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The mechanisms of action of cognitive bias modification for appetitive behaviours and associated disorders

Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Philosophy

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This thesis is submitted in accordance with the University of Liverpool PhD guidelines and regulations. The experimental chapters (Chapters Two to Seven) of this thesis will take the form of journal article manuscripts. Chapter Two was published during the preparation of this thesis, the specific detail with regards to journal submission and contribution of authors is given at the beginning of the chapter, as required.

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Abstract

The current thesis investigated Cognitive Bias Modification (CBM) for appetitive behaviours and associated disorders, specifically alcohol and chocolate consumption. In a series of experiments, I investigated (1) the effectiveness and (2) the psychological and psychophysiological mechanisms of action of Cue Avoidance Training (CAT) and Inhibitory Control Training (ICT). Specifically, I investigated if CAT and ICT are equally effective at reducing alcohol consumption in the laboratory and if these effects could be replicated in a more ecologically valid setting with 'real-word' environmental triggers. Furthermore, I investigated the neural correlates of CAT and tested psychological accounts of the mechanisms that underpin CBM, specifically *stimulus-response associations*, *devaluation* and several *alternative hypotheses*.

In the first experimental chapter (Chapter Two) I compared the effects of alcohol CAT and ICT on alcohol consumption in the laboratory, while at the same time investigating whether effects on alcohol consumption could be explained by *stimulus-response associations* or *devaluation.* Results showed that both interventions were equally effective for the reduction of alcohol consumption, and these behavioural effects were accompanied by changes in stimulus-response associations, but not devaluation. Chapter Three replicated the effects of ICT on alcohol consumption in a lounge laboratory, although exposure to alcohol advertisements greatly reduced their magnitude. Chapter Four used electroencephalography (EEG) to investigate the neural correlates of CAT during preparatory approach and avoidance motor responses, and demonstrated changes in components of the event-related potential associated with engagement of executive control (N200) and attentional processing (Late Positive Potential). In Chapter Five, results from two experiments suggest that automatic approach, impaired inhibitory

control and automatic affective associations for chocolate-related stimuli are not related to each other, which further casts doubt on the notion that changes in stimulus evaluation underlie the effects of these forms of CBM. The experiment reported in Chapter Six demonstrates that ICT leads to changes in attention and choice for alcohol-related stimuli, but no devaluation effects (assessed with self-report), which again casts doubt on the devaluation hypothesis. Finally, the experiment described in Chapter Seven suggests that ICT leads to the formation of stimulus-response associations, but not changes in signal detection.

To conclude, this thesis contributes new data which suggests that the effects of CAT and ICT on alcohol and chocolate consumption and choice are robust and are most likely to be explained by formation of stimulus-response associations during training rather than devaluation of appetitive stimuli or alternative mechanisms. Future research should attempt to optimize the behavioural effects of these interventions by exploring techniques to strengthen the formation of stimulus-response associations.

Declaration

No portion of this work has been submitted in support of any other application for degree or qualification at this or any other University or institute of learning.

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"Many ideas happen to us.
We have intuition,
we have feeling,
we have emotion,
all of that happens,
we don't decide to do it.
We don't control it."
Daniel Kahnemann, (2011).

Chapter One

General Introduction

1.1. Alcohol use disorders and heavy drinking

The Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (American Psychiatric Association, 2013) describes substance use disorders (SUDs; including alcohol use disorders) as a problematic pattern of using a substance. The problematic pattern is defined by a cluster of behavioural and physical symptoms displayed within 12-months. The symptoms include using the substance in larger amounts or for longer periods than one meant to, and worrying about stopping or failing efforts to control use. They also include spending time in obtaining the substance, cravings, developing tolerance and experiencing withdrawal, as well as failure to fulfil primary obligations and continuing the use no matter what problems it is causing. These symptoms result in impairments and distress in daily life. Depending on the number of symptoms identified, the severity of the SUDs can be assessed and categorised as follows: mild (two or three symptoms), moderate (four or five symptoms) or severe (six or more symptoms).

The UK Department of Health has recently revised its guidelines for 'safe' (responsible) alcohol consumption from 14 and 21 units per week for females and males respectively, to 14 units for both genders (January 2016). The latest National Health Service (NHS) report on alcohol use and misuse (Statistics on Alcohol, England; 2016) states that 28.9 million British people (58% of the population) reported consuming alcohol in the previous week, with 2.5 million drinking more than 14 units of alcohol on their heaviest drinking day (1 UK unit = 10ml /8g of pure alcohol). According to the same report, since 2003 secondary school students' behaviours and attitudes towards alcohol have changed, with a 24% decrease in drinking for students aged 11-15 years (from 62% in 2003, to 38% in 2014). The

same report shows that hospital admissions related to mental and behavioural disorders due to alcohol have doubled since 2004/2005, with 1.1 million estimated in 2014/2015. Similarly, there has been a 13% increase in deaths related to alcohol consumption from 2004 to 2014 (with an estimated 6831 deaths in 2014). Alcoholic liver disease accounts for 63% of these. Furthermore, the number of alcohol related prescriptions dispensed in England has doubled in the last 10 years, with a net cost of £3.93 million to the NHS, which is again double the amount spent 10 years earlier.

These statistics clearly demonstrate that regular heavy drinking is harmful to health and that the burden of alcohol-attributable disease is substantial in the UK, as it also is around the world. It is established that excessive alcohol misuse has a casual role in many diseases and injuries, as well as increasing the risk of many other health conditions (Statistics on Alcohol, England; 2016). In this context, it is important to identify the psychological processes that cause some people to drink to excess, in order to develop new behaviour change interventions, and / or to optimise existing interventions.

1.2. Theories of the development and maintenance of problem drinking (and other addictions)

There are numerous addiction theories, that focus on either individual or population level variables (West & Hardy, 2006). They adopt different approaches from biological and psychological, to economic and sociological, in order to explain how addiction develops and how it is maintained (for a review see West & Hardy, 2006). The existence of these multiple paradigms is due to the complex nature of addiction, which encapsulates (and distorts) multiple processes (such as those related to learning processes, decision making, 'impaired control', conflict and ambivalence), many of which are related and congruent with each other (Field & Cartwright-Hatton, 2015).

Learning processes

A behaviour that is linked to a pleasurable outcome (positive reinforcement), is likely to be repeated, whereas vice versa a behaviour linked to a negative outcome (punishment) is likely be avoided. This is called instrumental (operant) conditioning, and it's a good starting point that helps us to understand how substance use (and

misuse) develops, and how it influences voluntary behaviour (Drummond, Cooper, & Glautier, 1990).

Interacting with this operant conditioning is classical (Pavlovian) conditioning. When a substance (unconditioned stimulus) is used by individuals whenever they are in the presence of drug-related cues (e.g. the smell of beer; conditioned stimuli), and when these are consistently paired with each other, these cues (conditioned stimuli) will trigger conditioned responses, such as increased physiological arousal and subjective craving (Carter & Tiffany, 1999). For example, when the smell of beer in a pub elicits the pleasurable representations of the effects of alcohol, this initiates the instrumental response of 'ordering a pint'.

Furthermore, when classical conditioning interacts with operant conditioning, this leads to associative learning, the formation of direct associations between the specific cues and specific behavioural responses, which links these to mental representations. The repeated co-occurrence of events, observed at the same time and in the same environment, strengthens this association, and facilitates the activation of the response, when one of the events occurs. This is named stimulus-response learning (Hogarth, Balleine, Corbit, & Killcross, 2013), and leads to the formation of what are popularly termed 'habits' (see Tiffany, 1990). Addiction, thus, involves associative learning processes, which in turn prompt the development of automatic or habitual responding to drug-related cues.

Decision Making

These basic learning mechanisms are central to most theoretical accounts of addiction. However, it is important to note that associative learning principles in isolation cannot explain the development of addictions, because most individuals who use substances (such as alcohol) do not become addicted (Field & Cartwright-Hatton, 2015; Wiers et al., 2007). Other factors must also be involved. For example, rational decision-making processes ('choice') must be involved in addiction to some extent, because some of the best predictors of long-term abstinence in people with addiction are the degree of motivation to change their addictive behaviour (Miller, 1996; Prochaska, DiClemente, & Norcross, 1993).

Biological processes

Furthermore, the choice to engage (or not) with the addictive behaviour, is linked to behavioural pharmacology and the Disease Model of addiction (Gelkopf, 2002), via a dysfunctional reward system. These models of addiction imply that the initial use of the substance is a rational choice, but the development of addiction is caused by the compulsive repeated (ab)use of the substance, which compromises decision making processes and alters brain structures causing incapacity to control behaviour.

Different substances (alcohol, nicotine, sugar, etc.) have a variety of effects on the brain, but they primary common effects target the dopamine (DA) release and transmission in the brain reward circuits (mesolimbic systems). Specifically, the DA pathway is linked to the Ventral Tegmental area (VTA), which projects into the nucleus accumbens (NAcc), and the prefrontal cortex (PFC). Studies have shown that an increased number of DA receptors have been associated with protective effects from addiction to alcohol (Thanos et al., 2001). In fact, mesolimbic areas, via DA pathways, are responsible for the incentive salience of substances (e.g. the related reward: 'hedonic-pleasure'). Evidence shows that salient conditioned stimuli produce an increase in DA levels in the mesolimbic structures, which serve to draw attention towards the stimuli and that this hyper-attentive state towards the substance-related stimuli, promotes craving and motor preparation, facilitating relapse (Franken, 2003). Additionally, imaging studies demonstrate that these mesolimbic structures are highly activated in substance users when passively viewing substance-related cues (Schacht, Anton, & Myrick, 2013) and they are also activated in response to exposure to food stimuli (Wang et al., 2004).

Other structures are involved with the DA pathway: Several studies show that deficits in inhibitory control processes are linked with the DA structural neuro-adaptations in the PFC when individuals need to suppress competing responses due to reductions in the striatal DA receptors (Jentsch & Pennington, 2014). For example, significant negative correlation has been found between Body Mass Index (BMI) and PFC activity (Lowe, van Steenburgh, Ochner, & Coletta, 2009; Volkow et al., 2008). Similarly, imaging studies have found links between alcohol and abnormal functioning in the inferior FC (López-Caneda, Rodríguez Holguín, Cadaveira, Corral, & Doallo, 2014) and poorer inhibitory control (inferred from more

commission errors) to alcohol cues was reflected in delayed P300 components in heavy drinkers (Petit et al., 2012).

Motivational salience of substance-related cues

The Incentive-sensitization theory (Robinson & Berridge, 1993) focusses on the motivational properties of substance-related cues. The model explains how substance abuse hyper-sensitizes the release of DA to the mesolimbic areas, such that substance-related stimuli become salient (as associated with 'reward,' through classical Pavlovian conditioning). This repeated behaviour, promotes neuro-adaptations in the brain, which lead to compulsive seeking, consumption and relapse, even when the effects of the substance are enjoyed less. Thus, these salient stimuli automatically manifest themselves in behavioural tendencies such as directing the gaze and attention towards these cues (e.g. attentional bias; Franken, 2003; Field & Cox, 2008).

These tendencies, however, may be relatively automatic. Thus, for example the selective attention that is captured automatically by certain salient stimuli (named attentional bias) may not be associated with self-reported craving, but substance users become more aware of craving if pursuit of the substance is somehow obstructed (e.g. by running out of money to buy alcohol). The evidence that support this theory comes from various studies on hazardous drinkers who were exposed to substance-related cues relative to controls. They showed greater amplitudes of two components of event-related potentials (ERPs): the P300 and the Late Positive Potential (LPP; two biomarkers of the cognitive processing of motivationally salient stimuli; see Littel, Euser, Munafò, & Franken, 2012). Furthermore, greater activation of PFC regions (especially the orbitofrontal cortex (OFC) and the dorsolateral prefrontal cortex (DLPFC)) were observed across studies of substance-related cue activity (Wilson, Sayette, & Fiez, 2004).

Hyper-evaluation of substance-related cues

Other recent models focus on the overlap between cognitive and emotional processes. These models are not addiction theories per se, but can be directly applied, with implications for any goal-directed motivated behaviour. The Behavioural Stimulus Interaction (BSI) theory (Veling, Holland, & van Knippenberg, 2008) proposes a reciprocal causal relationship between motivational incentive-reward

related stimuli (positive or appetitive stimuli, such as alcohol or chocolate) and strong approach tendencies, and between non-appetitive stimuli (negative stimuli) and behavioural inhibition. The model demonstrates that by repeatedly associating inhibition of behaviour in response to a specific appetitive stimulus (via associative learning) we can impact on behaviour (Veling, Aarts, & Stroebe, 2013a), because the association learned devalues the stimulus (i.e., it becomes evaluated more negatively) which weakens the strength of the impulse that the stimulus evoked when encountered in the environment.

A related model was recently proposed in a theoretical paper from Guitart-Masip and colleagues (2014). The paper describes motivated behaviour as the result of an interaction between two processes: valence (ranging from positive reward and negative punishment) and action execution (ranging from motor response to inhibition or avoidance). Both are regulated by the dopaminergic system that is involved in the control of both motivated behaviour and reward prediction. Therefore, a positively valenced stimulus triggers a motor response (e.g. strong approach tendencies), whereas a negatively valenced (related to punishment) stimulus triggers inhibition of behaviours (or avoidance tendencies). Critically, the interaction between valence and action is bidirectional, so for example repeated approach to a stimulus can make it more positively valenced, whereas repeated avoidance (or inhibition) of a stimulus can make it more negatively valenced. Various studies, using different stimuli ranging from appetitive stimuli, such as alcohol and chocolate pictures, to geometrical shapes (Verbruggen et al., 2014) validate these two theories, showing devaluation effects for stimuli paired with behavioural inhibition or avoidance (Best, Lawrence, Logan, Mclaren, & Verbruggen, 2015; Bowditch, Verbruggen, & Mclaren, 2015; Chiu & Aron, 2014; Eberl et al., 2013; Gladwin et al., 2015; Houben & Jansen, 2015; Manning et al., 2016; Sharbanee et al., 2014; Verbruggen & Logan, 2009; Wiers, Rinck, Kordts, Houben, & Strack, 2010a; Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011).

Dual process models

Recently, dual process models (Wiers et al., 2007; Stacy & Wiers, 2010) have argued that substance misuse is the result of an imbalance between two motivational systems: an appetitive, fast and automatic system consisting of the creation and activation of associations and a more executive, slower and intentional system based

on the development of mental representations in accordance with goals (Hofmann, Friese & Strack, 2009; Gladwin & Figner, 2014; McClure & Bickel, 2014). Thus, behaviour is the product of this interaction and depends on individual differences in the strength of both systems (Hofmann, Friese, & Strack, 2009). For example, behaviour can be regulated by the executive system but only when enough cognitive resources are present. When these are lacking (as for example with the presence of appetitive cues in the environment and the repeated misuse of a substance) the executive system may be disrupted, and changes in the inhibitory control system may occur (Smith, Mattick, Jamadar, & Iredale, 2014), leading the automatic processes to guide behaviour (Gladwin & Figner, 2014).

Behavioural evidence supports these models. For example, it is only in social drinkers who exhibited poor response inhibition (inhibitory control), that automatic associations towards alcohol were associated with self-reported drinking behaviour (Houben & Wiers, 2009). Similar results were found in an appetite study which showed that individuals with lower inhibitory control consumed chocolate in accordance with the direction of their automatic associations towards chocolate (Hofmann, Friese, & Roefs, 2009). However, dual-process models have been subjected to criticism in regard to their evidence regarding the binary division of the processes underpinning behaviour (Conrey, Sherman, Gawronski, Hugenberg, & Groom, 2005; Keren & Schul, 2009). This has resulted in the call for a more integrative view of the processes, rather than a competing view of functions (Verbruggen, Mclaren, & Chambers, 2012). These concerns have been addressed with the development of more recent specifications that emphasise the substantial interactions between automatic and controlled processes (see Gladwin, Figner, Crone, & Wiers, 2011).

More importantly for this thesis, dual-process models have implications for the development of behaviour change interventions that target heavy drinking and other appetitive behaviours (Gladwin, Wiers, & Wiers, 2016; Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013a). These interventions focus either on the automatic system, by trying to reduce the influence of automatic cognitive bias on behaviour, such as approach tendencies or attentional biases; or on the reflective system, by strengthening self-regulation (inhibitory control) in order to affect behaviour. A metaphor that well summarises these views is the ‘wild horse and the

rider', the horse that needs taming versus the rider who needs to exercise and increase his / her strength (Friese, Hofmann, & Wiers, 2011).

1.3. Cognitive biases and appetitive motivation

A central question in addiction literature is why individuals persist in behaviour that is harmful for themselves. To answer this question research has focused on several biases in cognitive processing which are the product of motivated behaviour associated with appetitive stimuli (Stacy & Wiers, 2010). The three main processes most commonly examined are attentional biases, automatic approach biases and implicit associations.

Attentional bias refers to the selective attention that is captured automatically by certain salient stimuli. For example, food stimuli are processed more quickly than control (neutral) stimuli in healthy-weight individuals, and some studies show that this bias is exacerbated for obese or overweight individuals (for a review see: Field, Werthmann, Franken, Hofmann, Hogarth & Roefs, 2016). These findings are in accordance with the automatic approach biases which instead focus on the motivational orientation to automatically approach appetitive salient stimuli that are liked and wanted (craved) and avoid stimuli that are disliked (Wiers, Rinck, Dictus, & Van Den Wildenberg, 2009). In this case, studies show that overweight women, relative to controls or individuals with high levels of emotional or restrained eating show faster approach tendencies towards food (Havermans, Giesen, Houben, & Jansen, 2011; Veenstra & de Jong, 2010). Another commonly examined bias is automatic affective associations (Greenwald, McGhee, & Schwartz, 1998). This bias considers the associations retrieved automatically from memory between a specific category of appetitive stimuli (e.g. food) and two specific characteristics of the stimuli (e.g. two attribute categories: such as positive words and negative words). Experiments with chocolate cues showed that emotional eaters are faster to categorise chocolate cues with positive words, in comparison to negative words (Ayers et al., 2011), and this predicts following consumption (for reviews see Hoffmann et al., 2010; Jansen, Houben, & Roefs, 2015).

Together these findings show a consistent pattern for cognitive bias in appetitive stimuli, such as chocolate. As detailed in the next section, similar biases in cognitive processes are found for substance-related stimuli in substance users.

1.4. Automatic cognitive processes, components and measures in addiction

The focus here is on cognitive processes related to substance-related stimuli.

Attentional bias

The previously mentioned attentional biases are often measured by the Stroop task or by a Visual probe task (Field et al., 2016). The Stroop task involves participants responding to the different colours of the words presented on the screen whilst ignoring the semantic content of the word, which could be a substance-related word or a neutral/control word (e.g. when a participant sees the word 'beer' printed in blue, they are required to respond to the colour 'blue' ignoring the meaning of the word 'beer'; Williams, Mathews, & MacLeod, 1996). The logic is that substance users should be slower to respond to substance-related words as the semantic meaning interferes with the processing of the stimulus colour. Thus, attentional bias is measured as the differences in RTs between control and substance related words. Greater attentional bias is found in heavy drinkers and alcoholics when compared to light drinkers (Field & Cox, 2008). In the visual probe task control and substance related stimuli are presented on the screen simultaneously for a short period of time, followed by the presentation of a dot (probe) in the location of one of the previous stimuli (MacLeod, Mathews, & Tata, 1986). Individuals should be quicker to detect the probe when presented in the location where they were fixating (e.g. heavy drinkers are faster to detect the probe when this is located where the alcohol stimulus was presented, relative to the control stimulus; Field & Cox, 2008; Field, Mogg, Zetteler, & Bradley, 2004; Field et al., 2016).

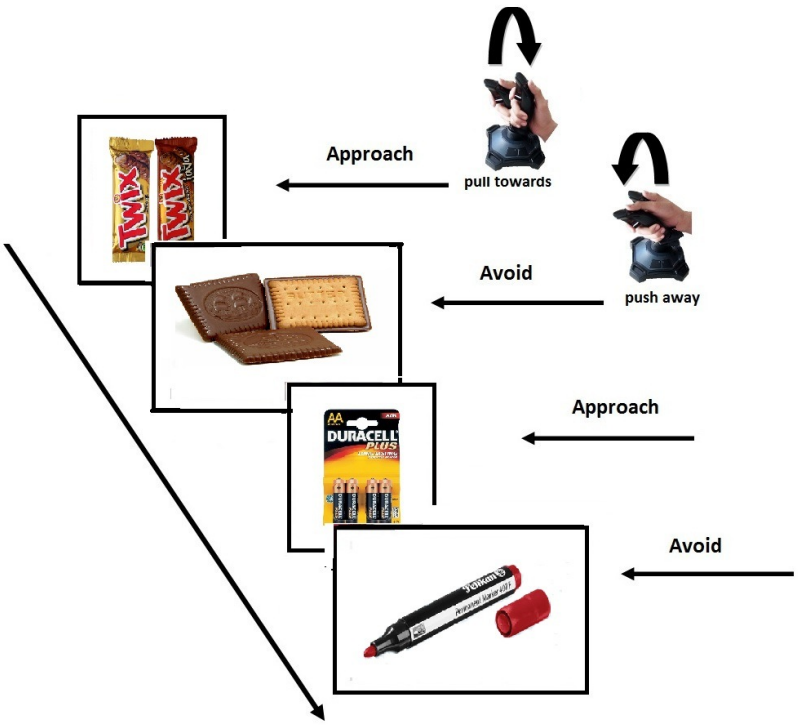
Approach bias

Automatic approach biases are measured by either the Approach Avoidance Task (A-AAT; Wiers et al., 2009) or the Stimulus-Response Compatibility task (SRC; De Houwer, Crombez, Baeyens, & Hermans, 2001). In the alcohol irrelevant AAT, a joystick is used to respond to the format of the picture. Alcohol and neutral images are "pulled" or "pushed", depending on the orientation of the picture (portrait or landscape format; see figure 1.1). Whereas in the relevant AAT participants use the joystick to respond directly to the alcohol picture (for differences between irrelevant and relevant AAT see Kersbergen et al., 2015). The movements of the

joystick are linked with a zooming or shrinking effect, increasing the sensation of approach or avoidance movements, respectively. Differences in the reaction times between pulling and pushing the different stimuli, measure the strength of these action tendencies. Similarly, in the SRC task participants rapidly categorise alcohol-related stimuli or control stimuli by moving a virtual manikin either towards or away from the stimuli. Here again differences in the reaction times between movements of the manikin towards and away from the different stimuli, measure the strength of these tendencies. Studies using these tasks have demonstrated that heavy drinkers are faster to approach alcohol stimuli rather than avoid them, in comparison to social drinkers (Field, Mogg, & Bradley, 2005; Watson, de Wit, Hommel, & Wiers, 2012; Wiers et al., 2009). These effects are more robust when alcohol stimuli are the relevant feature for categorisation in the task, regardless of whether the AAT or SRC tasks are used (Kersbergen et al., 2015).

Figure 1.1 Schematic overview of the irrelevant Approach Avoidance task (AAT).

