and temporal- impulsivity. Inhibitory control was challenged by introducing as a dual task, the random letter generation task, which requires inhibition of the pre-potent response to name the letters sequentially rather than randomly.

The results showed that challenging inhibitory control increased impulsive responding on the Stop Signal Task, with no impairment on responses to Go stimuli. Participants in the experimental condition showed less successful inhibition to a Stop signal, according to SSRTm values, suggesting that motor impulsivity, is dependent on inhibitory control. This is in agreement with previous research which has suggested motor impulsivity and inhibitory control are antipodes (Bickel et al., 2012).

There were differences between SSRT values when calculated using the mean compared to the integration method. There was a significant difference between the two groups when calculated using the mean method, whereas this difference only approached significance using the integration method. The integration method is applicable if the GO accuracy differs between groups, or if Stop accuracy differs from 50%. In the present study there were no group differences in Stop accuracy, however both groups had approximately 55% Stop accuracy. This high Stop accuracy suggests that the integration method may be a more appropriate calculation.

The lack of an effect of the experimental condition on either temporal- or reflection-impulsivity performance suggests that the temporal- and reflection- subtypes of cognitive impulsivity are distinct from motor impulsivity, and are not reliant on the functions that random generation taps. The current study found no evidence for increased cognitive- impulsivity on either subtype when inhibitory control was challenged. This supports the proposed distinction between motor- and cognitive- types of impulsivity, with only motor- impulsivity arising from impaired behavioural inhibitory control (Liotti, Pliszka, Perez, Kothmann, & Woldorff, 2005; J. M. Mitchell et al., 2005).

The finding that challenging inhibitory control does not increase cognitive- impulsivity is interesting. It has previously been suggested that successful inhibitory control of an initial response is required to allow slower cognitive mechanisms to guide behaviour (Barkley, 1997; Groman, James, & Jentsch, 2009). Previous research has suggested successful delayed discounting may be reliant on engaged inhibitory control (Diekhof & Gruber, 2010; Petry, 2001; Whitney, Jameson, & Hinson, 2004). However, our results support recent findings that indicate that taxing executive processes, via a random generation task, does not necessarily increase impulsive decision-making (Franco-Watkins et al., 2010). Taking these findings together it becomes clear that there is need for more research into the mechanisms that underlie the different types of impulsivity.

There were no significant differences in the generation of letters during the dual task between the different impulsivity measures. Random performance was slightly impaired while running in parallel with the Stop Signal Task, but showed no impairments when performed in parallel to the Single Key Paradigm or Information Sampling Task, presumably because inhibitory control mechanisms were being challenged by the Stop Signal and the Random Generation Task simultaneously. The results can lend support to our suggestion that cognitive impulsivity may not be reliant on the inhibitory control mechanisms challenged by random generation, as participants showed relatively random performance on the dual task but no deficits in the cognitive impulsivity measures.

There were limitations to the current study that should be considered. It is possible that the results reflect differences in difficulty of the three impulsivity measures. The Information Sampling Task was designed as a measure of reflection impulsivity that does not place high demands on visual search and visual working memory (Clark et al., 2006). The Single Key Impulsivity Paradigm is designed to be a simple measure of ability to delay gratification, requiring minimal attentional resources (Swann, Lijffijt, Lane, Steinberg, & Moeller, 2009). The Stop Signal is, perhaps, more difficult, and requires cognitive processes for the evaluation of the task demands in addition to processes for response inhibition. The Stop Signal is itself a dual task, requiring preparation of two responses (Go and Stop) (Verbruggen, Adams, & Chambers, 2012). The task requires engagement of attentional resources; continued monitoring of the Stop signal is necessary in order to initiate response inhibition, and maintenance of attention is required for both correct Go and Stop responses (Ray Li et al., 2008). The experimental condition did not affect measurements related to Go responses and instead affected only Stop responses, which involve inhibitory control. It is possible that this latter finding is due to different difficulty in performing the two responses (where Go stimuli require a pre-potent, 'easy' response).

In conclusion, the current study found that a dual task, which challenges predominantly inhibitory control, increased motor impulsivity but had no effect on reflection- or temporal- impulsivity. These findings provide support for the distinction between motor- and cognitive- impulsivity, and for the suggestion that taxing inhibitory control processes does not necessarily increase impulsive decision-making.

5 Impulsivity and inhibitory control – challenging inhibitory control via an acute dose of alcohol

Data from this chapter has been published in the following article:

Caswell, A.J., Morgan, M.J., & Duka, T. (2013). Acute alcohol effects on subtypes of impulsivity and the role of alcohol-outcome expectancies. *Psychopharmacology (Berl).*

5.1 Introduction

The previous study found evidence to suggest that challenging inhibitory control via a dual task affected motor- impulsivity, as tested by the Stop Signal Task, but did not affect reflection- or temporal- impulsivity, as measured by the Information Sampling Task and Single Key Impulsivity Paradigm respectively. Inhibitory control has been defined in many ways (e.g. see Harnishfeger, 1995; Nigg, 2000), but one form of inhibitory control can be termed 'behavioural' inhibitory control (Peter G. Enticott et al., 2006; Miyake et al., 2000).

It is known that alcohol affects behavioural inhibitory control; studies that have investigated the effects of alcohol uniformly find the drug to impair inhibitory control on measures of motor-impulsivity at doses ranging from 0.4 g/kg to 0.8g/kg (de Wit et al., 2000; M. T. Fillmore & Vogel-Sprott, 1999; Loeber & Duka, 2009; Mulvihill et al., 1997; Ramaekers & Kuypers, 2006).

However, studies that have investigated the effects of alcohol on reflection- and temporal- impulsivity, as types of cognitive- impulsivity, typically do not demonstrate an effect of alcohol. The majority of studies have found no effect of alcohol on pen-and-paper measures of temporal- impulsivity at doses of 0.4, 0.5 and 0.8 g/kg (Reynolds, Richards et al., 2006; Richards et al., 1999), however, a trend effect for alcohol (0.7 g/kg) to increase the ability to delay gratification has also been found (Ortner et al., 2003). On the Single Key Impulsivity Paradigm as an experiential measure of temporal-impulsivity alcohol, at 0.2, 0.4, 0.6, and 0.8 g/kg doses, has been found to have no effect (Dougherty et al., 2008; Dougherty et al., 2005). With regard to reflection- impulsivity, a moderate dose (0.6 g/kg) has no effect on the Matching Familiar Figures Task (George et al., 2005). Thus it appears that studies that have investigated the effects of alcohol on impulsivity find reliable effects on motor- impulsivity tasks, but find no effect on cognitive- impulsivity subtypes.

It is known that non-pharmacological cognitive factors, including expectancies of alcohol's effects, affect behavioural and cognitive responses to alcohol. Alcohol outcome expectancies are beliefs about the effects of alcohol (Merrill et al., 2009). Such expectancies can be positive or negative (B. T. Jones, Corbin, & Fromme, 2001), and include expectancies of cognitive and behavioural impairment (Fromme et al., 1993). Expectations of cognitive and behavioural impairment are thought to reflect the loss of inhibitory control anticipated by the participant. Participants expecting greater alcohol induced impairment perform more poorly on motor skill tasks (M. T. Fillmore & Vogel-Sprott, 1995a, 1995b) and rapid information processing tasks (0.62g/kg or placebo; M. T. Fillmore, Carscadden, & Vogel-Sprott, 1998) when receiving placebo or a moderate dose of alcohol.

Thus, the current literature suggests that measures of motor- impulsivity are highly sensitive to the effects of an acute dose of alcohol, whereas measures of cognitive-impulsivity, including reflection- and temporal- subtypes, are not. Hitherto, investigators have failed to explore the possible mechanisms by which alcohol can affect cognitive- impulsivity subtypes. It has been previously found that expectancies of cognitive and behavioural impairment from alcohol affect behavioural responding, and information processing, under both placebo and alcohol conditions (M. T. Fillmore & Vogel-Sprott, 1995a, 1995b; M. T. Fillmore, Carscadden, & Vogel-Sprott, 1998). This provides preliminary evidence that such expectancies may be a potential mechanism that could affect impulsive responding on measures of reflection- and temporal-impulsivity.

Therefore, the current study aims to investigate whether acute doses of alcohol (0.4 and 0.8g/kg alcohol) increase impulsive responding dose dependently on motor-, temporal- and reflection- impulsivity tasks. The study aims to replicate the findings that an inhibitory control challenge only affects motor- impulsivity. To extend current understanding, the study will also explore the effects of expectancies of impairment from alcohol, to investigate the contribution of perceived and expected loss of self-control on impulsivity.

To measure impulsivity we selected the same performance based behavioural tasks for each of the three subtypes as in the previous study: the Stop Signal Task (Logan, 1994) as a measure of motor- impulsivity, the Information Sampling Task (Clark et al., 2006) as a measure of reflection- impulsivity, and the Single Key Impulsivity Paradigm (Dougherty et al., 2005) as the measure of temporal- impulsivity.

5.2 Method

5.2.1 Participants

Forty eight paid participants (24 m, 24 f) were randomly assigned to the placebo condition (N=16), the low dose of alcohol (N=16) or the high dose of alcohol (N=16), using a double-blind procedure.

5.2.2 Procedure

5.2.2.1 General procedure:

Testing began after 11 a.m. On arrival at the laboratory, participants' breath alcohol concentration (%BACw/v; BAC) was measured with a breathalyser (Lion Alcolmeter SD-400, Lion Laboratories Ltd, Barry, UK) to ensure zero blood alcohol levels. Following completion of Questionnaires and the National Adult Reading Task, participants underwent the drink administration procedure. After a 10 minute break a further BAC was recorded (pre- cognitive tasks) by an independent experimenter and participants completed the Alcohol Visual Analogue Scales. The Information Sampling Task, Stop Signal Task and Single Key Impulsivity Paradigm were then presented in a random order, instructions and practice trials were completed prior to the experimental trials. Tasks lasted 30 minutes in total. On completion of the tasks, participants were again breathalysed (post- cognitive tasks) and completed the Alcohol Visual Analogue Scales, and Profile of Mood States Questionnaire, and were asked if they thought they had received alcohol or placebo. Participants were then informed of their breath alcohol levels and were required to remain in the laboratory until their BAC fell to below half the UK legal driving limit (0.17 %BACw/v).

5.2.2.2 Drink administration procedure (Loeber & Duka, 2009):

Participants were administered either high or low dose alcohol or placebo, according to a between-subjects randomized double-blind placebo-controlled design. Group assignment followed a randomization list prepared by a colleague not involved in any data assessment, and this colleague was also responsible for the preparation of the alcoholic or placebo beverage for each participant. The low dose of alcohol was administered at a dose of 0.4 g/kg, with 90% v/v alcohol, diluted with tonic water (Indian tonic water) to make up a drink of 500 ml and mixed with Angostura® aromatic bitters to mask the taste of the alcohol. The high dose of alcohol was mixed with a procedure identical to that of the low dose, but using a dose of 0.8g/kg. The placebo beverage consisted of 500 ml tonic water and Angostura® bitters only. The alcohol and the placebo beverage was divided into ten 50 ml portions and participants were instructed to consume the portions at 3-minute intervals in the presence of the experimenter (time of administration 30 minutes).

5.2.3 Materials

5.2.3.1 Questionnaires

Personal Details Questionnaire (PDQ): The personal details questionnaire is a brief questionnaire asking for age, date of birth, smoking status, alcohol use and current medication.

Beck Depression Inventory II (BDI; Beck et al., 1996): The beck depression inventory measures severity of depression.

*Alcohol Use Questionnaire (AUQ; Townshend & Duka, 2002)***:** The alcohol use questionnaire gives a measure of total alcohol units per week, binge score and alcohol use score.

*Barratt Impulsiveness Scale, Version 11 (BIS-11; Patton et al., 1995)***:** The Barratt Impulsiveness Scale is a 30-item checklist measuring impulsivity. The questionnaire gives a total impulsivity score, and three sub-scores: attentional, motor and non-planning impulsivity.

*Alcohol Outcome Expectancies (Fromme et al., 1993)***:** A 38-item questionnaire which assesses positive and negative expected effects of alcohol consumption. There are seven expectancy factors, four positive (sociability, tension reduction, liquid courage and sexuality), and three negative (cognitive and behavioural impairments, risk and aggression, and self-perception).

*Alcohol visual analogue scales (VAS; Duka et al., 1998)***:** The alcohol VAS is a set of 90mm visual analogue scales. Participants score how much a mood state (contented, lightheaded and relaxed) applies to them at that moment.

National Adult Reading Task (NART; Nelson & O'Connell, 1978): The NART gives an estimate measure of verbal IQ.

5.2.3.2 Cognitive and behavioural tasks

Information Sampling Task, version (i) (IST; Clark et al., 2006): The Information Sampling Task measures the tendency to acquire information before making a decision. Participants must open a matrix of boxes to reveal two colours underneath; participants must then select the colour which is in the majority. Participants win/lose 100 points if they choose correctly/incorrectly. Participants completed 10 trials.

The task gives a measure of number of boxes opened and the probability of being correct that the participant tolerates at the point of decision making [P(correct)]. Fewer boxes opened and a low P(correct) value indicate increased impulsivity.

Single Key Impulsivity Paradigm (SKIP; Dougherty et al., 2005): The Single Key Paradigm assesses ability to delay gratification. Participants are instructed to press the mouse-button to obtain a point reward. The magnitude of the point reward is dependent on the delay between consecutive responses. Participants completed one four minute trial.

The task gives a measure of average inter-response time (IRT, the average time delay between consecutive mouse clicks); short IRTs indicate increased impulsivity.

Stop Signal Task, version (iii) (SST; Logan, 1994): The Stop Signal Task assesses motor- impulsivity. Participants respond to the direction of visually presented green arrows but withhold this response whenever the arrow changes from green to red (the Stop Signal, occurs 25% of trials). Participants completed 120 trials.

The task gives a measure of Go accuracy and Go reaction times (Go RT), and Stop Signal Reaction Time (SSRTi). Large SSRTi values indicate poor inhibitory control, i.e. high impulsivity.

5.2.4 Statistical analysis

Baseline group demographics, including age, IQ, self-reported alcohol use and impulsivity, and alcohol outcome expectancies were analysed using one-way ANOVA to check for group differences.

Breath alcohol concentrations (BAC) were analysed pre- cognitive and behavioural tasks, to check that BAC differed between groups. Gender was subsequently included as a factor, to check that male and female BACs did not differ. A two (low vs. high alcohol) by two (pre- and post- tasks) mixed ANOVA to ensure that BAC did not significantly change during the time it took to complete the tasks.

To investigate the effect of alcohol dose on impulsivity, a one-way ANOVA, with alcohol condition as the fixed factor, was performed on each of the dependent variables of the three impulsivity measures; variables included were:

Stop Signal Task SSRTi, Go accuracy, Go RT;

Information Sampling Task number of boxes opened, P(correct);

Single Key Impulsivity Paradigm average IRT.

In all analyses post hoc tests were Bonferroni corrected if the assumption of equal variances was met, and Games-Howell corrected if not; all tests are Bonferroni corrected unless otherwise reported. All descriptive values stated in text are (Mean±s.e.m.) unless otherwise stated.

The assumptions of normality (Shapiro-Wilk statistic), and homogeneity of variance (Levene's test) are met, unless otherwise stated. If homogeneity of variance was violated, ANOVA statistics were Welch corrected. If both the assumptions of normality and equal variances were violated, Kruskal Wallis test was used in place of ANOVA; bonferroni corrected Mann-Whitney tests were subsequently performed to test for pairwise differences (accepted *p* value=.017).

In addition, one-way analyses of covariance (ANCOVA) were run with alcohol condition again as fixed factor and alcohol expectancies for 'cognitive and behavioural impairment' as the covariate. If the alcohol expectancy covariate was found to be significant, it was correlated with the impulsivity tasks, using Pearson's correlation coefficient, to determine the direction of any relationships.

Alcohol Visual Analogue Scales were analysed with mixed ANOVA with alcohol condition as between-group, and time (pre- and post- drink) as within-group factors. Main effects of time are reported to indicate whether responding on visual analogue scales changed over the time-frame of the experiment, however this will not be focused on within the discussion.

In addition post-hoc tests, explorative correlations were performed using Pearson's correlation coefficient, or Spearman's rho if the assumption of normality was violated. The impulsivity measures were correlated with the remaining alcohol expectancy factors. BAC pre- tasks, in the low and high dose conditions were also correlated with performance on the impulsivity measures, to establish whether responses on the impulsivity tasks were sensitive to small changes in breath alcohol. Mood ratings under the influence of alcohol were also correlated with the impulsivity measures.

5.3 Results

5.3.1 Baseline group demographics and alcohol outcome expectancies

There were no group differences on any baseline measure or cognitive alcohol expectancies, see Table 5.1 for descriptive values.

5.3.2 Breath Alcohol Levels

There was a significant difference between alcohol conditions and BAC pre- cognitive tasks, $F(2,45)=195.066, p<.001$; There were significant differences between placebo and low, placebo and high, and low and high dose groups ($ps<.001$). There were no significant gender differences of condition by gender interactions ($Fs<1.404$, $ps>.05$).

BAC did not change in the time it took to complete the tasks. There was not a significant effect of time (pre- vs. post-cognitive tasks) on BAC, $F(1,30)=.999, p=.325$, or a significant time by condition interaction, $F(1,30)=.600, p=.445$. There was a significant effect of condition, $F(1,30)=218.006, p<.001$, see table 5.2 for descriptive values.

	Placebo		**Low Dose**		**High Dose**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
BAC	.00±.00	.00±.00	.58±.03	.51±.03	1.15±.07	1.14±.02

Table 5.2 BAC pre- and post- cognitive tasks for placebo, low dose (0.4g/kg) and high dose (0.8g/kg) alcohol groups. Values are expressed as mean ±s.e.m.

In the placebo condition 7 participants believed they had received alcohol and 9 participants believed they had placebo; in the low dose 14 participants believed they had alcohol and 2 thought placebo; in the high dose all participants identified that they had received alcohol.

5.3.3 Stop Signal Task

Four participants were excluded as they failed to follow task instructions, and instead waited for the stop signal to appear, resulting in a mean Go reaction time of over 1000ms. An additional participant was excluded as he had an unusually low percentage go accuracy (2.22%). Assumption of normality was violated for Go accuracy, $W(43)=.614$, $p<.001$, Levene's was not violated ($p>.05$).

Motor- impulsivity, according to SSRTi, increased with alcohol dose, $F(2,40)=3.712, p=.033$, [significant linear contrast, $F(1,40)=7.424, p=.009$; non-significant quadratic contrast, $F(1,40)=.038, p=.846$]. Participants in the placebo condition exhibited reduced motor- impulsivity compared to the high dose condition ($p=.028$), but there were no significant differences between placebo and low dose or low and high dose groups (*ps*>.05), see Figure 5.1.

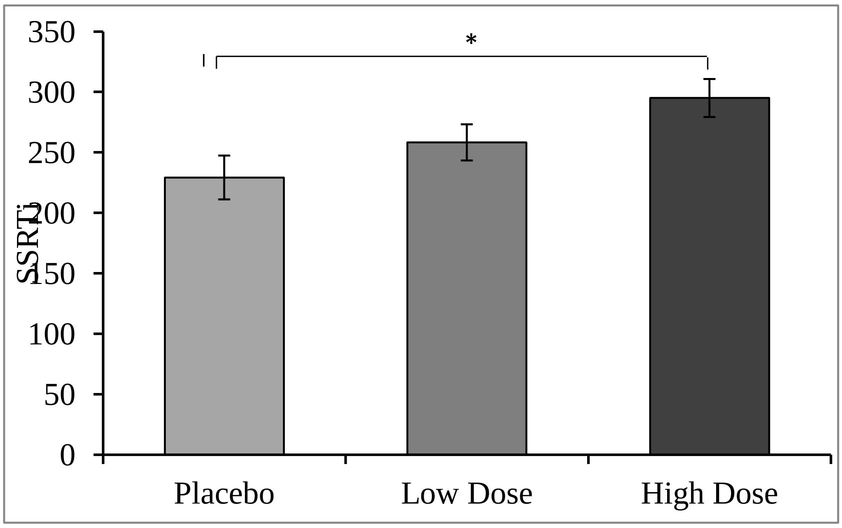

Figure 5.1. Stop Signal Reaction Times (SSRTi; msecs) on the Stop Signal task for the placebo, low dose (0.4g/kg) and high dose (0.8g/kg) alcohol groups. A higher SSRT indicates greater motor impulsivity. Bars represent Mean±s.e.m *indicates significant difference between groups (*p<.05)

There were no effects of alcohol dose on GoRT or Go accuracy (Fs<.096, ps>.05); see Table 5.2 for descriptive values

Covariate analysis showed no significant effects of impairment expectancies (*Fs*<2.749, *ps*>.05) on any of the dependent variables.

5.3.4 Information Sampling Task

Assumption of normality was violated for number of boxes opened, $W(48)=.949, p=.038$, Levene's was not violated ($p=.142$).

Alcohol at either dose had no effect on number of boxes opened, $F(2,45)=.325, p=.724$, or P(correct), $F(2,45)=.397, p=.674$, see Table 5.3 for descriptive values.

Covariate analysis revealed a significant effect of impairment expectancies on number of boxes opened, $F(1,43)=7.030, p=.011$, and on P(correct), $F(1,44)=5.203, p=.027$. Participants expecting greater impairment opened more boxes, $r(48)=.375, p=.009$, and tolerated less uncertainty, $r(48)=.333, p=.021$, on the task, see Figure 5.2. These relationships were only present in participants who believed they had received alcohol [boxes opened, $r(37)= .491, p=.002$; P(correct), $r(37)=.454, p=.005$]; participants who believed they had received placebo did not show a relationship between impairment expectancies and boxes opened, $r(11)=-.111, p=.746$, or P(correct), $r(11)= -.184, p=.588$.

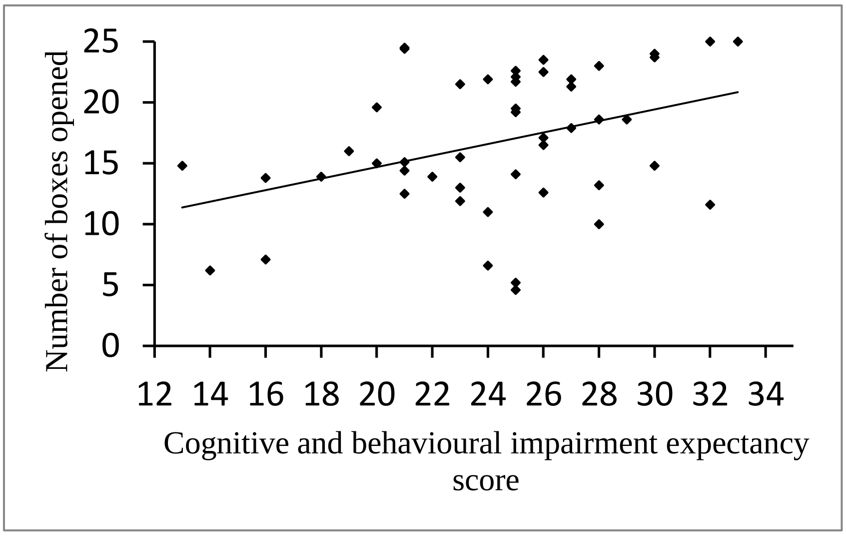

Figure 5.2. Scatterplot of the relationship between cognitive and behavioural impairment expectancy scores and the number of boxes opened on the Information Sampling Task.

5.3.5 Single Key Impulsivity Task

Assumption of normality was violated for average inter-response time, $W(48)=.465, p<.001$, Levene's was also violated ($p>.05$).

Alcohol did not affect average IRT, $H(2)=2.084, p=.353$, see Table 5.3 for descriptive values.

Covariate analysis showed no effect of impairment expectancies on average inter response time, $F(1,44)=.222, p=.640$.