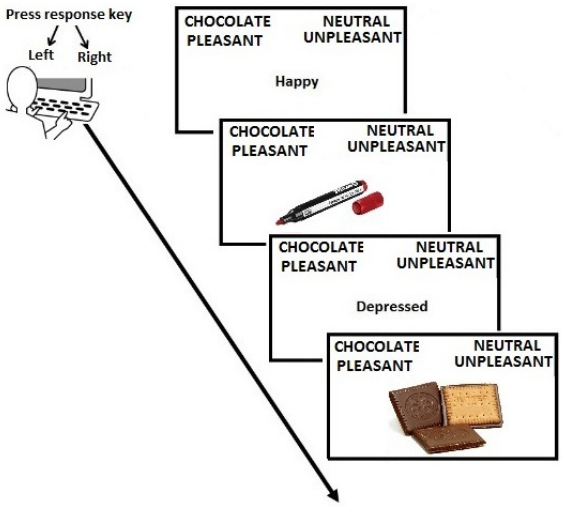
Example of trial approaching portrait and avoiding landscape pictures.



Implicit associations

Finally, automatic affective associations are measured by the Implicit Association Task (IAT; Greenwald, McGhee, & Schwartz, 1998). This is a double categorisation task that requires participants to classify stimuli, using two different response keys, into two categories: a target (e.g. alcohol vs. neutral) and an attribute (e.g. positive vs. negative; see figure 1.2). The underlying idea is that this simultaneous classification of targets and attributes is easier and faster when the target and the attribute are associated with each other. Therefore, the difference in the reaction times between compatible and incompatible trials reflects the strength of the implicit associations between the target stimuli and the attributes. IAT experiments on drinkers and alcoholics show consistently stronger associations between alcohol stimuli and negatively valenced words, relative to alcohol and positively valenced words. Nevertheless, heavy drinkers show a less negative alcohol bias in comparison to light drinkers (for a review see: Stacy & Wiers, 2010). However, an open debate on the validity of this measure is still ongoing (see Blanton et al., 2009). For example, when adopting a single version IAT (two separate IATs: one comparing positive and neutral words and the other comparing negative and neutral words) studies evidence both positive and negative associations towards substance-related stimuli (Houben & Wiers, 2008), whereas when adopting 'personalized' versions of the IAT positive implicit associations are found for substance-related stimuli (Houben & Wiers, 2007a, 2007b; Rooke, Hine, & Thorsteinsson, 2008).

Figure 1.2 Schematic overview of the bipolar valence pictorial Implicit association task (IAT).



The present thesis will focus on implicit associations and approach biases (attentional process will be investigated in a different frame-work, see page 24). However, it is necessary to point out how these cognitive processes may reflect shared underlying mechanisms (Jones, Hardman, Lawrence, & Field, 2017), because appetitive stimuli automatically capture attention, evoke approach tendencies and are positively evaluated (Strack & Deutsch, 2004; Wiers, Ames, Hofmann, Krank, & Stacy, 2010). For example, studies have shown that appetitive stimuli, such as high-calorie food images, in healthy (A. Meule, et al., 2014) and overweight individuals (Batterink, Yokum, & Stice, 2010; Houben, Nederkoorn, & Jansen, 2014) evoke stronger approach responses, leading to impaired inhibition, compared to when they are exposed to control images or low calorie food images. Thus, appetitive stimuli can provoke strong approach responses (Kemps & Tiggemann, 2015), which can impair our 'behavioural control' when these stimuli are re-encountered in the future. This is discussed in more detail in the next sections.

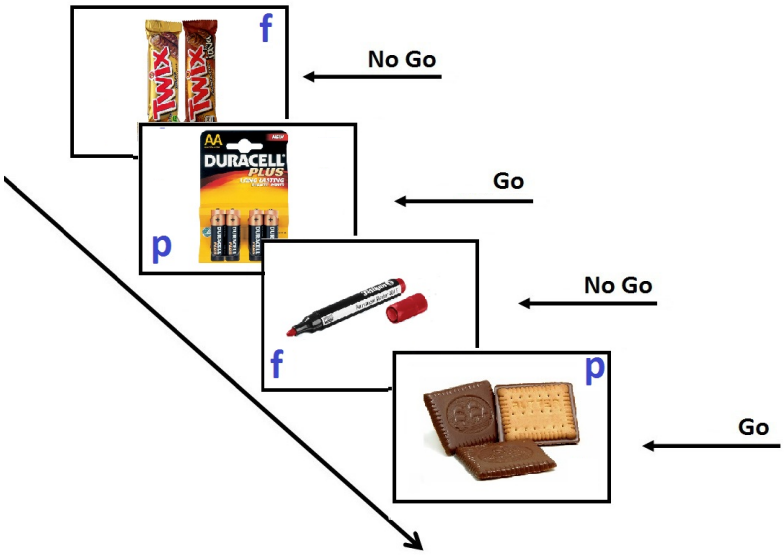
1.5. Cognitive control processes, components and measures in addiction

Biases in automatic cognitive processes play an important role in reward-driven behaviours, leading to the loss of control in substance users and the consumption of the substance. But, not everyone becomes addicted to a substance, since individuals have the ability to monitor, control and regulate their behaviour in accordance with their broader or longer-term goals (Hofmann, Friese, & Strack, 2009; Wiers et al., 2007). These abilities to suppress urges, delay responses and regulate them are executive functions which are part of cognitive control processes that support goal-directed behaviour (Bickel, Jarmolowicz, Mueller, Gatchalian, & McClure, 2012). The most common component (and the measure most related to the purpose of the present thesis) is inhibitory control, which is usually assessed by the behavioural ability to inhibit or cancel an action that has already been initiated (Verbruggen & Logan, 2009).

The most common tasks used to measure inhibitory control are the Go/No-Go task (GNGT; Newman and Kosson, 1986) and the Stop-Signal task (SST; Logan et al., 1984). In the GNGT individuals are required to inhibit their response consistently to a certain cue (No-Go) and consistently respond to another cue (Go) presented on the screen (see figure 1.3). While, in the SST, the 'Go' cue is presented always before the signal to stop and the 'Go' cues and the stop signals are not consistently

mapped. Both tasks yield a measure of successful inhibitions (reaction times, RTs) and unsuccessful inhibition (commissions errors). However, there are important differences between the two tasks: the GNGT targets the restraint (inhibition) of a response, while the SST relates to the cancellation of an action (Verbruggen et al., 2014). One advantage of the SST is that stop-signal RTs can be measured, as the estimation of the latency between when the stopping begins (e.g. the presentation of the signal) and when it ends, based on Go RTs and the probability of successful inhibition. Whereas, in the GNGT the slowing of responses to stimuli that had been paired with inhibition can only be measured through 'catch' trials, in which that stimulus then serves as a Go cue, are included (see Verbruggen et al., 2014).

Figure 1.3 Schematic overview of the Go/No-Go task (GNGT).
Inhibit to the letter "f" (No-Go cue) respond to the letter "p" (Go cue)



A recent meta-analysis demonstrated that performance in these tasks is impaired in heavy drinkers (Smith et al., 2014). Furthermore, studies have shown that alcohol-related cues may exacerbate these deficits (Jones and Field, 2015), especially in heavy drinkers and alcoholics (Kresch et al., 2013; Gauggel et al. 2010). Social drinkers, for example, made more commission errors to alcohol-related stimuli, compared to controls in a GNGT (Petit et al., 2012), errors that have been shown to increase even after exposure to alcohol olfactory cues (Monk, Sunley, Qureshi, & Heim, 2016), or after 'contextual cues', such as bar related sounds

(Pennington, Qureshi, Monk, & Heim, 2016). Likewise, laboratory evidence demonstrates impaired inhibitory control in overweight and obese individuals, relative to controls, suggesting that poor inhibition is associated with subsequent unhealthy food choices (Jasinska et al., 2012; Nederkoorn, Braet, Van Eijs, Tanghe, & Jansen, 2006; Nederkoorn, Coelho, Guerrieri, Houben, & Jansen, 2012; Nederkoorn, Dassen, Franken, Resch, & Houben, 2015).

One may sum up this evidence by affirming that harmful behaviours, such as excessive drinking and eating, are affected by multiple factors. In the thesis, I have mainly discussed automatic cognitive processes related to appetitive stimuli and executive functions, such as inhibition (necessary to stop a response which is no longer appropriate). These components are incorporated in dual-process models of goal-directed behaviours, which postulate that both automatic and controlled processes compete as determinants of appetitive-motivated behaviour. Laboratory studies evidence that both processes can be manipulated in order to influence behaviour and produce beneficial long-term behaviour change (see reviews: Friese, Hofmann, & Wiers, 2011; Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013). This research is discussed in the next section.

1.6. Changing behaviour through Cognitive Bias Modification (CBM)

In line with these insights, we have observed an increase in studies focusing on interventions to reduce risky behaviours, such as excessive drinking or eating (Allom, Mullan & Hagger, 2015; Jones, et al., 2016b, 2017; Kakoschke et al., 2017a). These studies focus on directly changing behaviour by using a cognitive training paradigm to weaken (or reverse) these cognitive biases, and/or strengthen self-control. These interventions are called 'Cognitive Bias Modification' (CBM) and are based on modified versions of cognitive assessment tasks (previously described, see page 9 onwards). In CBM tasks the stimulus-response contingency is manipulated (reversed) and repeated a number of times (e.g. alcohol-approach or alcohol-'Go' becomes alcohol-avoid or alcohol-'No-Go'), in order to alter participants' substance-related automatic associations, so that in the future those stimuli will evoke more appropriate responses, when they are encountered after receiving the training (Gladwin et al., 2016).

The initial development of CBM interventions started in laboratories with experiments (Allom Mullan & Hagger, 2015; Jones, et al., 2016b, 2017; Kakoschke

et al., 2017a). These experiments aimed to test theoretical predictions and investigate causality by examining whether cognitive biases could be changed and whether these changes would result in short-lived effects on behavioural measures (such as motivation to drink, or eat, via self-reported cravings or a bogus 'taste-test'; see Jones et al., 2016a) following a brief dose of CBM, relative to a matched control intervention. Successful results from laboratory studies provide strong justification for the evaluation of the effectiveness in clinical samples, using ideally randomized controlled trials (RCTs) of multiple sessions of CBM, compared to control (placebo-CBM) interventions, and in addition to usual treatments (for a reviews see: Allom Mullan & Hagger, 2015; Gladwin, Wiers & Wiers, 2016; Jones et al., 2016b, 2017; Kakoschke et al. 2017a).

The focus of the present thesis will be on two particular types of interventions that have found to be successful in reducing alcohol and unhealthy snacking consumption: one attempts to change motivational action tendencies (Cue Avoidance training, CAT; Wiers et al., 2011) and the other attempts to change inhibitory control (Inhibitory Control Training, ICT; Houben et al., 2012).

CAT is adapted from the AAT and participants are instructed to practice avoiding the appetitive stimuli (e.g. alcohol or chocolate) and approach neutral/control stimuli for most of the trials (90% contingency), by responding with a joystick to an irrelevant feature of the stimuli (e.g. the orientation of the stimuli: portrait versus landscape; Wiers, Rinck, Kordts, Houben, & Strack, 2010). To mask the explicit aims of the training a small number of trials (10%) are reversed.

Participants are trained to reduce their automatic approach bias towards that appetitive stimuli (e.g. alcohol) in order to consequently affect their behaviour and reduce their consumption of that substance (Wiers et al., 2013). For example, a single laboratory session of CAT was used to reverse alcohol biases and thereby reduce beer consumption in a subsequent taste-test (Wiers, Rinck, Kordts, Houben, & Strack, 2010b). More notably, these effects were extended in alcohol-dependent patients who showed a significant reduction in relapse rates in a follow-up one year later after receiving CAT compared to an active control intervention (Eberl et al., 2013; Wiers et al., 2011).

Likewise, similar effects have been reported in appetite research, in laboratory training studies which showed a reduction in unhealthy snack choices or a reduction in the consumption or craving of these after CAT (Becker, Jostmann,

Wiers, & Holland, 2015b; Brockmeyer, Hahn, Reetz, Schmidt, & Friederich, 2015; Fishbach & Shah, 2006; Jones et al., 2017; Schumacher, Kemps, & Tiggemann, 2016). A recent review in the area, across a range of unhealthy behaviours (such as smoking, alcohol consumption and unhealthy snacking), demonstrates that CAT is an effective intervention when individuals' approach-tendencies are successfully re-trained into avoidance, leading to reduction in consumption in both clinical and non-clinical samples, relative to controls (Kakoschke et al., 2017a).

ICT can be based on either the GNGT or the SST, and participants are instructed to practice behavioural inhibition to appetitive stimuli, by not responding to these stimuli that have been repeatedly paired to No-Go cues or to Stop signals, in order to form specific associations between specific-cues and the engagement of inhibitory control (Jones et al., 2016b, 2017). Similarly to the CAT, several studies have shown that a single session of alcohol ICT in the laboratory leads to a reduction in alcohol consumption for individuals exposed to the training, relative to controls (Houben, Havermans, Nederkoorn, & Jansen, 2012; Jones & Field, 2013).

Results have also been replicated in the eating domain, with reductions in choice and intake of unhealthy snacks (Houben & Jansen, 2011, 2015; Lawrence et al., 2015a,b; Veling, Aarts, & Stroebe, 2013a,b). For example, in a study by Veling, Aarts and Stroebe, (2013a) by pairing palatable foods with inhibition of behaviour, the consumption and evaluation of these snacks following ICT decreased. Two recent meta-analyses summarise findings from these two domains, demonstrating that ICT effectiveness of behavioural change in the laboratory is small but robust across studies (Standardized Mean Difference (SMD) = 0.43 in Jones et al., 2016b; and SMD = 0.38 in Allom, Mullan & Hagger, 2015). Unlike CAT, to date there have been no published trials that investigated the effectiveness of multiple sessions of ICT on clinical populations (e.g. alcohol-dependent patients), although evidence suggests that these effects may persist outside of the laboratory (Allom, Mullan & Hagger, 2015).

Taken together these findings on CBM seem promising. However, a great debate on the matter was aroused by a recent meta-analysis which concluded that CBM effectiveness is not robust across studies, due to the high risk of biases effecting experimental studies (Cristea, Kok, & Cuijpers, 2016). Nevertheless, experimental laboratory studies are essential in order to investigate the psychophysiological mechanisms that underlie CBM effects, before conducing

RCTs. For this reason, results from Cristea et al.'s meta-analysis should be considered with caution as it inappropriately combines experimental laboratory studies on students with clinical and online trials.

To sum up, most research in the field concludes that CBM leads to observable behavioural changes, especially when the cognitive biases were successfully modified (for reviews see: Allom, Mullan & Hagger, 2015; Gladwin et al., 2016; Jones et al., 2016b, 2017; Kakoschke et al., 2017a). Consequently, these interventions hold great clinical potential, as cost-effective add-ons to existing treatments for risky behaviours (such as excessive drinking or eating).

1.7 Neuro-cognitive mechanisms of CBM

As previously mentioned, altered brain functioning, specifically involving both reward circuits and inhibitory control circuits has been found in substance users (Courtney, Schacht, Hutchison, Roche, & Ray, 2016; Edward, 2001; Parvaz, 2012; Géraldine Petit, Maurage, Kornreich, Verbanck, & Campanella, 2014) and in overeaters and obese individuals (Burger & Stice, 2011; Carnell, Gibson, Benson, Ochner, & Geliebter, 2012). These changes generate reinforcing (conditioning) effects, which have been linked to changes in the neural processing of appetitive (salient) stimuli, which have been recently unified in models that attempt to explain the neural basis for both the addiction and the obesity epidemics (Jentsch & Pennington, 2014; Volkow, Wang, Fowler, & Telang, 2008).

Focusing on cue reactivity to rewarding stimuli, in particular two ERPs involving time-locked recordings to specific stimuli, measured by electroencephalography (EEG), were found to have increased amplitude during the cognitive processing of alcohol related stimuli: the frontal-central Positive peak (P300) and the Late Positive Potential (LPP). For a review see Littel, Euser, Munafò, & Franken (2012). Enhancement of these ERP components was also observed in adults exposed to food cues, relative to control cues (Nijs, Franken, & Muris, 2008). The enhancement of these components reflects the processing of motivationally salient cues (substance-related cues), and explains the allocation of attention and memory resources towards these stimuli (which are relevant to their motivational states) in SUD individuals (Franken, 2003; Littel, Euser, Munafò, & Franken, 2012).

Regarding the inhibitory control circuits, ERP studies during response inhibition in substance users relative to controls suggest that biomarkers of inhibition

are the frontal Negative peak (N200). This is found to be greater during unsuccessful inhibition, while the P300 biomarker is reduced during successful inhibition (Euser & Franken, 2012; Kok, Ramautar, De Ruiter, Band, & Ridderinkhof, 2004; Oddy & Barry, 2009; Ruchsow et al., 2008). Likewise N200 was enhanced when processing food-cues, relative to non food-cues during a GNGT in females who scored highly as external eaters and with greater BMI (Nijs, Franken, & Muris, 2009; Watson & Garvey, 2013).

Therefore, one or more of these brain mechanisms may mediate the effects of CBM. However, changes in brain activity following CBM have only recently been investigated (Bowley et al., 2013; Cabrera et al., 2016; den Uyl, Gladwin, Rinck, Lindenmeyer, & Wiers, 2016; den Uyl, Gladwin, & Wiers, 2016; Korucuoglu, Gladwin, & Wiers, 2014, 2016; Spierer et al., 2013; Verdejo-Garcia, 2016; Wiers et al., 2014; Wiers & Wiers, 2016; Zilverstand, Parvaz, Moeller, & Goldstein, 2016). One of the proposed mechanisms of CBM (Spierer et al., 2013; Wiers & Wiers, 2016) is linked to the modulation and strengthening of the PFC (involved in the cognitive processing and regulation of emotional information) and the dorsal ACC (involved in the resolution of emotional conflicts, for example during cravings). This hypothesis is supported by imaging literature on cognitive bias reactivity in anxiety, depression and addiction, prior to CBM. In abstinent alcoholics, compared to controls, alcohol approach biases have been associated with increased activity in the NAcc and the mPFC (Ernst et al., 2014; Wiers et al., 2014). Therefore, CBM may modify activation of these regions during performance in these tasks.

Recent research indirectly tested this hypothesis by stimulating the PFC and ACC with neuro-modulatory techniques, such as transcranial direct current stimulation (tDCS), which influences neural excitability and plasticity, with the intention of enhancing CBM effects. Findings in hazardous drinkers and alcohol-dependent patients are inconclusive, and show no robust moderating effects of tDCS on CBM (den Uyl, Gladwin, Rinck, et al., 2016; den Uyl, Gladwin, & Wiers, 2016). However, a recent exploratory tDCS study on women found a reduced N200 component and enhanced P300 component when responding to No-Go trials to both food cues and control stimuli: tDCS stimuli increased inhibitory control bio-markers and also modulated the reduction in calorie intake (Lapenta, Sierve, de Macedo, Fregni, & Boggio, 2014).

An additional hypothesis (Cabrera et al., 2016; Spierer et al., 2013; Verdejo-Garcia, 2016; Wiers & Wiers, 2016; Zilverstand et al., 2016), proposes reductions post-CBM in the activation of mesolimbic structures (see Schacht, Anton, & Myrick, 2013). As discussed previously, since mesolimbic structures are involved in the modulation of stimulus incentive salience (Koob & Volkow, 2010), and because CBM involves the formation of new stimulus-response associations by modifying the original salience (valence) of the stimuli (Veling et al., 2008), CBM may consequently reduce the activation of these structures. Most of the neuro-CBM imaging literature focuses on CAT interventions, specifically targeting anxiety and depression (Wiers & Wiers, 2016). Two recent fMRI studies investigating CAT neuro-mechanisms have been published in the addiction field; demonstrating reduced activation in the amygdala (Wiers, Stelzel, et al., 2015) and in the medial PFC (mPFC; Wiers, Ludwig, et al., 2015) in alcohol-dependent patients after multiple sessions of training. This suggests a blunting effect of CBM on the incentive salience of alcohol stimuli (Gladwin et al., 2016), even though these effects were inconsistently associated with changes in behavioural performance (Wiers, Ludwig, et al., 2015).

Imaging literature regarding ICT effects is certainly lacking (for a review of this see Verdejo-Garcia, 2016). One ICT study on hazardous drinkers is reported in the literature and adopts a GNG paradigm during EEG recordings (Bowley et al., 2013). Results during passive viewing of three different types of stimuli (alcohol, water and landscapes) showed that a brief single dose of ICT (in which individuals inhibited their responses to beer cues), or a brief regular intervention relative to an opposite 'Go training' (in which individuals responded to beer cues), reduced left frontal activity post-intervention relative to pre-training. However, these decreases did not reach statistical significance, but this may be due to the addition of the passive-viewing task post-ICT which may have weakened the effects. These trends seem to suggest some kind of improvement of the inhibitory control following training, as suggested by Spierer and colleagues (2013), but further studies are needed to validate these claims. Finally, one other study investigated neural correlates of ICT in healthy individuals, adopting an SST paradigm. This showed increased activation of the inferior frontal gyrus (IFG) during response preparation to 'Go cues' and a decrease in the same region during inhibition, which correlated with a general improvement in task performance (Berkman, Kahn, & Merchant, 2014).

In summary, the evidence base pertaining to the brain mechanisms that underlie the effects of CBM is limited and findings are very contradictory. Therefore, the mechanisms of action of CBM remain poorly understood. Future studies should focus on the brain mechanism that underlie as they provide insights that can contribute to the development and optimisation of these promising interventions (Verdejo-Garcia, 2016; Zilverstand et al., 2016).

1.8. What are the psychological mechanisms of action of CBM?

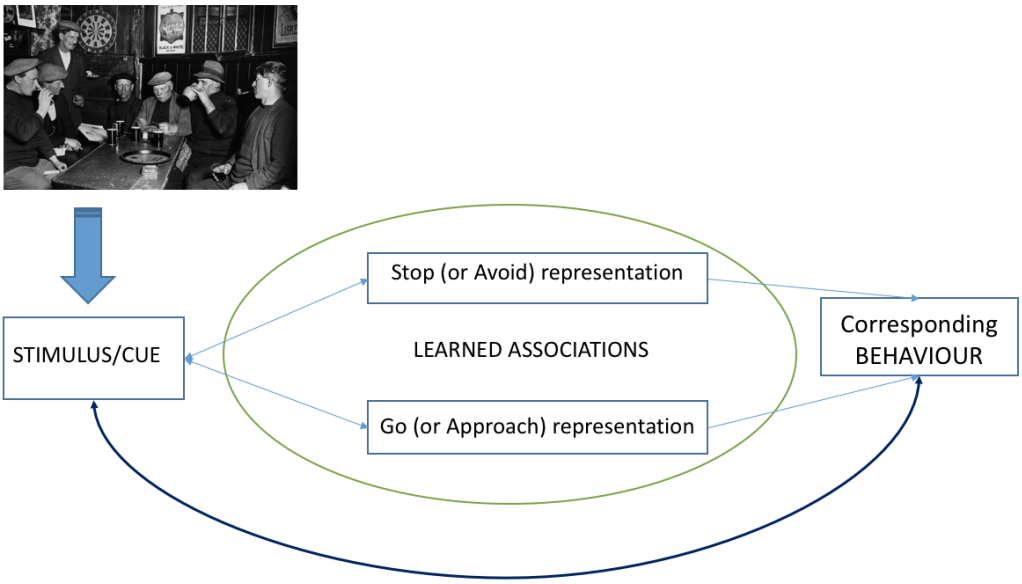
As summarised above, CBM interventions were developed from validated tasks that were used for the assessment of cognitive processing biases. They have been initially investigated in laboratory settings with samples of healthy participants (typically students) relative to a control group which did not receive the training. Most of the available evidence confirms the effectiveness of these interventions in the laboratory, and this justifies the investigation of the effectiveness of multiple sessions of CBM in RCTs with clinical populations (Allom, Mullan & Hagger, 2015; Gladwin et al., 2016; Jones et al., 2016b, 2017; Kakoschke et al., 2017a). However, despite these promising effects there is a need for more research to understand the effectiveness and mechanisms of action of CBM (Cristea, Kok &Cuijpers, 2016; Jones et al., 2017). Three main mechanisms of action have been proposed, as detailed below (for a review see Veling et al., 2017b).

1.8.1 Stimulus associations

The most influential explanation is that avoidance or inhibition are 'associatively mediated' in such a way that repeatedly avoiding or refraining from responding to motivationally-salient cues (e.g. alcohol stimuli), leads to the formation respectively of stimulus-avoidance (CAT) or stimulus-stop associations (ICT). Consequently, these learned associations should be manifested as automatic avoidance or inhibition when those cues are next encountered (Verbruggen et al., 2014). For a schematic overview see figure 1.4.

Figure 1.4 Schematic overview of the stimulus association hypothesis.

Behavioural avoidance or inhibition are associatively mediated. By repeatedly avoiding or refraining from responding to appetitive stimuli (e.g. alcohol stimuli), leads to the formation respectively of stimulus-avoidance or stimulus-stop associations. Consequently, these learned associations manifest as automatic avoidance or inhibition when those cues are next encountered (see Verbruggen, McLaren and Chambers, 2014).



Findings from CAT laboratory studies corroborate this view (Gladwin, Wiers & Wiers, 2016; Kakoschke et al., 2017a). They demonstrate that a single session of this intervention strengthens alcohol-avoidance associations (not positive and negative associations, as argued by Veling et al., 2008, see section below) and affects drinking outcomes among non-dependent heavy drinkers (Wiers et al., 2010; Sharbanee et al., 2014) and in alcohol dependent patients (Wiers et al., 2011; Eberl et al., 2013; Gladwin et al., 2015; Manning et al., 2016).

Furthermore, in some of these clinical studies these behavioural changes were mediated by changes in alcohol-avoidance associations (Wiers et al., 2011; Eberl et al., 2013; Gladwin et al., 2015), although this was not observed in a more recent randomised controlled trial (Manning et al., 2016). Additionally, a recent study that re-trained approach-avoidance tendencies to chocolate, via an approach-avoidance

IAT, showed that individuals trained to approach, relative to individuals trained to avoid, reported stronger cravings and approach tendencies (Kemps, Tiggemann, Martin, & Elliott, 2013). Similarly, alcohol dependent patients showed stronger implicit approach associations (via an approach-avoidance IAT) to alcohol, relative to controls (C. E. Wiers et al., 2017).

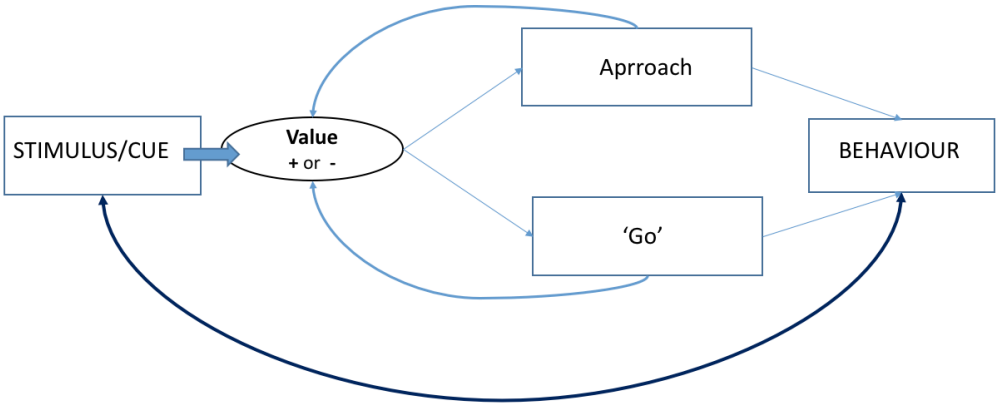
Similarly, ICT studies in both addiction and appetite research have shown that a single session creates stimulus-stop associations, which is inferred from the slowing of RTs during exposure to cues that were previously paired with behavioural inhibition (Verbruggen and Logan, 2008a, 2009; Chiu and Aron, 2014; Best et al., 2015; Bowditch, Verbruggen and Mclaren, 2016; Houben and Jansen, 2015), and this leads to reduced consumption in the laboratory (Jones et al., 2016b; Allom, Mullan and Hagger, 2015). This view is further corroborated by findings from a meta-analysis published by our group which shows that failures to inhibit to alcohol or food cues during ICT diminished the effect of ICT on alcohol or food intake in the laboratory, possibly because these failures to inhibit weakened the association between cues and successful response inhibition (Jones et al., 2016b).

1.8.2 Devaluation hypothesis

According to the Behavioural Stimulus Interaction (BSI) theory (Veling et al., 2008), appetitive stimuli automatically evoke appetitive tendencies (e.g. approach and 'going'), whereas aversive stimuli automatically evoke avoidance tendencies (e.g. avoidance and 'stopping'). Importantly, there are reciprocal causal relationships between perceived valence, approach / avoidance, and going versus stopping. Thus, the implication is that by actively and repeatedly inhibiting (or avoiding) a stimulus, this leads to the spontaneous devaluation of the stimulus itself (reduction of the stimulus hedonic value), which consequently weakens the potency of the impulse triggered by the stimulus (Veling et al., 2008; Havermans & Jansen, 2003). For a schematic overview see figure 1.5.

Figure 1.5 Schematic overview of the devaluation hypothesis.

Appetitive stimuli (a reward related stimulus, with a positive hedonic value) triggers strong appetitive tendencies. Whereas, when an aversive stimulus is encountered, the automatic response is to suppress the motor action (or avoid them). By actively and repeatedly inhibiting (or avoiding) the stimulus, this leads to the spontaneous devaluation of the stimulus itself (reduction of the stimulus' hedonic value), which consequently weakens the potency of the impulse triggered by the stimulus (see Veling et al., 2008).



Guitart-Masip and colleagues (2014) propose a similar model which describes motivated behaviour as the results of interactive processes between valence (positive or negative) and action execution (or behavioural inhibition or avoidance). A study by Veling, Aarts and Stroebe (2013a) support these views, whereby after pairing palatable foods with 'stop cues' in a GNGT, the subsequent choice of those foods decreased and this effect was mediated by a decrease in positive evaluation of those snacks. Several other studies have supported this hypothesis and demonstrated that stimuli paired with inhibition of behaviour (Ferrey, Frischen, & Fenske, 2012; Houben & Jansen, 2015; Kemps et al., 2013; Schonberg et al., 2014; Veling et al., 2017a; Veling, Aarts, & Papies, 2011; Veling, Aarts, & Stroebe, 2013a; Veling et al., 2017b; Wessel, Doherty, Berkebile, Linderman, & Aron, 2014) or overt avoidance responses (Kemps et al., 2013; Schonberg et al., 2014; Woud et al., 2013b) are evaluated more negatively, than stimuli paired with behavioural responding or

approach. In particular, findings from two ICT studies demonstrated that the reduction in alcohol consumption after a single training session was accompanied by changes in automatic evaluations of alcohol pictures, which became more negative after ICT (Houben et al., 2011, 2012).

Despite these positive findings, the overall literature with regards to the devaluation hypothesis is more mixed. A recent meta-analysis of ICT studies found no overall effect of ICT (versus a control manipulation) on stimulus devaluation when this was measured by implicit tasks, such as the IAT (Jones et al., 2016b). Devaluation effects, therefore, may be more robust when different measures of stimulus valuation such as subjective ratings or auction tasks are used (Veling, Holland & van Knippenberg, 2008; Ferrey, Frischen & Fenske, 2012; Wessel et al., 2014; Lawrence et al., 2015a; Veling et al., 2017b; although see Wiers, Stelzel, Gladwin, Park, et al., 2015).

Finally, it is important to note that the stimulus associations and the devaluation hypotheses are not mutually exclusive, and indeed they are unlikely to be. The formation of automatic alcohol-avoidance or alcohol-inhibition associations may ultimately lead to changes in drinking behaviour through a shared mechanism; namely both types of associations may lead to devaluation of alcohol-related cues, which in turn may blunt the ability of those cues to influence behaviour (see Guitart-Masip et al., 2014; Veling, Holland, & van Knippenberg, 2008).

1.8.3 Alternative hypotheses

An alternative assumption focuses on how CBM may in fact train individuals to attend more to stimuli paired with inhibition or avoidance (Anderson, Laurent, & Yantis, 2011; Stice et al., 2016). Recent work from a pilot trial on overweight and obese individuals, showed that individuals in the active ICT group relative to the control group reduced body fat, palatability and monetary ratings and attention towards high-calorie foods that were paired to inhibition during training, relative to low-calorie foods paired with responding (Stice et al., 2016). Additionally, these implicit and explicit behavioural were mirrored in the neural activity, showing decreases in the ICT group relative to the control group in regions implicated in both reward processing and attention. Similar findings were observed by Schonberg and colleagues (2014), showing that training motor approach towards specific high-calorie snacks and not others, increased the activation of brain regions implicated

with the processing of stimulus reward assessed via fMRI, and increased the approach behaviour, choice and attention towards these snacks paired with response. However, training effects on attention were observed also for food that were not chosen (i.e. paired with inhibition). However, not many studies have examined deliberately the hypothesis that ICT and CAT effectiveness may be mediated by subsequent changes in attentional process.

Finally, a further alternative explanation for the effects of ICT is that, rather than training participants to exercise inhibition in response to appetitive cues, the intervention works because it trains people to rapidly detect 'No-Go' or stop cues. An important implication of this explanation is that cues paired with inhibition during ICT may only automatically evoke inhibition in the same context in which ICT occurred; if cues are presented in a different context, behaviour will be unaffected. Specifically, Verbruggen et al. (2014) argued that the detection of the stop signal is one of the three cognitive processes that underpins successful inhibition (action control). This account is supported by a number of observations, including that reaction time slowing is seen when irrelevant perceptual distractors are introduced in the SST, indicating that a proportion of stopping latency is occupied by perceptual processes (Logan et al., 2014). Consequently, ICT signals may lead to improvements in the ability to detect these signals, primed by the associations, which indirectly improves general behavioural inhibition and affects behaviour.

1.9. Interim summary, and overview of empirical chapters, aims and hypotheses

1.9.1 Interim summary

This chapter has so far reviewed the major cognitive processes and the theories involved in the development and maintenance of addiction, with a focus on alcohol use disorders and other harmful behaviours. It has reviewed Dual process models which distinguish between automatic and controlled processes, and argued that these processes, and deficits in inhibitory control, increase vulnerability for substance misuse (Gladwin & Figner, 2014). It further described evidence, components and methods of assessment of automatic and controlled processes, specifying the key role they play in the development and maintenance of harmful behaviours, with a focus on alcohol problems (Wiers et al., 2007).

With regards to Dual process models, attention has focused on their clinical implications and applicability to the real-world, highlighting the important contribution of CBM interventions. According to most of the evidence discussed, CBM are promising interventions that aim to change risky behaviours by reversing cognitive biases (Allom Mullan & Hagger, 2015; Gladwin, Wiers, & Wiers, 2017; Jones et al., 2016b; Kakoschke et al., 2017a; Verdejo-Garcia, 2016). In particular, I discussed two interventions that proved to be successful in reducing alcohol (and unhealthy snacking) consumption: the CAT reversing implicit approach biases (Wiers et al., 2010) and ICT which strengthens associations between appetitive cues and automatic engagement of response inhibition (Houben et al., 2012).

With regards to the neurobiological underpinnings of CBM, the thesis described structural changes related to substance misuse and how specifically these two CBM interventions might partially reverse or compensate for these structural changes. So, for example, by decreasing the amplitude of ERPs linked to the processing of motivationally relevant stimuli (e.g. alcohol stimuli) or increasing the amplitude of components related with inhibitory control (Lapenta, Sierve, de Macedo, Fregni, & Boggio, 2014; Littel, Euser, Munafò, & Franken, 2012; Zilverstand et al., 2016). However, the neuro-imaging CBM literature is still in its infancy (Wiers & Wiers, 2016).

Finally, I provided an overview of different theoretical accounts of the mechanism of action of CBM. One hypothesis argues that training effectiveness is observed due to changes in devaluation of appetitive stimuli (devaluation hypothesis; Veling et al., 2008). It is suggested that these changes occur via learned stimulus-response associations (stimulus association hypothesis; which can stand alone or interact with the devaluation hypothesis). Finally, alternative accounts focus on changes in attentional process related to the stimulus-pairing learned, or improvements in the detection of the signal to inhibit (or avoid; Verbruggen et al. 2014; Veling et al., 2017b), or less likely targets improvements in the general inhibitory control capacity (Jones et al., 2017).

1.9.2 Overall aims of the thesis and justification for the general approach

The specific aims of the thesis are to (1) compare the effectiveness of CAT and ICT interventions for the reduction of alcohol consumption in the laboratory; (2) investigate their effectiveness in a 'real-word' settings; (3) elucidate which of the

proposed mechanisms of action are most likely to explain their effectiveness; and (4) clarify the neural mechanisms of CBM using electroencephalography (EEG). These questions are relevant for a number of reasons. First, each of these aims contributes to the broader goal of optimising these interventions in order to improve their effectiveness before evaluating them in the real world with RCTs. Secondly, this work will improve our understanding of the relationships between these cognitive processes and motivated behaviour. Finally, identification of the underlying mechanisms and generalizability of CBM will aid the development of theoretical models of CBM and cognitive processes in addiction.

It is important to acknowledge that although the present thesis is focussed on the broad construct of addiction, I studied the effects of CBM with two types of appetitive stimuli; alcohol and chocolate. This focus is justified because appetitive behaviours (towards either alcohol and chocolate) have been the focus of the majority of previous research in this area (see: Allom, Mullan & Hagger, 2015; Jones et al., 2016b, 2017; Kakoschke et al., 2017; Stice, Lawrence, Kemps, & Veling, 2016; Veling et al., 2017b; Wiers et al., 2013a). Further justification is provided by brain imaging studies which demonstrate similar brain mechanisms that underlie automatic cognitive processing biases and behavioural control linked to both types of appetitive stimuli (Burger & Stice, 2011; Carnell et al., 2012; Parvaz, 2012). It is additionally supported by a recent model which argues that there is an overlap between addiction and obesity pathways (Volkow et al., 2008).

1.9.3 Thesis outline

The current thesis contains six empirical chapters, each of which aims to shed light on two main research questions, (1) the effectiveness of CAT and ICT for the reduction of consumption or choice, and (2) the mechanisms underpinning their effectiveness. Specifically, in the first two chapters the focus is on the question of the effectiveness of these interventions in reducing alcohol consumption. This is done by comparing these two interventions and examining their effects in an ecologically valid setting. The following chapters investigate, separately, the neural correlates and the proposed psychological mechanisms of action that mediate the effects of CBM.

Chapter Two is focused on replicating findings in the literature of reductions on ad-libitum alcohol consumption as a result of a single brief dose of CAT or ICT in the laboratory (Jones et al., 2016b; Kakoschke et al., 2017a). Additionally, it directly

compares for the first time in literature the effectiveness of both types of trainings, and it investigates whether they led to theoretically predicted changes in implicit hedonic evaluations of alcohol stimuli (devaluation hypothesis), via the formation of alcohol-avoidance (in the CAT group) or alcohol-inhibition (in the ICT group) associations, learned during the respective trainings (stimuli association hypothesis).

The study described in *Chapter Three* seeks to extend previous results, by investigating if effects of ICT on drinking behaviour persist in a lounge laboratory after exposure to alcohol TV advertisements.

The study presented in *Chapter Four* seeks to identify the brain mechanisms that underlie the effects of a single session of alcohol-CAT in the laboratory. To the best of our knowledge, this study is the first attempt to focus on the effects of CAT on ERPs and readiness potentials, during the motor preparation to approach or avoid alcohol cues.

Chapter Five describes two cross-sectional studies which investigate whether implicit associations (positive vs. negative or approach vs. avoidance associations) of chocolate pictures underpin both automatic approach tendencies and inhibitory control processes.

Chapter Six presents a more direct and comprehensive test of the devaluation hypothesis of ICT and of the alternative attentional account. This was done by measuring both subjective ratings and behavioural choice to assess devaluation effects during a probe task in which eye movements were recorded, in order to test predictions that cues paired with inhibition are chosen and attended to less frequently, and evaluated more negatively. The design of this study is informed by the decision making literature which shows that attention, behavioural choice and preference are each determined by stimulus evaluation (Izuma et al., 2010; Krajbich & Rangel, 2011; Lim, O'Doherty, & Rangel, 2011; Sharot, De Martino, & Dolan, 2009).

The experiment described in *Chapter Seven* directly investigates an alternative explanation of ICT effects, namely the signal detection hypothesis (Veling et al., 2017b; Verbruggen et al., 2014). It investigates this hypothesis by comparing it to the associative hypothesis, as they make different behavioural predictions about changes in reaction times to appetitive cues after ICT depending on the testing context.

Chapter Eight provides a summary and general discussion of the overall findings of the thesis by linking them to theories and evidence discussed in this introductory chapter. An important part of this last chapter is devoted to discussing and explaining the underlying mechanism of action CBM. It furthermore considers limitations that affected the experiments and suggest new direction for future CBM research.

Chapter Two

Cue Avoidance Training and Inhibitory Control Training for the reduction of alcohol consumption: a comparison of effectiveness and investigation of their mechanisms of action

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The present experiment was designed in order to directly compare the effectiveness of Cue Avoidance Training (CAT) and Inhibitory Control Training (ICT) in reducing alcohol consumption in the laboratory. Additionally, I examined if these interventions lead to the theoretically predicted changes in alcohol-avoidance (CAT) or alcohol-inhibition (ICT) associations, and if they influence implicit evaluations of alcohol cues (Gladwin et al., 2016; Veling et al., 2017b).

This chapter has been published in Psychopharmacology (Di Lemma & Field, 2017). The reviewers requested supplementary analyses which were added mostly in the supplementary materials section of the manuscript; this is presented as such in the thesis in Appendix A (page 215). The content, format and presentation has been altered to be consistent with the present thesis structure.

The roles of the authors of the paper version in regards to publication are summarized below: I designed the study, which was reviewed and approved by Matt Field (primary supervisor). I collected, analysed the data and I wrote the manuscript. Matt Field gave comments at all stages of the study and reviewed the manuscript before submission and following peer review.

2.1. Abstract

Rationale: Both Cue Avoidance Training (CAT) and Inhibitory Control Training (ICT) reduce alcohol consumption in the laboratory. However, these interventions have never been directly compared and their mechanisms of action are poorly understood.

Objectives: I compared the effects of both types of training on alcohol consumption, and investigated if they led to theoretically predicted changes in alcohol-avoidance (CAT) or alcohol-inhibition (ICT) associations, and changes in evaluation of alcohol cues.

Methods: Heavy drinking young adults (N=120) were randomly assigned to one of four groups: (1) CAT (repeatedly pushing alcohol cues away with a joystick), (2) sham (control) CAT; (3) ICT (repeatedly inhibiting behaviour in response to alcohol cues); or (4) sham (control) ICT. Changes in reaction times and automatic evaluations of alcohol cues were assessed before and after training using assessment versions of tasks used in training and the implicit association test (IAT), respectively. Finally, participants completed a bogus taste-test as a measure of ad-libitum alcohol consumption

Results: Compared to sham conditions, CAT and ICT both led to reduced alcohol consumption although there was no difference between the two. Neither intervention affected performance on the IAT, and changes in reaction time did not suggest the formation of robust alcohol-avoidance (CAT) or alcohol-inhibition (ICT) associations after training.

Conclusions: CAT and ICT yielded equivalent reductions in alcohol consumption in the laboratory. However, these behavioural effects were not accompanied by devaluation of stimuli or the formation of alcohol-avoidance or alcohol-inhibition associations.

Keywords: alcohol, cognitive bias modification, devaluation, inhibitory control.

2.2. Introduction

According to dual-process models of addiction, loss of control over substance use arises from conflict between two partially independent systems: a fast 'impulsive' system that is triggered by automatic appetitive responses to substance-

related cues, and a slower 'reflective' system that is dependent on the integrity of executive functions which are weakened by chronic substance use and exposure to substance-related cues (Wiers et al., 2007; Hofmann, Friese & Strack, 2009; Gladwin & Figner, 2014; McClure & Bickel, 2014).

Regarding automatic processes, there is compelling evidence that alcohol related-cues evoke automatic approach tendencies. The strength of these tendencies can be assessed with the Approach Avoidance task (AAT; Wiers et al., 2009) or related tasks (Field, Kiernan, Eastwood, & Child, 2008). For example, during the AAT participants are instructed to 'approach' or 'avoid' alcohol or control pictures by moving a joystick towards or away from them. A number of studies with non-dependent drinkers have confirmed that, compared to light drinkers, heavy drinkers are faster when required to approach rather than avoid alcohol-related pictures (see Kersbergen, Woud, & Field, 2015; Watson, de Wit, Hommel, & Wiers, 2012).

Regarding reflective processes, heavy drinkers have impaired executive functions, including the ability to inhibit behaviour (Smith et al., 2014). Furthermore, alcohol-related cues may exacerbate these deficits (Jones & Field, 2015; Petit et al., 2012). Inhibitory control is typically assessed with computerized tasks such as the Go/No-Go and Stop-Signal tasks, both of which require participants to respond rapidly but inhibit responding when infrequent 'stop' or 'no-go' signals are presented (Verbruggen et al., 2014). A recent meta-analysis demonstrated that heavy drinkers perform poorly on these tasks, and this effect is robust across studies (Smith, Mattick, Jamadar, & Iredale, 2014). Other studies have demonstrated that the presence of alcohol-related cues impairs inhibitory control among alcohol consumers (Jones & Field, 2015; Petit et al., 2012).