	Placebo	**Low dose**	**High dose**	***p***
N	16 (8 m, 8 f)	16 (8 m, 8 f)	16 (8 m, 8 f)	
Age	20.81±2.83	19.63±1.09	22.38±5.23	*F*(2,45)=2.50, *p*=.093
NART, estimated verbal IQ	112.19±4.76	108.29±7.59	113.15±5.35	*F*(2,45)=2.57, *p*=.089
Barratt Impulsiveness Scale				
Total score	68.31±10.33	68.44±8.35	70.13±7.19	*F*(2,45)=.216, *p*=.807
Attentional subscale	18.00± 4.56	18.44±3.83	19.44±2.80	*F*(2,45)=.602, *p*=.552
Motor subscale	24.81±3.85	24.13±3.86	24.13±1.75	*F*(2,45)=.231, *p*=.795
Nonplanning subscale	25.50±4.94	25.88±3.12	26.56±4.34	*F*(2,45)=.263, *p*=.770
Alcohol Use Questionnaire				
Units of alcohol per week	28.67±12.77	16.36±4.09	14.35±3.59	*F*(2,45)=.118, *p*=.889
Binge score	36.56±23.73	36.73±19.27	29.88±25.83	*F*(2,45)=.450, *p*=.640
Alcohol Use score	65.23±28.63	65.87±31.85	56.53±36.99	*F*(2,45)=.403, *p*=.671
Alcohol Expectancies				
N	16	16	16	
Sociability	22.00±2.95	22.00±2.94	21.38±3.07	*F*(2,45)=1.163, *p*=.322
Tension reduction	9.53±1.59	9.06±1.65	9.06±1.98	*F*(2,45)=1.565, *p*=.220
Liquid courage	12.93±2.19	12.94±1.53	12.19±2.37	*F*(2,45)=.374, *p*=.690
Sexuality	9.33±1.63	9.13±1.82	9.13±1.82	*F*(2,45)=1.055, *p*=.357
Cognitive and behavioural impairments	25.27±2.74	25.56±2.45	24.38±4.33	*F*(2,45)=.195, *p*=.824
Risk and aggression	13.73±1.94	12.63±2.13	12.13±1.89	*F*(2,45)=.517, *p*=.600
Self-perception	10.00±1.56	10.00±1.63	10.44±1.99	*F*(2,45)=.350, *p*=.706

Table 5.1. Group characteristics (age, verbal IQ, alcohol use, smoking per day, alcohol expectancies) and trait measurements (self-reported impulsivity ratings) at baseline for placebo, low dose (0.4g/kg) and high dose (0.8g/kg) alcohol groups. Values are expressed as mean ±s.d.

	Placebo	Low dose	High dose	
Stop Signal Task				
N	15	16	12	
Go Accuracy (%)	96.29±1.40	95.49±1.84	95.46±1.04	$F(2,40)=.096$, $p=.909$
Go reaction time (msecs)	584.03±27.31	582.54±33.26	580.55±28.84	$F(2,45)=.003$, $p=.997$
Information Sampling Task				
N	16	16	16	
Number of boxes opened	17.42±1.56	16.92±1.08	15.81±1.62	$F(2,45)=.325$, $p=.724$
P(correct)	.88±.03	.89±.02	.88±.02	$F(2,45)=.397$, $p=.674$
Single Key Impulsivity Paradigm				
N	16	16	16	
Average IRT (secs)	2.55±.74	2.64±.89	14.84±5.90	$H(2)=2.084$, $p=.353$

Table 5.3. Go accuracy and average Go reaction time scores from the Stop Signal task, and Number of boxes opened from the Information Sampling task for placebo, low dose (0.4g/kg) and high dose (0.8g/kg) alcohol groups. Values are expressed as mean±s.e.m.

	Placebo		Low Dose		High Dose	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Alcohol VAS						
N	16	16	16	16	16	16
Lightheaded***	9.5± 3.00^{+}	28.19±5.87	6.81±3.71^{+}	46.88±5.34	7.75±2.99^{+}	59.63±5.47
Relaxed*	46.69±3.11^{+}	55.94±3.16	46.94±4.44	47.25±6.68	45.75±3.81^{+}	65.00±4.48
Contented	47.19±3.29^{+}	55.31±3.08	54.75±5.25	49.75±6.19	50.13±4.01)	62.56±5.82

Table 5.4. Alcohol VAS ratings pre- and post- drink consumption for placebo, low dose (0.4g/kg) and high dose (0.8g/kg) alcohol groups. Values are expressed as mean ±s.e.m. *Indicates a significant time by condition interaction (*$P<.05$, ***$P<.001$) $^{+}$Indicates a significant effect of time between pre- and post- beverage ratings ($^{+}P<.05$)

5.3.6 Mood changes

There were no significant group differences in any alcohol VAS mood ratings pre-drink. Lightheaded ratings showed a significant time by condition interaction, $F(2,45)=9.084, p<.001$, and a significant effect of time, $F(1,45)=130.956, p<.001$; all three alcohol conditions showed an increase in lightheaded scores between pre- and post- drink ratings (*ps*<.05), there was a significant difference post- drink between the three groups, $F(2,45)=8.073, p=.001$, participants in the high dose were more lightheaded post- drink compared to the placebo group ($p=.001$). A significant effect of condition, $F(2,45)=4.252, p=.020$, was found, with participants in the high dose feeling more lightheaded than those in the placebo group ($p=.017$); there were no other group differences (*ps*=.05). Ratings of relaxedness showed a significant time by condition interaction, $F(2,45)=3.731, p=.032$, and a significant effect of time, $F(1,45)=11.502, p<.001$. Participants in the placebo, $t(15)=-2.184, p=.045$, and high dose, $t(15)=-3.742, p=.002$, groups showed increased relaxedness with time. Participants in the low dose group did not differ pre- and post- drink, $t(15)=-.059, p=.953$. There was no effect of condition, $F(2,45)=1.247, p=.297$. See Table 5.4 for descriptive values.

5.3.7 Exploratory Correlations

Note: Go accuracy on the Stop Signal Task was not included in correlational analysis, as the majority of participants performed at ceiling.

5.3.7.1 Alcohol expectancies and impulsivity

For the Information Sampling Task, significant correlations were found between boxes opened and sociability expectancies, $r(48)=.398, p=.005$, as well as between boxes opened and tension reduction expectancies, $r(48)=-.314, p=.030$. The relationships were only present in the participants who believed they had received alcohol, ($r(37)=.439, p=.007$ and $r(37)=-.332, p=.044$ respectively) compared to participants who believed they had placebo (r(11)=.240, $p=.478$ and $r(11)=-.203, p=.549$ respectively). There were no other correlations between the impulsivity measures and alcohol expectancies.

5.3.7.2 Breath alcohol levels and impulsivity

BAC was positively correlated with average inter-response time in the Single Key Impulsivity Paradigm in the high alcohol dose, $r_s(16)=.549, p=.028$, but not in the low dose, $r_s(16)=-.039, p=.887$; in the high dose condition participants with higher BAC were less impulsive on the task. There were no other correlations between BAC and the impulsivity measures.

5.3.7.3 Mood ratings and impulsivity

There were no significant correlations between mood post- drink administration and the impulsivity measures.

5.4 Discussion

The results of the current study indicated that alcohol, in a dose linear way, affected motor- impulsivity. Participants who had consumed alcohol were less able to stop a motor response when a Stop signal was presented. Conversely, alcohol had no main effect on reflection- or temporal- impulsivity. Interestingly, alcohol expectancies of ‘cognitive and behavioural impairment’ were found to affect reflection- impulsivity, but not temporal- or motor- impulsivity.

The finding that alcohol impairs motor- impulsivity is in accordance with the hypothesis that alcohol acts to impair behavioural inhibitory control, and supports previous findings (de Wit et al., 2000; M. T. Fillmore & Vogel-Sprott, 1999; Loeber & Duka, 2009; Ramaekers & Kuypers, 2006; Rose & Duka, 2007). The effects of alcohol on motor-impulsivity were independent of cognitive alcohol outcome expectancies suggesting that cognitive processes associated with the ability to inhibit a pre-potent response may be different from those processes associated with the cognitive alcohol outcome expectancies. Indeed, previous studies which examined the effects of alcohol expectancies on performance have found only tasks of motor coordination (M. T. Fillmore & Vogel-Sprott, 1995a, 1995b) and continuous attention (M. T. Fillmore & Vogel-Sprott, 1998) to be modulated by the cognitive alcohol outcome expectancies.

There was no main effect of alcohol on temporal- impulsivity. This supports previous studies, which have used experiential and pen-and-paper tasks to show that alcohol does not affect this subtype (Dougherty et al., 2008; Ortner et al., 2003; Reynolds, Richards et al., 2006; Richards et al., 1999). The results do show some preliminary evidence that delay of gratification may have some relationship with alcohol intoxication, as breath alcohol levels correlated with average inter-response time, albeit only in the high dose condition. This finding supports a previous finding of a trend effect of alcohol on temporal- impulsivity and of a correlation between BAC and delay of gratification (Ortner et al., 2003), and should be explored further.

Expectancies of cognitive and behavioural impairment were found to be related to reflection- impulsivity, but were not related to any other subtype. Participants expecting greater levels of cognitive and behavioural impairment to result from alcohol, who believed that they had consumed alcohol, showed reduced reflection- impulsivity on the Information Sampling Task. Alcohol expectancies were stronger at modulating behaviour in this task than alcohol itself, again suggesting that this task may not be supported by the inhibitory control mechanisms challenged by alcohol.

The finding that expectancies of cognitive and behavioural impairment affect reflection- impulsivity is intriguing. The results are in accordance with previous research suggesting that cognitive, as well as pharmacological, factors can affect responses to alcohol (M. T. Fillmore & Vogel-Sprott, 1998; Marczinski & Fillmore, 2005). Furthermore, previous research has indicated that participants show compensatory behaviours on cognitive tasks when expecting to receive alcohol (M. T. Fillmore & Blackburn, 2002; Gustafson & Kallmen, 1990; Marczinski & Fillmore, 2005; R. M. Williams, Goldman, & Williams, 1981). The current results not only indicate that compensatory behaviours are engaged to prevent impulsive behaviour on the Information Sampling Task, but take these findings a step further. They show that the level of expected impairment to inhibitory control is related to the strength of the compensation, i.e. the greater the expected loss of inhibitory control, the less impulsive the participant behaves. The results contradict previous literature reporting greater expectation of cognitive and behavioural impairment to result in *poor* performance on psychomotor and rapid information processing tasks (M. T. Fillmore et al., 1998; M. T. Fillmore & Vogel-Sprott, 1995a, 1995b). This discrepancy may be due to the nature of the tasks; the Information Sampling Task does not involve motor coordination, and does not require the participant to process information rapidly. Importantly, the current data found the relationship between impairment expectancies and reflection- impulsivity to be present in the participants who believed that they had received alcohol and not in those who believed that they had received placebo, suggesting that the belief that alcohol was consumed facilitated the impact of expectancies on information sampling. These results have implications for decision making in association with alcohol.

Thus, it can be suggested that alcohol does not affect reflection- impulsivity through its pharmacological effects; instead it seems that cognitive alcohol outcome expectancies affect this form of impulsive decision making. It can be seen that participants expecting cognitive and behavioural impairment to result from alcohol, who believe that they have consumed alcohol, show compensatory responses to remedy this.

In addition, relationships were found between sociability and tension reduction expectancies and reflection- impulsivity. These findings are exploratory, were not driven by hypotheses and were not corrected for multiple comparisons and therefore need to be further explored. As before, these relationships were also only found in the participants who believed they had received alcohol.

There were limitations to the current study that should be considered. It is possible that the differential effects of alcohol reflect varying difficulty of the three impulsivity measures. The Stop Signal Task is, perhaps, the most difficult of the three tasks, requiring a rapid response and engagement of attentional resources (Ray Li et al., 2008). However there is no reason to suggest that the Information Sampling Task and Single Key Impulsivity Paradigm differ with regard to the cognitive demands they require. Both tasks are designed to require minimal attentional resources and neither requires a rapid response (Clark et al., 2006; Swann et al., 2009). It is also possible that, as participants received task instructions and practice trials under alcohol (or placebo), the results reflect differences in contingency learning. However, there is no evidence within the data to support this: alcohol findings on the Stop Signal Task were uniquely limited to response inhibition, Go accuracy and reaction times were not affected.

In conclusion, the current study provides evidence for a dissociation between the pharmacological effects of alcohol and the cognitive expectancies related to alcohol's effects on impulsivity. The disinhibiting effects of alcohol only affected the measure of motor- impulsivity. Reflection- impulsivity was not affected by acute administration of alcohol, but was affected by alcohol expectancies of cognitive and behavioural impairment: the higher the expected loss of inhibitory control the lower the impulsivity.

The results support the distinction between motor- impulsivity and other subtypes of impulsivity, with only motor- impulsivity being dependent on behavioural inhibitory control. There was a trend effect of alcohol on temporal- impulsivity in the high dose condition, providing further evidence of the dissociation between motor- and temporal- types of impulsivity. The study also provides preliminary evidence of a dissociation between reflection- impulsivity and other subtypes, with participants engaging compensatory mechanisms on the measure of reflection- impulsivity but not on measures of temporal- and motor- impulsivity.

6 The factor structure of impulsivity and the relationship of demographics and dispositions to impulsivity

6.1 Introduction

Researchers agree that impulsivity is multifaceted and best conceived of as consisting of several subtypes of behaviour (J. L. Evenden, 1999b) reflecting distinctive neurological pathways, pharmacological influences and cognitive processes (Peter G. Enticott et al., 2006; Pattij & Vanderschuren, 2008; Winstanley et al., 2006).

Previous investigators have focused on three subtypes of behavioural impulsivity: 'motor'- impulsivity, as an inability to inhibit a behavioural response, 'reflection'- impulsivity as the tendency to make decisions without gathering or evaluating necessary information, and 'temporal'- impulsivity as a failure to delay gratification. For a detailed introduction of these subtypes see section 1.1. The studies presented in this thesis have explored the processes underlying these three factors of impulsive responding. The contribution of inhibitory control processes, and biases in speed/accuracy trade-offs were examined in detail and the studies provide evidence that the subtypes of impulsivity may be dissociable, and mediated by differing underlying processes.

It was found that behavioural inhibitory control processes, as challenged by a dual task and an acute dose of alcohol, are relevant for the Stop Signal Task as a measure of motor- impulsivity, but are not engaged during performance on measures of temporal- and reflection- impulsivity. This provides evidence that motor- impulsivity may be distinct from reflection- and temporal- impulsivity. There was also preliminary evidence that reflection- impulsivity may be distinct from temporal- impulsivity as individuals expecting impairment from alcohol showed a tendency to compensate for this on the measure of reflection- impulsivity, but did not show such compensatory mechanisms on the measure of temporal- impulsivity.

However, the studies did highlight issues with the measurement of impulsivity. For example, instructions for speed or accuracy were found to affect reflection- impulsivity as indexed by the Matching Familiar Figures, but not the Information Sampling Task, suggesting important differences between the two tasks. This provides evidence that multiple tasks of a subtype may be subject to different underlying processes.

Taken together, these findings provide preliminary evidence that there are important differences between measures of impulsivity. The studies provide preliminary evidence that the subtypes may be distinct from one another, for example motor- impulsivity being the only subtype reliant on behavioural inhibitory control resources. However, the studies also raise important questions as to whether multiple measures of a subtype index the same underlying processes.

To help address these issues, the factor structure of impulsivity must also be established. Factor analysis studies can provide further insight into whether different types of impulsivity should be treated as distinct constructs. Furthermore, such studies can establish the validity of using multiple measures to index the same underlying construct.

6.1.1 Three factors of impulsivity

The three subtypes of motor-, reflection- and temporal- impulsivity are all discussed within current literature, however they are rarely investigated in conjunction with one another. It is commonly assumed that these subtypes are distinct from one another but are mediated by dissociable, but converging, underlying processes (P. G. Enticott & Ogloff, 2006; J. Monterosso & Ainslie, 1999; Winstanley et al., 2004).

There is some limited correlational and factor analysis research that has provided support for these three subtypes, as multiple measures within each subtype have been found to correlate with one another; there is also evidence that the subtypes are distinct from one another.

6.1.1.1 Relationships between self-report questionnaires and behavioural tasks

For the most part, research finds that self-report measures of impulsivity are distinct from behavioural tasks.

The Barratt Impulsiveness Scale has been found to not correlate with behavioural measures, including motor impulsivity tasks (the Stop Signal and Go/NoGo task) or delay discounting tasks (S.D. Lane et al., 2003; Lansbergen et al., 2007; Reynolds, Ortengren et al., 2006). However, there is some limited evidence that self-report impulsiveness is related to commission errors on the Go/NoGo task (Aichert et al., 2012; Reynolds, Ortengren et al., 2006).

Studies using factor analysis methods further support the suggestion that self-report impulsiveness is distinct from behavioural impulsivity; these studies predominantly find distinct factors of self-report and behavioural impulsivity (Broos et al., 2012; Havik et al., 2012; S.D. Lane et al., 2003; Malle & Neubauer, 1991; Meda et al., 2009). These studies suggest that self-report impulsiveness should be treated as a separate construct from behavioural impulsivity.

6.1.1.2 Relationships between behavioural tasks

In addition to exploring the relationship of behavioural tasks to self-report measures of impulsiveness, the relationships between multiple behavioural tasks have been investigated. There is some evidence to suggest that behavioural tasks 'within' subtypes of impulsivity correlate with one another (Dougherty et al., 2009). Multiple measures of motor- impulsivity have been found to correlate; participants with longer Stop reaction times on the Stop Signal Task make more commission errors on the Go/NoGo (Reynolds, Ortengren et al., 2006) and on the Immediate Memory Task (Dougherty et al., 2009). Multiple measures of delay discounting (pen-and-paper measures and an experiential task) have also been found to correlate with one another (Reynolds et al., 2008). In contrast, investigators have not found reliable relationships across measures of different subtypes (e.g. Reynolds et al., 2008), suggesting that the subtypes may be distinct from one another. There is no correlation between motor impulsivity and temporal impulsivity (Broos et al., 2012) or reflection impulsivity as measured by the Matching Familiar Figures Task (Messer, 1976).

These correlational studies provide preliminary evidence that multiple measures 'within' a subtype of impulsivity are related to one another, however they find few correlations between tasks indexing different subtypes (Broos et al., 2012; Dougherty et al., 2009; Reynolds, Ortengren et al., 2006; 2008). Consistent with this, factor analysis studies typically find that measures of temporal- impulsivity load onto a separate factor from motor- impulsivity tasks (Broos et al., 2012; S.D. Lane et al., 2003; Reynolds, Ortengren et al., 2006). Hitherto, no factor analysis studies have investigated measures of reflection- impulsivity.

6.1.2 Issues with current understanding of the three factors of impulsivity

Taken together, these studies provide preliminary evidence that the subtypes of impulsivity are well-defined and well-differentiated from one another. However, there is also evidence that more detailed classifications of impulsivity may be required.

Literature has suggested relationships may exist between subtypes that are not encompassed by the current distinctions of motor-, temporal- and reflection- impulsivity. For example, it has been hypothesised that temporal- impulsivity may index action restraint processes similar to those on the Immediate Memory and Go/NoGo tasks (Dalley et al., 2011) suggesting these tasks as belonging to one subtype, rather than differential temporal- and motor- subtypes.

There is some behavioural evidence that multiple measures of one subtype can, in fact, load onto different factors of impulsivity. Factor analysis has indicated that motor impulsivity tasks do not necessarily load onto one factor; the Immediate Memory Task/Continuous Performance Task and GoStop (a version of the Stop Signal Task) have been found to load onto separate factors (Dougherty et al., 2009; Reynolds et al., 2008). Furthermore, there are a number of known issues with the measurement of impulsivity that have not been considered in sufficient detail by previous investigators. These issues will be discussed below.

6.1.3 Task differences that may have implications for their factor loadings

6.1.3.1 Motor- impulsivity

While the Stop Signal, Immediate Memory (a continuous performance task) and Go/NoGo tasks have all been used as measures of ‘motor’- impulsivity, there are methodological differences that may have implications for the interpretation of the tasks.

On the Stop Signal Task, participants must initiate responding to a Go stimulus, but cancel the response on a small number of trials if a Stop signal is subsequently presented. This inhibition of an already activated and initiated behaviour, can be termed ‘action cancellation’, and is an index of ability to ‘stop’ (Dalley et al., 2011; Winstanley, 2011).

Go/NoGo tasks also present participants with Go and Stop stimuli, however on each trial only one stimulus (either Go *or* Stop) is presented. On this task participants must simply refrain from responding until the Go stimulus is presented; the Go response is not initiated and then cancelled as is the case on the Stop Signal Task. This form of inhibition can be labelled ‘action restraint’, and is an index of ability to ‘wait’ (Dalley et al., 2011; Winstanley, 2011).

The Immediate Memory Task (Dougherty et al., 2002) also measures ‘action restraint’ but requires more complex processing compared to the Go/NoGo. Participants are presented with a series of number strings and must make a Go response whenever a string is identical to the preceding string. In the task, commission errors occur when a participant makes a Go response to a catch trial; on these trials it is assumed that the participant has responded prematurely, before fully processing the sequence. The Immediate Memory Task therefore also requires ‘action restraint’ (Winstanley, 2011).

Despite the routine use of these three tasks as measures of motor- impulsivity, there is some evidence that action restraint and action cancellation processes actually reflect distinct neurological pathways (Dalley et al., 2011) suggesting that the tasks may index different processes underlying impulsive responding.

6.1.3.2 Temporal Impulsivity

Pen-and-paper and experiential tasks have both been used to index the tendency to delay gratification. However, it is known that asking an individual to imagine which of two options they would prefer is different from having them choose and experience the delay and reward (Odum, 2011). In addition, there is evidence that experiential tasks result in higher levels of impulsive responding (Winstanley, 2011), probably due to methodological differences between the tasks.

Pen-and-paper measures of temporal- impulsivity typically use hypothetical monetary rewards (for non-clinical populations). In contrast, experiential tasks use point rewards, which despite not being ‘real’ rewards, are received in the laboratory. There is evidence suggesting that different reward types have implications for impulsive responding. Investigators have found that when real rewards are used on pen-and-paper measures of delayed gratification, participants show less impulsive responding compared to when hypothetical rewards are used (Hinvest & Anderson, 2009; Madden et al., 1999). Furthermore, monetary, but not point, rewards are subject to expectations and experiences of inflation, and expected income and means in the future, all of which could also affect the perceived value of a future reward (Frederick et al., 2002).

As well as differences in the rewards utilised by pen-and-paper and experiential measures, there are differences between the tasks with regard to delays. Pen-and-paper measures require participants to make a series of choices between rewards, with delays ranging from days to years. In comparison, experiential tasks use much shorter delays, since the participant experiences them within the laboratory. It is known that more remote outcomes, i.e. rewards at longer delays, are perceived to be less desirable (Odum, 2011).

6.1.3.3 Reflection- impulsivity

Both the Matching Familiar Figures and Information Sampling Tasks have been developed to index reflection- impulsivity. The two tasks are thought to measure the same fundamental underlying process of reflection; evidence for this is taken from the finding that on both tasks the number of errors made is related to the volume of information acquired, a key criteria of reflection- impulsivity (Clark et al., 2006; J. L. Evenden, 1999a). However, there are also some methodological details between the tasks which have implications for their interpretation.

The Matching Familiar Figures and Information Sampling Task quantify the evaluation of information by different means. The Matching Familiar Figures Task indexes the tendency to reflect on and evaluate information by measuring latency from initial presentation of the problem, to making an initial decision. Time to making a response is considered a measure of the quantity of information gathered and evaluated (J. Kagan, 1965b). Specifically the combination of fast/inaccurate responding is identified as impulsive, and slow/accurate responding is identified as reflective (J. Kagan, 1965b). However, the task is known to be dependent on multiple confounding processes including information processing styles, working memory, attention, visual search (Clark et al., 2006; Messer, 1976; Zelniker & Jeffrey, 1976) and research has not been able to establish whether longer latencies are related to increased evaluation of the information provided (e.g. Ault et al., 1972; Drake, 1970; Zelniker et al., 1972).

The Information Sampling Task provides a *primary* index of information sampling, measuring the tendency to acquire information before making a decision (Clark et al., 2006). The task takes an index of the actual volume of information the individual acquires, instead of inferring this from the latency to making a response. The task is also designed to reduce demands on working memory and on complex processing and evaluation of material (Clark et al., 2006; Huddy et al., 2013). There are two versions of the Information Sampling Task available; (i) in the 'fixed win' condition, participants win a fixed amount of points if they make a correct decision, regardless of how much information they have acquired, (ii) in the 'reward conflict' condition participants lose points as they accumulate more information. The reward conflict condition is designed to introduce a conflict between reward and certainty; participants must choose between tolerating high uncertainty at the point of decision making (by gathering less information) but potentially winning a greater number of points, or choosing to accumulate more information and thereby sacrificing some points (Clark et al., 2006).

It is evident that there are differences between the tasks, and the Matching Familiar Figures is subject to additional confounding processes in comparison to the Information Sampling Task.

6.1.4 The contributions of demographics and dispositions to behavioural impulsivity

Investigators have found that self-report impulsiveness is associated with certain demographics and dispositions, including age and intelligence. Questionnaire measures of impulsiveness are sensitive to age-related changes, and self-reported impulsivity declines steadily between the ages of 10-30 (Steinberg et al., 2008). There is also a relationship between intelligence and impulsiveness: high self-report cognitive and nonplanning impulsiveness is associated with lower verbal and numerical intelligence, and reasoning (Aichert et al., 2012; Schweizer, 2002; Vigil-Colet & Morales-Vives, 2005); self-report impulsiveness is also associated with academic failure (Vigil-Colet & Morales-Vives, 2005).