Dual-process models have implications for the prevention and treatment of addiction. Specifically, the aim of 'Cognitive Bias Modification' (CBM) is to extinguish or reverse the aforementioned cognitive biases in order to reduce drinking behavior (Gladwin et al., 2016; Wiers et al., 2013a). For example, in Cue Avoidance Training (CAT; Wiers et al., 2011), participants practice making avoidance movements in response to alcohol-related cues, whereas in Inhibitory Control Training (ICT; Houben et al., 2011) participants practice inhibiting their behaviour in response to alcohol cues. The aim of both types of CBM is to alter participants' alcohol-related automatic associations so that alcohol cues will evoke more adaptive responses when they are encountered after CBM.

Development and initial evaluation of CBM interventions typically begins with laboratory studies which investigate the effects of a brief 'dose' of CBM on a behavioural measure of the motivation to drink (such as a bogus 'taste test'; see Jones et al., 2016a), in comparison to a matched control intervention. If these laboratory studies suggest that CBM can reduce the motivation to drink, this provides strong justification for evaluating the effectiveness of multiple sessions of CBM in clinical populations, ideally using randomized controlled trials (RCTs) (Allom, Mullan & Hagger, 2015; Gladwin et al., 2016; Jones, et al., 2016b; Kakoschke et al., 2017a).

Laboratory studies of CAT (see Kakoschke, Kemps and Tiggemann, 2017a) have demonstrated that a single session of this intervention strengthens alcohol-avoidance associations and reduces alcohol consumption, among non-dependent heavy drinkers (Wiers et al., 2010; Sharbanee et al., 2014). Subsequent trials of CAT with alcohol-dependent patients demonstrated a reduced likelihood of relapse after CAT (compared to a control intervention; Wiers et al., 2011; Eberl et al., 2013; Gladwin et al., 2015; Manning et al., 2016). These effects of CAT on drinking outcomes were mediated by changes in alcohol-avoidance associations in some of these clinical studies (Wiers et al., 2011; Eberl et al., 2013; Gladwin et al., 2015), although this was not observed in a more recent study (Manning et al., 2016). Similarly, several studies have demonstrated that a single session of ICT leads to reduced alcohol (or food) consumption in the laboratory (relative to a control intervention), and two recent meta-analyses of these findings have confirmed that this effect is small but robust across studies (Standardized Mean Difference (SMD) = 0.43 in Jones et al., 2016b; and SMD = 0.38 in Allom, Mullan & Hagger, 2015). There is also some evidence that these effects may persist to influence drinking outside of the laboratory (see Allom, Mullan & Hagger, 2015), although to date there are no published trials that investigated the effectiveness of multiple sessions of ICT for alcohol-dependent patients.

Despite these promising effects on drinking behaviour in the laboratory and outcomes after treatment, more research is needed to clarify the mechanisms of action of CBM. The most parsimonious explanation is that avoidance (and inhibition) can be associatively mediated, such that repeatedly avoiding motivationally-salient cues, or refraining from responding when exposed to those cues, leads to the formation of stimulus-avoidance (CAT) or stimulus-stop

associations (ICT), respectively. Subsequently, these learned associations should manifest as automatic avoidance or inhibition when those cues are next encountered (Verbruggen, McLaren and Chambers, 2014). The findings discussed above regarding the formation of alcohol-avoidance associations after CAT, and their importance as mediators of effects of CAT on drinking behaviour, are consistent with this view (see Gladwin, Wiers & Wiers, 2016; Kakoschke et al., 2017a). Regarding ICT, numerous studies have demonstrated the formation of 'stopping' associations (inferred from slowing of reaction times) when arbitrary cues are paired with inhibition of behaviour (Verbruggen and Logan, 2008a,b, 2009; Chiu and Aron, 2014; Best et al., 2015; Bowditch, Verbruggen & Mclaren, 2016; Houben & Jansen, 2015). In our recent meta-analysis of applied studies, we demonstrated that failures to inhibit during ICT diminished the effect of ICT on eating and drinking behaviour in the laboratory, presumably because each inhibition failure weakens the association between target cues and successful inhibition (Jones et al., 2016b).

Formation of automatic alcohol-avoidance or alcohol-inhibition associations may ultimately lead to changes in drinking behaviour through a shared mechanism; namely both types of associations may lead to devaluation of alcohol-related cues, which in turn may blunt the ability of those cues to influence behaviour (see Guitart-Masip et al., 2014; Veling, Holland, & Van Knippenberg, 2008). A number of studies have demonstrated that stimuli paired with inhibition of behaviour (Veling, Aarts & Papies, 2011; Ferrey, Frischen & Fenske, 2012; Veling, Aarts & Stroebe, 2013a; Wessel et al., 2014) or overt avoidance responses (Kemps et al., 2013; Schonberg et al., 2014; Woud et al., 2013b) are evaluated more negatively than stimuli paired with behavioural responding or overt approach, respectively. Particularly relevant here are findings from two studies which demonstrated that a reduction in alcohol consumption after a single session of ICT was accompanied by changes in automatic evaluations of alcohol pictures, which became more negative after ICT (Houben et al., 2011, 2012).

To our knowledge, no previous study has contrasted the effects of CAT and ICT on alcohol consumption in the laboratory, or investigated if both interventions yield equivalent changes in devaluation of alcohol-related cues. The primary aim of the present study was to investigate if both CAT and ICT would be equally effective at reducing alcohol consumption, relative to appropriate control groups ('Sham' training conditions which apply a 50% contingency; Kakoschke et al., 2017a). Our

secondary aim was to investigate if these interventions would lead to the development of alcohol-avoidance (CAT) or alcohol-inhibition (ICT) associations, and if changes in these associations would be accompanied by equivalent changes in automatic evaluations of alcohol-related cues.

2.3. Method

2.3.1 Participants

One hundred and twenty (86 females, 34 males) heavy drinkers were recruited from staff and students at the University of Liverpool via online and poster advertising. Inclusion criteria included average weekly alcohol consumption in excess of the United Kingdom Department of Health guidelines (at the time, these were 14 and 21 units per week for females and males respectively; note that these guidelines were revised in January 2016, after completion of this study). Participants were also required to be aged between 18 and 25, fluent in English, have normal or corrected to normal vision and no history of alcohol use disorders. The study was approved by the University of Liverpool Research Ethics Committee.

2.3.2 Design

A mixed design was employed. Participants were randomly assigned to one of four groups (using an online random number generator) that reflected the between-subjects factors of training type (CAT or ICT) and condition (active training or sham training). The within-subjects factor was time because assessment tasks (IAT, AAT, and GNGT) were administered before the training (pre-test) and afterwards (post-test).

2.3.3 Materials

Self-report measures

Participants were asked to complete the two-week Timeline Follow-Back Diary (TLFB), followed by the Alcohol Use Disorders Identification Test (AUDIT), the Temptation and Restraint Inventory (TRI), the Contemplation Ladder (CL) and the Readiness to Change Questionnaire (RTCQ). Finally, participants completed questions on their awareness of the aim of the experiment, questions and

participants' responses are reported in supplementary materials (see Appendix A, page 216). These self-report measures were incorporated in order to provide information about participants' alcohol consumption in orde to fully characterize the sample.

The *TLFB* (Sobell & Sobell, 1992) is a drinking diary that allows participants to recall and record retrospectively their alcohol consumption over the past two weeks. From the TLFB we derived a frequency measure of their alcohol consumption over the two weeks. The TLFB have been shown to have good psychometric properties with different drinking populations and to be a reliable method overall (Sobell and Sobell, 1995).

The *AUDIT* (Saunders et al., 1993) is a ten-item self-report questionnaire which measures hazardous pattern of alcohol consumption or dependence. Respondents are asked to rate how strongly each item on a 4-point Likert scale. A final score of 8 or more is associated with hazardous drinking, while a score of 13 (females) or 15 (males) or more, indicates alcohol dependence. These questionnaires have been shown to be highly reliable and consistent.

The *TRI* (Collins and Lapp, 1992) consists of a fifteen-item self-report measure of temptation and restrain rated on a 9-point Likert scale, where one refers to a lack of preoccupation and nine to intense preoccupation. The scale is formed by 5-factors: Govern (difficulty in controlling alcohol intake), Restrict (attempts to limit drinking), Emotion (negative affect as an emotion for drinking), Concern about drinking (plans to reduce intake/preoccupation about controlling drinking) Cognitive Preoccupation (thoughts about drinking). These factors form two higher-order factors: Cognitive Emotional Preoccupation (CEP, composed by Govern, Emotion and Cognitive preoccupation) which measures the temptation to drink and Cognitive

Behavioral Control (CBC, composed by Restrict and Concern about drinking) which measures the control/restriction on drinking. Previous validation studies have demonstrated the validity and internal reliability of the questionnaire (Collins, Koutsky and Izzo, 2000; Connors et al., 1998).

The *CL* (Biener and Abrams, 1991; Amodei and lamb, 2004; Hogue, Dauber, & Morgenstern, 2010) is a questionnaire designed as a ladder, with an 11-point Likert scale indicating different stages of motivation to change. The questionnaire measures the readiness to abstain from drinking. The ladder was developed on the basis of the Contemplation Ladder for smoking and it has been shown to have good concurrent validity and to predict smoking cessation (Biener and Abrams, 1991; Abrams and Biener, 1992; McDermunt and Haaga, 1998).

The *RTCQ* (Rollnick, Heather, Gold, & Hall, 1992) is a 12-item scale measuring the "stage of change" in which the heavy drinker taking the test falls into. The scale was developed as a part of a larger study by the National Drug and Alcohol Research Centre (NDARC). The scale was based on the stages of change model (Prochaska and DiClemente, 1986) which describes the different stages in which an individual with an addiction moves through in order to resolve his addiction: e.g. "Pre-contemplation", "Contemplation", "Action" and "Maintenance"; usually taking many cycles (relapse) before resolving their addiction. Validation studies have demonstrated satisfactory internal reliability and good concurrent validity of the questionnaire (Heather and Rollnick, 1993).

Experimental Tasks

Computer tasks were presented on a Dell desktop computer with a 15" monitor. Participants responded using a standard keyboard and a joystick. Tasks

were programmed and administered in Inquisit version 3.0 (Millisecond Software, 2009).

Twenty pairs of alcohol-related and matched neutral (control) pictures were used in the computer tasks (Barkby, Dickson, Roper, & Field, 2012; Field et al., 2004). Alcohol pictures depicted alcoholic drinks (e.g., bottles or glasses) and drinking scenes (e.g., models holding a beverage or drinking it) and each was matched to a neutral picture that depicted stationery (e.g., pens, staplers) and models using those items (e.g. holding pens or stapling paper).

Approach Avoidance Task (AAT) and Cue Avoidance Training (CAT; based on Wiers et al., 2010)

During each trial, an alcohol-related or control picture was presented in the centre of the screen and participants were required to rapidly categorize pictures according to their spatial orientation (landscape or portrait), but to ignore the content of the pictures. Participants were instructed to 'approach' pictures presented in one format (e.g., portrait orientation) by pulling the joystick towards them, and 'avoid' pictures presented in the other format (e.g., landscape orientation) by pushing the joystick away. During each trial the picture remained on screen until the participant responded or until a 1000 ms timeout had elapsed. Correct approach responses caused a zooming effect (the picture became larger), and correct avoidance responses caused a shrinking effect (the picture became smaller). Incorrect responses or failure to respond in time led to error feedback in the form of a red cross displayed in the centre of the screen for 500 ms.

The task comprised four blocks: a brief practice block (10 trials), a pre-test assessment block (80 trials), the cue avoidance or sham training block (480 trials, with a short break half-way through) and a post-test assessment block (80 trials). Participants were not informed when the task switched between assessment and training blocks. Picture format was counterbalanced, with half of participants instructed to pull landscape and avoid portrait format pictures, and reversed instructions for the remaining participants. Participants were required to make an equal number of push and pull responses in all blocks. Trial order within each block was randomized.

The pre-test and post-test assessment blocks were identical, and each contained 50% alcohol and 50% control pictures, half of each in portrait format and

half in landscape format. In these blocks, participants had to approach and avoid alcohol and control pictures with equal frequency. In the training block (in which only a subset of 10 of the alcohol-related and 10 matched control pictures were used; see supplementary materials), for participants in the active training group 90% of alcohol pictures were presented in the format requiring an avoidance movement, whereas 90% of control pictures were presented in the format requiring an approach movement. For participants in the sham training group, 50% of both alcohol and control pictures were presented in the format requiring an avoidance movement with the remaining requiring an approach movement.

Go/No-Go task (GNG) and Inhibitory Control Training (ICT; based on Houben et al., 2012)

During each trial, an alcohol-related or control picture was presented in the centre of the screen with one of two letters ('p' or 'f') superimposed on one of the four corners of the picture. Participants were instructed to press the space bar if the Go cue ('p') was present, but to withhold their response if the No-Go cue ('f') was present. During each trial the picture and letter remained on screen until the participant responded or until a 1500 ms timeout had elapsed. Feedback was presented on each trial: a centrally presented green circle (500 ms) for correct responding (pressing the spacebar before the 1500 ms timeout on Go trials, and successfully withheld responses on No-Go trials), and a red cross (500 ms) for incorrect responding (omission errors on Go trials and commission errors on No-Go trials).

The task comprised four blocks: a brief practice block (10 trials), a pre-test assessment block (80 trials), the inhibitory control or sham training block (480 trials, with a short break half way through) and a post-test assessment (80 trials). Participants were not informed when the task switched between assessment and training blocks. Trial order within each block was randomized.

The pre-test and post-test assessment blocks were identical. Each contained 50% alcohol and 50% control pictures, half of each accompanied by Go and No-Go cues, therefore participants had to respond and inhibit to alcohol and control pictures with equal frequency. In the training block (in which only a subset of 10 of the alcohol-related and 10 matched control pictures were used; see supplementary materials), for participants in the active training group 90% of alcohol pictures were

accompanied by No-Go cues, whereas 90% of control pictures were accompanied by Go cues. For participants in the sham training group, 50% of both alcohol and control pictures were accompanied by No-Go cues, and the remainder were accompanied by Go cues.

Pictorial Implicit Association task (IAT)

I adapted a bipolar alcohol valence IAT (described in Houben et al., 2012), which is a categorization task that assesses the strength of associations between alcohol pictures and valenced words. Participants were instructed to rapidly categorize stimuli into two target categories (alcohol or stationery) and two attribute categories (positive or negative valence), by responding with one of two different response keys. The rationale is that participants should be faster to categorize targets and attributes that are strongly associated (e.g., alcohol pictures and positively valenced words) during blocks of the task in which the target and attribute share a response key. A complete description of the task is provided in supplementary materials (see Appendix A, page 215).

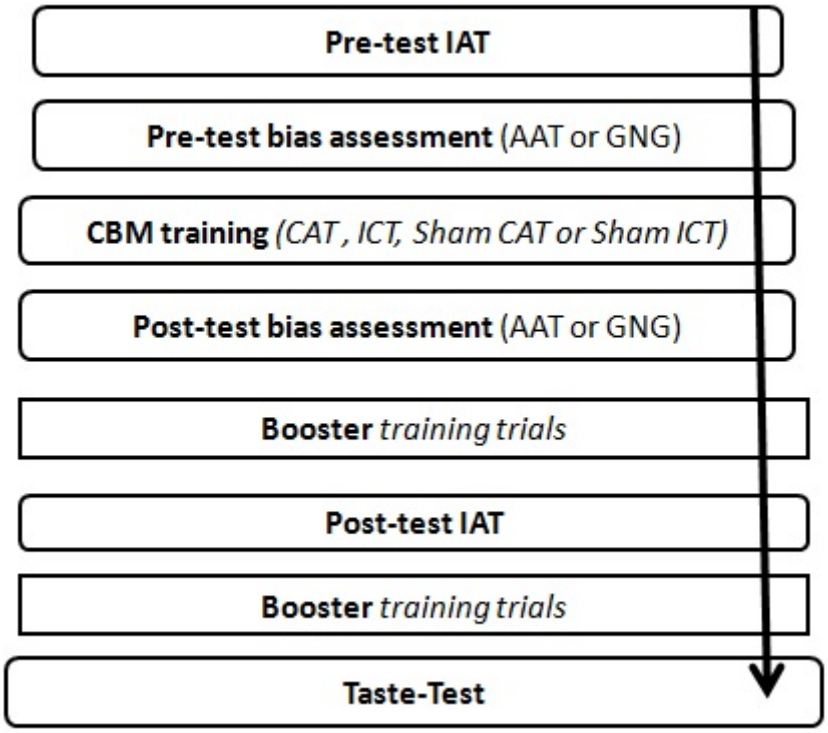
2.3.4 Procedure (Figure 2.1)

Participants were advised that the aim of the study was to investigate relationships between cognitive performance and individual differences in drinking habits. Testing sessions took place between 12:00 and 19:00 in a quiet laboratory. Participants provided informed consent and a breathalyser reading (all participants had a breath alcohol content of zero), before being seated at a desk approximately 1m away from the computer monitor. Participants completed the pre-test IAT followed by the pre-test AAT or GNG task (depending on group allocation). They then completed the training block of the CAT or ICT before immediately completing the post-test assessment (AAT or GNG task). Participants then completed an additional 80 'booster' CAT or ICT training trials (with the same contingencies that were applied during the training block) before completing the post-test IAT. They then completed a further 80 'booster' trials before completing the alcohol taste-test: Four chilled drinks (200ml each) were presented simultaneously: beer (Fosters, 4% alcohol by volume (ABV)), cider (Magners original, 4.5% ABV) and two soft drinks (Coca Cola and Fanta Orange). Participants were instructed to rate and rank each drink on 10 different characteristics (e.g. fruitiest, sweetest and fizziest; see Jones et

al., 2011), and they were informed that they could "drink as much or as little as they liked in order to give a valid answer to the questions". After 10 minutes had elapsed, the drinks were removed and the volume of each drink consumed was recorded, out of sight of the participant.

Participants then provided general demographic information and completed the following battery of questionnaires: a two week Timeline Follow-Back retrospective alcohol diary (TLFB; Sobell & Sobell, 1992), the Alcohol Use Disorders Identification Test (AUDIT; Saunders et al., 1993), the Temptation and Restraint Inventory (TRI; Collins & Lapp, 1992), the Contemplation Ladder (CL; Biener & Abrams, 1991; Hogue, Dauber, & Morgenstern, 2010), and the Readiness to Change Questionnaire (RTCQ; Rollnick, Heather, Gold, & Hall, 1992). Participants' awareness of the experimental hypotheses was assessed using a funnelled debriefing self-report measure adapted from previous studies (Jones & Field, 2013). I assessed participants' beliefs about the general aims of the experiment, and their awareness of the purpose of the training and the taste-test; the wording of questions and participants' responses are reported in supplementary materials (see Appendix A, page 215). Half of the participants in each group completed the awareness check before the questionnaire battery. At the end of the experiment participants were debriefed, breathalysed and compensated either with course credits or shopping vouchers (£15 Sterling).

Figure 2.1 Schematic overview of the experimental procedure.
See method section for details.



2.3.5 Data processing prior to analysis

For the IAT, I computed the *D*-measure (Greenwald, Nosek, & Banaji, 2003), which indicates the strength of associations between alcohol and positive versus negative words. See supplementary materials for details (reported in Appendix A, page 216). In order to investigate changes in cue-approach and cue-inhibition associations in the AAT and GNG tasks after CAT and ICT, respectively, I first excluded trials with errors and those with outlying reaction times (faster than 200ms or slower than 2000ms, then those that were more than 3 SDs above the mean) before comparing reaction times on each trial type at pre-test and post-test assessments (see supplementary materials reported in Appendix A, page 216, for details about task performance and errors).

2.4. Results

2.4.1 Group characteristics (Table 2.1)

All variables in Table 2.1 (with the exception of gender ratio) were analysed using univariate ANOVAs with a between-subjects factor of group (4: active CAT,

sham CAT, active ICT, sham ICT). After Bonferroni correction ($\alpha = .003$) to account for multiple contrasts, there were no significant group differences on any of these variables (Fs < 3.03, *p*s > .003). There were more female than male participants in all groups, and this gender imbalance was particularly pronounced in the sham CAT and active ICT groups ($\chi 2$ (3) = 8.37, $p = .04$).

Table 2.1 Group characteristics. Values are mean ± SD.

	CAT	**Sham CAT**	**ICT**	**Sham ICT**
Age (years)	20.37 (2.14)	20.40 (2.09)	20.07 (1.95)	20.43 (1.87)
Gender ratio (M/F)	11:19	5:25	5:25	13:17
Weekly alcohol consumption	24.14 (10.63)	24.72 (9.98)	24.43 (13.78)	26.70 (11.00)
AUDIT	14.60 (6.21)	13.23 (3.99)	13.40 (5.84)	14.47 (5.65)
Contemplation Ladder	3.33 (2.50)	2.37 (2.50)	3.03 (2.40)	3.77 (2.92)
TRI Concern	7.10 (4.75)	5.37 (2.82)	6.33 (3.04)	7.27 (4.40)
TRI Restrict	9.97 (5.40)	7.53 (4.18)	8.33 (4.06)	10.80 (4.98)
TRI Govern	10.17 (6.63)	7.10 (4.50)	8.30 (4.73)	10.50 (4.89)
TRI Emotion	10.30 (5.47)	8.70 (5.49)	9.20 (4.10)	11.27 (6.03)
TRI Cognitive Preoccupation	5.73 (3.09)	5.33 (3.25)	5.03 (2.57)	6.63 (3.32)
TRI Concern About Drinking	7.10 (4.75)	5.37 (2.82)	6.33 (3.04)	7.27 (4.40)
RTCQ Pre-contemplation	0.00 (3.41)	0.67 (3.05)	0.37 (3.45)	-1.30 (3.63)
RTCQ Contemplation	-0.40 (4.55)	-1.90 (3.12)	-0.93 (3.08)	0.33 (3.99)
RTCQ Action	-3.70 (3.27)	-4.23 (4.14)	-3.67 (3.22)	-3.00 (4.22)

Weekly alcohol consumption = self-reported typical weekly alcohol intake, in UK units. *AUDIT* = Alcohol Use Disorders Identification Test, values range from 0-40. *TRI* = Temptation and Restraint Inventory subscales range from 3 to 27; *RTCQ* = Readiness to Change Questionnaire subscales range from -8 to +8.