In addition to evidence of a relationship between age and intelligence, and self-reported impulsiveness, there is also research finding that age and intelligence may be factors contributing to performance on behavioural measures of impulsivity. There is evidence of a relationship between age and behavioural impulsivity; in particular, age-related changes have been recorded on measures of both reflection- and motor- impulsivity. For a detailed description of the relationship between age and behavioural impulsivity please see section 1.4.2. There is also evidence that intelligence may have implications for behavioural impulsivity. Investigators have found that intelligence is associated with temporal- impulsivity, and have also found a relationship between intelligence and reflection- impulsivity under certain circumstances (S.D. Lane et al., 2003). For a detailed description of the relationship between intelligence and behavioural impulsivity please see section 1.4.1.

Further from evidence that age and intelligence are related to self-report impulsiveness (Aichert et al., 2012; Schweizer, 2002; Steinberg et al., 2008; Vigil-Colet & Morales-Vives, 2005) and certain factors of behavioural impulsivity (e.g. Block et al., 1974; de Wit et al., 2007; Eska & Black, 1971; Plomin & Buss, 1973; Shamosh et al., 2008), there is evidence that self-report impulsiveness may, in itself, have merit as a predictor of behavioural impulsivity (e.g. de Wit et al., 2007). It is known that self-report and laboratory measures of impulsivity are far from homogenous (Dick et al., 2010) and the Barratt Impulsiveness Scale does not consistently correlate with behavioural measures, including motor impulsivity tasks (the Stop Signal and Go/NoGo task) and delay discounting tasks (S.D. Lane et al., 2003; Lansbergen et al., 2007; Reynolds, Ortengren et al., 2006; Reynolds et al., 2008). However, there is also some evidence that questionnaire measures of trait impulsiveness may have relevance for behavioural impulsivity (Bjork et al., 2004; Dick et al., 2010; Dougherty et al., 2008): self-report impulsiveness has been found to be related to motor impulsivity on the Go/NoGo task (Aichert et al., 2012; Reynolds, Ortengren et al., 2006) and Immediate Memory Task (Marsh et al., 2002). Researchers have also found nonplanning impulsiveness on the Barratt Impulsiveness Scale to be a significant predictor of delay discounting (de Wit et al., 2007). It is clear that the relationship between self-report and behavioural impulsivity is far from straightforward, however there is some evidence that questionnaires have merit as predictors of behaviour.

Finally, it is possible that alcohol use may be predictive of impulsivity (e.g. Nederkoorn et al., 2009). Self-report measures of impulsivity have been found to be sensitive to drinking behaviours, including quantity of alcohol consumed, and binge drinking patterns (Balodis et al., 2009; Carlson et al., 2010; Fossati et al., 2001) as well as drug use behaviours (e.g. Bond et al., 2004; S. D. Lane et al., 2007). In clinical populations, there is consistent evidence that alcohol dependent individuals display deficits in reflection- (Lawrence et al., 2009a, 2009b), motor- (Bjork et al., 2004; Joos et al., 2012; Lawrence et al., 2009a) and temporal- (Bjork et al., 2004; Dom, D'Haene et al., 2006; Petry, 2001) impulsivity. However, there is only limited evidence of a relationship between behavioural impulsivity and drinking behaviours in normal populations. There is some evidence of a relationship between social, and binge, drinking and motor impulsivity. Research has found binge drinkers to have fast reaction times in comparison to non-bingers (Scaife & Duka, 2009); further research suggests that female, but not male, heavy drinkers (minimum 11.5 units per week, mean 17.4) display impaired response inhibition on the Stop Signal Task (Nederkoorn et al., 2009). Research has also found that heavy adolescent drinkers show deficits in temporal impulsivity (M. Field, Christiansen, Cole, & Goudie, 2007). There is currently no evidence that social drinkers show impairments in reflection impulsivity (Solowij et al., 2012).

6.1.5 The current study

In conclusion, current literature on impulsivity suggests and discusses three subtypes of behavioural impulsivity, alongside self-report impulsiveness. These three subtypes can be termed reflection-, motor- and temporal- impulsivity.

A small number of correlational and factor analysis studies have been conducted helping to establish the factor structure of impulsivity. However such studies have predominantly focused on motor- and temporal- subtypes, and there are currently no studies that have utilised measures representing all *three* subtypes of impulsivity, including reflection- impulsivity. Furthermore, there is some behavioural evidence that multiple measures of one subtype can, in fact, load onto different factors of impulsivity.

While the available studies provide us with a tentative understanding of the distinctions and relationships between subtypes, it is evident that larger factor analytic studies applying additional impulsivity measurements for multiple subtypes are needed (S.D. Lane et al., 2003; Meda et al., 2009).

The current study will examine the factor structure of impulsivity in detail, applying multiple measures of the different subtypes to confirm that the three proposed subtypes of motor-, temporal- and reflection- impulsivity can indeed be categorised into these three factors.

The study applies a large number of impulsivity tasks, encompassing each of the three proposed subtypes. The primary dependent variable of each task will be identified by the literature, and exploratory factor analysis will be used to explore the underlying factor structure and provide evidence for the currently accepted distinctions between behavioural impulsivity tasks. It is expected that there will be a distinction between self-report and behavioural tasks. It is not clear whether the behavioural tasks will load onto the three factors of motor-, temporal- and reflection- impulsivity, as the literature commonly assumes, or whether additional sub-factors of impulsivity will be identified.

In addition to the primary impulsivity measures previously discussed, two additional measures will again be utilised: the Tower of London task (Shallice, 1982) and the Iowa Gambling Task (Bechara et al., 1994). Investigators have employed pre-planning times (latency to respond) on the Tower of London as an index of both impairments in inhibitory control, suggesting it may have implications for motor- impulsivity (Steinberg et al., 2008). They have also suggested planning tendencies on the Tower of London task may overlap with reflection- impulsivity (Bickel et al., 2012). Investigators have also suggested gambling tasks may have some utility as measures of risk and uncertainty based impulsive choice, alongside measures of reflection impulsivity (Winstanley et al., 2010). It is thought that the Iowa Gambling Task provides a measure of decision making under initially ambiguous conditions (Dannon et al., 2010). However, the task is also thought to be dependent on multiple processes including learning to sacrifice immediate rewards in favour of long-term gain (Dannon et al., 2010), as well as sensitivity to reward, punishment and future consequences (Bechara et al., 1994). The current study will include these two measures to explore the validity of these tasks as measures of impulsivity, and to establish which category of impulsivity they fall under. The two versions of the Information Sampling Task (fixed win and reward conflict) will be treated as two separate tasks, as the reward conflict condition is known to require additional processes to the fixed win condition (Clark et al., 2006).

The study will apply principal axis factoring to identify the factors of impulsivity. Factor analysis methods are used to identify any latent variables that cause variables to co-vary. Using principal axis factoring during factor extraction the shared variance of a variable is separated from its unique and error variance to identify the underlying factor structure; factors are thus based on the shared variance between variables and variables that share variance are clustered together. Principal axis factoring was selected as opposed to principal components analysis as the latter tends to provide inflated estimates of the variance accounted for by the factors (Costello & Osborne, 2005). The reasons for selecting one dependent variable per task to include in the analysis are two-fold. Firstly, it is known that factor analytic studies depend heavily on the number of indicators included per expected factor (Russo, Leone, Lauriola, & Lucidi, 2008); retaining only one variable per task should circumvent this issue. Secondly, financial and practical limitations prevent us from recruiting the large number of participants required to provide an adequate sampling size for a larger factor analysis.

A secondary analysis will explore the contributions of demographic (age) and dispositional (IQ and self-report trait impulsiveness) factors, as well as drinking behaviours, to behavioural impulsivity. There is evidence that these demographics and dispositions may have merit as predictors of behavioural impulsivity, however there has previously been no research exploring the relationship of these demographics to multiple types of behavioural impulsivity in a systematic manner. A series of multiple regressions will be performed, with behavioural impulsivity scores as the outcome variables. As a general rule in multiple regression analysis variables expected to predict the outcome variable are added into the model first, and then exploratory variables are added into a second step (A. Field, 2013). Therefore, age, IQ and self-report impulsiveness will be included in the first step of the model and binge-drinking score will be included for exploratory analysis in the second step.

6.2 Method

6.2.1 Participants

160 participants (80 male, 80 female) were recruited. Participants were all undergraduate and postgraduate students at the University of Sussex.

6.2.2 Procedure

Participants completed a questionnaire pack and the National Adult Reading Task, followed by a battery of cognitive tasks. Cognitive tasks were completed in a random order.

6.2.3 Materials

6.2.3.1 Questionnaires

Personal Details Questionnaire (PDQ): The personal details questionnaire asks for age, date of birth, smoking status, alcohol use and current medication.

Beck Depression Inventory II (BDI-II; Beck et al., 1996): The depression inventory measures severity of clinical depression.

Alcohol Use Questionnaire (AUQ; Townshend & Duka, 2002): The questionnaire gives a measure of total units per week, binge score and alcohol use score (AUQ score).

Barratt Impulsiveness Scale, Version 11 (BIS-11; Patton et al., 1995): The Barratt Impulsiveness Scale is a 30-item checklist measuring impulsivity. The questionnaire gives a total impulsivity score, and three sub-scores: attentional, motor and nonplanning impulsivity.

Multidimensional Mood State Questionnaire (MDMQ; Steyer, Schwenkmezger, Notz & Eid, 1997): The questionnaire gives scores on each of the following continuums: good-bad, awake-tired, calm-nervous.

6.2.3.2 Cognitive and behavioural tasks

National Adult Reading Task (NART; Nelson & O'Connell, 1978): The National Adult Reading Task gives an estimate measure of verbal IQ.

Information Sampling Task (IST; Clark et al., 2006): The Information Sampling Task measures the tendency to acquire information before making a decision. Participants must open a matrix of boxes to reveal two colours underneath; participants must then select the colour which is in the majority. There are two conditions of experimental trials available: (i) *Fixed win condition* Participants win or lose 100 points regardless of how many boxes they have opened; participants complete 10 trials. (ii) *IST reward conflict* For every box opened, participants lose 10 points from a bank of 250. If a participant chooses correctly they win the remaining points in the bank; participants complete 10 trials.

The task gives a measure of the probability of being correct that the participant tolerates at the point of decision making [P(correct)].

Matching Familiar Figures Test (MFF20; Cairns & Cammock, 1978; J. Kagan et al., 1964): The Matching Familiar Figures Task measures the tendency to acquire information before making a decision. Participants have to select the one of six visually presented stimuli which is identical to an original image. Participants complete 20 trials.

The task gives a composite Impulsivity score (I-score).

Tower of London Task (TOL; Fimbel et al., 2009; Shallice, 1982): The Tower of London task is a measure of planning tendencies. On each trial participants are required to rearrange a set of three disks to a shown configuration of three piles. Participants complete 30 trials of progressive difficulty.

The task gives a measure of pre-planning time (average time before first move).

Stop Signal Task, version (ii) (SST; Logan, 1994): The Stop Signal Task assesses motor impulsivity. Participants respond to the direction of visually presented green arrows but withhold this response whenever the arrow changes from green to red (the Stop Signal, occurs 25% of trials). Participants complete 120 trials.

The task gives a measure of Stop Signal Reaction Time (SSRTi). Large SSRTi values indicate poor inhibitory control.

Go/NoGo (adapted from Kim et al., 2007): The Go/NoGo measures behavioural disinhibition. Participants are presented with a series of triangles; they are instructed to respond as quickly as possible whenever a triangle is pointing upwards (Go trials), using the space-bar, but to withhold this response if a triangle is pointing in any other direction (Stop trials). Participants complete 120 trials.

The task gives a measure of percentage of commission errors, when a Go response is made in response to a Stop signal.

Immediate Memory Task (IMT; Dougherty et al., 2002): The Immediate Memory Task is a variant of the Continuous Performance Task, measuring behavioural disinhibition. On each trial a 5-digit number string is presented. Participants are instructed to press the mouse button if a number string is identical to that which preceded it, but to withhold this response if the number differs. The task contains ‘catch’ trials, where the number string is almost identical to the preceding trial but differs by one digit. Participants completed two blocks of 180 seconds, with a 20 second rest period between blocks.

The task gives a measure of commission errors. Commission errors occur when a participant makes a premature Go response to a catch trial.

Single Key Impulsivity Paradigm (SKIP; Dougherty et al., 2005): The Single Key Impulsivity Paradigm assesses ability to delay gratification, using a free-operant procedure. Participants are instructed to press the mouse-button to obtain a point reward. The magnitude of the point reward is dependent on the delay between consecutive responses. Participants complete a four-minute trial.

The task gives a measure of average inter-response time (the average time delay between consecutive mouse clicks).

Two Choice Impulsivity Paradigm (TCIP; Dougherty et al., 2005): The Two Choice Impulsivity Paradigm measures tolerance for delayed reward and preference for smaller, immediate rewards over larger, delayed rewards. On each experimental trial two shapes are presented (a circle and a square). Participants are instructed to choose between the shapes to receive points. One shape corresponds to a small reward available after a short delay (3 points after a 3 second delay); the second shape corresponds to a larger, more delayed reward (9 points after a 9 second delay). Participants complete 30 trials.

The task gives a measure of the number of smaller sooner reward choices.

Monetary Choice Questionnaire (MCQ; Kirby et al., 1999): The Monetary Choice Questionnaire measures preference for large delayed rewards over small, more immediate rewards. For each item, participants must choose between a large delayed reward (LDR), and a smaller more immediate reward (SIR). Participants complete 27 items.

The task gives a measure of discounting of delayed rewards (*k*).

Delay Discounting Questionnaire, version (ii) (DDT): The Delay Discounting Task is a variation on the MCQ, measuring preference for large delayed rewards over smaller immediate rewards. The procedure is identical to the MCQ. Participants complete three blocks of 50 trials, and one block of 62. Stimuli are presented in a fixed random order.

The task gives a measure of discounting of delayed rewards (*k*).

6.2.4 Statistical analysis

6.2.4.1 Principal axis factoring

Principal axis factoring was conducted on the 12 items with orthogonal rotation (varimax).

Variables included were:

Information Sampling Task (i)fixed win (ii)reward conflict P(correct);

Matching Familiar Figures Task I-score;

Tower of London preplanning time;

Delay Discounting Task mean *k* value;

Monetary Choice Questionnaire mean *k* value;

Single Key Impulsivity Paradigm average IRT;

Two Choice Impulsivity Paradigm number of impulsive choices;

Immediate Memory Task percentage commission errors;

Go/NoGo percentage commission errors;

Stop Signal Task SSRTi;

Iowa Gambling Task final score;

Barratt Impulsiveness Scale total score.

All variables are coded so that large values indicate increased impulsivity.

In addition explorative correlations were performed, between all dependent variables, using Pearson's correlation coefficient.

6.2.4.2 Analysis of demographics and dispositions

Gender differences in impulsivity were checked using one-way ANOVA.

A series of multiple regressions were performed to investigate the effects of age, IQ, self-report impulsiveness and binge drinking on behavioural impulsivity. Outcome variables were the main dependent variables from each laboratory measure. All variables were coded so that large values indicate increased impulsivity. Age, IQ and Barratt Impulsiveness total score were included within the first step of the model (model 1); binge score was subsequently added in the second step (model 2). Barratt Impulsiveness total score, rather than scores on the three subscales, was included to avoid issues of multicollinearity, as the subscales were found to correlate highly with one another. Results were Bonferroni corrected to adjust for multiple tests (12 multiple regressions were performed). The accepted *p* value was $p<.004$.

6.3 Results

6.3.1 Principal axis factoring

6.3.1.1 Missing data and exclusions

NART 23 participants did not complete the NART, because they were second language English, or dyslexic. BIS-11 Data were missing for one participant. SST Data were missing for three participants, a further 8 were excluded for GoRTs>1000msecs, or 100% Stop accuracy. IMT Data were missing for three participants from the IMT, one participant was excluded for having <50% response accuracy to target trials. SKIP Data for 3 participants was missing from the SKIP, a further 6 participants were excluded for making >1000 responses on the task; it was assumed that these participants did not leave enough time between responses to infer the response-reward contingencies. DDT Data were missing for 1 participant from the DDT, and a further 14 participants were excluded according to the inclusion criteria (see Johnson & Bickel, 2008). MCQ Data for 3 participants was missing from the MCQ. Go/NoGo Data were missing from 2 participants on the Go/NoGo, 5 were excluded for making >10% commission errors, or >20% omission errors. IGT Data were missing for 20 participants, as the IGT was added late into the study. 103 participants were included in the final analysis.

6.3.1.2 Correlations between tasks

The full correlation matrix is presented in Table 6.1.

Correlations	**G/NG**	**IMT**	**IST(i)**	**IST(ii)**	**MFF20**	**TOL**	**SKIP**	**TCIP**	**DDT**	**MCQ**	**IGT**	**BIS-11**
SST	0.023	**-0.184***	**-0.18***	**0.193***	0.088	0.080	-0.035	-0.119	-0.026	-0.153	-0.107	-0.037
Go/NoGo		**0.231****	0.003	0.073	-0.012	0.095	0.117	-0.113	-0.045	-0.137	0.062	-0.109
IMT			**0.181***	0.075	0.025	-0.079	0.123	-0.048	-0.087	-0.036	0.083	0.139
IST(i)				**0.367*****	**0.186***	-0.054	0.082	0.050	-0.020	**0.242****	**0.207***	-0.049
IST(ii)					0.148	0.031	**0.187***	0.046	0.002	0.154	**0.173***	0.042
MFF20						-0.026	0.083	-0.008	-0.068	0.022	0.018	-0.022
TOL							**0.242****	0.109	0.158	-0.041	**-0.170***	-0.031
SKIP								0.005	0.119	0.107	0.154	0.109
TCIP									0.083	0.114	0.137	0.051
DDT										**0.344*****	-0.026	-0.135
MCQ											0.102	0.034
IGT												-0.086
Sig. (1-tailed)	**G/NG**	**IMT**	**IST(i)**	**IST(ii)**	**MFF20**	**TOL**	**SKIP**	**TCIP**	**DDT**	**MCQ**	**IGT**	**BIS-11**
SST	0.408	**0.031***	**0.034***	**0.025***	0.188	0.210	0.364	0.116	0.396	0.062	0.140	0.356
Go/NoGo		**0.009****	0.489	0.232	0.453	0.169	0.120	0.128	0.327	0.084	0.266	0.138
IMT			**0.034***	0.225	0.403	0.215	0.108	0.317	0.191	0.358	0.201	0.081
IST(i)				**0.000*****	**0.030***	0.294	0.204	0.308	0.422	**0.007****	**0.018***	0.310
IST(ii)					0.067	0.376	**0.029***	0.321	0.493	0.060	**0.040***	0.337
MFF20						0.398	0.202	0.469	0.248	0.412	0.427	0.412
TOL							**0.007****	0.136	0.055	0.342	**0.043***	0.378
SKIP								0.481	0.116	0.141	0.060	0.137
TCIP									0.203	0.125	0.084	0.306
DDT										**0.000*****	0.398	0.087
MCQ											0.152	0.365
IGT												0.193

Table 6.1. Table showing correlation matrix, and significance values, for the 12 tasks. Significant values are highlighted in bold, * indicates significant correlation (*p<.05, **p<.01, ***p<.001). SST= Stop Signal Task; Go/NoGo= Go/NoGo Task; IMT= Immediate Memory task; IST(i)= Information Sampling Task (fixed win condition); IST(ii)= Information Sampling Task (reward conflict condition); MFF20=Matching Familiar Figures task; TOL= Tower of London task; SKIP= Single Key Impulsivity Paradigm; TCIP= Two Choice Impulsivity Paradigm; DDT= Delay Discounting Task; MCQ= Monetary Choice Questionnaire; IGT= Iowa Gambling Task; BIS-11= Barratt Impulsiveness Scale

There were no correlations between self-report impulsivity and any of the behavioural tasks. There were no correlations between the TCIP and any other task.

Participants who were more impulsive on the IST fixed win condition were also more impulsive on the reward conflict condition of the task (r=.367, p<.001), the MFF20 (r=.186, p=.030) and made poorer choices on the IGT (r=.207, p=.018). Participants who were more impulsive on the reward conflict version of the IST, also made poorer choices on the IGT (r=.173, p=.040) and were more impulsive on the SKIP (r=.187, p=.029).

Participants who were more impulsive on the IST fixed win task were less impulsive on the SST (r=-.180, p=.034) but were more impulsive on the IMT (r=.181, p=.034) and MCQ (r=.242, p=.007). The IST reward conflict condition was also related to performance on the SST (r=.193, p=.025).

Impulsive participants, according to the SKIP, also displayed longer pre-planning times on the TOL (r=.242, p=.007). Participants who made better choices on the IGT had shorter pre-planning times on the TOL (r=-.170, p=.043).

Impulsivity on the DDT was related to impulsivity on the MCQ (r=.344, p<.001).

Participants who were more impulsive on the IMT were also more impulsive on the Go/NoGo (r=.231, p=.009), but were less impulsive on the SST (r=-.184, p=.031).

6.3.1.3 Principal axis factoring

The Kaiser-Meyer-Olkin measure of sampling adequacy was .509, on the lower boundary of acceptability. Five variables (SST, TOL, TCIP, DDT, BIS-11) had individual KMO statistics <.5, below the acceptable sampling limit, however these factors were retained as removing them did not clarify the analysis. Bartlett’s test of sphericity was significant, $x^2(78)=119.318$, p=.002, indicating that the null hypothesis that the correlation matrix is an identity matrix can be rejected.

An initial analysis was run to obtain eigenvalues for each component in the data. Six factors had eigenvalues over Kaiser’s criterion of 1, and in combination explained 64.2% of the variance; see Table 6.2 for eigenvalues for the extracted factors.

Factor	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.92	14.74	14.74	1.31	10.08	10.08	1.10	8.47	8.47
2	1.53	11.79	26.54	1.00	7.73	17.81	0.85	6.57	15.04
3	1.42	10.89	37.43	0.90	6.96	24.76	0.85	6.56	21.60
4	1.29	9.90	47.33	0.76	5.83	30.60	0.84	6.46	28.05
5	1.17	8.97	56.30	0.69	5.31	35.91	0.74	5.66	33.72
6	1.02	7.85	64.15	0.38	2.92	38.82	0.66	5.11	38.82
7	0.93	7.19	71.34						
8	0.85	6.54	77.88						
9	0.76	5.87	83.74						
10	0.63	4.88	88.62						
11	0.52	4.02	92.64						
12	0.51	3.90	96.54						
13	0.45	3.46	100.00						

Table 6.2. Table showing Eigenvalues for the extracted factors, with total variance explained by extracted factors.

The scree plot (Figure 6.1) was uninformative, with no clear point of inflexion, and indicated no clear number of factors.

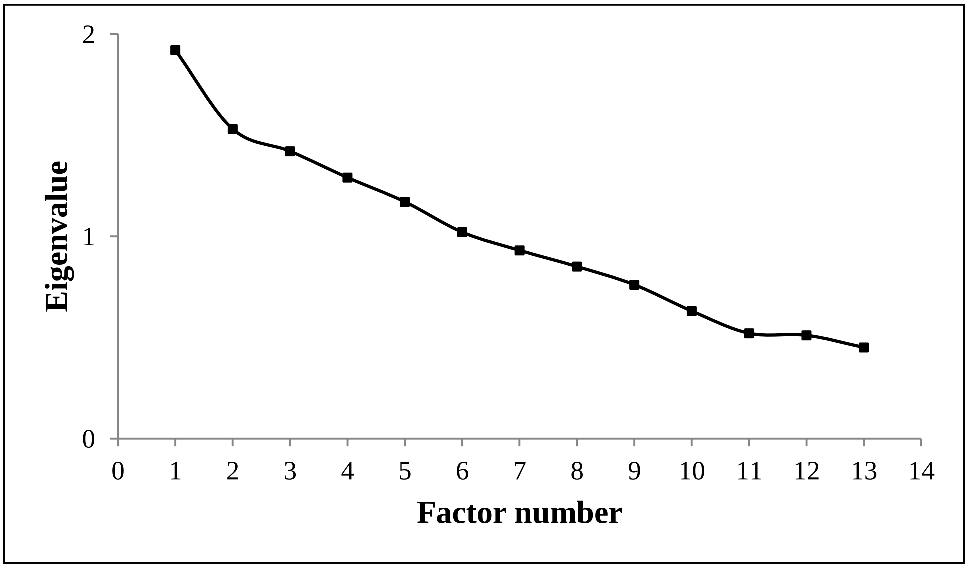

Figure 6.1. Scree plot indicating number of factors for extraction in the analysis.

Six factors were retained in the analysis. (1) factor 1 represents responding on the IST, MFF20 and IGT; (2) factor 2 represents delay discounting on pen-and-paper measures (DDT and MCQ); (3) factor 3 represents responding on the TOL and SKIP; (4) factor 4 represents inhibitory control on the SST, the IST(reward conflict) also loaded on factor 4, however this loading was discarded as the loading of the task to factor 1 was considerably larger; (5) factor 5 represents self-report impulsivity on the BIS-11; (6) factor 6 represents action restraint on the Go/NoGo and IMT. The TCIP did not load onto any of the factors.

See table 6.3 for factor loadings.