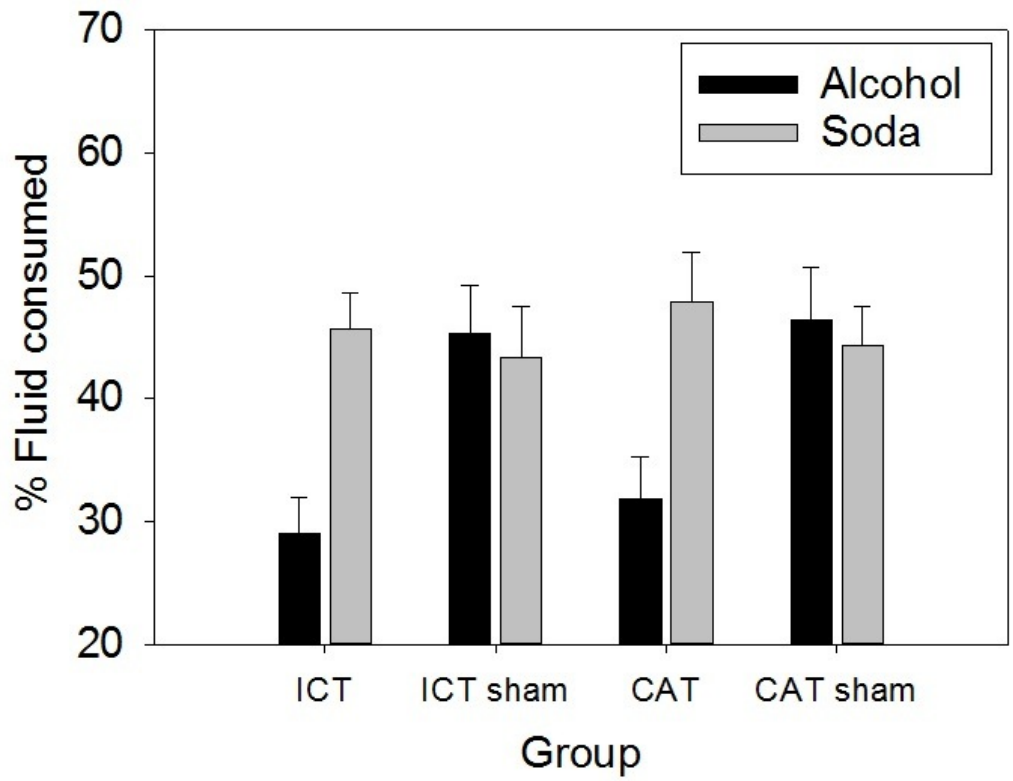
Contemplation Ladder is a 10-point Likert scale (0 = no willingness to change; 10 = taking action to change).

2.4.2 Effects of training on alcohol consumption (Figure 2.2)

Alcohol and soft drink consumption were calculated as a percentage of the total volume of each type of fluid available. Group differences in alcohol and soft drink consumption were analysed using a 2 × 2 × 2 mixed design ANOVA, with a within-subject factor of Drink Type (2: alcohol, soft drink) and between-subject factors of Training Type (2: CAT or ICT) and Condition (2: active training, sham training). Results revealed a statistically significant main effect of Drink Type ($F(1,116) = 15.75$, $p < .01$) that was subsumed under a significant Drink Type × Condition interaction ($F(1,116) = 26.08$, $p < .01$).

Participants in the active training conditions consumed less alcohol (M = 30.39%, SD = 17.67), than participants in the sham training conditions (M = 45.86%, SD = 22.06). This difference was significant, $t(118) = 4.24$, $p < .01$; representing a medium to large effect size (Cohen's $d = .78$). However, there were no significant differences in soda consumption between the active training conditions (M = 46.76%, SD = 19.16) and the sham training conditions (M = 43.80%, SD = 20.04; $t(118) = .83$, $p = .41$; $d = .15$). Importantly, the 3 way interaction between Drink Type, Training Type and Condition was not significant ($F(1,116) = .01$, $p = .94$). Therefore, both types of training (CAT and ICT) were equally effective at reducing alcohol consumption.

Figure 2.2 Alcohol and Soda consumption during the taste test, calculated as a percentage of the total volume of each type of fluid available, separated by training groups. Values are means (error bars indicate SEM).



2.4.3 Reaction times before and after Cue Avoidance Training (Table 2.2a)

Approach and Avoidance RTs were subjected to a 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Time (2: pre-test, post-test), Picture Type (2: alcohol, control), Movement (2: approach, avoidance) and a between-subject factor of Condition (2: active training, sham training). The main effect of Movement was statistically significant ($F(1,58) = 19.31$, $p < .01$), reflecting faster RTs to initiate approach rather than avoidance movements. The hypothesized 4-way interaction Time × Picture Type × Movement × Condition was not significant ($F(1,58) = 3.47$, $p = .07$), and there were no other significant main effects or interactions ($Fs < 2.53$, $ps > .12$).

In order to explore separately data at pre- and post-test I run three way ANOVAs separate for the pre-test and the post-test. At pre-test, the Picture type × Movement × Condition interaction was not significant ($F(1, 58) = .05$, $p = .82$).

However, there were main effects of Picture type (F (1, 58) = 4.17, p = .05) and Movement (F (1, 58) = 6.63, p = .01), and the Picture Type × Movement interaction, was not significant (F (1, 58) = 3.36, p = .07). Overall, participants were faster to approach rather than avoid alcohol pictures (t (59) = 3.09, p < .01, d = .40) but RTs to approach and avoid control pictures did not differ (t (59) = .99, p = .33, d = .13). At post-test, the Picture Type × Movement × Condition interaction was statistically significant (F (1,58) = 5.63, p = .02). The Movement × Condition interaction was not significant for control pictures (F (1, 58) = .72, p = .40) but it was significant for alcohol pictures (F (1,58) = 3.92, p = .05). Participants in the sham training group were significantly faster to approach rather than avoid alcohol pictures, t (29) = -3.43, p < .01, d = .70. However, this effect was absent in the active training group, as RTs to approach and avoid alcohol pictures were similar, t (29) = 1.00, p = .32, d = .18).

This pattern was confirmed by an analysis of overall 'approach bias' scores, which were calculated by computing the speed of avoidance (minus approach) of alcohol pictures and subtracting the speed of avoidance (minus approach) of control pictures, such that positive values indicate a bias for speeded approach of alcohol pictures, and negative values indicate a bias for speeded avoidance of alcohol pictures. Groups did not differ on overall bias at pre-test (t (58) = .23, p = .82, d = .06), whereas at post-test, overall alcohol approach bias was smaller in the active training group compared to the sham training group (t (58) = 2.37, p = .02, d = .61). Furthermore, within-group contrasts testing for change over time revealed that, for participants in the active training group, overall bias scores changed from positive at pre-test (M = 23.91 ms) to negative at post-test (M = - 21.57 ms), however this difference was not significant (t (29) = 1.97, p = .06, d = .36). For participants in the sham training group, overall bias scores were positive at pre-test (M = 18.67 ms), and not significantly different at post-test (M = 31.74 ms), (t (29) = .61, p = .55, d = .11).

Table 2.2a Reaction times (milliseconds) to approach and avoid alcohol and control pictures during the approach-avoidance task (AAT). Values are shown separately for active training and sham control training groups, and at pre-test (before cue avoidance training) and post-test (after cue avoidance training).

Values are mean ± SD.

	Active Training	**Sham Control**
Pre-test		
Approach alcohol	*758.07 (147.68)*	*743.76 (128.53)*
Avoid alcohol	*799.10 (162.06)*	*763.97 (117.97)*
Approach control	*772.22 (169.59)*	*769.85 (143.04)*
Avoid control	*789.35 (166.34)*	*771.38 (133.15)*
Post-test		
Approach alcohol	*754.96 (135.66)*	*748.45 (148.04)*
Avoid alcohol	*767.10 (134.64)*	*797.80 (185.41)*
Approach control	*749.20 (133.61)*	*764.13 (177.99)*
Avoid control	*782.91 (150.91)*	*781.74 (178.17)*

2.4.4 Reaction times before and after Inhibitory Control Training (Table 2.2b)

Go reaction times were analysed with a mixed design ANOVA, with within-subject factors of Time (2: pre-test, post-test) and Picture Type (2: alcohol, control) and a between-subjects factor of Condition (2: active training, sham training). There was a statistically significant main effect of Picture Type ($F(1,58) = 15.73$, $p < .01$) reflecting, on average, slower Go RTs on trials with alcohol pictures than neutral pictures. However, the hypothesized Time × Picture type × Condition interaction was not significant ($F(1,58) = .80$, $p = .37$), and there were no other significant main effects or interactions ($Fs < 2.84$, $ps > .10$). Therefore, contrary to hypotheses, ICT that involved pairing alcohol cues with inhibition of responding did not lead to a slowing of Go RTs on trials when alcohol cues were presented. I also conducted a supplementary analysis to investigate if RT slowing might be detected by focussing

only on responses to alcohol pictures that were used during training, and only on the first few trials of the pre-test and post-test blocks. This analysis did not detect any evidence for RT slowing to alcohol cues after active ICT training. See supplementary materials for details (reported in Appendix A, page 215).

Table 2.2b Reaction times (milliseconds) on 'Go' trials with alcohol and control pictures during the Go / No-Go (GNG) task. Values are shown separately for active training and sham control training groups, and at pre-test (before inhibitory control training) and post-test (after inhibitory control training).
Values are mean ± SD.

	Active Training	**Sham Control**
Pre-test		
Alcohol cues	*519.68 (54.24)*	*501.64 (52. 49)*
Control cues	*518.46 (54.83)*	*491.80 (48.53)*
Post –test		
Alcohol cues	*521.73 (58.20)*	*506.16 (52.38)*
Control cues	*509.85 (53.84)*	*492.45 (45.92)*

2.4.5 Automatic evaluations of alcohol pictures (Table 2.2c)

Automatic evaluations of alcohol pictures, assessed with the IAT *d measure*, were analysed using a 2 × 2 × 2 ANOVA, with a within-subject factor of Time (2: pre-test, post-test) and between-subject factors of Training Type (2: CAT or ICT) and Condition (2: active training, sham training). The critical Time × Training Type × Condition interaction was not significant ($F(1, 116) = 1.78$, $p = .19$) and there were no other significant main effects or interactions ($Fs < .41$, $ps > .52$). Therefore, automatic evaluations of alcohol cues did not change from pre-test to post-test after either type of training, contrary to predictions. However, I note that participants held robust associations between alcohol and positive words at both pre-test and post-test, as evidenced by the observation that d values were positive and significantly greater than zero (one-sample t-tests compared to zero; pre-test $t(119) = 4.41$, $p < .01$; post-test $t(119) = 6.48$, $p < .01$).

Table 2.2c Automatic evaluations of alcohol pictures as inferred from participants' performance on the implicit association task (IAT), at pre-test and post-test. Positive values indicate stronger associations between alcohol pictures and positively valenced words rather than negatively valenced words. Values are *D* measures (mean ± SD).

	CAT	**Sham CAT**	**ICT**	**Sham ICT**
Pre-test	*.27 (.58)*	*.21 (.73)*	*.21 (.53)*	*.30 (.63)*
Post-test	*.20 (.48)*	*.28 (.54)*	*.34 (.44)*	*.30 (.43)*

2.5. Discussion

The primary finding in the present study was that participants who completed a single session of CAT or ICT consumed less alcohol during a bogus taste test than participants who completed control ('sham') versions of these interventions. Most importantly, I observed no significant difference in the magnitude of the effect produced by these two forms of CBM. In addition, and contrary to expectations, I did not observe robust strengthening of alcohol-avoidance or alcohol-inhibition associations after CBM, and neither form of CBM led to devaluation of alcohol-related cues, as inferred from an implicit association task.

Regarding the effects of CBM on alcohol consumption, our findings replicate previous demonstrations of reduced alcohol consumption after a single, brief session of CAT (see Kakoschke, Kemps and Tiggemann, 2017a) and ICT (see Allom, Mullan & Hagger, 2015; Jones et al., 2016b), compared to control CBM. Importantly, the present study is the first head-to-head comparison of these two forms of CBM, and our findings suggest that both are likely to be equally effective for the reduction of alcohol consumption. It is important to note that this was a laboratory investigation of a single session of CBM and I inferred participants' motivation to drink alcohol based on how much alcohol they consumed during a bogus taste-test (see Jones et al., 2016a). The present findings are an important proof of concept, and it is important to investigate their relevance in real-world settings, and investigate if multiple sessions of ICT and CAT would prompt comparable

reductions in alcohol consumption if delivered to alcohol-dependent patients (see Cristea, Kok & Cuijpers, 2016). It would also be of interest to investigate whether a combined intervention would yield larger or more robust effects than either intervention on its own, as suggested by some recent laboratory studies (Kakoschke et al., 2017a; Kakoschke, Kemps, & Tiggemann, 2017b).

Contrary to hypotheses, I did not observe robust increases in the strength of alcohol-avoidance associations in participants who completed a single session of CAT. However, the between subject group difference was significant at post-test, with the sham training (control) group showing an 'approach bias', bias which was absent in the active CAT. However, these results need to be interpret with care as changes were not significant. Closer inspection of the previous literature demonstrates that changes in alcohol-avoidance associations after CAT are often observed (Wiers et al., 2010, 2011, Eberl et al., 2013, 2014; Sharbanee et al., 2014; Gladwin et al., 2015) but there are notable exceptions, even in studies in which CAT led to changes in brain activation during exposure to alcohol cues (C. E. Wiers, Stelzel, et al., 2015a) or improved abstinence rates after treatment (Manning et al., 2016). One interpretation for these findings is that there are methodological limitations to tasks that are used to measure alcohol-avoidance associations, such as the approach-avoidance IAT (used in some of the above studies) and slowing of reaction times during the irrelevant-feature AAT (used in the present study). For example, the irrelevant-feature AAT has poor internal reliability and predictive validity (in comparison to alternative tasks such as the relevant-feature Stimulus-Response Compatibility Task; see Kersbergen, Woud & Field, 2015), which may render it relatively insensitive for the purposes of assessing changes in alcohol-avoidance associations that are expected to arise after CAT.

Similarly, and again contrary to hypotheses, I did not observe any slowing of reaction time to alcohol cues, which would indicate the formation of alcohol-inhibition (or 'stopping') associations, after ICT. Numerous laboratory studies that used arbitrary stimuli (Lenartowicz, Verbruggen, Logan, & Poldrack, 2011; Verbruggen & Logan, 2008b, 2009; Verbruggen et al., 2014), and indeed some studies that used alcohol-related stimuli (Jones & Field, 2013; Noël et al., 2016) have demonstrated the robustness of these stop-learning effects, so in a sense our findings are surprising. However, other studies, particularly those that investigated ICT in applied domains, did not demonstrate the predicted formation of cue-stopping

associations, in some cases even after multiple sessions of ICT (Houben et al., 2012; Lawrence et al., 2015a). The reasons for these discrepant findings are unclear, however recent laboratory studies suggest that stop-learning effects may be sensitive to a number of factors including task instructions (Best et al., 2015), the presence of an executive setting (i.e. a setting in which participants might be required to inhibit; Chiu & Aron, 2014), or individual differences in the motivational response to the stimuli used (Stice et al., 2016). Alternatively, and in common with our discussion of the internal reliability of reaction time measures obtained from the irrelevant AAT (above), it is possible that reaction times on 'Go' trials are not sufficiently reliable or sensitive to detect changes that arise as a result of a brief session of ICT. Further work is required to identify a reliable measure of cue-stopping associations that is sensitive to the effects of ICT.

Furthermore, I observed no effect of either form of CBM on devaluation of alcohol cues, as inferred from participants' performance on a bipolar implicit association test (IAT). This suggests that the reduction in alcohol consumption after both CAT and ICT cannot be attributed to changes in automatic evaluations of alcohol pictures. I opted to use the IAT to measure devaluation on the basis of two previous studies which used the same measure to demonstrate that a single session of ICT led to robust changes in automatic evaluations of alcohol pictures (Houben et al., 2011, 2012). Therefore, I failed to replicate these earlier findings, as did another recent study which also investigated the effects of a single session of ICT on the same task (Bowley et al. 2013). There are a number of possible explanations for why the effects of CBM on stimulus devaluation as inferred from IAT performance do not appear to be robust across studies. First, as a reaction time measure it may be subject to similar confounds that complicate interpretation of changes in the speed of avoidance or slowed responding to target stimuli after CAT and ICT respectively, as discussed above. Second, the IAT may not be sufficiently sensitive to detect changes in automatic stimulus evaluations after a brief session of CBM (Woud et al., 2013a; Woud et al., 2013b; Becker et al., 2015). Third, devaluation effects may be more robust when different measures of stimulus valuation such as subjective ratings or auction tasks are used instead of the IAT (Veling, Holland & van Knippenberg, 2008; Ferrey, Frischen & Fenske, 2012; Wessel et al., 2014; Lawrence et al., 2015a; Veling et al., 2017b; although see Wiers, Stelzel, Gladwin, Park, et al., 2015).

Our study has additional limitations, in addition to some notable strengths. In common with most other laboratory CBM studies, group allocation was single rather than double blinded: the experimenter was aware of group allocations, but participants were not. This increases the risk of bias in such studies (Cristea, Kok & Cuijpers, 2016). However, participants were led to believe that there was no experimental manipulation in the study, and indeed their responses during formal debriefing indicated that the vast majority of participants (across all groups) believed this cover story, and only a tiny minority (6 out of 120 participants; 5%) developed awareness of the intended purpose of CBM (see supplementary file, Appendix A, page 216). Therefore, it seems unlikely that demand characteristics could account for the effects of CAT and ICT on alcohol consumption. Additionally, our sample was predominantly female and I did not record participants' ethnicity, however supplementary analyses confirmed that participant sex did not moderate any of the effects (see Appendix A, page 216). Our study also has strengths, including the large sample size and the use of a 50:50 contingency between alcohol pictures and avoidance (or inhibition) in the sham (control) conditions. This type of control manipulation helps to resolve ambiguity regarding interpretation of findings from previous studies that compared CBM with control conditions that attempted to increase (rather than extinguish or reverse) cognitive biases (Houben et al., 2012; Kakoschke et al., 2017a; Wiers et al., 2010), which could have inflated the apparent effect size of CBM by increasing value of appetitive stimuli in these 'control' conditions (Schonberg et al., 2014).

To conclude, I demonstrated that a single, brief session of CAT or ICT yielded equivalent reductions in alcohol consumption in the laboratory. However, neither form of CBM resulted in robust strengthening of alcohol-avoidance or alcohol-inhibition associations, and neither led to devaluation of alcohol-related cues. Further research is required to identify the psychological mechanisms that underlie the effects of these forms of CBM on alcohol consumption.

Chapter Three

An investigation of the effects of Inhibitory Control Training on alcohol consumption in an ecologically valid setting

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3.1 Abstract

Rationale: Studies have shown that ICT can reduce alcohol consumption in the laboratory. However, it is important to investigate whether this effect persists even after people have been exposed to environmental cues that trigger drinking, such as exposure to alcohol advertisements. I expect to replicate the effects of ICT on alcohol consumption in an ecologically valid setting, after exposure (or not) to real-world environmental triggers (TV adverts).

Methods: Heavy drinking young adults (N=80) were randomly assigned to receive either active ICT (repeatedly inhibiting behaviour in response to alcohol cues) or a control intervention (sham training) in a naturalistic laboratory. Participants then watched a TV comedy show, which was interrupted by 3 advertisement breaks. Half of the participants in each group were exposed to alcohol adverts, and the remaining participants were exposed to neutral adverts. Immediately afterwards participants completed a bogus taste-test as a measure of ad-libitum alcohol consumption.

Results: Participants who received ICT consumed less alcohol, compared to participants that received sham training. However, this effect was only robust for those individuals exposed to neutral adverts. In participants who were exposed to alcohol advertising the effect of ICT on alcohol consumption was not robust.

Contrary to expectations, exposure to alcohol advertising did not reliably increase alcohol consumption during the taste test.

Conclusions: ICT effects on drinking behaviour are likely to be abolished after exposure to alcohol adverts. The present findings are an important proof of concept of the effects of ICT on drinking behaviour in relatively naturalistic settings.

Keywords: Alcohol, Advertising, Ecological setting, Exposure, Inhibitory Control Training.

3.2 Introduction

The ability to stop or change a response is referred to as 'inhibitory control' and it can be assessed with different paradigms (for details see page 12), by measuring successful motor inhibition when prompted by stimuli in a context which requires a predominant response (Verbruggen et al., 2014). Laboratory studies using training versions of these paradigms, ICT, have consistently shown short-lived reductions in alcohol consumption following a brief session of this intervention (see Allom, Mullan & Hagger, 2015; Jones et al., 2016b).

Results from the previous chapter (see study 2.1, page 47) replicated ICT effects on alcohol consumption, even though alcohol-related stimuli were not devalued and cue-inhibition associations did not seem to change. To date there have been no published trials that investigated if these effects may persist outside of the laboratory, or if multiple sessions of ICT might be an effective treatment intervention for alcohol-dependent patients (Cristea, Kok, & Cuijpers, 2016). However, findings from ICT in appetite research (Veling et al., 2017b), suggest that behavioural effects should persist outside of the laboratory, as recent studies show effects on weight loss across several weeks in overweight individuals who are dieting to lose weight (Lawrence et al., 2015; Stice et al., 2016; Veling, van Koningsbruggen, Aarts, & Stroebe, 2014). Thus, it is important to investigate if a similar pattern holds for alcohol ICT.

Current studies suggest that ICT prompts people to drink less when measured immediately (Allom, Mullan & Hagger., 2015; Jones et al., 2016b), but in order to influence behaviour in the 'real world' (outside of the laboratory), ICT should evoke adaptive responses such as making people less sensitive to the effects of alcohol cues (e.g. contextual forces driving consumption; Heim & Monk, 2017). We know that

exposure to alcohol advertising is a potent cue that has immediate and sustained effects on alcohol consumption. For example, heavy drinking is often triggered by alcohol related environmental cues (Gauggel et al., 2010) and people who have been exposed to sensory properties of alcohol beverages report increased craving, salivation and impaired response inhibition (Monk et al., 2016; Thomas, Drobes, & Deas, 2005; Witteman et al., 2015). Systematic reviews of studies on alcohol advertising have generally shown that exposure to alcohol related adverts is an influential contributor to alcohol consumption and alcohol harm in young adults (Anderson, De Bruijn, Angus, Gordon, & Hastings, 2009; de Bruijn et al., 2016; Koordeman, Anschutz, & Engels, 2011; Koordeman, Kuntsche, Anschutz, van Baaren, & Engels, 2011; Siegel et al., 2016; Smith & Foxcroft, 2009). In addition to a well-established cumulative effect, exposure to alcohol advertising also has an immediate effect on alcohol intake in the laboratory, which is robust albeit small in magnitude (Stautz et al., 2016).

The present study aims to investigate if previous demonstrations of reduced alcohol consumption after a single brief session of ICT can be replicated even in participants who have been exposed to alcohol advertising. If I can demonstrate this, it would suggest that ICT (and other forms of CBM) is more likely to make people less responsive to alcohol cues in real-world settings, because it would suggest that ICT and other forms of CBM could have a protective effect in the contemporary 'alcohol-genic' environment. Therefore, it is essential to test contextual influences as these are part of the real-world drinking environment and shape drinking behaviour and beliefs, as suggested by recent studies showing that alcohol consumption and beliefs vary across social and environmental contexts (Monk & Heim, 2014; Monk, Pennington, Campbell, Price, & Heim, 2016).

Specifically, I aim to replicate reductions in alcohol consumption in participants who received ICT compared to those who received sham training, and replicate increases in alcohol consumption in participants who have been exposed to alcohol advertising compared to participants who have been exposed to neutral adverts. More importantly I aim to examine whether a brief session of ICT (vs. sham training) would moderate the effect of alcohol advertising on alcohol consumption. The primary hypothesis is that participants who receive a brief session of ICT will consume less alcohol than participants who receive sham training, and the magnitude

of this group difference will be reduced in participants who are exposed to alcohol advertising (compared to those who are exposed to neutral advertisements).