	Factor					
	1	2	3	4	5	6
IST(i)	**0.650**	-0.109	0.083	-0.19	-0.090	-0.085
IST(ii)	**0.623**	-0.071	-0.022	0.279	0.037	-0.029
IGT	**0.293**	-0.078	-0.115	0.158	0.062	-0.110
MFF20	**0.272**	-0.054	-0.008	0.060	-0.004	-0.016
DDT	0.110	**0.654**	-0.139	0.016	-0.123	-0.030
MCQ	-0.220	**0.577**	0.048	-0.174	0.072	-0.156
TOL	-0.074	-0.049	**0.838**	-0.053	0.038	-0.009
SKIP	0.183	-0.187	**0.280**	0.027	-0.149	-0.240
SST	-0.080	-0.072	-0.053	**0.762**	-0.025	-0.059
BIS-11	0.035	-0.052	-0.009	-0.028	**0.795**	-0.026
GNG	-0.022	-0.071	-0.094	0.056	-0.120	**0.565**
IMT	-0.132	-0.067	0.060	-0.221	0.174	**0.454**
TCIP	-0.077	0.106	-0.120	-0.170	0.042	-0.173

Table 6.3. Table showing factor loadings after rotation. Significant factor loadings are highlighted in bold. IST(i)= Information Sampling Task (fixed win condition); IST(ii)= Information Sampling Task (reward conflict condition); IGT= Iowa Gambling Task; MFF20=Matching Familiar Figures task; DDT= Delay Discounting Task; MCQ= Monetary Choice Questionnaire; TOL= Tower of London task; SKIP= Single Key Impulsivity Paradigm; SST= Stop Signal Task; BIS-11= Barratt Impulsiveness Scale; GNG= Go/NoGo Task; IMT= Immediate Memory task; TCIP= Two Choice Impulsivity Paradigm.

6.3.2 Demographics and dispositions

6.3.2.1 Participant demographics

Of the 160 participants recruited, 23 were excluded from the analysis as an estimate of verbal IQ could not be recorded (participants were 2nd language English speakers, or dyslexic), additionally one participant was excluded as they failed to give a measure of self-report impulsiveness. For participant demographics see table 6.4.

	Mean	**S.D.**	**Range**
Age	20.38	3.08	18-40
IQ	108.2	7.1	90-124
BIS-11	65.36	10.13	41-88
Binge score	29.31	22.22	0-111

Table 6.4. Table showing participant age, intelligence, self-report impulsivity and binge drinking demographics.

There were no gender differences in impulsivity (*Fs*<3.761); see Table 6.5 for details.

DV	Male	Female	*F*
IST fw Boxes opened	0.87±0.01	0.89±0.01	*F*(1,158)=1.537, *p*=.217
IST rc Boxes opened	0.77±0.01	0.76±0.01	*F*(1,158)=.016, *p*=.900
MFF20 I score	-0.26±0.21	0.26±0.18	*F*(1,158)=3.691, *p*=.056
IGT Final Score	17.61±3.54	10.29±3.06	*F*(1,138)=2.339, *p*=.128
SST SSRTi	272.76±9.74	267.86±8.03	*F*(1,147)=.151, *p*=.698
GNG Commission errors	3.86±0.62	3.25±0.38	*F*(1,151)=.712, *p*=.400
IMT Commission errors	29.50±1.24	30.82±1.51	*F*(1,154)=.464, *p*=.497
TOL time	16980.32±600.05	16069. 00±523.09	*F*(1,158)=1.311, *p*=.254
SKIP IRT	4.52±0.65	5.49±1.12	*F*(1,149)=.543, *p*=.462
TCIP Impulsive number	6.56±0.76	7.58±0.82	*F*(1,158)=.816, *p*=.368
DDT Mean k	0.0311±0.0189	0.0298±0.0180	*F*(1,143)=.002, *p*=.960
MCQ Mean k	0.0240±0.0040	0.0156±0.0018	*F*(1,155)=3.761, *p*=.054

Table 6.5. Gender differences on each of the impulsivity measures. Values are presented as mean±sd. IST fw= Information Sampling Task (fixed win condition); IST rc= Information Sampling Task (reward conflict condition); MFF20=Matching Familiar Figures task; IGT= Iowa Gambling Task; SST= Stop Signal Task; GNG= Go/NoGo Task; IMT= Immediate Memory task; TOL= Tower of London task; SKIP= Single Key Impulsivity Paradigm; TCIP= Two Choice Impulsivity Paradigm; DDT= Delay Discounting Task; MCQ= Monetary Choice Questionnaire.

Assumption of normality was violated for age, W(160)=.587, p<.001, and binge score, W(160)=.892, p<.001. Assumption of normality was not violated for IQ, W(137)=.142, p=.142, and binge score, W(159)=.984, p=.061.

There were significant univariate correlations between age and IQ and binge score, and also between Barratt Impulsiveness and binge score, see table 6.6.

Correlations	**IQ**	**Binge score**	**BIS-11**
Age	0.366	-0.268	.067
IQ		-.109	-.025
Binge score			0.191
Sig. (2-tailed)	**IQ**	**Binge score**	**BIS-11**
Age	.000	.001	.405
IQ		.204	.774
Binge score			.016

Table 6.6. Correlations between age, IQ, Barratt Impulsiveness score (BIS-11) and binge drinking score.

6.3.2.1 Multiple regression analyses

Model 1 was a significant predictor of planning on the Tower of London [*F*(3,132)=7.685, *p*<.001, R^2=.149]; age (*p*<.001) and self-report impulsivity (*p*=.044) were significant predictors. The addition of binge score in the second model did not improve model fit [*F*(4,131)=5.939, *p*<.001. R^2change=.005]; in the second model, age remained a significant predictor (*p*<.001), but self-report impulsivity did not (*p*=.070). Neither IQ nor binge score predicted Tower of London performance in either model, see Table 6.7 for details

TOL		*B*	*SE* B	β		
Step 1	Constant	-8547.194	6336.466		-1.349	0.180
	Age	**-553.093**	**133.722**	**-0.359**	**-4.136**	**0.000*** **
	IQ	78.912	57.320	0.119	1.377	0.171
	BIS-11	**-77.271**	**37.982**	**-0.164**	**-2.034**	**0.044***
Step 2	Constant	-7873.710	6390.254		-1.232	0.220
	Age	**-579.484**	**137.290**	**-0.376**	**-4.221**	**0.000*** **
	IQ	77.993	57.384	0.118	1.359	0.176
	BIS-11 score	-70.784	38.753	-0.150	-1.827	0.070
	Binge score	-15.710	18.179	-0.073	-0.864	0.389

Table 6.7. Regression model for performance on the Tower of London Task (TOL) Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2. *Indicates significance (*p<.05, **p<.01, ***p<.001)

Neither model was a significant predictor of performance on any other behavioural task:

SST: Model 1, $F(3,121)=.637$, $p=.592$. $R^2=.016$; Model 2, $F(4,120)=.691$, $p=.599$, R^2change=.007; see Table 6.8.

SST		*B*	*SE* B	β		
Step 1	Constant	263.729	98.036		2.690	0.008
	Age	1.448	2.015	0.070	0.718	0.474
	IQ	-0.571	0.881	-0.063	-0.648	0.518
	BIS-11	0.569	0.570	0.091	0.998	0.320
Step 2	Constant	273.157	98.622		2.770	0.007
	Age	1.008	2.072	0.049	0.487	0.627
	IQ	-0.554	0.882	-0.061	-0.629	0.531
	BIS-11 score	0.650	0.577	0.104	1.127	0.262
	Binge score	-0.260	0.281	-0.087	-0.925	0.357

Table 6.8. Regression model for performance on the Stop Signal Task (SST). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

IMT: Model 1, $F(3,128)=3.087$, $p=.030$ $R^2=.067$; Model 2, IMT, $F(4,127)=2.314$, $p=.059$, R^2change=.001; see Table 6.9.

IMT		*B*	*SE* B	β		
Step 1	Constant	46.602	17.489		2.665	0.009
	Age	-0.207	0.365	-0.052	-0.568	0.571
	IQ	-0.257	0.159	-0.149	-1.622	0.107
	BIS-11	0.234	0.104	0.193	2.254	0.026*
Step 2	Constant	45.846	17.646		2.598	0.010
	Age	-0.173	0.376	-0.044	-0.460	0.647
	IQ	-0.257	0.159	-0.149	-1.616	0.109
	BIS-11	0.226	0.107	0.186	2.119	0.036*
	Binge score	0.020	0.050	0.036	0.404	0.687

Table 6.9. Regression model for performance on the Immediate Memory Task (IMT). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

Go/NoGo: Model 1, $F(3,127)=1.229$, $p=.302$, $R^2=.028$; Model 2, $F(4,126)=1.096$, $p=.361$, R^2change=.005; see Table 6.10.

Go/NoGo		*B*	*SE* B	β		
Step 1	Constant	13.028	6.088		2.140	0.034
	Age	0.080	0.130	0.058	0.614	0.540
	IQ	-0.071	0.055	-0.122	-1.293	0.198
	BIS-11	-0.054	0.036	-0.132	-1.496	0.137
Step 2	Constant	13.557	6.127		2.213	0.029
	Age	0.056	0.134	0.040	0.418	0.677
	IQ	-0.071	0.055	-0.122	-1.297	0.197
	BIS-11	-0.048	0.037	-0.116	-1.288	0.200
	Binge score	-0.015	0.017	-0.077	-0.840	0.402

Table 6. 10. Regression model for performance on the Go/NoGo. Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

SKIP: Model 1, $F(3,125)=.743$, $p=.528$, $R^2=.018$; Model 2, $F(4,124)=.679$, $p=.608$, R^2change=.004; see Table 6.11.

SKIP		*B*	*SE* B	β		
Step 1	Constant	1.894	11.361		0.167	0.868
	Age	0.011	0.264	0.004	0.040	0.968
	IQ	-0.101	0.098	-0.097	-1.028	0.306
	BIS-11	0.064	0.066	0.085	0.961	0.338
Step 2	Constant	1.222	11.424		0.107	0.915
	Age	0.050	0.271	0.018	0.185	0.853
	IQ	-0.102	0.098	-0.098	-1.037	0.302
	BIS-11	0.054	0.068	0.072	0.789	0.432
	Binge score	0.023	0.032	0.066	0.705	0.482

Table 6.11. Regression model for performance on the Single Key Impulsivity Paradigm (SKIP). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

TCIP: Model 1, $F(3,132)=1.182$, $p=.319$, $R^2=.026$; Model 2, $F(4,131)=.894$, $p=.000$, R^2change=.002; see Table 6.12.

TCIP		*B*	*SE* B	β		
Step 1	Constant	4.393	10.066		0.436	0.663
	Age	-0.393	0.212	-0.171	-1.848	0.067
	IQ	0.082	0.091	0.083	0.902	0.369
	BIS-11	0.027	0.060	0.039	0.455	0.650
Step 2	Constant	4.684	10.178		0.460	0.646
	Age	-0.404	0.219	-0.176	-1.848	0.067
	IQ	0.082	0.091	0.083	0.894	0.373
	BIS-11	0.030	0.062	0.043	0.490	0.625
	Binge score	-0.007	0.029	-0.021	-0.234	0.815

Table 6.12. Regression model for performance on the Two Choice Impulsivity Paradigm (TCIP). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

DDT: Model 1, $F(3,119)=1.722$, $p=.166$, $R^2=.042$; Model 2, $F(4,118)=1.288$, $p=.279$, R^2change=.000; see Table 6.13.

DDT		*B*	*SE* B	β		
Step 1	Constant	-0.020	0.175		-0.114	0.910
	Age	-0.002	0.004	-0.057	-0.584	0.561
	IQ	0.002	0.002	0.118	1.207	0.230
	BIS-11	-0.002	0.001	-0.170	-1.885	0.062
Step 2	Constant	-0.017	0.177		-0.097	0.923
	Age	-0.002	0.004	-0.061	-0.603	0.548
	IQ	0.002	0.002	0.118	1.205	0.230
	BIS-11	-0.002	0.001	-0.168	-1.834	0.069
	Binge score	0.000	0.001	-0.015	-0.164	0.870

Table 6.13. Regression model for performance on the Delay Discounting Task (DDT). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

MCQ: Model 1, $F(3,132)=1.096$, $p=.353$, $R^2=.024$; Model 2, $F(4,131)=.835$, $p=.505$. R^2change=.001; see Table 6.14.

MCQ		*B*	*SE* B	β		
Step 1	Constant	0.035	0.024		1.441	0.152
	Age	0.000	0.001	0.015	0.159	0.874
	IQ	0.000	0.000	-0.121	-1.311	0.192
	BIS-11 total score	0.000	0.000	0.099	1.148	0.253
Step 2	Constant	0.036	0.025		1.459	0.147
	Age	0.000	0.001	0.009	0.093	0.926
	IQ	0.000	0.000	-0.122	-1.311	0.192
	BIS-11	0.000	0.000	0.104	1.175	0.242
	Binge score	0.000	0.000	-0.025	-0.275	0.784

Table 6.14. Regression model for performance on the Monetary Choice Questionnaire (MCQ). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

MFF20: Model 1, $F(3,132)=.063$, $p=.979$. $R^2=.001$; Model 2, $F(4,131)=.115$, $p=.977$, R^2change=.002; see Table 6.15.

MFF20		*B*	*SE* B	β		
Step 1	Constant	-0.863	2.291		-0.376	0.707
	Age	0.000	0.048	0.000	0.004	0.997
	IQ	0.008	0.021	0.036	0.389	0.698
	BIS-11	0.002	0.014	0.011	0.125	0.901
Step 2	Constant	-1.010	2.315		-0.436	0.663
	Age	0.006	0.050	0.012	0.119	0.905
	IQ	0.008	0.021	0.037	0.398	0.692
	BIS-11	0.000	0.014	0.002	0.021	0.983
	Binge score	0.003	0.007	0.048	0.521	0.603

Table 6.15. Regression model for performance on the Matching Familiar Figures Task (MFF20). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

IST(fixed win): Model 1, *F* (3,132)=.416, *p*=.742, R^2=.009; Model 2, *F*(4,131)=.599, *p*=.664. R^2change=.009; see Table 6.16.

IST. FW		*B*	*SE* B	β		
Step 1	Constant	0.078	0.143		0.543	0.588
	Age	0.002	0.003	0.053	0.564	0.574
	IQ	0.000	0.001	-0.033	-0.358	0.721
	BIS-11	0.001	0.001	0.077	0.889	0.375
Step 2	Constant	0.059	0.144		0.408	0.684
	Age	0.002	0.003	0.076	0.788	0.432
	IQ	0.000	0.001	-0.032	-0.339	0.735
	BIS-11	0.001	0.001	0.059	0.665	0.507
	Binge score	0.000	0.000	0.097	1.071	0.286

Table 6.16. Regression model for performance on the Information Sampling Task, fixed win condition (IST. FW). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

IST(reward conflict): Model 1, *F*(3,132)=3.226, *p*=.025 R^2=.068; Model 2, *F*(4,131)=2.471, *p*=.048. R^2change=.002; see Table 6.17.

IST.rc		*B*	*SE* B	β		
Step 1	Constant	-0.106	0.118		-0.897	0.371
	Age	0.001	0.002	0.028	0.307	0.760
	IQ	0.002	0.001	0.169	1.873	0.063
	BIS-11	0.002	0.001	0.190	2.251	0.026*
Step 2	Constant	-0.114	0.120		-0.950	0.344
	Age	0.001	0.003	0.038	0.412	0.681
	IQ	0.002	0.001	0.170	1.876	0.063
	BIS-11	0.002	0.001	0.182	2.104	0.037*
	Binge score	0.000	0.000	0.045	0.510	0.611

Table 6.17. Regression model for performance on the Information Sampling Task, reward conflict condition (IST. RC). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

IGT: Model 1, $F(3,121)=.637$, $p=.592$. $R^2=.016$; Model 2, $F(4,120)=.691$, $p=.599$. R^2change=.007; see Table 6.18.

IGT		*B*	*SE* B	β		
Step 1	Constant	58.155	46.186		1.259	0.211
	Age	-0.272	0.884	-0.031	-0.307	0.759
	IQ	-0.392	0.410	-0.096	-0.956	0.341
	BIS-11	-0.382	0.281	-0.128	-1.36	0.177
Step 2	Constant	52.808	46.418		1.138	0.258
	Age	-0.041	0.909	-0.005	-0.045	0.964
	IQ	-0.386	0.410	-0.095	-0.941	0.349
	BIS-11	-0.448	0.287	-0.149	-1.557	0.122
	Binge score	0.141	0.131	0.105	1.078	0.283

Table 6.18. Regression model for performance on the Iowa Gambling Task (IGT). Age, IQ and self-report impulsivity, according to the Barratt Impulsiveness Scale total score (BIS-11) are included in Step 1; binge score on the alcohol use questionnaire is added in Step 2.

6.4 Discussion

6.4.1 Principal axis factoring

The current study found six factors of impulsivity. (1) The first represents reflection-impulsivity with loadings from the Information Sampling Task, the Matching Familiar Figures Task and the Iowa Gambling Task. (2) The second factor represents delay discounting on pen-and-paper measures, with loadings from the Monetary Choice Questionnaire and Delay Discounting Task. (3) The third represents voluntary cognitive control on the Tower of London Task and Single Key Impulsivity Paradigm. (4) The fourth factor represents action cancellation with a loading from the Stop Signal Task. (5) The fifth represents self-report impulsiveness with a loading from the Barratt Impulsiveness Scale. (6) The sixth factor represents action restraint with the Immediate Memory task and Go/NoGo loading onto this factor.

The data support the suggestion of a distinct reflection- impulsivity subtype, as the Matching Familiar Figures Task and Information Sampling Task loaded onto one factor. Furthermore, the study provides support for the grouping of risk- and uncertainty- based decision making as the Iowa Gambling Task loaded onto the reflection-impulsivity factor (Winstanley et al., 2010). The study provided evidence for two subtypes of motor- impulsivity; the Stop Signal Task loaded onto one factor of action cancellation and the Go/NoGo and Immediate Memory Task loaded onto a factor indexing action restraint. In addition, the study did not support the categorisation of a single temporal-impulsivity subtype; pen-and-paper measures of temporal impulsivity clustered onto one factor, however the two experiential paradigms did not. As expected, self-report impulsiveness loaded separately from all behavioural measures of impulsivity.

6.4.1.1 Reflection- impulsivity

The current study found the Information Sampling, Matching Familiar Figures and Iowa Gambling Tasks to load onto one factor. The results support the classification of both the Matching Familiar Figures and Information Sampling Task as measures of reflection-impulsivity. The loading of the Matching Familiar Figures Task is low in comparison to the Information Sampling Task, but still greater than the loading on any other factor.

Reflection impulsivity traditionally refers to the tendency to gather and evaluate information before making a decision in situations where there are several possible alternative solutions and there is some uncertainty as to which is correct (J. Kagan, 1965a, 1965b; J. Kagan et al., 1964). The Matching Familiar Figures Task (J. Kagan et al., 1964) and the Information Sampling Task (Clark et al., 2006; Clark et al., 2003; Clark et al., 2009) are the two main measures of reflection impulsivity, requiring participants to answer a problem, allowing them to acquire as much or as little information as they wish before deciding on a solution.

The Matching Familiar Figures Task has previously been criticised for being too confounded with intelligence, working memory, visual search and information processing styles (Block et al., 1974; Clark et al., 2006; Southgate et al., 2008); the Information Sampling Task was developed to circumvent some of these issues (Clark et al., 2006). The current study found that the Matching Familiar Figures Task and Information Sampling Task do load onto a single factor, suggesting that the two tasks index the same primary underlying process measure despite the additional confounding processes required by the Matching Familiar Figures Task.

Interestingly the Iowa Gambling Task also loaded onto the reflection-impulsivity factor. This provides tentative support for the grouping of risk- and uncertainty- based choices as a distinct subtype of impulsivity (Winstanley et al., 2010). It has been suggested that the Iowa Gambling Task represents decision-making under ambiguous conditions (Dannon et al., 2010). It can be hypothesised that poor decision making on the Gambling Task represents insufficient reflection on-, or information sampling of-, the contingencies of the task.

The Information Sampling Task, reward conflict condition, was found to also load onto an additional factor alongside the Stop Signal Task. The factor loading on the reflection- impulsivity subtype was considerably larger, however this additional loading needs further exploration. It appears that the reward conflict condition of the task may also involve processes similar to those on the Stop Signal Task.

These findings suggest that reflection- impulsivity is a valid category of impulsivity, and provides further evidence that risk- and uncertainty- based decisions involve converging underlying processes. The results provide evidence that lack of evaluation of the available information may contribute to risky decision-making.

6.4.1.2 Motor- impulsivity

The current study found measures of motor- impulsivity to load onto two separate factors. Motor- impulsivity traditionally refers to the inability to inhibit a behaviour, when that behaviour is no longer appropriate, and is thought to encompass aspects of action restraint and action cancellation (Chamberlain et al., 2007; Chamberlain & Sahakian, 2007; Ramaekers & Kuypers, 2006; Strakowski et al., 2009; Winstanley et al., 2006) (Winstanley, 2011). The primary measures of motor impulsivity are the Stop Signal (Logan, 1994, 2011; Logan et al., 1997), Go/NoGo and the Immediate Memory task (a version of the continuous performance task) (Broos et al., 2012). These measures involve a Go task, with a secondary Stop task running in parallel; participants must selectively respond to Go stimuli and withhold responses when Stop stimuli are presented. In the current literature these three tasks are treated interchangeably, however, it has been suggested that the tasks actually have important methodological differences and index different forms of inhibitory control (Eagle, Bari et al., 2008).

On the Stop Signal task participants must initiate responding to a Go stimulus, but subsequently inhibit the response on a small number of trials if a Stop signal is presented. To stop successfully participants must withhold the already activated Go response: only if the Stop process completes before the Go process does the participant successfully inhibit the Go response (Verbruggen & Logan, 2008). This inhibition of an already activated and initiated behaviour, has been termed ‘action cancellation’ (Winstanley, 2011). In contrast, on the Go/NoGo and Immediate Memory Task participants must simply refrain from responding until the Go stimulus is presented. This form of inhibitory control has been labelled ‘action restraint’ (Winstanley, 2011).

The current study did not find all three tasks to load onto a single ‘motor-impulsivity’ factor, instead they loaded onto separate action restraint and action cancellation factors; the Stop Signal Task, measuring action cancellation, loaded onto its own distinct factor, whilst the Immediate Memory Task and Go/NoGo, both measuring action restrain, loaded together. Furthermore, the results indicated that the two task types were dissociable; participants who were more impulsive on the Immediate Memory Task were also more impulsive on the Go/NoGo, but were *less* impulsive on the Stop Signal Task. This further indicates that action restraint and action cancellation are distinct, and action restraint capacity does not infer action cancellation capacity.

Thus the current data provide compelling support for the suggestion that action restraint, on the Go/NoGo and Immediate Memory Task, and action cancellation on the Stop Signal Task involve different underlying processes (Winstanley, 2011). The results indicate that the two forms of inhibitory control can be behaviourally characterised in a ‘normal’ population, however the implications of this dissociation between action restraint and cancellation are not immediately clear. The distinction may have relevance for behavioural and pharmacological treatments for clinical populations.

6.4.1.3 Temporal- impulsivity

Research has used both pen-and-paper and experiential tasks to index temporal-impulsivity (the tendency to delay gratification, as seen in the preference for small immediate rewards over large delayed rewards).

The current study found that both pen-and-paper measures of delay discounting loaded onto one factor; however, neither laboratory paradigm loaded onto the same factor. The

Two Choice Impulsivity Paradigm did not load onto any factor, and the Single Key Impulsivity Paradigm loaded onto the same factor as Tower of London Task.

It has been proposed that experiential tasks result in different responding to pen-and-paper measures (Odum, 2011; Winstanley, 2011), a suggestion supported by the findings of the current study.

6.4.1.3.1 Pen-and-paper measures of temporal- impulsivity

The study found that the two pen-and-paper measures loaded onto one factor. The two tasks use different reward and delay values, and the results suggest that individuals respond consistently across measures even if such values differ. This provides evidence that different versions of pen-and-paper measures are tapping the same construct.

6.4.1.3.2 Two Choice Impulsivity Paradigm

The Two Choice (Impulsivity) Paradigm has both methodological similarities and differences to pen-and-paper measures of delay discounting. Ostensibly, the two tasks require the participant to select one of two presented choices, where one choice represents a smaller-sooner reward, and the other a larger-later reward. However, the Two Choice Paradigm was not found to load onto the same factor as the pen-and-paper measures.

Differences in the magnitude of reward- and delay-values on the two task types may explain the discrepancies in the factor loadings. The contingencies on the Two Choice Paradigm were set at 3 points after a 3 second delay, for the smaller-sooner reward, and 9 points after a 9 second delay, for the larger-later reward; in comparison, the pen-and-paper measures have varying delays that range from compared to weeks and months to years. On the Two Choice Paradigm, delay values are considerably smaller, representing seconds, compared to the much larger delays on the pen-and-paper measures; it is possible that the larger delay was still perceived as relatively short, and was not sensitive to individual differences in delay discounting. It is also possible that the difference between the delay to the smaller-sooner reward (3 seconds) and that of the larger-later reward (9 seconds) was not large, or discrete, enough, and were not differentiated by the participants. Investigators have suggested that participants do not find it sufficiently aversive to delay gratification for such a short period of time (Winstanley et al., 2006).

A further difference between the tasks is that rewards on the Two Choice Paradigm are referred to as ‘points’ rather than money. This removes the influence of any expectations and experiences of inflation, and expected income and means in the future, all of which could also affect the perceived value of a future reward (Frederick et al., 2002). The task is also not subject to individual expectations regarding the subjective probability of receiving the delayed reward (Frederick et al., 2002), as the participant ‘receives’ the rewards during responding on the task.

On both tasks, it is assumed the participant is aware of both the task contingencies; however, compared to the pen-and-paper measures where the reward- and delay-values are presented directly, on the Two Choice Paradigm the participant learns these values in training trials and they are not explicitly stated. Furthermore it is not checked whether the participant is aware of the contingencies, before the commencement of the experimental trials.

6.4.1.3.3 Single Key Impulsivity Paradigm and Tower of London Task

The current research found that the Single Key Impulsivity paradigm, utilised as a measure of temporal- impulsivity alongside pen-and-paper measures and the Two Choice Paradigm, loaded separately from temporal measures, and loaded with the Tower of London task.

The Single Key Impulsivity Paradigm is methodologically very different from both the pen-and-paper measures and the Two Choice Paradigm measures. In the task participants indicate preference to delay gratification by waiting to respond for a larger reward, as opposed to responding sooner to receive a smaller reward; the participant dictates the delay they are willing to tolerate by making a response. In contrast, on the pen-and-paper measures and the Two Choice Paradigm, participants make a choice between two options directly presented to them. These differences may explain why the Single Key Paradigm did not load onto the same factor as the pen-and-paper measures.

However, it is not immediately evident why the Single Key Paradigm and Tower of London Task loaded onto the same factor. The processes underlying the Single Key

Paradigm are relatively unexplored. The task is conceptually similar to Mischel's original 'marshmallow' experiments. In the marshmallow experiments young children were physically presented with a choice between two food rewards, the child had to stop themselves from eating the immediately available reward and wait for the experimenter to return so they could eat the larger reward (e.g. W. Mischel et al., 1972). On both the marshmallow experiment and the Single Key Paradigm, participants must delay responding in order to receive a larger reward (e.g. 2 marshmallows or a greater number of points). On both tasks, the choice to wait is ongoing and the individual can make the decision to terminate the wait at any point by making a response (in comparison, on the Two Choice Paradigm and pen-and-paper measures, the participant makes the initial decision to wait and then the delay is enforced until the reward is received). It has been suggested that both the Tower of London Task and the marshmallow experiment require engagement of 'voluntary cognitive control' mechanisms (Asato, Sweeney, & Luna, 2006; Walter Mischel et al., 2011; Miyake et al., 2000), a suggestion that can be extended to the Single Key Paradigm. In order to delay responding on both tasks (to achieve a larger reward on the marshmallow experiment/Single Key Paradigm, and make fewer errors on the Tower of London Task) participants must recruit such control. Thus, it can be hypothesised that this factor represents a type of cognitive control over behaviour.

It has previously been suggested that measures of temporal- impulsivity index action restraint capacities, similar to those on the Go/NoGo and Immediate Memory task (Dalley et al., 2011). However, the current study provides evidence that any form of control engaged on the Single Key Paradigm is distinct from the action restraint recruited on the Go/NoGo and Immediate Memory tasks, as the tasks loaded onto separate factors and there were no relationships between the factors. Control processes recruited on the Single Key Paradigm appear to be also distinct from those on the Stop Signal Task.

The results suggest that cognitive control processes are distinct from behavioural inhibitory control processes. The implications of this are unclear and need further research. Investigators have suggested previously, that behavioural inhibition of an initial response is necessary to allow successful self-regulation and controlled responding (e.g. Barkley, 1997; Taylor & Jentsch, 1999), however the current study provides evidence that this is not necessarily the case.

6.4.1.4 Self-report impulsiveness

The current study found self-report impulsiveness on the Barratt Impulsiveness Scale to load separately from behavioural measures of impulsivity. This supports previous evidence that self-report impulsiveness loads separately from the Matching Familiar Figures Task (Malle & Neubauer, 1991), the Stop Signal Task (Broos et al., 2012; S.D. Lane et al., 2003; Malle & Neubauer, 1991) and measures of delay discounting (Broos et al., 2012; S.D. Lane et al., 2003; Meda et al., 2009). The current study further supports the suggestion that self-report and behavioural impulsiveness should be grouped into separate domains (Malle & Neubauer, 1991).

6.4.2 Demographics and dispositions

The current study found that age was a significant predictor of pre-planning time on the Tower of London task; older participants took longer before making an initial move on the task. Self-report impulsiveness was also a significant predictor in Step 1 of the analysis, although was no longer significant after binge scores were included in the model. Age, IQ, self-report impulsiveness and binge drinking behaviours were not significant predictors of any other behavioural measure.

There was no relationship between intelligence and any of the impulsivity measures. The study found no evidence of a relationship between intelligence and motor-impulsivity, consistent with previous research finding no relationship between IQ and the Stop Signal Task as a measure of motor- impulsivity (Friedman et al., 2006; Logan, 1994). The study also found no evidence of a relationship between intelligence and temporal- impulsivity. These results do not support previous research finding that intelligence is associated with an improved ability to delay gratification (de Wit et al., 2007; Shamosh et al., 2008). It is not clear why there was not a relationship between intelligence and tendency to delay gratification; this relationship has been previously found to occur even when rewards are entirely hypothetical, as was the case in the current study (Shamosh et al., 2008). The current study also found no evidence of an association between intelligence and any measure of reflection- impulsivity. Previous findings of a relationship between the Matching Familiar Figures Task, as a measure of reflection- impulsivity, and intelligence are inconsistent. Research has found both a relationship between IQ and the Matching Familiar Figures Task (Block et al., 1974; Eska & Black, 1971; Plomin & Buss, 1973) and also no relationship between the two (Helmers et al., 1995; Larsen, 1982). The type of intelligence testing used in the current study may explain the lack of relationship between intelligence and the Matching Familiar Figures Task; the study used an estimate of verbal IQ, and it has previously been suggested that verbal skills are unrelated to performance on the task (Eska & Black, 1971). While the relationship of IQ to the Information Sampling Task has not previously been investigated, the task was developed to avoid placing large demands on working memory, a capacity known to be strongly related to intelligence (Clark et al., 2006; Colom, Abad, Quiroga, Shih, & Flores-Mendoza, 2008), suggesting that IQ may not be a strong predictor of Information Sampling performance. It is important to note that the mean IQ of the participants was above the national average; further research is needed to establish whether this has implications for the findings.

There was no evidence of any age-related changes in any of the traditionally used impulsivity measures. However, older participants were found to have longer pre-planning times on the Tower of London, providing evidence of age-related changes on the task occurring between young- and mid-adulthood. Previous research has investigated differences between child (age 8-13), adolescent (age 14-17) and young-adult (age 18-30) populations and has found that Tower of London performance matures between childhood and adolescence, but has found no differences between adolescence and young-adulthood (Asato et al., 2006). The current study may have been more sensitive to changes occurring after adolescence, age was used as a continuous predictor rather than categorising participants into discrete age brackets; the current study also had a higher upper age limit, assessing individuals ranging from young- to mid-adulthood (age 18-40).

Age was not found to predict performance on any other behavioural task. It is possible that this was a consequence of the relatively limited age range included within the study (ages 18-40); while previous research has found evidence of age- related changes in impulsivity, such differences are typically seen when comparing between age-brackets, or within discrete periods of childhood and late-adulthood. Previous investigators have observed that reflection impulsivity on the Matching Familiar Figures Task reduces with age in young children (J. Kagan et al., 1964), but found no changes in older adults, aged 60-79 (Larsen, 1982). Inhibitory control on the Stop Signal Task has been observed to diminish through late adulthood, but there is no evidence of changes between young- and mid- adulthood (B. R. Williams et al., 1999); there is also no evidence of age-related changes on the Go/NoGo (Johnstone et al., 2007). Differences in tendency to delay gratification have been found when comparing between young adults (mean age 20) and older adults (mean age 67) (Green et al., 1994).

Self-report impulsiveness was not found to predict performance on any behavioural task, other than the Tower of London. However, on the Tower of London, self-report impulsiveness was only associated with performance, when age and IQ, but not binge-drinking scores, were included in the model; the relationship did not remain when alcohol use was included as a predictor.

Interestingly the Tower of London is not a traditional measure of impulsivity, and is typically employed as a measure of planning abilities. It has been suggested, however, that the task may have relevance for impulsivity and that a lack of planning may contribute to reflection- impulsivity (Bickel et al., 2012) and it is also thought that the task may function as a an index of inhibitory control (Steinberg et al., 2008) thus having relevance for motor- impulsivity. The current study provides preliminary evidence that pre-planning times on the Tower of London may have merit as a measure of impulsivity, as it is related to self-report impulsiveness, but the effect of binge drinking patterns on this relationship should be explored further. It is not clear whether the Tower of London task indexes one of the currently understood motor-, temporal- or reflection- subtypes, and this is an avenue of research that needs to be explored further.

Self-report impulsiveness was not found to predict behavioural impulsivity on any other task. Previous evidence of a relationship between self-report impulsiveness and behavioural impulsivity is, at best, inconsistent. The Barratt Impulsiveness Scale has been found to not correlate with behavioural measures, including motor impulsivity tasks (the Stop Signal and Go/NoGo task) and delay discounting tasks (S.D. Lane et al., 2003; Lansbergen et al., 2007; Reynolds, Ortengren et al., 2006; Reynolds et al., 2008).

However, previous investigators have found that self-report impulsiveness is related to performance on the Go/NoGo task (Aichert et al., 2012; Reynolds, Ortengren et al., 2006) and Immediate Memory Task (Marsh et al., 2002), and previous investigators have also found nonplanning impulsiveness on the Barratt Impulsiveness Scale to be a significant predictor of delay discounting (de Wit et al., 2007).

The current study found no evidence of a relationship between binge drinking and behavioural impulsivity. Previous research has barely explored the relationship of social and binge drinking to behavioural impulsivity. There is some evidence that social drinking is not related to reflection impulsivity on the Information Sampling Task (Solowij et al., 2012), but may be related to motor impulsivity. Previous investigators have found binge drinkers to have fast reaction times in comparison to non-bingers, (Scaife & Duka, 2009) and have suggested that female, but not male, heavy drinkers (minimum 11.5 units per week, mean 17.4) display impaired response inhibition on the Stop Signal Task (Nederkoorn et al., 2009).

6.4.3 Limitations of the study

There were limitations to the study that should be discussed. For the factor analysis, one variable was selected per task. The reasons for this were twofold. Firstly, it is known that factor analysis studies depend heavily on the number of indicators included per expected factor (Russo et al., 2008). Secondly, a much larger number of participants would be required to provide an adequate sampling size for a larger factor analysis. In our analysis, the measures of sampling adequacy are at the lower boundary of acceptability; ideally a larger sample needs to be recruited. Despite the effort to avoid imbalances in the number of indicators per expected factors, in reality these are unavoidable. The two versions of the Information Sampling Task are very similar, as are the two pen and paper measures of delay discounting. These methodological overlaps may have implications for the factor structure.

Concerning the analysis of the relationship of age and intelligence to impulsivity, it is clear that the current study allows only a limited insight into the relationships between age and behavioural impulsivity; participants were all young- mid-adulthood providing no insight into developmental changes in childhood or adolescence. The exploration of the relationships between self-report impulsiveness and behavioural impulsivity was also limited by the inclusion of only the total impulsiveness score (the Barratt Impulsiveness Scale also provides motor, attentional and nonplanning sub-scores). Subscales of the Barratt Impulsiveness Scale correlate highly with one another (Reynolds, Ortengren et al., 2006), and so only total score was included to avoid issues of multicollinearity. Unfortunately, this may have resulted in a failure to detect any relationships between individual sub-scales and the behavioural tasks. In particular it should be established whether planning tendencies on the Tower of London task are related to one particular subscale on the Barratt Impulsiveness Scale (for example nonplanning scores) or whether they are related to more general increases in self-report impulsiveness. The analysis did find significant correlations between age and IQ amd binge score, and also between self-reported impulsivity and binge score. These correlations suggest that multicolliniearity may still be a problem in the analysis, despite efforts to avoid this (for example by selecting only the total Barratt Impulsiveness score instead of the three subscores). No information regarding income or socio-economic status was recorded, despite research finding that this plays an important role in the relationship between age and temporal impulsivity (Green et al., 1996).

6.4.4 Conclusions

In conclusion, the current study employed multiple measures of impulsivity, and found six dissociable factors of impulsivity. Previous research has discussed three factors of motor-, temporal- and reflection- impulsivity, and has proposed that these factors may be distinct from one another. However, there has previously been very little systematic research validating these subtypes or the various measures.

The current study supports the suggestion of a distinct ‘reflection’ impulsivity subtype; the Matching Familiar Figures Task and Information Sampling Task loaded onto a single factor. Furthermore, the study provides support for the incorporation of risk- and uncertainty- based decision-making as the Iowa Gambling Task loaded onto the reflection-impulsivity factor (Winstanley et al., 2010). The study provided evidence for two subtypes of motor- impulsivity; the Stop Signal Task loaded onto one factor of action cancellation and the Go/NoGo and Immediate Memory Task loaded onto a factor indexing action restraint. The study did not support the generic categorisation of ‘temporal- impulsivity’; pen-and-paper measures of temporal impulsivity clustered onto a single factor, however, the two laboratory paradigms did not. As expected, self-report impulsiveness loaded separately from all behavioural measures of impulsivity.

The study found that age was a significant predictor of pre-planning time on the Tower of London task; self-report impulsiveness was also a significant predictor before binge score was included as a predictor. The study provides preliminary evidence that the Tower of London task may have merit as a behavioural measure of impulsivity, related to self-report impulsiveness. Age, IQ, self-report impulsiveness and binge drinking behaviours were not significant predictors of any other behavioural measure; previous research has not found consistent evidence of a relationship between such demographics and dispositions and behavioural impulsivity. The current study utilised a relatively limited population, participants were all young- to mid- adulthood, and all came from a 'normal' population (no diagnoses of psychiatric disorders); further research should explore the relationships of such demographics and dispositions in a wider population.

7 General Discussion

7.1 Summary of the studies

This thesis set out to explore three subtypes of behavioural impulsivity: ‘reflection’-, ‘temporal’- and ‘motor’- impulsivity. These facets of impulsivity are thought to be dissociable from one another, but also to share some common underlying processes (P. G. Enticott & Ogloff, 2006; J. Monterosso & Ainslie, 1999; Winstanley et al., 2004).

Studies 1, 2 and 3 investigated such processes, focusing on transient inhibitory control resources and speed/accuracy biases to establish whether these processes contribute to performance on each of the subtypes. These studies provide information on whether there are processes common to multiple subtypes of behavioural impulsivity, or whether such processes are points of divergence between subtypes. For each of the studies a behavioural task was selected to index motor-, reflection- and temporal- impulsivity, and inhibitory control and speed/accuracy processes were challenged during performance on these tasks. For a summary of the results see table 8.1. In addition to this, the relationships between stable demographics and dispositions to behavioural impulsivity were investigated in study 4.

In parallel, the factor structure of impulsivity was also investigated (study 5) to establish whether the primary measures of impulsivity can indeed be categorised into the three factors of reflection-, temporal- and motor- impulsivity.

Study 1 investigated the reliance of the three subtypes on the speed-accuracy trade-off. Three studies were completed modifying conscious and non-conscious control over behaviour, using direct instructions for speed or accuracy and cognitive priming of related schema. The speed-accuracy trade-off was manipulated during performance on the Matching Familiar Figures and Information Sampling Task as measures of reflection- impulsivity, the Stop Signal Task as a measure of motor- impulsivity and the Delay Discounting Task as a measure of temporal- impulsivity. The studies found that all three of the subtypes of impulsivity are affected, to an extent, by imbalances in the speed/accuracy trade-off. The data showed that the combination of instructions and cognitive priming, as a means of externally generating conscious and non-conscious control of behaviour, was most successful at modifying the trade-off. The Instructions-only manipulation modified the Matching Familiar Figures and the Stop Signal Task.

The cognitive priming-only manipulation did not affect any impulsivity measure, but instead trait impulsivity did affect behaviour.

Study 2 investigated whether taxing inhibitory control will increase reflection-, temporal- and motor- impulsivity. Inhibitory control was challenged, via a random letter generation task presented during responding to three impulsivity measures: the Information Sampling Task (reflection- impulsivity), Single Key Impulsivity Paradigm (temporal- impulsivity) and the Stop Signal Task (motor- impulsivity). The Stop Signal Task was affected by the inhibitory control challenge: participants in the experimental condition displayed increased motor- impulsivity, evidenced in longer stop signal reaction times compared to the control group. The manipulation did not affect reflection- or temporal- impulsivity measures. These data provide evidence that the mechanisms underlying the motor subtype of impulsivity are dissociable from the temporal and reflection subtypes, and that engagement of inhibitory control is not necessary to prevent impulsive decision-making.

Study 3 investigated the effects of a disinhibiting dose of alcohol on impulsivity. The study also explored the effect of expected impairment from alcohol, thought to represent expected loss of self-control. Impulsivity was tested using the Stop Signal Task, the Single Key Impulsivity Paradigm and the Information Sampling Task for motor-, temporal- and reflection- impulsivity respectively. The Stop Signal Task was affected by impaired inhibitory control resulting from alcohol. Reflection- impulsivity on the Information Sampling Task was affected by expected level of impairment, but not by alcohol itself; participants expecting greater cognitive and behavioural impairment by alcohol displayed compensatory mechanisms to become less impulsive. Temporal-impulsivity was not affected by either alcohol dose or outcome expectancies. These data further support the suggestion that the mechanisms underlying the motor subtype of impulsivity are dissociable from the temporal and reflection subtypes, as motor-impulsivity was sensitive to the disinhibiting effects of alcohol whereas temporal and reflection subtypes were not. The study also provided some preliminary evidence that cognitive self-control mechanisms may have implications for reflection- impulsivity.

Study 4 investigated the contribution of age, intelligence, alcohol use and self-report impulsivity to behavioural impulsivity. Several tasks measuring different aspects of impulsivity were employed. The study found no evidence of a relationship between age, intelligence, self-report impulsivity, or binge drinking behaviours and any of the impulsivity tasks. There was a relationship between age and planning tendencies on the Tower of London task, and there was some preliminary evidence of a relationship between self-report impulsivity and planning tendencies.

Further from this, study 6 explored the underlying factor structure of behavioural impulsivity using exploratory factor analysis. Several tasks measuring different aspects of impulsivity were employed; the tasks were selected as frequently used measures motor-, temporal- and reflection- impulsivity. In addition, two additional tasks were included, thought to measure cognitive processes related to impulsivity, but not considered as direct impulsivity measures, for example planning and risk taking. Principal axis factoring revealed six factors of impulsivity. The study found one subtype of reflection- impulsivity, with the Information Sampling Task, Matching Familiar Figures Task and Iowa Gambling Task all loading together on this factor. The study provided preliminary evidence of two facets of motor- impulsivity; the Stop Signal Task loaded onto a distinct action cancellation factor, whereas the Go/NoGo and Immediate Memory Task loaded together onto an action restraint factor. The two pen-and-paper measures of temporal- impulsivity (the Monetary Choice Questionnaire and Delay Discounting Task) were found to load onto one factor, however experiential tasks of temporal- impulsivity did not load onto this factor. The Tower of London Task and Single Key Impulsivity Paradigm loaded onto a distinct factor, potentially indexing cognitive control. Self-report impulsivity loaded onto a factor distinct from all behavioural tasks. The study supports the suggestion of a distinct factor of reflection-impulsivity. There was evidence of dissociation between action cancellation and action restraint within measures of motor- impulsivity. There was no evidence that pen-and-paper and experiential measures of temporal-impulsivity measure the same underlying construct.

	'MOTOR'			'REFLECTION'								'TEMPORAL'	
	SST			IST						MFFT		DDT	SKIP
				Fixed win condition			Reward conflict condition						
	SSRT	Go%	GoRT	Boxes opened	P(correct)	errors	Boxes opened	P(correct)	errors	I-score	E-score	Mean *k*	IRT
STUDY 1													
Instructions	—	**Yes**	**Yes**	—	—	—	—	—	—	**Yes**	—	—	
BIS-11	—	—	—	—	—	—	—	—	—	—	—	—	
Cognitive priming	—	—	—	—	—	—	—	—	—	—	—	—	
BIS-11	—	—	**Yes**	**Yes**	**Trend**	—	—	—	—	—	**Yes**	—	
Instructions/priming	N/a	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	—	**Yes**	
BIS-11	N/a	—	—	—	—	—	—	—	—	—	—	—	
STUDY 2													
Dual task	**Yes**	—	—	—	—	—							—
STUDY 3													
Alcohol dose	**Yes**	—	—	—	—	N/a							—
Impairment expectancies	—	—	—	**Yes**	**Yes**	N/a							—

Table 8.1. Table summarising the results from studies 1,2 and 3. Study 1 consisted of three studies manipulating the speed/accuracy trade-off Study (1a) instructions (1b) cognitive priming (1c) combination of instructions and cognitive priming (instructions/imagery); the study also explored the relationship of self-report impulsivity (BIS-11) to behavioural impulsivity. Study 2 consisted of an inhibitory control challenge via a random letter generation dual task. Study 3 consisted of an inhibitory control challenge via alcohol dose, alongside the effect of expected impairment to self-control. — indicates no significant result was found; N/a indicates these data were not analysed. SST= Stop Signal Task; IST= Information Sampling Task; MFFT= Matching Familiar Figures Task; DDT= Delay Discounting Task; SKIP= Single Key Impulsivity Paradigm

7.2 Behavioural impulsivity

Individuals who are impulsive are often characterized as making premature decisions, preferring immediate gratification and having difficulty inhibiting motor responses. State and trait impulsivity has been found to be elevated in clinical populations (Winstanley et al., 2004), but it is also a function of normal behaviour.

Current impulsivity research has been hampered by the fact that different researchers adopt different definitions of impulsivity, encompassing a broad array of behavioural and cognitive outputs (J. Evenden, 1999) and multiple measures of impulsivity are rarely simultaneously administered to participants (Dougherty et al., 2005). Research has focused on three primary types of impulsivity: motor- (failure to inhibit a behavioural response), temporal- (failure to delay gratification) and reflection- (failure to gather and evaluate information) impulsivity and a wide array of tasks has been developed to index each of these subtypes. A distinction has been made between motor-impulsivity at the point of response execution, compared to reflection- and temporal-impulsivity as types of 'cognitive' impulsivity that occur at the point of decision-making (Congdon & Canli, 2008).

It is often posited that these subtypes of impulsivity reflect differing, but converging, underlying cognitive and behavioural processes (P. G. Enticott & Ogloff, 2006; J. Monterosso & Ainslie, 1999; Winstanley et al., 2004). However, there has been a lack of systematic research which has resulted in a lack of understanding of the factor structure of impulsivity, as well as of the processes underlying impulsive behaviour.

The current studies provide insight into the factor structure of impulsivity, and the various processes that underlie the different facets of impulsivity.

7.2.1 Reflection- Impulsivity

In everyday life, situations occur where a decision is required, but where there are several possible alternative solutions and there is some uncertainty as to which is correct (J. Kagan, 1965a, 1965b; J. Kagan et al., 1964). Individuals have been found to differ in the tendency to gather and evaluate information before making a decision in such situations, and can be classified as impulsive or reflective based on this disposition ('reflection-impulsivity'). The Matching Familiar Figures Task (J. Kagan et al., 1964) and the Information Sampling Task (Clark et al., 2006; Clark et al., 2003; Clark et al., 2009) have been developed to index this tendency; both tasks require participants to answer a problem, allowing them to acquire as much or as little information as they wish before deciding on a solution.

However, there have been criticisms of current understanding of reflection- impulsivity. Importantly, the two main measures of the subtype index the tendency to evaluate information in different ways. These task differences have implications for our understanding of the deficits seen in clinical populations. For example, investigators have found that ecstasy users (current and ex users) display increased impulsivity on the Matching Familiar Figures (Morgan et al., 2006; Morgan et al., 2002) but do not show impairment on the Information Sampling Task (Clark et al., 2009).