3.3 Methods

3.3.1 Participants

Eighty (54 women, 26 men) heavy drinkers were recruited from staff and students at the University of Liverpool via online and poster advertising. Inclusion criteria included average weekly alcohol consumption in excess of the United Kingdom Department of Health guidelines at the time of the study (see study 2.1, page 35). Participants were also required to be aged between 18 and 35, fluent in English, have normal or corrected to normal vision and have no history of alcohol use disorders. The study was approved by the University of Liverpool Research Ethics Committee.

3.3.2 Design

A mixed design was employed. Participants were randomly assigned to one of four groups that reflected the between-subjects factors of ICT (active training or sham training) and TV advert condition (alcohol or neutral adverts). Picture type was a within-subjects factor, because both alcohol and control cues were presented during ICT.

3.3.3 Materials and Tasks

Computer tasks were presented on a Dell desktop computer with a 15" monitor. Participants responded using a standard keyboard. Tasks were programmed and administered in Inquisit version 3.0 (Millisecond Software, 2009).

Alcohol-related and matched neutral (control) pictures were equivalent to the stimuli used in other studies throughout the thesis (see study 2.1, page 35).

The ICT was similar to the task described in the previous chapter based on Houben et al. (2012). The training block was identical to that described in study 2.1 (see page 39), the only difference was that in the present study the pre-test and post-test assessment blocks were removed. These blocks were omitted for two main reasons. Primarily, because the primary purpose of the present study was not to investigate the mechanisms of action of ICT (although changes in stimulus-response associations over the course of the training block were analysed). Secondly, because

ICT effects on behaviour may have been neutralized by a GNGT assessment block, unless a booster training block would have been added before the advertisement manipulation, which would have made the study longer.

The TV programme used in the present study was a popular BBC comedy quiz show, named QI, in which funny impossible questions are asked to a panel of guests and points are awarded not only for right answers but also for the most original and interesting answers. Each series looks at a different letter of the alphabet. In the chosen episode (Series K, Episode 8: 'Keys') one alcohol reference was present and was cut-out of the video at minute 2:30.

The programme was interrupted by advert breaks, ranging between one minute and fifty seconds to a maximum of two minutes. Each advert break contained three TV advertisements, which were matched for length (ranging from 30 seconds to one minute) and advert style (e.g. using the objects advertised or marketing a life style related to the object). Adverts were either alcohol-related or related to neutral everyday objects (control condition). If individuals were exposed to the alcohol adverts condition, three alcohol ads (e.g. Bulmers apple cider, Bacardi Rum, Coors lager, Fosters lager, Magners apple cider, Smirnoff vodka) and one neutral advert (to disguise the aims) were presented during each break. Of the alcohol adverts 33% (two out of six: the Magners cider and the Fosters beer) corresponded to the selected alcoholic beverages presented in the subsequent bogus taste-test (participants were not made aware of this). In the neutral advertising condition (control condition) participants were presented with three different non-alcohol adverts chosen from current electronic and popular goods categories: headphones (e.g. Beats, Ministry of Sound, Sony), phones or smart watches (e.g. Galaxy S7, Microsoft Lumia 950, Apple watch) and cars (e.g. Smart, Toyota Hybrid and Toyota Yaris). No soft-drink adverts were presented in the breaks (see Appendix B for links to the specific episode an all the adverts used, page 227).

3.3.4 Procedure (Figure 3.1)

Participants were initially given a cover story to mask the true purpose of the study. The cover story informed them that the study investigated the relationships between cognitive performance, taste perception and humour and in particular stated that the main aim of the study was to investigate whether cognitive performance and taste perception are linked and influenced by watching a comedy show. Testing

sessions took place between 12:00 and 18:30 in the 'Lounge lab' in the Department of Psychological Sciences. The Lounge Lab is set up to mimic a living room and contains a sofa, TV, coffee table, book shelves, candles and soft lighting (see Figure 3.2).

Participants provided informed consent and a breathalyser reading (all participants had a breath alcohol content of zero), before being seated on a sofa approximately 1m away from the laptop which was placed on the coffee table in front of them. Participants completed the ICT or sham training (depending on group allocation) in the laboratory alone. When the task was complete they rang a buzzer which prompted the experimenter to return to the lab and start the TV programme that was interrupted by three different advert breaks. Half of the participants in each ICT group (active or sham training) were exposed to either the alcohol advertising condition or the neutral advertising (control) condition. Immediately after watching the TV programme participants completed a bogus taste-test, which was identical to the one described in the previous chapter (see study 2.1, page 39). After 10 minutes, drinks were removed and the volume of each drink consumed was recorded out of sight of the participant.

Participants then provided general demographic information and completed the following battery of questionnaires (for details see page 35): a two week Timeline Follow-Back retrospective alcohol diary (TLFB; Sobell & Sobell, 1992), the Alcohol Use Disorders Identification Test (AUDIT; Saunders & Babor, 1993) and the Contemplation Ladder (CL; Hogue, Dauber, & Morgenstern, 2010). Participants' beliefs about the general aims of the experiment, their awareness of the purpose of the ICT tasks and of the taste-test were assessed using the self-report awareness measure previously described in study 2.1 (see page 39 and Appendix A, page 215). At the end of the experiment participants were fully debriefed on the aim and procedures, breathalysed and were compensated either with course credits or shopping vouchers (£15 Sterling).

Figure 3.1 Schematic overview of the experimental procedure. See method section for details.

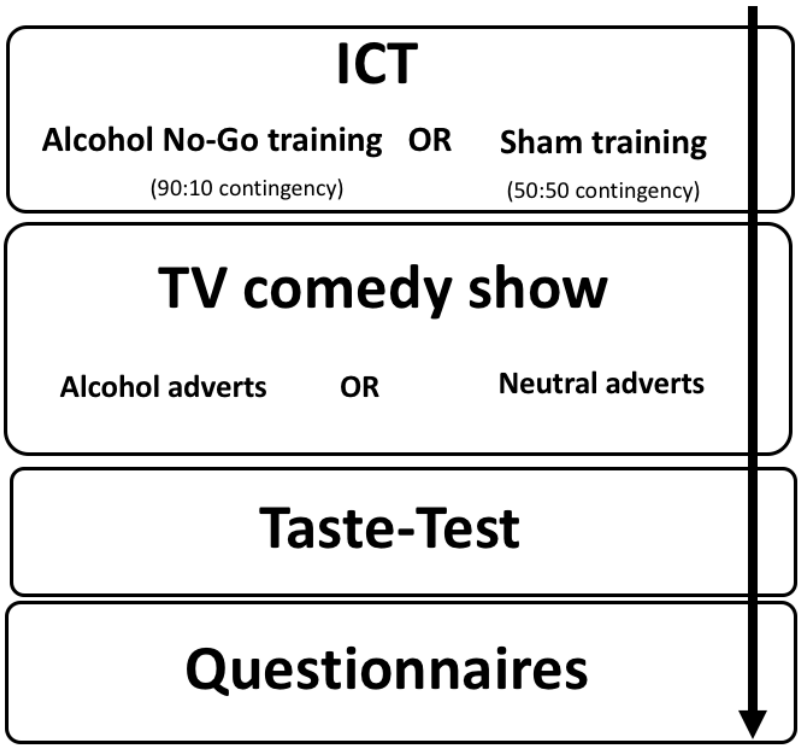


Figure 3.2 Photo of the University of Liverpool lounge laboratory.

3.3.5 Data reduction and analysis

Consistent with study 2.1, Alcohol and Soda consumption were calculated as a percentage of the total volume of each type of fluid available. Additionally, in order to investigate the formation of cue-inhibition associations during ICT, I investigated changes over time in Go RTs in the first and last 8 trials of each type at the beginning and the end of the training. RTs were reduced and analysed in exactly the same way as in the previous chapter (see study 2.1, page 42).

Participants made very few inhibition errors (M=3.36, SD=3.81), and the number did not differ by group ($F(3, 76) = .53$, $p = .66$). Therefore, error data are not reported further.

3.4 Results

3.4.1 Group characteristics (Table 3.1)

A 2 × 2 MANOVA with Training Type (2: active training or sham) and Advertising condition (2: alcohol or neutral adverts) showed that there were no significant main effects of Training Type ($F(5, 72) = .77$, $p = .58$), Condition ($F(5, 72) = 1.23$, $p = .31$), and no interaction ($F(5, 72) = .90$, $p = .48$). Therefore, groups were well matched. A Chi Square test confirmed that groups were also well-matched for gender ratio ($\chi 2(3) = .23$, $p = .97$).

Table 3.1 Group characteristics, allocated to either alcohol advert or neutral advert exposure and ICT condition. Values are mean ± SD.

	ICT + alcohol	**ICT + control**	**Sham + alcohol**	**Sham+ control**
Age (years)	23.60 (4.70)	20.75 (3.39)	20.90 (3.04)	20.70 (1.81)
Gender ratio (M/F)	6:14	6:14	7:13	7:13
Weekly alcohol consumption	24.89 (16.20)	24.88 (12.29)	25.90 (15.45)	20.23(10.29)
AUDIT	10.65 (4.90)	12.15 (4.95)	12.60 (6.43)	11.00 (4.39)
CL	2.35 (2.83)	2.95 (2.54)	2.55 (2.69)	2.60 (2.85)

Weekly alcohol consumption = self-reported typical weekly alcohol intake, in UK units. *AUDIT* = Alcohol Use Disorders Identification Test, values range from 0-40. Contemplation Ladder is a 10-point Likert scale (0 = no willingness to change; 10 = taking action to change).

3.4.2 Effects of training on alcohol consumption (Figure 3.3)

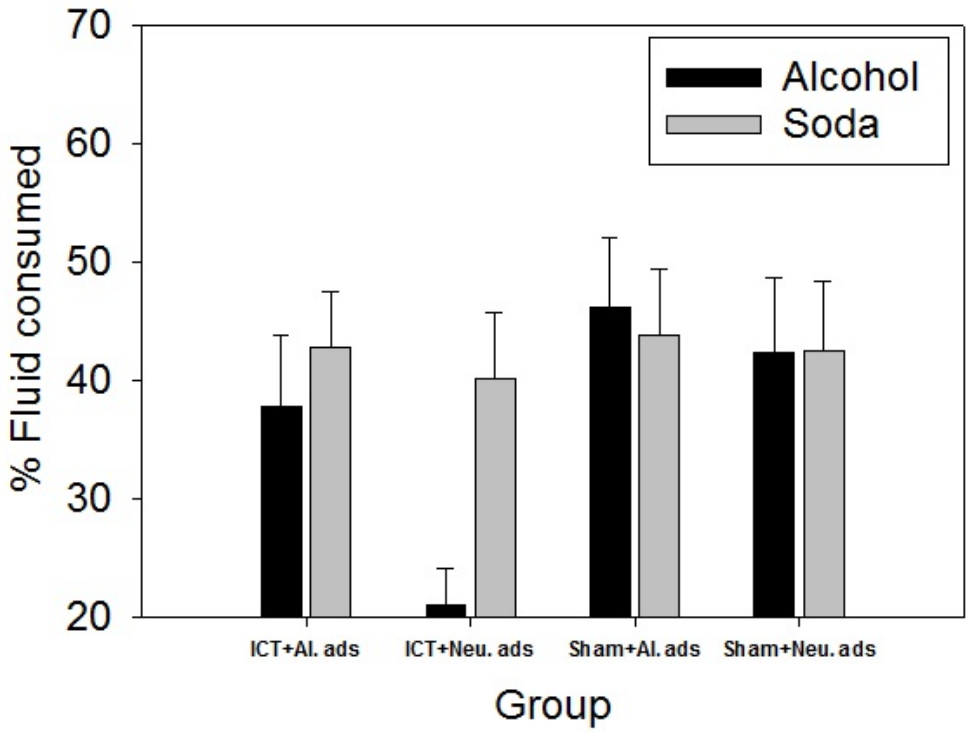
Group differences in alcohol and soft-drink consumption after training were analysed using a 2 × 2 × 2 mixed design ANOVA, with a within-subject factor of Drink Type (2: alcohol or soft drink) and between-subject factors of Training Type (2: active training or sham) and Advertising condition (2: alcohol or neutral adverts). Results revealed a statistically significant main effect of Drink Type ($F(1, 76) = 4.51$, $p = .04$) which was subsumed under a significant Drink Type × Training Type interaction ($F(1, 76) = 6.45$, $p = .01$). Importantly, the 3-way interaction between Drink Type, Training Type and Advert Condition was not significant ($F(1, 76) = 1.29$, $p = .26$). The interaction between Drink Type × Advert Condition ($F(1, 76) = 2.63$, $p = .11$) and the main effect of Advert Condition were also not significant ($F(1, 76) = 1.61$, $p = .21$).

At face value, these findings suggest that participants who received ICT consumed less alcohol than participants who received sham training, and this effect was not moderated by the type of advertisements (alcohol or neutral) that they were exposed to. However, inspection of Figure 3.3 suggests that the effect of ICT on alcohol consumption was much more pronounced in participants who were exposed to neutral adverts, compared to participants who watched alcohol adverts.

Therefore, I conducted planned post-hoc contrasts to investigate the effects of ICT separately in participants who were exposed to alcohol adverts and in participants who were exposed to neutral adverts. These analyses demonstrated that there were no group differences in soft-drink consumption ($ps > .1$). However, participants who received ICT consumed less alcohol than participants who received sham training, but this difference was only statistically significant among participants who were exposed to neutral adverts ($t(38) = 3.01$, $p < .01$, $d = .95$); it was not statistically significant among participants who were exposed to alcohol adverts ($t(38) = .99$, $p = .33$; $d = .31$). Therefore, this suggests that the effect of ICT on alcohol consumption was only robust in participants who had been exposed to neutral

adverts; ICT did not influence alcohol consumption in participants who had been exposed to alcohol adverts.

Figure 3.3 Alcohol and Soda consumption calculated as a percentage of the total volume of each type of fluid available for training groups after receiving the manipulation. Values are means (SE).



3.4.3 Effect of the training on RTs over time (Table 3.2)

In order to analyse the formation of cue-inhibition associations, a 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Time (2: beginning of training or end of training), Picture type (2: alcohol or neutral), and between-subject factors of Training Type (2: active training or Sham) and Advertising condition (2: alcohol or neutral adverts), were used to compare differences in Go RTs over the course of the training blocks for both the active ICT and the control group (Sham training).

Results showed a main effect of Picture type ($F (1, 76) = 35.31$, $p < .01$) with overall slower responses to alcohol pictures relative to control stimuli, a significant Time × Training type interaction ($F (1, 76) = 5.80$, $p = .02$) a significant Time × Picture type interaction ($F (1, 76) = 8.36$, $p = .01$), all of which were subsumed under

the hypothesized three-way interaction Time × Picture type × Training Type (F (1, 76) = 5.77, p = .02), which was statistically significant. Additionally, the 3-way interaction Time × Training Type × Advert Condition (F (1, 76) = 3.47, p = .07), did not reach statistical significance. There were no other significant main effects or interactions, including the critical four-way interaction Time × Picture type × Training Type × Advert Condition (Fs < 2.57, ps > .11).

In order to find the source of the Time × Picture Type × Training Type interaction, post-hoc t-tests separately for groups (active training or sham) were computed. Among participants who received sham ICT, RTs to both alcohol (t (39) = -1.12, p = .27) and neutral cues (t (39) = -.68, p = .50) did not change over the course of training. Whereas among participants who received active ICT, they became significantly faster to respond to neutral cues over the course of training (t (39) = 3.29, p < .01, d = 0.8), but their reaction times to alcohol cues did not change (t (39) = -.78, p = .44).

Table 3.2. Reaction times (milliseconds) on 'Go' trials with alcohol and control pictures during the Go / No-Go (GNG) task. Values are shown separately for active training and sham control training groups, and at the begging and end of the training. Values are mean ± SD.

	Active training	**Sham training**
Alcohol stimuli - beginning of the training	*541.27 (56.50)*	*531.48 (51.39)*
Control stimuli - beginning of the training	*527.45 (56.88)*	*513.07 (50.79)*
Alcohol stimuli - end of the training	*544.24 (69.21)*	*538.43 (49.21)*
Control stimuli - end of the training	*504.15 (54.29)*	*521.79 (44.65)*

3.4.4 Participants' awareness of the experiment

I probed participants' awareness of the intended purpose of the ICT task and of the taste-test, in addition to their awareness of the overall aims of the study. To achieve this, I used a combination of open-ended and multiple choice questions, as described in study 2.1 (see page 39). First, participants provided a written response to an open-ended question 'What was the general purpose of the experiment?'. The vast majority of participants (90%; one participant did not complete this part of the questionnaire) were unaware of the general aims. Answers to this question were varied, but recurring themes focussed on how humour impacts on taste sensations for the different beverages presented. Thus, participants' responses to this question generally suggested that they believed the cover story that was presented at the beginning of the study. However, some participants (N=14) seemed to be aware of the advertising manipulation (with 17.5% of participants mentioning advertising in their responses). A Chi Square test confirmed that there was a significant relationship between group allocation to the advertising condition (alcohol or neutral adverts) and the response selected ($\chi 2$ (3) = 12.81, p = .01), with the majority of participants who explicitly mentioned advertising as an aim of the study being in the alcohol advertisement condition (table 3.3).

Table 3.3 Frequencies of participants' responses who were aware (and unaware) of the advertising experimental manipulation (alcohol or neutral adverts condition).

	ICT+alcohol	**ICT+control**	**Sham+alcohol**	**Sham+control**
Aware	*6*	*0*	*7*	*1*
Unaware	*14*	*20*	*13*	*19*

The next question was a multiple choice question in which participants indicated what they believed to be the purpose of the ICT computer task (table 3.4). The majority of the participants believed the cover story that the study was an investigation of the relationship between cognitive performance, taste perception and humour; because the majority selected that the purpose of the training task was to 'measure my ability to control myself when I think of alcohol' (51%), thus believing

that the task was an assessment version (regardless of which group to which they were allocated). Only two participants (2.5%) both from the ICT group thought that the purpose of the training task was to 'teach me to control myself when I think of alcohol'. Although it appears that participants in the active training groups were more likely to select this option, a Chi Square test confirmed that there was no significant relationship between group allocation and the response option selected ($\chi 2(12) = 6.66$, $p = .88$).

Table 3.4 Frequencies of participants' responses to the question that probes their awareness of the purpose of ICT.

	ICT+alcohol	ICT+control	Sham+alcohol	Sham+control
a. *Train me to think more quickly*	0	1	1	1
b. *Measure how quickly I can categorise things*	6	2	7	4
c. *Measure my ability to control myself when I think of alcohol*	10	11	9	11
d. *Teach me to control myself when I think of alcohol*	1	1	0	0
e. *I do not know what this task was measuring*	3	4	3	4

The final multiple choice question assessed participants' awareness of the purpose of the bogus taste-test. Results evidenced that the majority of participants were aware of the real purpose of the taste-test, with 47 participants (58%) correctly identifying that this task was a measure of their motivation to drink alcohol. To explore the influence of this factor, I repeated the analysis of the taste-test data (see above figure 3.3) with the addition of awareness (2: aware, unaware) as an additional between-subjects factor. This analysis revealed that the main effect of drink type ($F(1, 71) = 4.04$, $p = .05$) and the two-way significant interaction drink type × training type ($F(1, 71) = 7.12$, $p = .01$), reported previously, remained statistically significant. Importantly, the four-way interaction between drink type, training type, condition and awareness was not significant ($F(1, 71) = 2.81$, $p = .10$) and there were no other significant interactions or main effects ($Fs < 2.71$, $ps > .10$). Therefore, participants' awareness of the purpose of the taste-test did not influence the primary findings.

3.5 Discussion

The primary finding in the present study was that, as hypothesised, participants who completed a single session of ICT, in a more ecologically valid setting (a 'lounge lab'), reduced their alcohol intake during a bogus taste-test, relative to participants who completed the control ('sham') version of this intervention. However, contrary to expectations, exposure to alcohol advertising did not reliably increase alcohol consumption during the taste-test. Furthermore, although the interaction was not statistically significant, the effect of ICT on alcohol intake was more robust in individuals who were exposed to neutral adverts compared to those exposed to alcohol advertising, for whom ICT effects were less robust. Most importantly, these results suggest that the beneficial effects of ICT in the laboratory may be abolished after exposure to alcohol adverts (e.g. in a real world setting).

Regarding the effects of ICT on alcohol consumption, our findings are in line with previous demonstrations of reduced alcohol consumption after a single brief session of ICT (see Allom, Mullan & Hagger, 2015; Jones et al., 2016b; see study 2.1, page 42), compared to sham training (control). No group differences were observed for soda consumption. Importantly, the present study is the first to explore the effects in an ecologically valid setting, containing environmental factors that are known to influence drinking in the real world (e.g. alcohol TV adverts). Our findings suggest that ICT is less likely to be effective when individuals are exposed to alcohol advertising. Thus, more clinical trials and real-world studies are needed in order to test if their behavioural effects (typically found in neutral laboratory settings) are robust enough to persist outside of the laboratory, in an 'alcohol-genic' environment (see Cristea, Kok & Cuijpers, 2016).

Contrary to hypotheses, advertising had no main effect on alcohol intake. Participants exposed to alcohol adverts did not drink significantly more, relative to participants who had been exposed to neutral adverts. These results are in line with a recent new study from Stautz et al. (2017) showing null effects of advertising conditions (e.g. alcohol-promoting, alcohol-warning or neutral control) on alcohol consumption, during a taste-test in a bar-laboratory. The findings in the present chapter may be attributed to the fact that participants exposed to the alcohol advertisements condition, relative to the neutral adverts, were more aware of the experimental manipulation. Participants in the alcohol advertisement condition who noticed that they had been exposed to alcohol-related adverts may have deliberately

tried to drink less than what they would do normally in order to present themselves favourably. The effects of similar 'self-presentation' concerns have been described in previous studies (Davis, Thake, & Vilhena, 2010; Melson, Monk, & Heim, 2016). Thus, future studies should aim to refine the experimental protocol, in order to better mask the aims of the advertisement manipulation. Additionally, the present results may be attributed to the study's lack of statistical power; particularly if I consider the findings from a recent systemic review which demonstrates that alcohol advertisement increases consumption in the laboratory, but with a small effect size (see Stautz et al., 2016). The present study was not powered to detect this small effect size, or its interaction with ICT. Additionally, the adoption of a taste-test in the present study may have influenced the results. I inferred participants motivation to drink alcohol based on alcohol consumption during a taste-test (see Jones et al., 2016b), while most studies included in Stautz and colleagues review (2016) measured ab-lib consumption during viewing. Future studies should investigate these effects by replicating the study whilst allowing participants to access and consume alcohol while watching TV (during exposure), rather than afterwards (as in the present study and Stautz et al. 2017 study).