The Matching Familiar Figures indexes the tendency to reflect on and evaluate information by measuring latency from presentation of the problem to making an initial decision. Latency to making a response is considered a measure of the quantity of information gathered and evaluated and shorter latencies are usually related to more errors (J. Kagan, 1965b). Specifically the combination of fast/inaccurate responding is identified as impulsive (J. Kagan, 1965b). The validity of the Matching Familiar Figures Task rests on the assumption that longer latencies are indicative of increased evaluation of the available information (J. Kagan, 1965b). However, the task is known to be dependent on multiple, potentially confounding, processes including field dependence/independence, working memory, attention, visual search (Clark et al., 2006; Messer, 1976; Zelniker & Jeffrey, 1976) and research has not been able to establish whether longer latencies are necessarily related to increased evaluation of the information provided (e.g. Ault et al., 1972; Drake, 1970; Zelniker et al., 1972).

To circumvent these issues, the Information Sampling Task is designed to provide a primary index of information sampling, measuring the tendency to acquire information before making a decision (Clark et al., 2006). The task takes an index of the actual volume of information the individual acquires, thus avoiding the need to infer this from the latency to making a response, and from this it can be calculated how much uncertainty the participant tolerates at the point of decision-making. The task clearly displays the sampled information on-screen until a decision is made, thus removing demands on working memory (Clark et al., 2006; Huddy et al., 2013).

Despite differences in the confounding processes the two tasks are subject to, it is thought that both tasks measure the same primary underlying process. Evidence for this is inferred from the finding that on both tasks, the number of errors made is related to the volume of information sampled, a key criteria of reflection- impulsivity (Clark et al., 2006).

Manipulating speed and accuracy biases (study 1) consistently altered responding on the Matching Familiar Figures Task. It is known that the trade-off is very relevant for this task, as it categorises participants as impulsive based on the tendency to prioritise speed over accuracy (S. J. Dickman & Meyer, 1988). In comparison, the Information Sampling Task was developed to avoid such a reliance on the trade-off, and to provide a primary index of the tendency to evaluate before making a decision (Clark et al., 2006). Direct instructions for speed or accuracy altered performance on the Matching Familiar Figures; however, the Information Sampling Task was only affected under conditions of the combination of instructions and cognitive priming. It appears that performance on the Matching Familiar Figures Task is modifiable by strategic control over behaviour (initiated via direct instructions). In comparison, the Information Sampling Task is not modifiable by use of direct instructions, without the addition of cognitive priming. The studies provide evidence that the two tasks despite having both been created as measures of reflection- impulsivity, differ in terms of their susceptibility to speed accuracy trade-off instructions.

Behavioural inhibitory control processes do not appear to underlie reflection-impulsivity. Neither the dual task nor alcohol challenges to inhibitory control were found to affect reflection- impulsivity (studies 2 and 3) but did increase impulsive responding on the Stop Signal Task, thus providing evidence that reflection-impulsivity is distinct from behavioural inhibitory control processes engaged during performance on the Stop Signal.

While there was no evidence of a role of behavioural inhibitory control on reflection-impulsivity, there was evidence of a type of cognitive self-control as having implications for this subtype. In addition to exploring the disinhibiting effects of alcohol, the effects of cognitive alcohol outcome expectancies were also investigated in study 3, in particular the contribution of expected impairment from alcohol to impulsivity was explored. This expectancy reflects the expected loss of self-control from drinking. Interestingly, the study found that participants expecting greater levels of cognitive and behavioural impairment to arise from alcohol, who believed that they had consumed alcohol, showed reduced reflection- impulsivity on the Information Sampling Task; participants appeared to compensate for the expected impairment, by opening more boxes, and tolerating less uncertainty before making a decision. This relationship between expected impairment and compensation was only seen when individuals believed that they had received alcohol; participants who believed that they had received placebo did not show such a relationship. These data provide some preliminary evidence that cognitive control mechanisms can be exerted to over-ride expected impairment to cognitive and behavioural functioning, and that such mechanisms have implications for reflection- impulsivity.

Age, intelligence, binge drinking behaviours and self-report impulsivity (study 4) were not found to affect reflection-impulsivity.

The study investigating the contribution of speed and accuracy biases to reflection-impulsivity employed both the Matching Familiar Figures Task and the Information Sampling Task to index reflection- impulsivity; however, the two studies exploring the role of inhibitory control processes only implemented the Information Sampling Task. In parallel to these studies, factor analysis was applied to a large number of tasks, including the two measures of reflection- impulsivity, to explore the factor structure of impulsivity (study 5). The factor analysis confirmed the suggestion of one subtype of 'reflection- impulsivity'. The study found both the Matching Familiar Figures and Information Sampling Task, as measures of reflection-impulsivity, to load onto one factor. This research provides the first *direct* evidence that the Matching Familiar Figures and Information Sampling Task index the same primary underlying process. The results of the factor analysis provide some evidence that if the dual task and alcohol dose studies were to be repeated using the Matching Familiar Figures Task, then the results found on the Information Sampling Task would be replicated.

Interestingly the Iowa Gambling task also loaded onto the ‘reflection-impulsivity’ factor. The gambling task was included in an exploratory capacity, as it is known to be complex and dependent on multiple cognitive processes. These processes are thought to include learning to sacrifice immediate rewards in favour of long-term gain, decision-making under ambiguous circumstances (Dannon et al., 2010) and sensitivity to reward, punishment and future consequences (Bechara et al., 1994); it has also been suggested that performance on gambling tasks may not necessarily be indicative of impulsivity (Verdejo-García et al., 2008). The task was found to load onto the reflection- subtype thus providing preliminary support for the grouping of risk- and uncertainty- based choices as a distinct subtype of impulsivity (Winstanley et al., 2010). The results suggest that the Iowa Gambling task primarily represents decision-making under ambiguous conditions (Dannon et al., 2010) and it can be hypothesised that poor decision making represents insufficient reflection on- or information sampling of- the contingencies of the task.

In summary, the studies provided support for the categorisation of one subtype of reflection- impulsivity. It is evident that speed/accuracy biases have implications for the subtype, in particular the Matching Familiar Figures Task is particularly sensitive to imbalances in the trade-off. The Information Sampling task is less modifiable by direct instructions (i.e. overt strategic control by the participant); however the task is still sensitive to biases when cognitive priming of related concepts is introduced. Behavioural inhibitory control does not appear to underlie performance on measures of reflection- impulsivity; however, there is preliminary evidence that cognitive control mechanisms have implications for this subtype as participants were seen to exert cognitive control mechanisms to counteract expected impairments to reflection-impulsivity.

7.2.2 Motor- impulsivity

Not all impulsivity arises during decision-making; it is also known that there are individual differences in the ability to inhibit a motor response, when that action is not appropriate. In contrast to impulsivity at the point of decision-making, this form of impulsivity occurs at the point of response execution, and impulsive individuals are less able to inhibit such a behavioural response (Chamberlain et al., 2007; Chamberlain &

Sahakian, 2007; Ramaekers & Kuypers, 2006; Strakowski et al., 2009; Winstanley et al., 2006). To measure this form of ('motor') impulsivity, tasks have been developed, including the Stop Signal Task(Logan, 1994, 2011; Logan et al., 1997), Go/NoGo and the Immediate Memory Task (a version of the continuous performance task) (Broos et al., 2012). These measures involve a Go task, with a secondary Stop task running in parallel; participants must selectively respond to Go stimuli and withhold responses when Stop stimuli are presented. Individuals displaying slow or inaccurate responding to stop signals are labelled as impulsive (Eagle, Baunez et al., 2008).

The primary process thought to contribute to motor- impulsivity is behavioural inhibitory control. It is has been suggested that motor impulsivity and behavioural inhibition are antipodes (Bickel et al., 2012), and failures in behavioural inhibitory control are categorised as motor- impulsivity. The current studies provided confirmation that inhibitory control processes are central to responding on motor- impulsivity tasks. Challenging behavioural inhibitory control via a dual task and dose of alcohol (studies 2 and 3) was found to affect responding to Stop signals on the Stop Signal Task, without affecting Go responses on the task, (neither Go accuracy nor reaction times were affected). Participants showed less successful inhibition to Stop signals, under conditions of the dual task and alcohol, as evidenced in longer stop signal reaction times.

In addition to investigating the contribution of inhibitory control processes to motor- impulsivity, the role of speed/accuracy biases were also investigated. Speed and accuracy biases (study 1) were also found to have relevance for Go responding on the Stop Signal Task. It has been suggested that the Stop Signal Task, requires a trade-off between fast responding to Go stimuli, with stopping response to a small number of Stop trials running in parallel (Logan, 1994); successful responding to Go stimuli (fast responding) has been suggested to imply failure on the parallel Stop task (failed inhibition to a Stop stimulus) (Verbruggen & Logan, 2009b). In study 1, Go responses on the task were consistently affected by the instructions for speed or accuracy, however, inhibitory control on the task was not affected. This partially supports research suggesting that the Stop Signal Task involves a trade-off between speed of responding and inhibitory control (Bissett & Logan, 2011; Leotti & Wager, 2010), however it also suggests that fast Go responding does not necessarily imply poor inhibitory control to the Stop trials. Interestingly, it appears that inhibitory control is not modifiable by strategic responding and it appears that whilst the Go responses are dependent on speed/accuracy biases, inhibitory control may not be so readily affected.

Thus, the studies found that speed/accuracy biases affect responding to Go stimuli but do not affect inhibitory control, whereas the availability of inhibitory control resources affects responding to Stop stimuli, but does not affect responding to Go stimuli. These studies provide an interesting dissociation in the processes underlying motor- impulsivity, suggesting that inhibitory control resources are central to successful Stopping on measures of motor- impulsivity, whereas speed and accuracy biases have implications for Go responding. This provides evidence that the Go and Stop responses are dissociable, and provides support for the suggestion that the two are relatively independent (Logan & Cowan, 1984).

Inhibitory control processes were found to be a point of divergence between motor- impulsivity and other subtypes of impulsivity, as it was found that neither reflection- nor temporal- impulsivity were affected under conditions of impaired inhibitory control (studies 2 and 3). This provides preliminary evidence that motor- impulsivity is distinct from other facets of impulsivity.

To further confirm the distinction between motor- impulsivity and reflection- and temporal- types of impulsivity, and to establish whether the various measures of motor- impulsivity cluster onto one factor, exploratory factor analysis was performed. However, rather than the predicted single factor of motor- impulsivity, the factor analysis found that the Stop Signal task loaded onto one factor of impulsivity, and the Go/NoGo and Immediate Memory Task loaded onto a separate factor. Despite the use of Stop Signal and Go/NoGo type tasks interchangeably within available literature on impulsivity, it has been previously suggested that the two task types may index different underlying processes (Eagle, Bari et al., 2008). On the Stop Signal Task, participants must inhibit (cancel) an already activated Go response, and thus the task has been proposed to index a type of ‘action cancellation’. In comparison, on the Go/NoGo and Immediate Memory Task, participants must simply refrain from responding until a Go signal is presented, and thus these two tasks have been suggested to index ‘action restraint’ (Winstanley, 2011).

The factor analysis found that the Stop Signal Task measuring action cancellation loaded onto its own distinct factor, whilst the Immediate Memory Task and Go/NoGo measuring action restraint loaded together. Furthermore, a dissociation was found between the two task types; participants who were more impulsive on the Immediate Memory Task were also more impulsive on the Go/NoGo, but were *less* impulsive on the Stop Signal Task. These results provide preliminary evidence that motor-impulsivity should be characterised as consisting of two distinct subtypes of action restraint and action cancellation. These findings have implications for the understanding of the experimental studies in which speed and accuracy biases and inhibitory control resources were manipulated. Importantly, none of these experimental studies implemented a measure of action restraint. As a result, the current studies cannot provide information on whether inhibitory control processes and speed/accuracy biases are relevant for action restraint, as well as action cancellation.

Age, intelligence, binge drinking behaviours and self-report impulsivity (study 4) were not found to affect action cancellation or action restraint.

In summary, the studies provide evidence motor- impulsivity should be characterised as consisting of two dissociable subtypes of action restraint and action cancellation. It is clear that inhibitory control processes are necessary for successful action cancellation and speed/accuracy processes are also relevant responding to Go stimuli, but do not appear to be central to inhibitory control processes themselves. The reliance of action restraint mechanisms on inhibitory control and speed and accuracy biases was not investigated.

7.2.3 Temporal- impulsivity

Temporal- impulsivity refers to the tendency to delay gratification when presented with a choice between a small reward available immediately, and a larger reward available after a delay. Investigators have found that impulsive individuals prefer immediate gratification (Ainslie, 1975; Crean et al., 2000).

To measure the tendency to delay gratification in the laboratory, participants are required to choose between a smaller immediate reward and a large delayed reward, making multiple responses to varied reward values and time intervals. Measures of temporal- impulsivity are traditionally pen-and-paper based, for example the monetary choice questionnaire (Kirby et al., 1999) or the delay discounting task. On these measures, participants make a series of choices between two (usually hypothetical) amounts of money, available at different time points. Experiential tasks have also been developed to index temporal- impulsivity that allow the participant to experience both the reward and delay within the laboratory, for example the Single Key- and the Two Choice- Impulsivity Paradigm (Dougherty et al., 2005).

A number of processes have been suggested to underlie temporal- impulsivity; it has been often suggested that inhibitory control processes are essential for the ability to delay gratification. It has previously been argued that the desire for immediate reward is innate (an 'impulse'), and that self-regulatory processes must be engaged to resist such an inborn behavioural bias to delay gratification (Baumeister & Heatherton, 1996; Diekhof & Gruber, 2010). At the level of behavioural inhibitory control, it has been suggested that (behavioural) inhibition, of an initial response, provides a necessary delay in the decision process, allowing successful self-regulation and controlled responding (Barkley, 1997; Taylor & Jentsch, 1999). However, the current studies found no evidence that behavioural inhibitory control processes contribute to temporal- impulsivity. Challenging behavioural inhibitory control, via a dual task and an alcohol dose (studies 2 and 3), did not increase impulsive responding on the Single Key Paradigm. Furthermore, when an acute dose of alcohol was used to challenge behavioural inhibitory control, there appeared to be a trend effect of alcohol to increase the ability to delay gratification i.e. alcohol reduced impulsivity. This finding needs to be explored further, as it was not clear by which mechanism this reduction in impulsivity occurred, however it provides further evidence that behavioural inhibitory control processes are not required to prevent impulsive responding.

Biases for speed or accuracy have not been traditionally discussed as contributing to temporal- impulsivity and direct instructions for speed or accuracy were not found to alter responding on a pen-and-paper measure (study 1a). However, when cognitive priming was implemented in addition to the instructions (study 1c), participants instructed to respond quickly were more impulsive and displayed an increased preference for immediate rewards compared to those instructed to respond slowly. This provides preliminary evidence that speed and accuracy processes may have implications for the tendency to delay gratification.

Together these studies provide preliminary evidence that behavioural inhibitory control processes do not underlie impulsive responding on the Single Key Impulsivity Paradigm, and that speed and accuracy biases may contribute under certain conditions to performance on pen-and-paper measures of temporal- impulsivity.

Further from exploring the processes underlying the tendency to delay gratification, the factor structure of impulsivity was investigated to establish whether multiple measures of temporal- impulsivity can be found to load onto one factor of impulsive responding (study 5). However, the results of the factor analysis in fact found pen-and-paper and experiential measures of temporal- impulsivity to load onto different factors. The two pen-and-paper measures loaded onto one factor, whereas the Single Key Impulsivity Paradigm loaded onto a distinct factor together with the Tower of London task. The second experiential measure, the Two Choice paradigm, did not load onto either factor.

These data indicate that pen-and-paper and experiential measures of temporal- impulsivity are distinct from one another, and that the two may index different underlying processes. It appears that despite the development of experiential tasks to index temporal- impulsivity, such tasks do not replicate traditional measures of the subtype.

Factor analysis found that the two pen-and-paper measures of temporal- impulsivity loaded onto one factor. The two tasks use different reward and delay values, and the results suggest that individuals respond consistently across measures even if such values differ. This provides evidence that different versions of pen-and-paper measures are indexing the same underlying processes. It is important to note that on both tasks, the choices were hypothetical as participants did not receive any rewards. Investigators have previously found that participants show less impulsive responding when real rewards are utilised on pen-and-paper measures, compared to when hypothetical rewards are used (Hinvest & Anderson, 2009; Madden et al., 1999) and have also found less consistent responding on pen-and-paper measures when payoff is subject to chance, for example paradigms where participants receive one of their choices, compared to when rewards were entirely hypothetical or real (Shamosh et al., 2008).

The Single Key Impulsivity Paradigm loaded onto a separate factor from pen-and-paper measures of temporal- impulsivity, despite the task having been designed to index the tendency to delay gratification (Dougherty et al., 2005). The task is methodologically very different from pen-and-paper measures on which participants make a choice between two options directly presented to them. On the Single Key Paradigm participants indicate preference to delay gratification by waiting to respond to receive a larger reward, as opposed to responding sooner to receive a smaller reward; the participant dictates the delay they are willing to tolerate by making a response. The factor analysis provides evidence that the processes underlying performance on the Single Key Paradigm differ from those underlying the traditional pen-and-paper measures of temporal- impulsivity.

These results provide evidence that the Single Key Paradigm does not index temporal-impulsivity as it is currently understood. This poses a problem for studies 2 and 3 in which the task was applied as a measure of temporal- impulsivity, as it is now unclear exactly what processes the task indexes. To establish the processes that the task does measure, the results from the factor analysis and experimental studies must be revisited.

Instead of loading with the pen-and-paper measures, the Single Key Paradigm loaded onto a factor with the Tower of London. It is not immediately evident why these tasks load together, however it has been suggested that the two tasks perhaps measure a type of ‘voluntary cognitive control of behaviour’ (Asato et al., 2006; Walter Mischel et al., 2011). It is hypothesised that in order to delay responding on both tasks (to achieve a larger reward on the Single Key Paradigm, and make fewer errors on the Tower of London) participants must recruit such control.

Further from this, there is evidence that any cognitive control processes recruited on the Single Key Paradigm are distinct from behavioural inhibitory control processes. The factor analysis found the Single Key Paradigm to load separately from the Go/NoGo and Immediate Memory Task, as the two primary measures of action restraint, suggesting that the Single Key Paradigm does not index behavioural action restraint. The factor analysis and experimental studies also provide evidence that the Single Key Paradigm is distinct from the action cancellation processes underlying performance on the Stop Signal Task. Neither of the experimental studies challenging inhibitory control increased impulsive responding on the Single Key Paradigm but did affect responding on the Stop Signal Task; in support of this, the factor analysis found the Single Key Paradigm and Stop Signal Task to load separately.

Taken together these studies provide evidence that the any cognitive control processes recruited in the Single Key Paradigm (and the Tower of London Task) are distinct from the behavioural types of inhibitory control recruited by measures of action restraint and action cancellation. In addition, there was some preliminary evidence that, at high doses of alcohol, alcohol intoxication is associated with a tendency to delay gratification (or *increased* cognitive control depending on the interpretation of the task) in the Single Key Paradigm (study 3). This provides further evidence that any processes underlying performance on the task are distinct from action cancellation processes.

Thus, there is compelling evidence that the Single Key Paradigm does not index temporal- impulsivity as it is currently understood. It appears that the processes indexed by the Single Key Paradigm are more closely related to those on the Tower of London, perhaps indexing a form of cognitive control. There is additional evidence that cognitive control recruited on the task is not reliant on behavioural action restraint and cancellation processes.

The Two Choice Paradigm was not related to any other measure of impulsivity. It is evident that the task does not index the same processes as those underlying decisions on traditional pen-and-paper measures of temporal- impulsivity, and thus needs further investigation.

In summary, the factor analysis provides preliminary evidence that pen-and-paper and experiential measures of temporal- impulsivity do not index the same underlying processes, and suggests that the Single Key Impulsivity Paradigm may not index temporal- impulsivity. There was some evidence that performance on the Single Key Paradigm may represent a type of cognitive control. These findings have implications for the interpretation of the experimental studies in which speed and accuracy biases and inhibitory control resources were manipulated. The study in which speed/accuracy biases were manipulated employed a pen-and-paper measure of temporal- impulsivity. However, the studies challenging behavioural inhibitory control via a dual task and alcohol dose, used the Single Key Paradigm which was at the time thought to index the temporal- subtype. The results from the factor analysis have subsequently provided evidence that in fact the Single Key Paradigm indexes cognitive control, and does not index temporal- impulsivity as it is currently understood.

7.3 Self-report impulsivity

The majority of clinical research uses self-report measures to assess impulsivity (Winstanley et al., 2010). The Barratt Impulsiveness Scale (BIS-11, Patton et al., 1995) is the foremost self-report measure of impulsivity, recognising multiple types of impulsivity encompassing attentional, motor and nonplanning impulsivity (Patton et al., 1995; Stanford et al., 2009).

Previous investigators have found that self-report measures do not consistently correlate with behavioural measures of impulsivity (e.g. Reynolds et al., 2008), suggesting that the two may index different underlying processes. The Barratt Impulsiveness Scale has been found to not correlate with behavioural measures, including motor- impulsivity tasks (the Stop Signal and Go/NoGo task) and delay discounting tasks (S.D. Lane et al., 2003; Lansbergen et al., 2007; Reynolds, Ortengren et al., 2006; Reynolds et al., 2008). However, there has also been some evidence that self-report impulsivity is related to performance on the Go/NoGo task (Aichert et al., 2012; Reynolds, Ortengren et al., 2006) and Immediate Memory Task (Marsh et al., 2002), and investigators have also found nonplanning impulsivity on the Barratt Impulsiveness Scale to be a significant predictor of tendency to delay gratification (de Wit et al., 2007).

The current studies provide support for the suggestion that self-report and behavioural measures of impulsivity are heterogeneous. Factor analysis (study 5) found the Barratt Impulsiveness Scale to load onto a separate from behavioural measures of impulsivity. Self-report impulsivity was not related to behavioural impulsivity on any task. These data support previous research that self-report impulsivity loads separately from the Matching Familiar Figures Task (Malle & Neubauer, 1991), the Stop Signal Task (Broos et al., 2012; S.D. Lane et al., 2003; Malle & Neubauer, 1991) and measures of tendency to delay gratification (Broos et al., 2012; S.D. Lane et al., 2003; Meda et al., 2009). The current study further supports the suggestion that self-report and behavioural impulsivity should be grouped into separate domains (Malle & Neubauer, 1991).

However, when investigating the relationships of participant demographics and dispositions (study 4), self-report impulsivity, as indexed by the Barratt Impulsiveness Scale, did (partially) predict performance on the Tower of London Task. This provides preliminary evidence that the Barratt Impulsiveness Scale may be primarily related to planning tendencies however this relationship was not evident in the factor analysis, and so needs further investigation. Self-report impulsivity did not predict performance on any of the primary behavioural measures of impulsivity.

Together the studies support the suggestion that self-report and behavioural measures are far from homogenous (Dick et al., 2010). Multiple explanations for the discrepancy between subjective and behavioural measures have been suggested (Dougherty et al., 2005). It has been suggested that self- report questionnaires assess stable trait individual differences, and reflect established cognitive and affective processes; compared to this behavioural tasks measure state impulsivity (Bjork et al., 2004; Dick et al., 2010; Dougherty et al., 2008). Other explanations include the suggestion that an individual who perceives himself as being impulsive may attempt to compensate for this in the laboratory (Wingrove & Bond, 1997), and that questionnaire measures are subject to bias from self-awareness and demand characteristics (Helmers et al., 1995). It may simply be that the behavioural tasks developed do not tap the behaviours identified in the questionnaire measures. Whilst it is evident that both types of measures are sensitive to deficits in impulsivity, further research is needed to explore and identify parallels between self-report and behavioural measures.

7.4 Establishing the points of convergence between subtypes

Thus far, the studies have provides insight into the different factors of impulsivity. The studies support the suggestion of a reflection- subtype, however provide evidence that motor- impulsivity should be further characterised as consisting of two distinct action restraint and cancellation subtypes. The studies also provide evidence that experiential measures designed to measure temporal- impulsivity, do not in fact index this subtype as it is currently understood. It has been discussed how inhibitory control and speed and accuracy processes contribute to each subtype individually, however it should also be addressed whether these processes are common *between* subtypes, which will now be discussed.

7.4.1 Inhibitory control

Challenging behavioural inhibitory control via a dual task, and an acute dose of alcohol (studies 2 and 3) was seen to consistently increase impulsivity on the Stop Signal Task, but not performance on the Information Sampling Task, or Single Key Paradigm. The results provide evidence that only motor- impulsivity is reliant on behavioural inhibitory control processes. Thus, it appears that behavioural inhibitory control processes are a point of divergence between the subtypes of impulsivity with only motor- impulsivity arising from impaired inhibitory control. The factor analysis (study 5) provides further evidence that the Stop Signal is distinct from all other behavioural tasks, as the task was found to load separately from all other measures of impulsivity.

These data provide support for a distinction between motor- and cognitive- types of impulsivity (Congdon & Canli, 2008). However, factor analysis provided evidence that behavioural impulsivity may consist of additional factors to the three subtypes of motor-, reflection- and temporal- impulsivity. The additional categories of impulsivity provide further points of discussion for the reliance of impulsivity on inhibitory control processes.