Furthermore, I observed that participants in the active training group became significantly faster to respond to neutral cues after ICT. Contrary to expectations, I did not observe any slowing of RTs to alcohol cues, which would indicate the formation of alcohol-inhibition associations (or 'stopping' learning effects), after ICT. Individuals generally were slower to alcohol cues, suggesting maybe a ceiling effect on RTs. These findings are in line with results from our previous chapter (see study 2.1, page 42) and some applied studies (Houben et al., 2012; Lawrence et al., 2015a). Yet, they contradict RTs stop-learning effects findings replicated in many alcohol ICT studies (Jones & Field, 2013; Lenartowicz et al., 2011; Noël et al., 2016; Verbruggen & Logan, 2008b, 2009; Verbruggen et al., 2014). As mentioned in the previous chapter, these mixed findings on stop-learning effects may be attributed to various factors related to the task, such as its set-up (Best et al., 2015; Chiu & Aron, 2014; Stice et al., 2016) or its insufficient sensitivity to detect RTs changes resulting from ICT (for details see study 2.1, page 49).

The reported study presents a few limitations. Sample size is definitely an issue; as results from recent reviews on ICT effectiveness (Allom, Mullan & Hagger 2015; Jones et al., 2016b, 2017) and from advertising on ad-lib consumption (Stautz

et al., 2016) reveal that effect sizes are small. Thus, suggesting that the study should be replicated with a larger sample size. Additionally, in common with most other translational studies, group allocation was single rather than double blinded: the experimenter was aware of group allocations, but participants were not. This increases the risk of bias in such interventions (see Cristea, Kok & Cuijpers, 2016). Even if participants were led to believe that there was no experimental manipulation in the study, and indeed the majority of participants believed the cover story, 17.5% were aware of the advertisement manipulation. Therefore, future studies should address this issue in order to avoid demand effects on alcohol consumption. Finally, approximately half of our sample was aware of the true purpose of the taste-test. However, taste-test awareness did not influence our primary findings, demonstrating that regardless of participants' awareness, the active training group consumed less alcohol than controls (see Jones et al., 2016a). Finally, similarly to the previous reported study (see study 2.1, page 49) a strength of the present study is the inclusion of a Sham control group (50:50 contingency) which avoids the inflation of the training effect size (Schonberg et al., 2014).

To conclude, the effects of a single session of ICT on alcohol consumption were diminished if people were exposed to alcohol advertising, before their consumption was measured. Thus, suggesting that ICT effects in an ecologically valid laboratory are likely to be neutralised after exposure to alcohol advertising. The present findings are an important step towards understanding and implementation of this intervention in the real-world. Further research is required to optimise this intervention, by elucidating the mechanisms underpinning ICT and further investigating potential moderating effects of other external factors on ICT outcomes.

Chapter Four

Event-related potentials when preparing to approach and avoid alcohol cues following Cue Avoidance Training

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4.1 Abstract

Introduction: CAT reduces alcohol consumption in the laboratory. However, the neural mechanisms that underlie the effects of this intervention are poorly understood. In this study, I investigated the effects of a single session of CAT on ERPs and readiness potentials during preparation of approach and avoidance movements to alcohol cues.

Methods: Heavy drinking young adults (N=60) were randomly assigned to complete either Cue Avoidance Training (CAT; repeatedly making avoidance movements to alcohol pictures with a joystick), or Cue Approach Training (repeatedly making approach movements to alcohol pictures). After training, I recorded participants' ERPs and readiness potentials, as they were preparing to make approach and avoidance responses to alcohol and control pictures, adopting a contingent negative variation paradigm (CNV).

Results: In participants who completed a single session of CAT, the amplitude of the N200 ERP component was increased when they were preparing to approach rather than avoid alcohol pictures (the action that was incongruent to that learned during training), whereas the amplitude of the late positive potential (LPP) was less negative when they were preparing to avoid alcohol pictures, relative to control pictures (the action that was congruent to that learned during training). In the cue approach training group there were no differential effects on the N200, although

in this group the LPP was also less negative when participants were preparing to perform the action that was congruent to that learned during training. There were no group differences in preparatory readiness potentials.

Conclusions: After a single session of CAT, the N200, a marker of executive control and conflict resolution was enhanced when participants were required to respond to alcohol cues with an approach movement, which is incongruent with the response learned during the training block. Whereas congruency effects were found for the LPP, which may indicate enhanced attentional processing when making a motor movement that is compatible with that learned during training. These findings help to clarify the neural mechanisms that underlie the effects of CAT on behaviour.

Keywords: AAT, alcohol, cognitive bias modification, event related potentials, preparatory states.

4.2 Introduction

In alcohol consumers, alcohol-related cues evoke automatic approach tendencies, and these automatic tendencies are thought to influence drinking behaviour. A number of studies have measured the strength of these tendencies via the Approach Avoidance task (AAT; Wiers et al., 2009) and related tasks (Field et al., 2008) and demonstrated that non-dependent heavy drinkers, compared to light drinkers, are faster to approach alcohol pictures rather than avoid them (see Kersbergen et al. 2015; Watson, de Wit, Hommel, & Wiers, 2012).

In alcohol-dependent patients, stronger automatic tendencies to approach alcohol are associated with activation in brain regions that underlie cue reactivity and craving (Schacht et al., 2013) such as the nucleus accumbens and medial prefrontal cortex (mPFC, Ernst et al., 2014; Wiers et al., 2014). These functional magnetic resonance imaging (fMRI) studies, because of their spatial resolution, help to clarify the neural structures involved in approach and avoidance tendencies. However, given that automatic approach and avoidance tendencies are activated within milliseconds of perceiving a salient stimulus, fMRI lacks the temporal resolution to fully characterise the underlying brain mechanisms. This can be achieved by investigating event related potentials (ERPs), via the electroencephalogram (EEG), as participants complete these computerised tasks.

Surprisingly, very few EEG studies have investigated specific ERPs associated with automatic approach-avoidance tendencies in heavy drinkers and alcohol-dependent patients. To date only two studies have measured ERPs in alcohol consumers as they prepare to make a motor response during an alcohol approach-avoidance task. Both studies investigated these biases following administration of a small dose of alcohol (relative to a placebo), by adopting different measures (e.g. desynchronization of cortical oscillation, and amplitude asymmetries). Both demonstrated that preparatory motor states seem to play a key role in performance on the AAT, by showing greater desynchronization of cortical oscillation when preparing to approach alcohol following alcohol administration (Korucuoglu et al., 2014a) and by observing greater preparatory lateralized activity when preparing to approach soft-drinks, in heavy drinkers who were attempting to control their alcohol consumption (Korucuoglu et al., 2016).

More relevant to the focus of the present study are studies that used EEG to measure brain activity during an AAT with emotional stimuli. In one study, participants performed two blocks of an AAT, one that required emotion-congruent responses (i.e. approach positive pictures and avoid negative pictures) and another that required emotion-incongruent responses (i.e. approach negative and avoid positive; Ernst et al., 2013). Results evidenced increased amplitude of the N200, a bio-marker of cognitive control and conflict resolution (Clayson & Larson, 2011), during emotion-incongruent compared to emotion-congruent trials. In a more recent study (Bamford et al., 2015) the amplitude of the Late Positive Potential (LPP), an ERP component associated with attentional processing of salient stimuli (Hajcak, MacNamara, & Olvet, 2010; Macnamara, Foti, & Hajcak, 2009) was increased when participants were preparing to make an emotion-congruent response compared to an emotion-incongruent response. Similarly, when avoiding angry faces in highly avoidant individuals, congruency effects were observed after the administration of cortisol (Van Peer et al., 2007) by enhanced P150 and P300 amplitudes, early ERP positive components associated with the attentional processing of emotional stimuli (Hauk, Rockstroh, Elbert, & Peter, 2002). Moreover, these ERP components appear to play important roles in other addiction literature. In particular, the amplitude of P300 and LPP are significantly enhanced in substance users, relative to non-users, during exposure to substance-related cues (Standardized Mean Difference (SMD) = 0.46 in Littel, Euser, Munafò, & Franken, 2012), whereas the N200 in drinkers has

shown to be linked to executive control deficits in substance users (Petit, Kornreich, Verbanck, & Campanella, 2013).

As previously discussed CBM interventions aim to train participants to overcome automatic approach tendencies and other cognitive biases, with a view to reducing alcohol consumption or other appetitive motivated behaviours such as food intake (Gladwin, Wiers, & Wiers, 2016; Kakoschke et al., 2017; Wiers, Gladwin, Hofmann, Salemink, & Ridderinkhof, 2013). A specific form of CBM is Cue Avoidance Training (CAT), based on the AAT in which participants categorise alcohol-related and control pictures by making approach and avoidance movements using a joystick (for details see page 41). This intervention results in a reduction in the strength of automatic alcohol-approach associations such that alcohol cues evoke automatic avoidance responses when they are encountered in the future (Wiers et al., 2011). Importantly, compared to control interventions, CAT prompts reductions in alcohol consumption in the laboratory among non-dependent heavy drinkers (see study 2.1, page 31; Sharbanee et al., 2014; Wiers, Rinck, Kordts, Houben, & Strack, 2010) and it reduces the likelihood of relapse to drinking after treatment in alcohol-dependent patients (Wiers et al., 2011; Eberl et al., 2013; Manning et al., 2016). Despite these consistent findings for CAT, there are concerns about the efficacy of diverse forms of CBM in the broader addiction literature (Cristea, Kok & Cuijpers, 2016).

The psychological mechanisms that underpin the behavioural effects of CAT are fairly well-understood: reversal of the automatic approach bias (Eberl et al., 2013) and in particular, the strengthening of automatic alcohol-avoidance associations (Gladwin et al., 2015) can account for the beneficial effects of CAT on long-term outcomes in alcohol-dependent patients. However, the brain mechanisms that underlie these changes in alcohol-avoidance and alcohol-approach associations after CAT have only recently been investigated, and they remain poorly understood (den Uyl, Gladwin, Rinck, Lindenmeyer, & Wiers, 2016; den Uyl, Gladwin, & Wiers, 2016; Wiers et al., 2014; Wiers & Wiers, 2016). Two recent fMRI studies demonstrated reduced activation in the amygdala (Wiers, Stelzel, et al., 2015) and in the mPFC (Wiers, Ludwig, et al., 2015) in alcohol dependent patients after multiple sessions of CAT, which is suggestive of a blunting of activity in neural substrates of alcohol cue reactivity (Schacht et al., 2013).

To date, only one study has analysed brain activation using EEG to investigate how this might be affected by CAT in heavy drinkers (den Uyl, Gladwin, & Wiers, 2016), finding null effects on the P300 component (which was the only ERP component investigated) after a brief session of CAT. However, the main aim of the study was to investigate if transcranial direct current stimulation (tDCS) would enhance CBM effects, and EEG was recorded during an oddball cue-reactivity task. Therefore, the purpose of the present study was to extend the work on CBM and of the processes underlying approach biases, by investigating changes in ERPs that arise as a result of a single session of alcohol-CAT in a sample of non-dependent heavy drinkers.

In the present study I measured participants' brain activity as they completed a modified version of an AAT with alcohol pictures, during a response-preparation period (Preparatory AAT; see Korucuoglu, Gladwin, & Wiers, 2014), immediately after they had been trained to associate alcohol with either avoidance or approach. I investigated ERPs and motor readiness potentials as critical antecedents of the execution of goal directed behaviour that should be capable of detecting neural effects of associations learned (during CAT) on preparatory motor readiness, without being contaminated by motor activity. The most widely used EEG marker of motor preparation (the intention to perform an action) is the contingent negative variation paradigm (CNV), which reflects a slow negative inflection in EEG signals (ERP oscillations) over frontal-central and parietal-central areas during the preparation period between a warning stimulus (S1) and an imperative stimulus (S2) (e.g. the time interval between two events; Walter et al., 1964). To the best of our knowledge this study is one of the few to explore the effects of CAT on EEG responses (ERPs and readiness potentials) to alcohol pictures when participants are preparing to approach or avoid those pictures.

Participants were randomly allocated to one of two training groups, either 'Approach Alcohol' (repeatedly approaching alcohol pictures and avoiding neutral pictures, 90-10% contingency) or 'Avoid Alcohol' (reversed contingencies; Cue Avoidance Training; CAT). Contrary to the studies described in previous chapters the 'Approach Alcohol' control condition was employed instead of a Sham training (50% contingency), in order to increase the subjective value of the alcohol stimuli and inflate training effects (Schonberg et al., 2014), helping to disentangle and detect more effectively CAT neuro mechanisms. Before the training, participants completed

an assessment version (AAT) and after training they completed a similar task (Preparatory AAT), whilst their brain activity was recorded.

In line with the findings on emotional stimuli, I predict to observe changes in manual reaction times, in amplitudes on a range of early ERP components (P300, N200, LPP) and in the readiness potentials of the CNV, between the two opposite trainings, when preparing to perform actions that were congruent with contingencies that were applied during the training phase, compared to those that were incongruent with those learned during the training phase. Specifically, on the basis of previous studies (Bamford et al., 2015; Ernst et al., 2013; van Peer et al., 2007), I hypothesised that, in the 'Approach Alcohol' group, P300 and LPP amplitudes would be enhanced during preparation to approach alcohol stimuli, while an enhanced N200 should be observed when preparing to avoid alcohol stimuli. By contrast, in the 'Avoid Alcohol' group, I expect to see an enhancement of P300 and LPP amplitudes during preparation to avoid alcohol stimuli, alongside an enhanced N200 when preparing to approach alcohol stimuli. Exploratory analyses were conducted on the CNV, with a similar prediction to observe greater readiness potentials on congruent trials.

4.3 Methods

4.3.1 Participants

Sixty heavy drinkers (42 females, 18 males) were recruited from staff and students at the University of Liverpool via online and poster advertising. Similar to previous studies, inclusion criteria included average weekly alcohol consumption in excess of the United Kingdom Department of Health guidelines at the time of the study (see study 2.1, page 35). Participants were also required to be aged between 18 and 35, fluent in English, have normal or corrected to normal vision and no history of alcohol use disorders. The study was approved by the University of Liverpool Research Ethics Committee.

4.3.2 Design

A between-subjects design was employed. Participants were randomly assigned to groups that differed in the cue-movement contingency that was applied during the training phase. Participants learned to associate alcohol cues with either

approach (cue approach training group) or avoidance (cue avoidance training (CAT) group).

4.3.3 Materials and tasks

Computer tasks were programmed and administered in Inquisit version 3.0 (Millisecond Software, 2009), and were administered on a Dell desktop computer with a 15" monitor. Participants responded using a joystick.

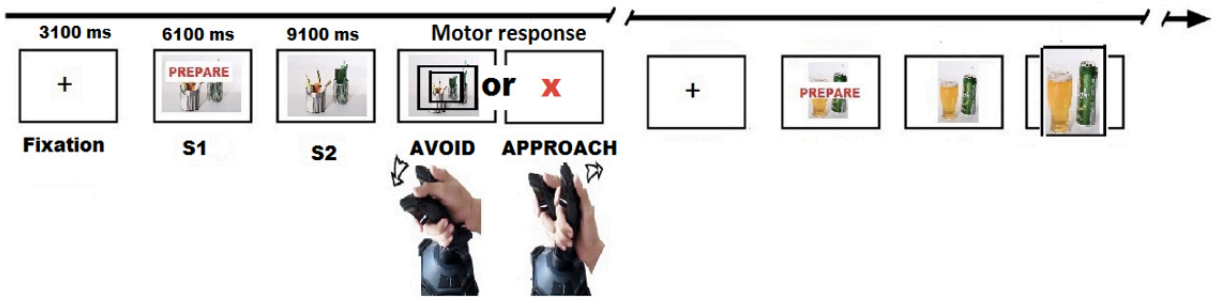
Alcohol-related and matched neutral (control) pictures were equivalent to the stimuli used in previous described studies (see study 2.1, page 35).

The task comprised five blocks: a pre-test AAT assessment block (10 practice trials and 80 test trials), the training block (480 trials, with a short break half-way through), and finally the preparatory AAT, which was a post-test assessment block (8 practice trials and 200 test trials, interrupted with short breaks every 25 trials). The AAT and CAT were identical to the task described in study 2.1 (see page 38) based on Wiers et al. study (2010). While the preparatory AAT was adapted from Korucuoglu, Gladwin and Wiers (2014). The preparatory AAT (post-test assessment block) was interrupted halfway through (after 100 trials) by a booster training block (180 trials), which was then followed by the remaining 100 post-test assessment trials. Participants were not informed when the task switched between assessment and training blocks. Picture format was counterbalanced, with half of participants instructed to pull landscape and avoid portrait format pictures, and reversed instructions for remaining participants. Participants were required to make an equal number of push and pull responses in all blocks. Trial order within each block was randomized.

The pre-test and post-test assessment blocks contained 50% alcohol and 50% control pictures, half of each in portrait format and half in landscape format. In these blocks, participants had to approach and avoid alcohol and control pictures with equal frequency. In the training block, for participants in the avoidance training (CAT) group, 90% of alcohol pictures were presented in the format requiring an avoidance movement, whereas 90% of control pictures were presented in the format requiring an approach movement. For participants in the approach training group these stimulus-response mappings were reversed (i.e. approach alcohol and avoid control pictures). These contingencies were also applied during the booster training block (that occurred midway through the post-test assessment block).

In order to capture neural activity during preparatory motor states, the trial sequence in the post-test assessment block differed from that in other blocks (see Korucuoglu, Gladwin and Wiers, 2014). During this block, on each trial, following the fixation cross (3000 ms), the picture appeared on the screen with the word "PREPARE" superimposed on top (3000 ms). During this preparation period, participants were asked to prepare their motor response (approach or avoid), depending on the feature of the stimulus (e.g. landscape or portrait), but to withhold it until the word "PREPARE" disappeared. Any responses made during the preparation period were not registered. After 3000ms, the 'prepare' text was removed, and participants were able to make their response. During each trial the picture remained on screen until the participant responded or until a 1000 ms timeout had elapsed (see figure 4.1). Zooming effects for correct responses and error feedback for incorrect responses were identical to those applied during other blocks.

Figure 4.1 Schematic representation of the experimental trial procedure of the 'Preparatory' AAT. Example of trial: avoid Landscape pictures and approach Portrait pictures).



4.3.4 EEG recordings

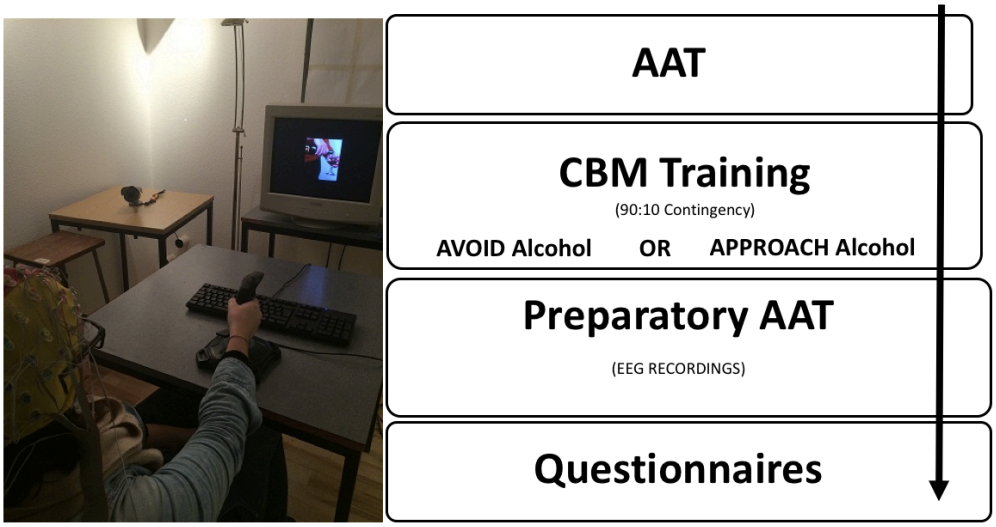
EEG activity was recorded during the post-test assessment block during the preparation phase of each trial. EEG activity was recorded continuously using 64 channels (scalp electrodes) based on the extended 10/20 system using a Biosemi ActiveTwo system (Biosemi, Amsterdam, Netherlands). The electrode cap was aligned using four anatomical landmarks; nasion, occipital protuberance and left and right pre-auricular points. Electrode gel was used to ensure that electrode to skin impedance was always below 10 kΩ. Vertical electrooculograms (EOG) were

recorded in parallel with EEG signals above and below the right eye using flat disc electrodes, and all signals were recorded continuously with 1024 Hz sampling frequency. The recording bandpass filter was set at 0.1 – 200 Hz. Data was spatially transformed to reference-free data using the common average reference method (Lehmann, 1984).

4.3.5 Procedure (Figure 4.2)

Participants were tested between 12:00 and 18:30 in the EEG laboratory on the University of Liverpool campus, for a single experimental session which lasted no more than two hours. Participants provided informed consent and a breathalyser reading (all participants had a breath alcohol content of zero), before being seated at a desk approximately 1.5m away from the computer monitor. After providing informed consent, electrodes were fitted and tested before participants completed the pre-test assessment, training, and the post-test assessment blocks of the task. Finally, the EEG cap and electrodes were removed before participants provided general demographic information and completed three questionnaires (for details see page 35): the Timeline Follow-Back retrospective alcohol diary (TLFB; Sobell & Sobell, 1992), the Alcohol Use Disorders Identification Test (AUDIT; Saunders & Babor, 1993) and the Readiness to Change Questionnaire (RTCQ; Rollnick, Heather, Gold, & Hall, 1992). At the end of the experiment participants were debriefed and compensated either with course credits or shopping vouchers (£20 Sterling).

Figure 4.2 Schematic overview of the experimental procedure. For details see methods section.



4.3.6 Data reduction and analysis

In order to analyse behavioural data (latencies to approach and avoid alcohol and control pictures) during the pre-test and post-test blocks, and over time during the training block, I first excluded trials with errors and those with outlying reaction times. Two separate outlier cut-offs were computed: one for the pre-training and training blocks, and another for the post-training block (in which reaction times were affected by the introduction of the preparatory phase at the start of each trial). Similarly, to previous studies RTs faster than 200ms or slower than 2000ms, then those that were more than 3 SDs above the mean for that block, were excluded. After excluding trials with errors and outliers in this way, RTs were analysed using mixed-design ANOVAs as detailed below.