Factor analysis suggested two distinct subtypes of behavioural action restraint and action cancellation, rather than the predicted single 'motor'- impulsivity subtype. In the two studies manipulating behavioural inhibitory control via a dual task and alcohol dose, only the Stop Signal Task was used. The Stop Signal Task indexes action cancellation (according to the factor analysis) and thus from the data, it can only be confidently concluded that action cancellation processes were challenged by the dual task and alcohol dose. As a measure of action restraint was not included within these two studies, it is unknown whether behavioural action restraint processes were also challenged by the two manipulations.

It has previously been proposed that the ability to delay gratification invokes action restraint capacities similar to those activated on the Go/NoGo and Immediate Memory Task (Dalley et al., 2011). It has been suggested that to delay gratification, participants must wait (show restraint) for a larger reward (Dalley et al., 2011), and the Go/NoGo and Immediate Memory tasks require participants to wait for a Go signal before making a behavioural response (Winstanley, 2011). The factor analysis found pen-and-paper measures of temporal- impulsivity to load separately from the Go/NoGo and Immediate Memory Task, providing evidence that any restraint processes engaged on measures of temporal- impulsivity are not the same as those on measures of behavioural action restraint.

While factor analysis found evidence that the Single Key Paradigm does not index temporal- impulsivity as it is currently understood, there is evidence that the task is distinct from the behavioural measures of action restraint and cancellation, as the task loaded separately to the Stop Signal Task, Go/NoGo and Immediate Memory Task. The studies using a dual task and alcohol dose to challenge inhibitory control provide further evidence that the Single Key Paradigm is distinct from the Stop Signal Task. However, as a measure of behavioural action restraint was not included in either of these studies it is not known whether the manipulations also challenged behavioural action restraint capacities, and therefore it cannot be experimentally confirmed whether any inhibitory control processes on Single Key Paradigm are distinct from behavioural action restraint processes. From the results, it is unclear exactly what processes the Single Key Paradigm indexes.

The studies provide evidence that reflection- impulsivity is distinct from behavioural inhibitory control capacities. Neither the alcohol, nor the dual task, challenge to inhibitory control increased reflection- impulsivity. Furthermore, in the factor analysis, the primary measures of the reflection- impulsivity were found to load onto a separate subtype of impulsivity from the behavioural measures of action restraint and cancellation. It can be hypothesised that if inhibitory control processes are required to prevent impulsive responding on measures of reflection- impulsivity, they may be more complex and cognitive in nature. There was some preliminary support for this suggestion found in the relationship of alcohol expectancies and reflection- impulsivity. Participants expecting a greater level of impairment to self-control from alcohol, who believed that they had received alcohol, exhibited compensatory mechanisms to remedy this. Participants expecting high levels of impairment, became less impulsive on the Information Sampling Task, and acquired more information before making a decision.

Importantly, this relationship was only seen in participants who believed that they had received alcohol; participants who believed that they had consumed placebo did not show compensatory mechanisms. These findings provide some preliminary evidence that engagement of cognitive control mechanisms has implications for reflection-impulsivity. It is important to note that any cognitive control engaged on the task appears to be distinct from that on the Single Key Paradigm as the tasks loaded separately from one another in the factor analysis.

Overall, these findings support the suggestion that impulsivity is not a unitary construct, and should be conceived of as consisting of dissociable subtypes. Performance on the Stop Signal Task is reliant on inhibitory control resources, whereas measures of reflection- impulsivity, pen-and-paper measures of temporal- impulsivity and the Single Key Paradigm do not appear to be. It is likely that the Go/NoGo and Immediate Memory Task are also reliant on behavioural inhibitory control, however neither task was included within studies 2 and 3 and this suggestion cannot be confirmed from just the results of the factor analysis.

7.4.2 Speed/accuracy trade-offs

The current research suggests that multiple types of impulsivity are affected, to an extent, by imbalances in the speed accuracy trade-off.

The instructions-only manipulation was found to affect reflection- impulsivity, as measured by the Matching Familiar Figures Task, and also affected responding to Go signals on the Stop Signal Task. Inhibitory control on the Stop Signal Task was not affected and performance on the Information Sampling Task and Delay Discounting Task was also unaffected by the instructions.

Cognitive priming of speed or accuracy schema (study 1b) did not affect any impulsivity measure; however trait impulsivity was related behavioural impulsivity on the tasks under conditions of the priming. It is thought that trait impulsivity reflects ‘built-in’ patterns of behaviour. Interestingly, where direct instructions were employed (studies 1a and c), there were no effects of trait impulsivity. This suggests that whilst the instructions-only manipulation (study 1a) did not encourage behavioural impulsivity on all four tasks, the instructions over-rode the effects of trait impulsivity on behaviour.

Interestingly, the combination of instructions, for speed or accuracy, and cognitive priming affected all four impulsivity measures. Go reaction times and Go accuracy were affected on the Stop Signal. Reflection- impulsivity on both the Information Sampling Task and Matching Familiar Figures Task was affected. The manipulation also increased impulsive responding on the Delay Discounting Task. This provides evidence that all the impulsivity measures used in the studies are sensitive to biases for speed or accuracy, under certain conditions and also that that the combination of instructions and cognitive priming can affect performance on the task more deeply.

Thus, the studies suggest that all subtypes of impulsivity are reliant, to an extent, on biases for speed or accuracy. However, it is also apparent that only certain tasks are modifiable by strategic control over responding for speed or accuracy.

7.5 Impulsivity, demographics, and dispositions

There were no consistent relationships found between stable demographics and dispositions on behavioural impulsivity.

There was some evidence that age was a significant predictor of pre-planning time on the Tower of London task (study 4); older participants had longer pre-planning times. Self-report impulsivity was also a significant predictor of Tower of London performance, although was not significant after binge scores were included in the analysis.

This study finds evidence that older adults take longer to plan responses, in contrast, there was some evidence in the experimental study implementing cognitive priming (study 1b) that age is related to *increased* reflection- impulsivity. Older participants were less efficient on the Matching Familiar Figures, and opened fewer boxes and tolerated more uncertainty in the reward conflict version of the Information Sampling task. It is not clear why there was this dissociation in the relationship of age to reflection- impulsivity and planning, and these findings should be investigated further. The factor analysis found measures of reflection- impulsivity to load separately from the Tower of London task, suggesting that the mechanisms underlying the tasks are dissociable and may not be subject to the same age-related changes.

However, it is important to note that these relationships were not present in either of the studies associated with the cognitive priming (studies 1a and c) and it is not known whether these relationships were present because of the cognitive priming manipulation, or whether they are unique to this particular group of participants. Furthermore, age, intelligence, self-report impulsivity and binge drinking behaviours were not significant predictors of any other behavioural measure in the large exploratory study (study 4).

7.6 How modifiable is behavioural impulsivity?

The current studies provide evidence that behavioural impulsivity is modifiable. However, there is also evidence that it is not possible to consistently induce impulsive behaviour without altering the associated cognitions, and also that individuals are able to over-ride any state changes, either through conscious control of responding, or through general trait patterns of responding.

Challenging inhibitory control, via the dual task and acute dose of alcohol (studies 2 and 3), only affected Stopping responses on the Stop Signal Task. Instructions for speed or accuracy (study 1a) modified performance only on the Matching Familiar Figures and also affected responses to Go, but not Stop, stimuli on Stop Signal Task. It appears that such manipulations have a relatively specific effect; they only disrupt impulsivity on tasks that are reliant on such resources.

The studies find evidence that it is not possible to consistently manipulate state impulsivity without modifying the associated cognitions. The instructions for speed or accuracy, without the associated cognitive priming (study 1a), only affected the Matching Familiar Figures Task and Go responding on the Stop Signal Task. In comparison, the combination of instructions, and cognitive priming (study 1c), was the only manipulation that successfully modified responding on all behavioural tasks. In this manipulation, participants were instructed to respond quickly or accurately, and were primed with ‘matching’ disinhibition or restraint constructs. It is evident that the combination of instructions, encouraging conscious, strategic, control over behaviour, and cognitive priming, thought to encourage non conscious control over behaviour, was successful at inducing global increases in state impulsivity. These results suggest that it is not possible to alter state impulsivity without also manipulating the associated cognitions.

It also seems to be the case that individuals are able to exert self-control to modify their own responding. Participants who anticipated high levels of impairment to arise from alcohol, who believed that they had received alcohol, displayed compensatory mechanisms to remedy this (study 3). Participants expecting such impairment showed reduced reflection- impulsivity, acquiring more information before making a decision. This provides evidence that individuals are able to over-ride any expected increases in impulsivity. The exact mechanisms by which this compensation works are unknown; it is clear that this compensation was specific to performance on the Information Sampling Task and it should be further investigated under what conditions this phenomenon occurs.

Cognitive priming of speed or accuracy schema, without the associated instructions (study 1b), did not affect any impulsivity measure. Interestingly, trait impulsivity was related to impulsivity on the Matching Familiar Figures, Information Sampling and Stop Signal Task, under conditions of the priming. It has been suggested that trait impulsivity reflects ‘built-in’ patterns of behaviour; however there has previously been only limited evidence that self-report impulsivity is related to behavioural impulsivity. In the current studies these relationships between trait impulsivity and responding on the behavioural tasks were not present in the large exploratory study (study 4). It is perhaps the case that the priming manipulation potentiated any effects of trait impulsivity; however, the reasons for this need further investigation. Where direct instructions for speed, or accuracy, were employed (studies 1a and c), there were no effects of trait impulsivity. This suggests that whilst the instructions-only manipulation did not induce behavioural impulsivity on all behavioural tasks, the instructions over-rode the effects of trait impulsivity on behaviour.

In summary, it is evident that behavioural impulsivity is modifiable, to an extent, by challenging available resources (for example inhibitory control) or through initiating strategic control over responding (through instructions). However, impulsivity cannot be induced consistently unless the behavioural output and associated cognitions are altered in conjunction with one another. Furthermore, it is evident that, under certain circumstances, individuals are able to over-ride expected impulsive behaviour.

7.7 Limitations of the studies

There were methodological limitations to the studies that should be briefly discussed. Power analysis was not used at any point to indicate the optimum number of participants per study. Future studies should incorporate such power analysis. There were also concerns that asking participants to complete questionnaires prior to the experimental tasks may have primed participants to become more or less impulsive. In future questionnaire and behavioural measures should be completed on separate days and under differing conditions to avoid such priming effects, however time and financial constraints prevented this.

There were some more considerable issues with the studies, primarily concerning task selection and defining underlying processes and impulsivity in the empirical studies. These will be discussed below.

7.7.1 Task selection

One main consideration when designing the studies was the selection of measures of impulsivity.

Impulsivity was initially defined as consisting of three potential subtypes: reflection-, temporal- and motor- impulsivity. This hypothesised structure of impulsivity, determined the selection of behavioural tasks in the three studies exploring the processes underlying types of impulsivity (studies 1-3, the experimental manipulations of inhibitory control and speed/accuracy biases). Ideally, instead of adopting this method of task selection, the large factor analysis study would have been completed first to allow us to make task choices based on the results. Unfortunately, the time taken to run the study, with 160 participants, prevented this.

Because of such constraints, we were required to make task choices based on background literature and our own understanding of the tasks.

One major consideration when selecting the tasks was that research suggests that the measures differ in the complexity of their underlying (confounding) processes. The most obvious example is comparing the two primary measures of reflection- impulsivity: the Matching Familiar Figures and the Information Sampling Task. The Matching Familiar Figures is known to be dependent on multiple, potentially confounding, processes (Clark et al., 2006; Messer, 1976; Southgate et al., 2008; Zelniker & Jeffrey, 1976) and so it is difficult to identify whether impulsive behaviour on the Matching Familiar Figures represents a lack of reflection. Compared to the complexity of processes underlying performance on the Matching Familiar Figures, the Information Sampling Task is designed to provide a *primary* index of information sampling, without multiple confounding processes (Clark et al., 2006).

The Information Sampling Task was chosen for the studies challenging inhibitory control (studies 2 and 3; the dual task and alcohol challenges), as it is fundamentally simple in comparison to the Matching Familiar Figures. Choice of the Matching Familiar Figures would have resulted in complications in interpreting the results; it would have been unclear whether the dual task would have interfered with working memory required for the task; perhaps the alcohol dose would have affected visual search in study 3. Compared to this, when speed and accuracy biases were manipulated (study 1), including the Matching Familiar Figures alongside the Information Sampling Task was essential; the task is intrinsically dependent on speed/accuracy trade-offs, so could be used as a sort of manipulation check as a lack of effect on the task would indicate that the manipulation did not succeed in altering behavioural responding on the tasks.

Fortunately, the results of the factor analysis (study 5) indicate that the Information Sampling and Matching Familiar Figures Task ultimately measure one underlying construct, and therefore it can be suggested that performance on the Matching Familiar Figures should be related to performance on the Information Sampling Task and the two can be similarly manipulated.

However, the results of the factor analysis study did not always confirm our predictions, and issues did arise from our method of task selection. In particular issues arose from the selection of tasks indexing the ‘temporal’ subtype of impulsivity.

When exploring the effects of biases in the speed accuracy trade-off, (study 1) a pen-and-paper measure of temporal- impulsivity was used. In comparison, when exploring the effects of inhibitory control (studies 2 and 3) the Single Key Impulsivity Paradigm was selected; this experiential task was selected as it was unclear whether the use of a pen-and-paper measure would not be comparable to the behavioural tasks used for the reflection- and motor- subtypes. Subsequently, the factor analysis study revealed that the pen-and-paper and experiential measures do not load onto one factor. The pen-and-paper measures were found to load together, the Single Key Impulsivity Paradigm loaded onto a factor with the Tower of London task. We therefore cannot confidently claim we would replicate our results if we replaced the pen-and-paper measure with the experiential task, and vice versa. It is apparent that the tasks do not necessarily measure the same underlying processes, and so the results cannot be confidently interpreted.

7.7.2 Defining underlying processes and impulsivity

An additional issue is that current literature refers to these forms of impulsivity both as processes (Wiers, Ames, Hofmann, Krank, & Stacy, 2010) and behaviours (Winstanley et al., 2010), and does so interchangeably. It is not always clear whether impulsivity is considered to be a process in itself contributing behaviour, or if it is the behavioural output of multiple underlying processes.

This issue was fundamental in the definition of inhibitory control and motor-impulsivity, as well as speed/accuracy and reflection- impulsivity.

As discussed in relation to inhibitory control (study 2), it is evident that the concept of motor- impulsivity and behavioural inhibition are antipodes, and share definitional features (Bickel et al., 2012). Failures in behavioural inhibition that lead to failed suppression of a behavioural response can be labelled motor- impulsivity. Furthermore, the Stop Signal Task is employed both, as a measure of inhibitory control in the executive function field, and as a measure of motor- impulsivity (Logan, 1994; Miyake et al., 2000; Ray Li et al., 2008). This results in a circular argument - it is, arguably, redundant challenging ‘inhibitory control’ on a task that measures ‘inhibitory control’ to claim that the task measures ‘inhibitory control’!

Despite this, the inhibitory control challenges were deemed to have merit as means of dissociating the different types of impulsivity. The dual task and alcohol studies do provide some evidence, that whilst inhibitory control mechanisms underlie performance on the Stop Signal Task, they have less validity as mechanisms underlying the Information Sampling Task and Single Key Impulsivity Paradigm.

This issue also applies to understanding of reflection- impulsivity. Within current literature it is ambiguous as to whether reflection- impulsivity is a process occurring within a stage decision-making, i.e. if it contributes to impulsive decision-making, or if it is the output of multiple sub-processes. It needs to be further established by which mechanisms these forms of impulsivity occur, and whether interventions should be targeting, for example, reflection- impulsivity per se, or prior underlying processes. For example, these definitional issues were problematic in the discussion of speed/accuracy trade-offs and reflection impulsivity. It is unclear whether acting quickly, rather than accurately, is the behavioural output arising from 'reflection-impulsivity' (with reflection-impulsivity being defined as a lack of gathering or evaluating information), or whether this bias is the underlying process in itself.

7.8 Theoretical implications

The studies provide evidence that the three subtypes of motor-, temporal- and reflection- impulsivity differentially rely on inhibitory control processes and biases for speed or accuracy. However, the factor analysis indicates that additional factors of impulsivity are required to fully characterise impulsive behaviour.

Impulsive responding is, almost universally, recorded in recreational and pathological drug-users. The present studies have contributed to understanding of the characterisation of impulsivity, and provide a platform for further research including into how the different factors of impulsivity may make differing contributions to drug use initiation, escalation, maintenance and relapse. It should also be investigated whether these types of impulsivity interact with one another to contribute to drug-use behaviours. The diversity of impulsivity has important implications for current understanding of such responding in these clinical populations and further research is needed to establish how these types of impulsivity contribute to a vulnerable phenotype for drug addiction.

The finding that there is one subtype of reflection- impulsivity, which is distinct from behavioural inhibitory control processes, furthers current understanding of impulsive decision-making. In addition to confirming the suggestion of a distinct subtype of reflection- impulsivity, the findings have clinical implications. Investigators have previously found that drug-using populations, including alcohol dependent individuals (Joos et al., 2012; Lawrence et al., 2009a, 2009b), cannabis users (Clark et al., 2009; Solowij et al., 2012) and current amphetamine and opiate users and ex-users of both drugs (Clark et al., 2006) display increased levels of reflection- impulsivity. The studies provide evidence that such impairment reflects one underlying deficit in decision-making, however further research is needed to explain whether reflection- impulsivity pre-dates drug use, or is a consequence of such use. Investigators have found evidence of similar deficits in reflection- impulsivity in problem gamblers; problem gambling has been suggested to have relevance as a model of drug addiction that is not confounded by the direct, damaging, effects of drug use (e.g. Lawrence et al., 2009b). These findings provide preliminary evidence that reflection- impulsivity may be a pre-curser to drug use (Lawrence et al., 2009b), a suggestion that merits further investigation.

The current studies provide evidence that action restraint and action cancellation can be behaviourally characterised in normal populations. This confirms animal and theoretical models that the two involve different underlying processes (Eagle, Bari et al., 2008; Winstanley, 2011). Drug using populations have been found to display deficits on both action restraint and cancellation. Alcohol dependent individuals have impaired action cancellation on the Stop Signal Task (Joos et al., 2012; Lawrence et al., 2009a) and also display impaired action restraint on the Immediate Memory Task (Bjork et al., 2004). Cocaine users also have impaired action cancellation on the Stop Signal Task (Mark T. Fillmore & Rush, 2002) and impaired restraint on the Go/NoGo task (Hester & Garavan, 2004; Kaufman et al., 2003; Verdejo-Garcia et al., 2007). Cigarette smokers show impaired action restraint on the Go/NoGo task (Luijten et al., 2011) and methamphetamine abusers exhibit poor action cancellation on the Stop Signal Task (J. R. Monterosso et al., 2005). The studies provide evidence that the two types of behavioural inhibitory control should be explored as separate constructs. From the above it becomes evident that drug-users show deficits on both forms of behavioural inhibitory control. The implications of this have not been established and need further investigation. It may be the case that the two forms of behavioural inhibitory control are associated differentially with initiation and maintenance of drug use. With regards to action cancellation, investigators have found that pathological (assessed using the DSM-IV criteria), but not ‘problem’ gamblers show impaired action cancellation on a version of the Stop Signal task, suggesting that impaired action cancellation may contribute to escalation and severity of gambling behaviours (Brevers et al., 2012). It should be investigated whether the same relationship appears between action cancellation and drug use, and whether action restraint processes contribute to escalation of gambling and drug-use behaviours in a similar manner.

For the most part, research investigating clinical populations utilises pen-and-paper measures to index temporal- impulsivity. Drug using populations display deficits in temporal- impulsivity, preferring more immediate gratification, compared to normal populations. Investigators have generally found that alcohol dependent individuals (both those currently using and currently abstinent) prefer immediate rewards compared to controls (Bjork et al., 2004; Dom, D'Haene et al., 2006; Joos et al., 2012; Petry, 2001). Deficits in temporal- impulsivity are also seen in opioid addicts (Kirby & Petry, 2004; Kirby et al., 1999; Madden et al., 1997) and cocaine abusing populations (Coffey et al., 2003; Kirby & Petry, 2004; Moeller et al., 2002). The mechanism by which tendency to delay gratification is related to pathological behaviours is unclear. Research has found that problem, and pathological, gamblers also display impulsive responding on pen-and-paper measures of impulsivity (Brevers et al., 2012) again suggesting that such deficits may pre-date drug use. It is possible that the preference for immediate rewards, over delayed gratification, may have implications for treatment outcomes if drug-using individuals prefer immediate drug gratification over the ‘delayed’ reward of abstinence. The exact implications of the findings regarding the Single Key Paradigm are not immediately obvious. The studies do, however, provide evidence for a dissociation between cognitive and behavioural inhibitory control, a finding that needs further investigation.

The studies provide evidence that the global deficits in impulsivity (deficits across multiple factors of impulsivity) do not originate from one source of impairment. Investigators have previously suggested that frontal cortical brain regions associated with inhibitory control are directly affected by long-term exposure to drugs of abuse (Duka et al., 2011; Goldstein & Volkow, 2011; Taylor & Jentsch, 1999) and have attributed the impulsivity displayed in drug using populations to these impairments. However, the completed studies find evidence that global deficits in impulsivity are not a result of impaired behavioural inhibitory control. While it is evident that types of motor- impulsivity (encompassing both action restraint and cancellation) are a consequence of impaired behavioural control, the studies found no evidence that other forms of impulsivity are also affected by such impairments.

These findings have implications for treatment options. Further research is necessary to establish the processes and brain substrates underlying the different types of impulsivity, and to determine the causes of impulsive responding in clinical populations as different types of impulsivity cannot be attributed to one underlying deficit. In light of this, it is evident that there can be no one cure-all remedy to prevent behavioural impulsivity.

It is evident that the nature of impulsivity is extremely diverse, with multiple underlying processes. The studies found no evidence for one primary underlying process contributing to all forms of impulsive behaviour. Investigators should embrace the diverse nature of impulsivity (Winstanley et al., 2010) and work towards determining the contributions of the different subtypes to pathological behaviours.

7.9 Future directions

It is clear that the current understanding of impulsivity is too limited. The classification of behaviours into ‘cognitive’ or ‘motor’ types of impulsivity is too simplistic, as are even more specific definitions of ‘motor’- and ‘temporal’- impulsivity. It appears that tasks supposedly measuring the same subtype (for example experiential and pen-and-paper measures of delay of gratification) do not necessarily assess the same processes. Further research would benefit from more specific definitions of the behavioural and cognitive processes investigated.

To extend current understanding of the processes contributing to the different factors of impulsivity, the experimental studies would benefit from being replicated using the six factors identified in the factor analysis, rather than the three factors of reflection-temporal- and motor- impulsivity. The factor analysis suggests that the processes underlying both pen-and-paper measures and experiential measures of delay of gratification (including the Single Key paradigm) do not include behavioural inhibitory control. The Single Key Paradigm, in particular, needs further investigation to establish exactly what processes contribute to performance on the task, in particular whether action restraint processes contribute to performance on the task. To investigate this, the studies challenging inhibitory control should be repeated administering a measure of action restraint, such as the Go/NoGo, to further confirm that behavioural inhibitory control processes are not engaged during performance on the task.

The processes manipulated in these studies were limited, as they focused on a particular subset of impulsivity measures. Nevertheless, they provide compelling evidence that the subtypes of impulsivity are dissociable, and are dependent on different underlying processes. Further research should investigate the role of additional cognitive processes that were not manipulated or investigated. There was evidence of different types of inhibitory and cognitive control on a variety of tasks, including the Stop Signal, Information Sampling Task, and Single Key Impulsivity Paradigm however the exact processes need further investigation.

In summary, the completed studies provide a number of avenues for further research. Factor analysis has helped to establish a number of factors of impulsivity, that incorporate a number of distinctions not identified in the three factors of reflection-, motor- and temporal- impulsivity. There are additional processes that should be investigated, including establishing the types of inhibitory and cognitive control that contribute to performance on the tasks. The results have important implications for current understanding of the impairments to impulsivity displayed in clinical populations. The experimental studies manipulating inhibitory control and speed/accuracy processes provide evidence that different forms of impulsive responding do not originate from one source of impairment, for example impaired inhibitory control, and it is evident that further research is necessary to establish the processes underlying the different types of impulsivity.

7.10 Conclusions

This thesis investigated three subtypes of behavioural impulsivity: 'reflection'-, 'temporal'- and 'motor'- impulsivity, and followed the predication that these subtypes are dissociable but may also share common underlying processes (P. G. Enticott & Ogloff, 2006; J. Monterosso & Ainslie, 1999; Winstanley et al., 2004). The studies investigated processes that may be common to the subtypes, focusing on whether inhibitory control resources and biases for speed or accuracy underlie impulsive responding. The factor structure of impulsivity was also examined, to establish whether the primary measures of the proposed subtypes can indeed be categorised into these three factors.

The studies provide information on the factor structure of impulsivity, and the processes that underlie each facet of impulsivity.

In places, the studies confirmed the subtypes discussed within current literature. For example, the studies support the suggestion of a reflection- impulsivity subtype. The Matching Familiar Figures and Information Sampling Task, as the two primary measures of the subtype, loaded onto one factor of impulsivity. It was found that behavioural inhibitory control resources are not necessary for reflection-impulsivity however biases for speed or accuracy do have important implications for this subtype.

Facets of motor- impulsivity appear to be distinct from other types of impulsivity, and are the only subtype reliant on behavioural inhibitory control. Biases for speed or accuracy were seen to affect responding to Go stimuli, but did not affect inhibitory control on one measure of motor- impulsivity. However, factor analysis provided evidence that further categorisations of motor- impulsivity may be required to fully characterise impulsive responding, as two dissociable subtypes indexing action cancellation and action restraint processes were identified. This provides evidence that action restraint and action cancellation should be investigated as distinct constructs.

With regards to temporal-impulsivity, inhibitory control processes were not found to underlie performance on an experiential task whereas biases for speed or accuracy were found to contribute to performance on pen-and-paper measures. However, despite the use of experiential tasks which have been developed by investigators to index this subtype, factor analysis provided evidence that such tasks may in fact be more closely related to a form of cognitive control, instead of temporal-impulsivity as it is currently understood.

In addition to information on the factor structure of impulsivity, the studies found evidence that individuals reporting themselves to be impulsive, according to Barratt Impulsiveness Scale, do not necessarily display increased impulsivity on behavioural tasks. This supports the suggestion that self-report and behavioural measures of impulsivity are far from homogenous.

The studies also provide evidence that behavioural impulsivity is modifiable to a degree by manipulating inhibitory control and speed/accuracy resources; however it appears that to consistently modify impulsive responding, the associated cognitions must also be altered. Instructions for speed or accuracy were only found to consistently alter responding, when the associated cognitions were manipulated using cognitive priming techniques. Furthermore, it appears that individuals are able to over-ride expected impairment with regards to reflection- impulsivity as individuals expecting impairment to this subtype were seen to display compensatory mechanisms to remedy this.

Overall, this thesis provides evidence that types of impulsivity can be differentiated based on their reliance on inhibitory control resources, and biases for speed or accuracy. However, factor analysis provided evidence that the categories of motor-, temporal- and reflection- impulsivity are not sufficient to characterise impulsive responding, and that to fully define impulsivity additional factors are required, such as distinct facets of action restraint and cancellation.

8 Bibliography

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9 Appendices

APPENDIX 1 - Personal Details Questionnaire

Please answer all of the following questions:

1) **Gender:** (Please circle) Male / Female

2) **Age:** _______ Years ________ Months

3) **Is your first language English?** (Please circle) Yes / No

4) **What level of education have you reached?** (Please tick)

□ G.C.S.E □ A level / BTEC / NVQ □ HND / Degree and up

5) **If you are currently studying, what classification do you expect to get?** (please state)

____

____

6) **Please state any past or current medical conditions:**

____

____

7) **Are you currently taking any medication?** (Please circle) Yes / No
If yes, please state what:

____

____

8) **What is your current smoking status?** (Please tick)

□ Never smoked □ Ex-smoker □ Occasional smoker (e.g. 1-4/day)
□ Moderate smoker (5-14/day) □ Heavy smoker (15+/day)

9) **Have you ever suffered from or been treated for any of the following?** (Please tick)

□ Schizophrenia □ Alcohol dependency □ Illicit drug dependency
□ Depression □ Anxiety □ Eating disorder
□ Dyslexia □ Serious head injury □ ADHD

If yes, when was this? □ ___ years ago □ Still in treatment

Any other psychological problems (Please describe)

____

APPENDIX 2 – Beck Depression Inventory II

On this questionnaire are groups of statements. Please read each group of statements carefully. Then pick out the *one* statement which best describes the way you have been feeling **for the past week, including today.** Circle the number or underline the statement you choose. Be sure to read all the statements in each group before making your choice.

1.
0 I do not feel sad.
1 I feel sad.
2 I am sad all the time and I can't snap out of it.
3 I am so sad and unhappy that I can't stand it.

2.
0 I am not particularly discouraged about the future.
1 I feel discouraged about the future.
2 I feel I have nothing to look forward to.
3 I feel the future is hopeless and that things cannot improve.

3.
0 I do not feel like a failure.
1 I feel I have failed more than the average person.
2 As I look back on my life, all I can see is a lot of failures.
3 I feel I am a complete failure as a person.

4.
0 I get as much satisfaction out of things as I used to.
1 I don't enjoy things the way I used to.
2 I don't get real satisfaction out of anything anymore.
3 I am dissatisfied or bored with everything.

5.
0 I don't feel particularly guilty.
1 I feel guilty a good part of the time.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

6.
0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

7.
0 I don't feel disappointed in myself.
1 I am disappointed in myself.
2 I am disgusted with myself.
3 I hate myself.

8.
0 I don't feel I am any worse than anybody else.

1 I am critical of myself for my weaknesses or mistakes.
2 I blame myself all the time for my faults.
3 I blame myself for everything bad that happens.

9.
0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but I would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

10.
0 I don't cry any more than usual.
1 I cry more now than I used to.
2 I cry all the time now.
3 I used to be able to cry, but now I can't cry even though I want to.

11.
0 I am no more irritated by things than I ever was.
1 I am slightly more irritated now than usual.
2 I am quite annoyed or irritated a good deal of the time.
3 I feel irritated all the time.

12.
0 I have not lost interest in other people.
1 I am less interested in other people than I used to be.
2 I have lost most of my interest in other people.
3 I have lost all of my interest in other people.

13.
0 I make decisions about as well as I ever could.
1 I put off making decisions more than I used to.
2 I have greater difficulty in making decisions more than I used to.
3 I can't make decisions at all anymore.

14.
0 I don't feel that I look any worse than I used to.
1 I am worried that I am looking old or unattractive.
2 I feel that there are permanent changes in my appearance that make me look unattractive.
3 I believe that I look ugly.

15.
0 I can work about as well as before.
1 It takes an extra effort to get started at doing something.
2 I have to push myself very hard to do anything.
3 I can't do any work at all.

16.
0 I can sleep as well as usual.
1 I don't sleep as well as I used to.

2 I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
3 I wake up several hours earlier than I used to and cannot get back to sleep.

17.
0 I don't get more tired than usual.
1 I get tired more easily than I used to.
2 I get tired from doing almost anything.
3 I am too tired to do anything.

18.
0 My appetite is no worse than usual.
1 My appetite is not as good as it used to be.
2 My appetite is much worse now.
3 I have no appetite at all anymore.

19.
0 I haven't lost much weight, if any, lately.
1 I have lost more than five pounds.
2 I have lost more than ten pounds.
3 I have lost more than fifteen pounds.

I am purposely trying to lose weight by eating less: YES____ NO____

20.
0 I am no more worried about my health than usual.
1 I am worried about physical problems such as aches and pains, or upset stomach, or constipation.
2 I am very worried about physical problems and it's hard to think of much else.
3 I am so worried about my physical problems that I cannot think about anything else.

21.
0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I have almost no interest in sex.
3 I have lost interest in sex completely.

APPENDIX 3 – Alcohol Use Questionnaire

The following questions ask you about your habitual use of various types of alcoholic drinks. Please consider your drinking for the last 6 months in answering the questions, and take your time to give an accurate answer to each question.

1. On how many days per week do you drink wine, or any wine-type product, eg. sherry, port, martini? ________ Please state your usual brand(s) ____________________________

2. On those days you do drink wine (or similar), about how many glasses (pub measure) do you drink? ________ If unsure, please estimate the number of bottles or parts of a bottle ________

3. How many glasses (pub measure) of wine do you have in a week, in total? ________

4. On how many days per week do you drink beer or cider (at least half a pint)? ________
Please state usual brand (eg. Carling, Harvey's, Strongbow etc.) _______________________

5. On those days you do drink beer/cider, about how many pints do you typically have? ______

6. How many pints of beer/cider do you drink in a week, in total? ________

7. On how many days per week do you drink spirits (whisky, vodka, gin, rum etc.)? ________ Please state usual brand (eg. Smirnoff, Bells, Gordon's) ____

8. On those days you do drink spirits, about how many shorts (pub measure) do you typically have? ________ If unsure, please estimate number of bottles or parts of a bottle ____________

9. How many drinks of spirits do you have in a week, in total? ________

10. On how many days per week do you drink alcopops? ________ Please state usual brand (eg. Hooch, Bacardi Breezer, WKD etc.) ___________________________________

11. On those days you drink alcopops, about how many bottles do you typically have? _____

12. How many bottles of alcopops do you have each week, in total? __________

13. (10) When you drink, how fast do you drink? (Here, a drink is a glass of wine, a pint of beer, a shot of spirits, straight or mixed). Please circle the correct response

Drinks per hour: 7+ 6 5 4 3 2 1
1 drink in 2 hours
1 drink in 3 or more hours

14. (11) How many times have you been drunk in the last 6 months? By 'drunk' we mean loss of co-ordination, nausea, and/or inability to speak clearly ________

15. (12) What percentage of times that you drink do you get drunk? ________

16. What percentage of times that you get drunk do you suffer from hangovers? ________

17. On a scale of 1-10, how bad are your hangovers? ________

18. When do you usually drink alcohol? Please circle the correct response
most days / weekends / only on special occasions

APPENDIX 4– Barratt Impulsiveness Scale

Please circle the number which corresponds to the choice that best describes you. Try to describe the way you USUALLY act and feel, not just how you are feeling right now.

1 = rarely/never   2 = occasionally   3 = often   4 = almost always/always

1	I plan tasks carefully.	1	2	3	4
2	I do things without thinking.	1	2	3	4
3	I make up my mind quickly.	1	2	3	4
4	I am happy-go-lucky.	1	2	3	4
5	I don't "pay attention".	1	2	3	4
6	I have "racing" thoughts.	1	2	3	4
7	I plan trips well ahead of time.	1	2	3	4
8	I am self-controlled.	1	2	3	4
9	I concentrate easily.	1	2	3	4
10	I save regularly.	1	2	3	4
11	I "squirm" at plays or lectures.	1	2	3	4
12	I am a careful thinker.	1	2	3	4
13	I plan for job security.	1	2	3	4
14	I say things without thinking.	1	2	3	4
15	I like to think about complex problems.	1	2	3	4
16	I change jobs.	1	2	3	4
17	I act "on impulse".	1	2	3	4
18	I get easily bored when solving thought problems.	1	2	3	4
19	I act on the spur of the moment.	1	2	3	4
20	I am a steady thinker.	1	2	3	4
21	I change residences.	1	2	3	4
22	I buy things on impulse.	1	2	3	4
23	I can only think about one problem at a time.	1	2	3	4
24	I change hobbies.	1	2	3	4
25	I spend or charge more than I earn.	1	2	3	4
26	I often have extraneous thoughts when thinking.	1	2	3	4
27	I am more interested in the present than the future.	1	2	3	4
28	I am restless at the theatre or lectures.	1	2	3	4
29	I like puzzles.	1	2	3	4
30	I am future orientated.	1	2	3	4

APPENDIX 5– Alcohol Expectancy Questionnaire

This questionnaire is interested in people's expectations of alcohol. Please answer the following questions.

If I were under the influence from drinking alcohol........

	Disagree			Agree
1) I would feel courageous	1	2	3	4
2) I would have difficulty thinking	1	2	3	4
3) I would act tough	1	2	3	4
4) I would act sociable	1	2	3	4
5) I would be clumsy	1	2	3	4
6) I would feel energetic	1	2	3	4
7) I would feel shaky or jittery the next day	1	2	3	4
8) I would feel calm	1	2	3	4
9) My writing would be impaired	1	2	3	4
10) I would take risks	1	2	3	4
11) I would be humorous	1	2	3	4
12) My problems would seem worse	1	2	3	4
13) I would feel sexy	1	2	3	4
14) I would feel brave and daring	1	2	3	4
15) I would act aggressively	1	2	3	4
16) It would be easier to talk to people	1	2	3	4
17) I would feel dizzy	1	2	3	4
18) I would feel self-critical	1	2	3	4
19) My senses would be dulled	1	2	3	4
20) I would feel creative	1	2	3	4
21) I would feel peaceful	1	2	3	4
22) My responses would be slow	1	2	3	4
23) I would be outgoing	1	2	3	4
24) I would neglect my obligations	1	2	3	4
25) I would enjoy sex more	1	2	3	4
26) I would feel unafraid	1	2	3	4
27) I would be loud, boisterous, or noisy	1	2	3	4
28) I would feel dominant	1	2	3	4
29) My head would feel fuzzy	1	2	3	4
30) It would be easier to express feelings	1	2	3	4
31) I would be friendly	1	2	3	4
32) I would be a better lover	1	2	3	4
33) My body would feel relaxed	1	2	3	4
34) I would feel guilty	1	2	3	4
35) I would be talkative	1	2	3	4
36) I would feel moody	1	2	3	4
37) It would be easier to act out my fantasies	1	2	3	4
38) I would feel powerful	1	2	3	4

APPENDIX 6– Alcohol Visual Analogue Scales

How do you feel **NOW**? Please draw a vertical mark on each line, in the position you feel best represents your current state.

A 'normal' rating of these states would be near to the 'not at all' mark:

Light headed

not at all ____ very much

Irritable

not at all ____ very much

A 'normal' rating of these states would be in the middle of the line:

Stimulated

not at all ____ very much

Alert

not at all ____ very much

Relaxed

not at all ____ very much

Contented

not at all ____ very much

Pleasant Glow

not at all ____ very much

APPENDIX 7– Multidimensional Mood State Questionnaire

Right now I feel…

	definitel y not	Not	not really	a little	very much	extremel y
	|	|	|	|	|	|
1. content	1	2	3	4	5	6
2. rested	1	2	3	4	5	6
3. restless	1	2	3	4	5	6
4. bad	1	2	3	4	5	6
5. worn-out	1	2	3	4	5	6
6. composed	1	2	3	4	5	6
7. tired	1	2	3	4	5	6
8. great	1	2	3	4	5	6
9. uneasy	1	2	3	4	5	6
10. energetic	1	2	3	4	5	6
11. uncomfortable	1	2	3	4	5	6
12. relaxed	1	2	3	4	5	6
13. highly activated	1	2	3	4	5	6
14. superb	1	2	3	4	5	6
15. absolutely calm	1	2	3	4	5	6
16. sleepy	1	2	3	4	5	6
17. good	1	2	3	4	5	6
18. at ease	1	2	3	4	5	6
19. unhappy	1	2	3	4	5	6
20. alert	1	2	3	4	5	6
21. discontent	1	2	3	4	5	6
22. tense	1	2	3	4	5	6
23. fresh	1	2	3	4	5	6
24. happy	1	2	3	4	5	6
25. nervous	1	2	3	4	5	6
26. exhausted	1	2	3	4	5	6
27. calm	1	2	3	4	5	6
28. wide awake	1	2	3	4	5	6
29. wonderful	1	2	3	4	5	6
30. deeply relaxed	1	2	3	4	5	6

APPENDIX 8– Profile of Mood States

Please rate from 0= not at all to 4=extremely, how the different adjectives represent your current mood state

0	1	2	3	4	Friendly
0	1	2	3	4	Tense
0	1	2	3	4	Happy
0	1	2	3	4	Angry
0	1	2	3	4	Worn out
0	1	2	3	4	Unhappy
0	1	2	3	4	Confused
0	1	2	3	4	Lively
0	1	2	3	4	Unable to concentrate
0	1	2	3	4	Sorry for things done
0	1	2	3	4	Shaky
0	1	2	3	4	Listless
0	1	2	3	4	Overjoyed
0	1	2	3	4	Peeved
0	1	2	3	4	Agreeable
0	1	2	3	4	Sad
0	1	2	3	4	Active
0	1	2	3	4	On edge
0	1	2	3	4	Grouchy
0	1	2	3	4	Fatigued
0	1	2	3	4	Muddled
0	1	2	3	4	Blue
0	1	2	3	4	Energetic
0	1	2	3	4	Spiteful
0	1	2	3	4	Hopeless
0	1	2	3	4	Satisfied
0	1	2	3	4	Panicky
0	1	2	3	4	Helpful
0	1	2	3	4	Unworthy
0	1	2	3	4	Annoyed
0	1	2	3	4	Cheerful
0	1	2	3	4	Exhausted
0	1	2	3	4	Resentful
0	1	2	3	4	Forgiving
0	1	2	3	4	Discouraged
0	1	2	3	4	Relaxed
0	1	2	3	4	Bewildered
0	1	2	3	4	Sluggish
0	1	2	3	4	Uneasy
0	1	2	3	4	Kindly

0	1	2	3	4	Lonely
0	1	2	3	4	Miserable
0	1	2	3	4	Efficient
0	1	2	3	4	Bitter
0	1	2	3	4	Pleased
0	1	2	3	4	Alert
0	1	2	3	4	Ready to fight
0	1	2	3	4	Restless
0	1	2	3	4	Good-natured
0	1	2	3	4	Gloomy
0	1	2	3	4	Desperate
0	1	2	3	4	Rebellious
0	1	2	3	4	Nervous
0	1	2	3	4	Helpless
0	1	2	3	4	Weary
0	1	2	3	4	Elated
0	1	2	3	4	Forgetful
0	1	2	3	4	Deceived
0	1	2	3	4	Full of pep
0	1	2	3	4	Warm-hearted
0	1	2	3	4	Carefree
0	1	2	3	4	Furious
0	1	2	3	4	Uncertain about things
0	1	2	3	4	Worthless
0	1	2	3	4	Anxious
0	1	2	3	4	Vigorous
0	1	2	3	4	Terrified
0	1	2	3	4	Good-tempered
0	1	2	3	4	Guilty
0	1	2	3	4	Bushed
0	1	2	3	4	Bad-tempered
0	1	2	3	4	Refreshed

APPENDIX 9– Rey Auditory-Verbal Learning Test

Instructions:
I am going to read a list of words. Listen carefully, for when I stop, we will wait for 2 minutes and then I will ask you to say back as many words as you can remember. It doesn't matter in what order you repeat them. Just try to remember as many as you can.

List A
Drum
Curtain
Bell
Coffee
School
Parent
Moon
Garden
Hat
Farmer
Nose
Turkey
Color
House
River

Alphabetised	**Tick if recalled**
Bell	
Coffee	
Color	
Curtain	
Drum	
Farmer	
Garden	
Hat	
House	
Moon	
Nose	
Parent	
River	
School	
Turkey	
TOTAL CORRECT:	

APPENDIX 10 National Adult Reading Task

CHORD
ACHE
DEPOT
AISLE
BOUQUET
PSALM
CAPON
DENY
NAUSEA
DEBT
COURTEOUS
RAREFY
EQUIVOCAL
SUPERFLUOUS
SIMILE
BANAL
QUADRUPED
CELLIST
FACADE
ZEALOT
DRACHM
AEON
PLACEBO
ABSTEMIOUS
DETENTE
IDYLL
NAIVE
CATACOMB
GAOLED
THYME
HEIR
RADIX
ASSIGNATE
HIATUS
SUBTLE
PROCREATE
GIST
GOUGE
PUERPERAL
AVER
GAUCHE
TOPIARY
LEVIATHAN
BEATIFY
PRELATE
SIDEREAL
DEMESNE
SYNCOPE
LABILE
CAMPANILE

APPENDIX 11 Priming task

Today's study consists of a number of computerised tasks that you will have to complete.

Before you begin you are going to complete a memory task. You are now going to read a short story and at the end of the study I will ask you to repeat as many details of the story as you can, so please try to remember it.

When I am reading the story to you I would like you to try to put yourself into the character's shoes. In a way, I want you to imagine that you are that character, even if they do not behave the way that you are used to.

Female passages

Speed condition

Jane has always been a woman who makes up her mind quickly, and who rushes through life; this has resulted in an extremely successful career and a happy personal life. She has a tendency to act without thinking, and on impulse, and seems to never sit still. She does everything in a rush without stopping to breath, and has been extremely successful because of this. As a young woman, before going to university Jane took a gap year unexpectedly. She had been accepted into a university but decided at the last minute to join a friend who was spending 6 months travelling around South America and Australia. Jane loved the six months away: meeting new people and visiting amazing places. After returning from her gap year Jane spent the next three years at university, graduating with a First. After university Jane went on to have a very successful career, earning a reputation as being an intuitive, intelligent and impulsive woman who gets results. In addition to her career, Jane has a very content personal life. She remains happily married after meeting her husband whilst on an unplanned holiday with friends. She is popular among her friends, where she has a reputation for being fun and carefree company. Even now, at retiring age she has a tendency to act on impulse and race through life. When she was younger friends would sometimes tell her to slow down, but she is glad she didn't – if she had she wouldn't have achieved all she has done in her life.

Accuracy condition

Jane has always been a steady woman who makes up her mind in a careful and thoughtful manner; this has resulted in an extremely successful career and a happy personal life. She has a tendency to think through her actions very carefully, rarely acts on impulse, and has high self control. She does everything conscientiously, and has been extremely successful because of this. As a young woman, before going to university Jane took a gap year. During her gap year she found a full time job and worked hard, allowing her to save enough money to visit South Africa. The year also allowed her more time to research universities, and seek out career advice, resulting in a very happy three years at a top university and a First. After university Jane went on to have a highly successful career, earning a reputation among her peers as being a conscientious and intelligent woman who does not rush to judgment and so gets results. In addition to her career, Jane has a very content personal life. She remains happily married after meeting her husband at work, and is popular among her friends, where she has a reputation for being kind and considerate, as well as dependable. Even now, at retiring age she is known to be reliable and reluctant to make a quick judgment. When she was younger friends would sometimes tell her to lighten up, but she is glad she didn't – if she had she wouldn't have achieved all she has done in her life.

Control condition

Jane has always been a kind and friendly woman; this has resulted in an extremely successful career and a happy personal life. As a young woman, before going to university Jane took a gap year. This gave her time to earn money to travel to South Africa for six months. Jane loved the six months away: meeting new people and visiting amazing places. After returning from her gap year Jane spent the next three years at university, graduating with a First. She then went on to have a highly successful career, earning a good reputation among her peers. In addition to her career, Jane has a very content personal life. She remains happily married after meeting her husband at the age of 27, and is popular among her friends. Even now, at retiring age she has a large group of friends, and is a member of a number of clubs and regularly frequents social events. Jane feels she has achieved a lot in her life.

Male passages

Speed condition

John has always been a man who makes up his mind quickly, and who rushes through life; this has resulted in an extremely successful career and a happy personal life. He has a tendency to act without thinking, and on impulse, and seems to never sit still. He does everything in a rush without stopping to breath, and has been extremely successful because of this. As a young man, before going to university John took a gap year unexpectedly. He had been accepted into a university but decided at the last minute to join a friend who was spending 6 months travelling around South America and Australia. John loved the six months away: meeting new people and visiting amazing places. After returning from his gap year John spent the next three years at university, graduating with a First. After university John went on to have a very successful career, earning a reputation as being an intuitive, intelligent and impulsive man who gets results. In addition to his career, John has a very content personal life. He remains happily married after meeting his husband whilst on an unplanned holiday with friends. He is popular among his friends, where he has a reputation for being fun and carefree company. Even now, at retiring age he has a tendency to act on impulse and race through life. When he was younger friends would sometimes tell him to slow down, but he is glad he didn't – if he had he wouldn't have achieved all he has done in his life.

Accuracy condition

John has always been a steady man who makes up his mind in a careful and thoughtful manner; this has resulted in an extremely successful career and a happy personal life. He has a tendency to think through his actions very carefully, rarely acts on impulse, and has high self control. He does everything conscientiously, and has been extremely successful because of this. As a young man, before going to university John took a gap year. During his gap year he found a full time job and worked hard, allowing his to save enough money to visit South Africa. The year also allowed his more time to research universities, and seek out career advice, resulting in a very happy three years at a top university and a First. After university John went on to have a highly successful career, earning a reputation among his peers as being a conscientious and intelligent man who does not rush to judgment and so gets results. In addition to his career, John has a very content personal life. He remains happily married after meeting his husband at work, and is popular among his friends, whise he has a reputation for being kind and considerate, as well as dependable. Even now, at retiring age he is known to be reliable and reluctant to make a quick judgment. When he was younger friends would sometimes tell him to lighten up, but he is glad he didn't – if he had he wouldn't have achieved all he has done in his life.

Control condition

John has always been a kind and friendly man; this has resulted in an extremely successful career and a happy personal life. As a young man, before going to university John took a gap year. This gave his time to earn money to travel to South Africa for six months. John loved the six months away: meeting new people and visiting amazing places. After returning from his gap year John spent the next three years at university, graduating with a First. He then went on to have a highly successful career, earning a good reputation among his peers. In addition to his career, John has a very content personal life. He remains happily married after meeting his husband at the age of 27, and is popular among his friends. Even now, at retiring age he has a large group of friends, and is a member of a number of clubs and regularly frequents social events. John feels he has achieved a lot in his life.