Brain Electrical Source Analysis v.6.0 program (BESA, GmbH, Germany; Scherg & Berg, 1990) was used to analyse EEG data during the preparatory phase of each trial in the post-test block. EOG artefacts were removed by a principal component analysis procedure (Berg & Scherg, 1994), and muscle artefact rejection was completed manually by visual inspection before averaging. A CNV paradigm (Tecce, 1972; Kappeman & Luck 2011) was used to investigate continuous EEG data, during the remaining epochs of 3000ms from the preparation phase of the trials, with ERPs time-locked from the onset of the picture that appeared on the screen with the word "PREPARE" superimposed (S1) until the word "PREPARE" disappeared from the screen which signalled to participants that they could make their response (S2; see figure 4.1). These epochs were averaged across all trials of the post-assessment block, for each condition (approach alcohol, avoid alcohol, approach control, avoid control). Filtering was done on the averaged data at 0.01 – 40 Hz. The notch filter was set at 50 Hz. For individual electrode analysis, grand averages were computed and exported to Matlab R2009a (Mathworks: Natick, MA). Then, identification and analysis of ERPs (associated with the processing of the stimuli) and of the readiness potential of the CNV (related to the preparatory motor action) was guided by visual inspection of the waveforms in a CNV paradigm. This led to the identification of three peak ERP amplitudes (P100, N200 and LPP). However, contrary to expectations, P300 ERP was not detected. For the detected ERPs, five clusters of electrodes were detected and ERP amplitude data were analysed using repeated measures ANOVAs in SPSS v.22 (IBM Inc., USA). A similar cluster

analysis was also conducted on four 500ms intervals on the CNV readiness potential to examine training effects on preparatory motor actions.

4.4 Results

4.4.1 Group characteristics

Table 4.1 shows summary data for the self-report measures separately for groups (2: avoidance training, approach training). A MANOVA showed that groups were not well matched ($F(7, 52) = 2.53$, $p = .03$). There were significant between group differences in age ($F(1, 58) = 6.68$, $p = .01$; participants in the approach training group were younger) and AUDIT scores ($F(1, 58) = 7.16$, $p = .01$; participants in the approach training group had higher scores). No other differences were observed for weekly alcohol consumption and readiness to change (RTCQ); ($Fs < 1.38$, $ps > .25$). A Chi Square test confirmed that groups were well-matched for gender ratio ($\chi 2(1) = 1.27$, $p = .26$).

Table 4.1 Participant characteristics by group. Values are mean ± SD.

	Avoidance training group	**Approach training group**
Age (years)	26.77 (5.12)	23.67 (4.11)
Gender ratio (M/F)	11:19	7:23
Weekly alcohol consumption	24.40 (10.90)	22.49 (12.93)
AUDIT	10.10 (4.29)	14.10 (6.09)
RTCQ Pre-contemplation	-1.00 (3.82)	-1.17 (2.93)
RTCQ Contemplation	0.27 (3.32)	0.93 (3.50)
RTCQ Action	-0.37 (4.33)	-1.63 (4.02)

Weekly alcohol consumption = self-reported typical weekly alcohol intake, in UK units.

AUDIT = Alcohol Use Disorders Identification Test, values range from 0-40.

RTCQ = Readiness to Change Questionnaire subscales range from -8 to +8.

4.4.2 Behavioural data (Table 4.2)

Pre-test

Reaction times to initiate approach and avoidance movements were subjected to a 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Picture type (2: alcohol, control) and Movement (2: approach, avoidance) and a between-subject factor of Group (2: avoidance training, approach training). The main effect of Movement was statistically significant ($F(1,58) = 7.01$, $p = .01$), reflecting faster RTs to initiate approach rather than avoidance movements. The hypothesised two-way interaction Picture type × Movement ($F(1,58) = .08$, $p = .79$) was not significant, and there were no other significant main effects or interactions ($Fs < 2.37$, $ps > .13$).

Post-hoc exploratory planned contrasts for the sample as a whole showed that participants were in general faster to initiate approach movements rather than avoidance movements to both alcohol pictures (M = 757.05, SD = 150.52 vs. M = 783.58, SD = 155.75, $t(59) = -2.14$, $p = .04$, $d = .17$) and control pictures (M = 752.05, SD = 141.58 vs. M = 774.88, SD = 154.50, $t(59) = -2.13$, $p = .04$, $d = .15$). Latencies to approach ($t(59) = .58$, $p = .57$) and avoid ($t(59) = -1.03$, $p = .31$) alcohol and control pictures did not differ. Therefore, contrary to expectations, participants did not possess an automatic tendency to approach rather than avoid alcohol pictures (relative to control pictures) during the pre-test block.

Training block

In order to explore the formation of cue-response associations over the course of the training block, RTs to initiate approach and avoidance movements were subjected to a 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Time (2: first 8 trials of each type at the beginning of the training block vs. the last 8 trials of each type at the end of the training block), Picture type (2: alcohol, control) and Movement (2: approach, avoidance) and a between-subject factor of Group (2: avoidance training, approach training). Again, the main effect of Movement was statistically significant ($F(1, 58) = 5.58$, $p = .02$), RTs to initiate approach were generally faster than avoidance movements. Additionally, the three-way interaction Picture type × Movement × Group was significant ($F(1,58) = 19.25$, $p < .01$), and the two-way interaction Picture type × Group ($F(1,58) = 3.88$, $p = .06$) and the three-way interaction Movement × Time × Group both were not significant ($F(1,58) =$

3.22, p = .08). Importantly, the critical four-way interaction Time × Picture type × Movement × Group was not significant (F (1,58) = 1.44, p = .24) and there were no other significant main effects or interactions (Fs < 2.52, ps > .12).

Given the significant three-way interaction that was not qualified by time, data were averaged across the beginning and end of the training block. Planned contrasts separately for each group revealed that participants in the avoidance training group were faster to avoid alcohol pictures (M = 747.27, SD = 132.15) compared to control pictures (M = 787.20, SD = 147.36), t (29) = -3.01, p = .01, d = .29, but latencies to approach alcohol and control pictures did not differ (t (29) = 1.75, p = .09). By contrast, participants in the approach training group were faster to approach alcohol pictures (M = 732.82, SD = 134.54) compared to control pictures (M = 769.93, SD = 129.04; t (29) = -2.11, p = .04, d = .28), and they were also faster to avoid control pictures (M = 731.73, SD = 147.88) compared to alcohol pictures (M = 800.29, SD = 165.47; t (29) = 3.81, p < .01, d = .44).

Post-training block

RTs to initiate approach and avoidance movements immediately after the preparatory phase of each trial were subjected to a 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Picture type (2: alcohol, control) and Movement (2: approach, avoidance) and a between-subject factor of Group (2: avoidance training, approach training). The main effect of Movement was not significant (F (1,58) = 3.43, p = .07). The expected three-way interaction Picture type × Movement × Training condition was not significant (F (1,58) = 1.01, p = .32), and there were no other significant main effects or interactions (Fs < .09, ps > .76).

Post-hoc planned contrasts, split by training group showed that participants in the avoidance training group were faster to approach rather than avoid alcohol pictures (M = 580.20, SD = 132.27 vs. M = 600.96, SD = 148.55); t (29) = -2.03, p = .05, d = .15. None of the other contrasts (e.g. approach alcohol vs. approach control; approach control. vs avoid control) in the avoidance training group were statistically significant (ts < 1.12, ps > .27). In the approach training group, none of the contrasts were statistically significant (ts < 1.24, ps > .23).

Table 4.2. Reaction times (milliseconds) to approach and avoid alcohol and control pictures during the approach-avoidance task (AAT), the post-training assessment task (Preparatory AAT) and at the beginning and end of the training blocks. Values are mean ± SD.

	Avoidance training group	**Approach training group**
AAT (Pre-CAT)		
Approach alcohol	*748.96 (143.32)*	*765.14 (159.44)*
Avoid alcohol	*794.91 (173.07)*	*772.24 (138.36)*
Approach control	*751.07 (143.71)*	*753.03 (141.71)*
Avoid control	*783.19 (167.43)*	*766.57 (142.79)*
CAT (during training blocks)		
Beginning - Approach alcohol	*763.00 (120.89)*	*729.92 (129.96)*
Beginning - Avoid alcohol	*759.65 (152.37)*	*808.47 (167.91)*
Beginning - Approach control	*735.52 (116.63)*	*765.07 (137.76)*
Beginning - Avoid control	*770.25 (147.24)*	*745.22 (148.33)*
End - Approach alcohol	*744.39 (139.96)*	*735.73 (163.46)*
End - Avoid alcohol	*734.89 (135.02)*	*792.12 (177.41)*
End - Approach control	*725.33 (116.58)*	*774.79 (139.42)*
End - Avoid control	*804.15 (165.03)*	*718.25 (165.64)*
Preparatory AAT (Post-CAT)		
Approach alcohol	*580. 02 (132.27)*	*572.29 (167.69)*
Avoid alcohol	*600.96 (148.55)*	*582.05 (132.68)*
Approach control	*582.34 (146.16)*	*567.17 (154.77)*
Avoid control	*596.33 (157.45)*	*585.59 (137.53)*

4.4.3 ERP components and readiness potentials

Butterfly plot (Figure 4.3)

ERPs in response to alcohol and control stimuli across all trials are illustrated in the form of a butterfly plot and topographic maps of the selected components in figure 4.3. The CNV and the grand average ERPs indicate that the topography across recording sites was generally consistent with that reported by other studies (Brunia & van Boxtel, 2001; Tecce, 1972).

The first component peaked at around 123 ms and showed positivity in the occipital electrodes and negativity over frontal electrodes, and this is consistent with characteristics of the P100 component that is implicated in early visual processing (Hopf et al., 2002). This component is best represented by the first positive peak following presentation of the first stimulus (S1) on electrodes P07 and P08, which were analysed together as a first cluster.

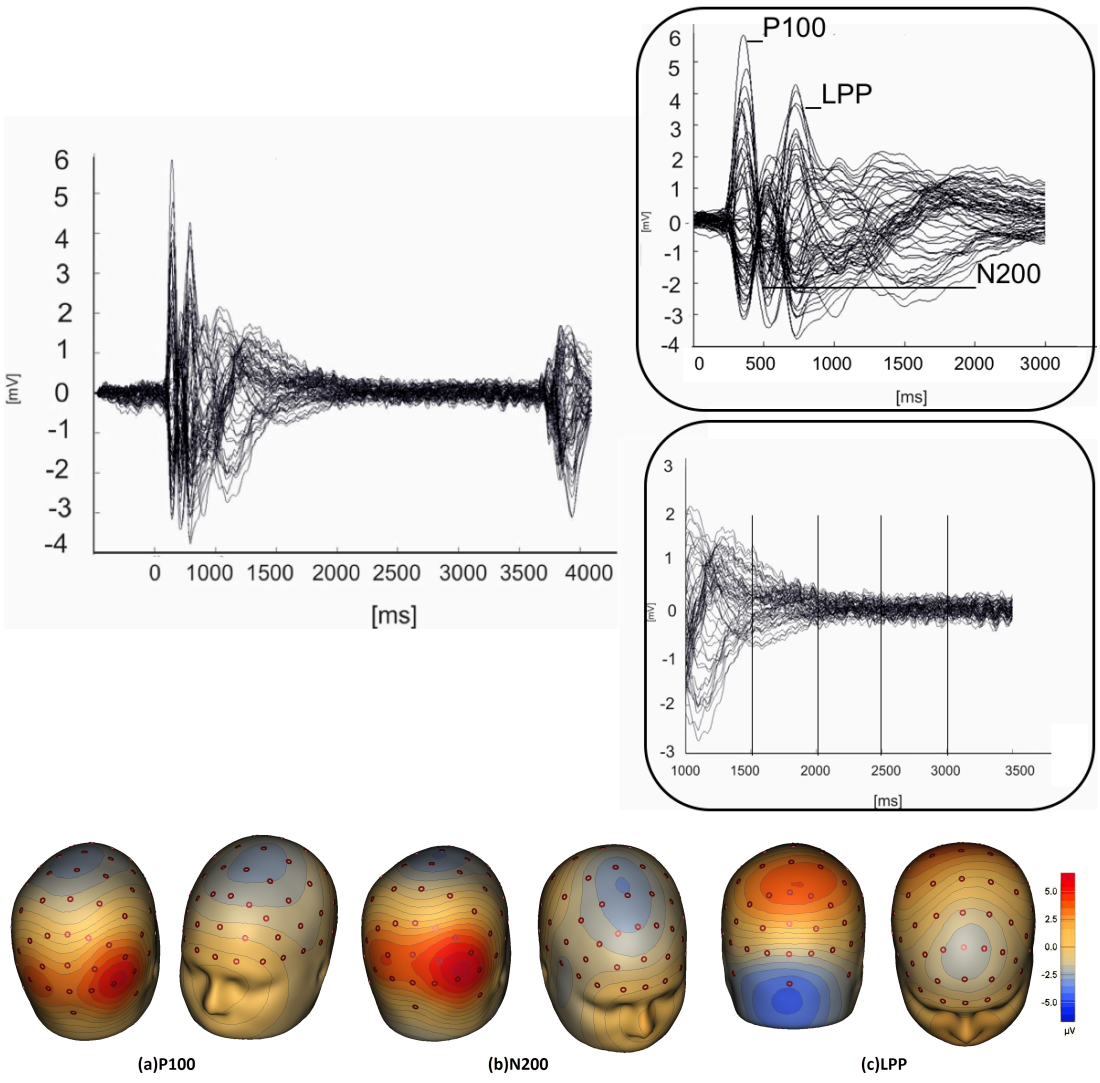
The second component, which peaked at around 261 ms, showed strong central cortical negativity and parietal positivity and this is consistent with characteristics of the N200 (Patel & Azzam, 2005). This component is best represented as the first negative peak occurring after P100 on electrodes Fz and Cz, and these were analysed together as a second cluster.

The third component peaked at around 570 ms in the parietal (Pz, P2, P1) and mid-line electrodes (Fz, Cz), with strong negativity over the central occipital sites (Fz, Cz) and positivity over the central parietal sites (Pz, P2 and P1). This component is consistent with characteristics of the late positive potential (LPP).

Contrary to hypotheses, the anticipated P300 was not observed, consequently it was not reported or analysed. This is in line with the emotional studies where the P300 is not consistently observed (Bamford et al., 2015; Ernst et al., 2013).

Additionally, the plot evidenced no changes in electrophysiological activity occurred before the stimulus that indicated the motor response (S2). However, exploratory analyses were conducted on the readiness potential of the CNV in steps of 500 ms in the mid-line electrodes (Fz and Cz cluster) for four intervals starting from 1000 to 3000 ms, in order to confirm (as observed from the plot) null effects on the readiness potentials. These null effects may be due to the fact that both studies that observed effects on motor preparation (using respectively two different measures) did so after administration of a dose of alcohol (Korucuoglu et al., 2014, 2016).

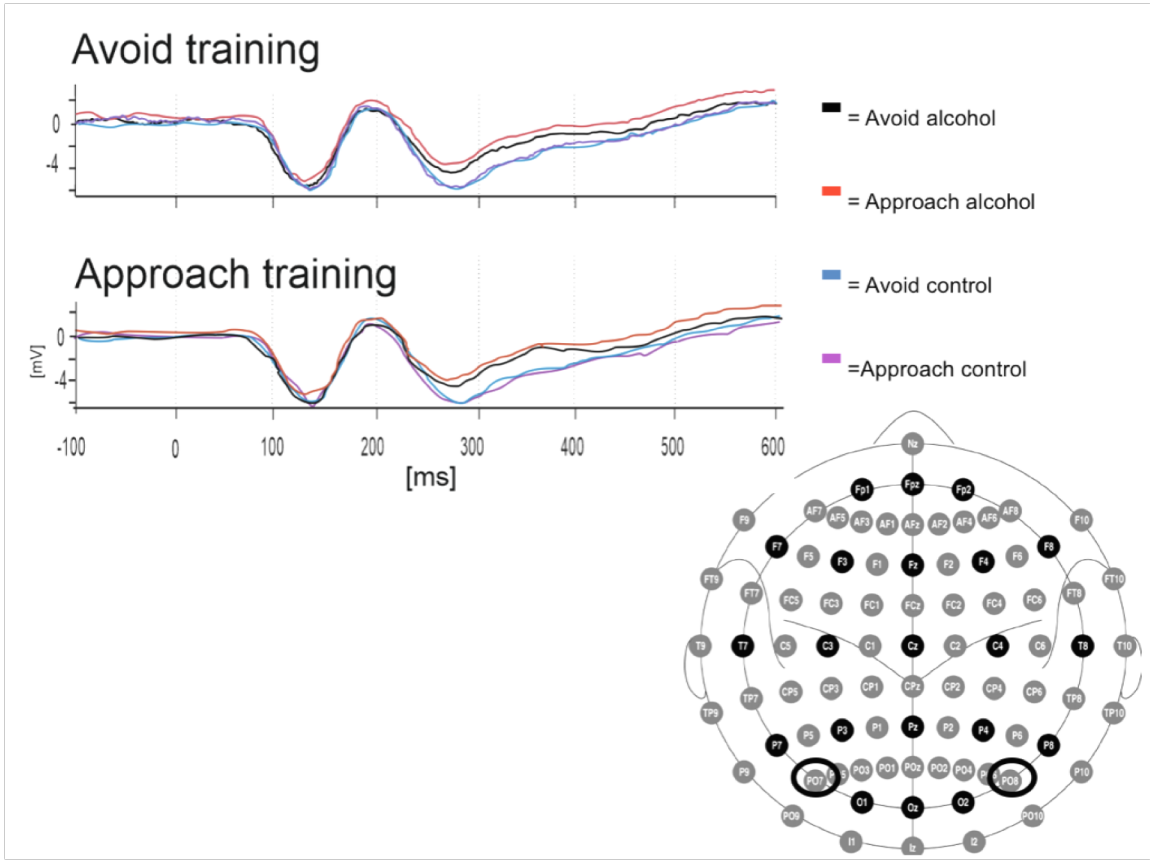
Figure 4.3 Butterfly plot of grand average ERP responses and readiness potential to alcohol and control stimuli during the preparatory phase, and corresponding scalp topographies. Peak latencies of distinct ERP components (123-143, 261-281 and 570-610 ms) are highlighted. Four 500ms intervals of the readiness potential to preparatory states to motor actions are highlighted. The topographic maps of grand average ERPs overlaid on the volume rendering of the human head are shown below. (a) Latency component peaking at 123 ms (P100). (b) Latency component peaking at 261 ms (N200). (c) Latency component peaking at 570 ms (LPP).



P100 (Figure 4.4)

P100 amplitudes (averaged across electrodes P07 and P08) were subjected to a 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Picture type (2: alcohol, control) and Movement (2: approach, avoidance) and a between-subject factor of Group (2: avoidance training, approach training). The main effect of Movement was statistically significant ($F(1,58) = 7.49$, $p = .01$), reflecting a stronger peak in the P100 to initiate approach rather than avoidance movements. However, the three-way interaction Picture type × Movement × Training condition was not observed ($F(1,58) = .16$, $p = .69$) and there were no other significant main effects or interactions ($Fs < 2.09$, $ps > .15$). Therefore, the cue avoidance training manipulation did not influence P100 amplitudes to alcohol-related pictures. However, the fact that a P100 was identified brings strength to the protocol used as shown that individuals were engaged in attentional processing.

Figure 4.4 Grand average of ERP responses to alcohol and control stimuli during the preparation to respond to the AAT. Latency component 123ms (P100) at parietal (P07 and P08) electrode sites as shown below by the 64-channel sensor net layout.

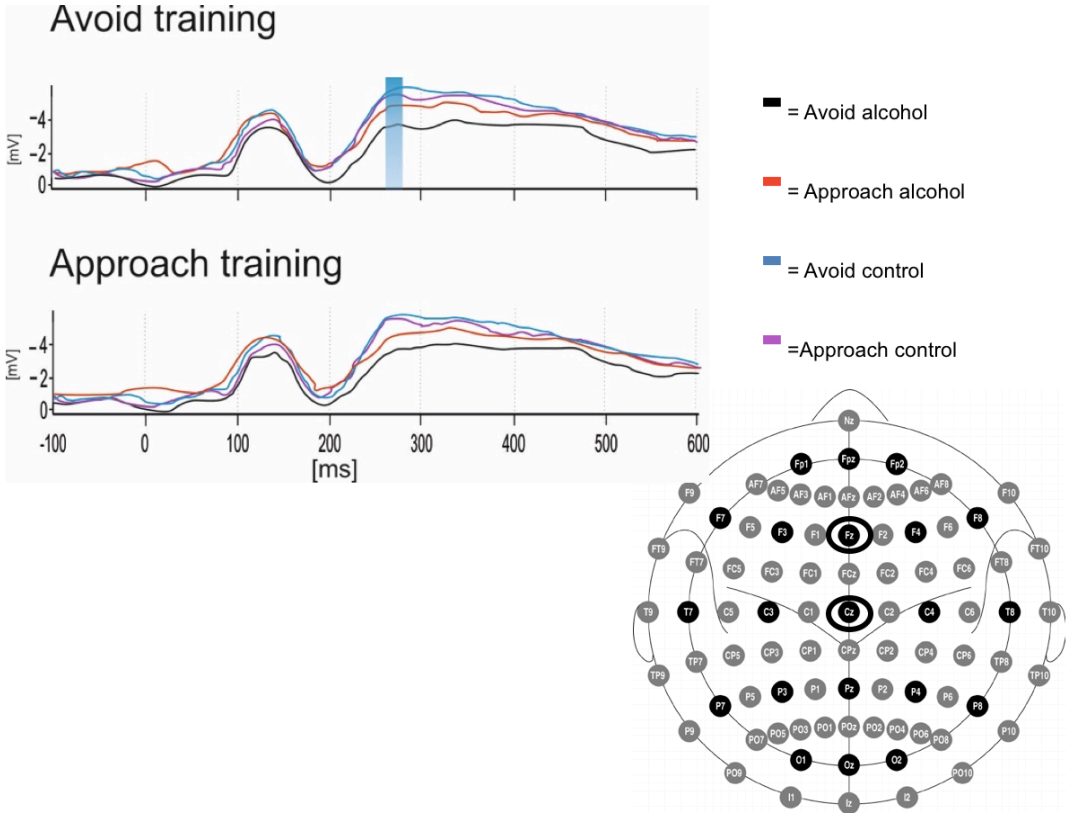


N200 (Figure 4.5)

A similar ANOVA was conducted to explore the influence of cue avoidance training on N200 amplitudes (averaged across electrodes Fz and Cz). A significant main effect of Picture type (F (1,58) = 37.65, $p < .01$), was subsumed under the hypothesized three-way interaction Picture type × Movement × Group (F (1,58) = 8.74, $p = .01$). There were no other significant main effects or interactions (Fs < 1.41, ps > .24).

Post-hoc t-tests performed separately on each group demonstrated greater negativity for control pictures relative to alcohol pictures in both groups of participants. More importantly, greater negativity in the N200 was seen in the avoidance training group when they were preparing to approach alcohol pictures compared to when preparing to avoid those pictures (t (29) = 2.34, $p = .03$, $d = .24$). However, N200 amplitudes to control pictures did not differ during preparation of approach and avoidance in this group (t (29) = -1.11, $p = .28$). In the approach training group, N200 amplitudes when preparing to approach vs. avoid did not differ for either type of picture (alcohol: t (29) = -1.24, $p = .23$; control: t (29) = 1.06, $p = .30$).

Figure 4.5 Grand average ERP responses to alcohol and control stimuli during the preparation to respond to the AAT. Latency component 261ms (N200) at midline (Fz, Cz) electrode sites as shown below by the 64-channel sensor net layout.



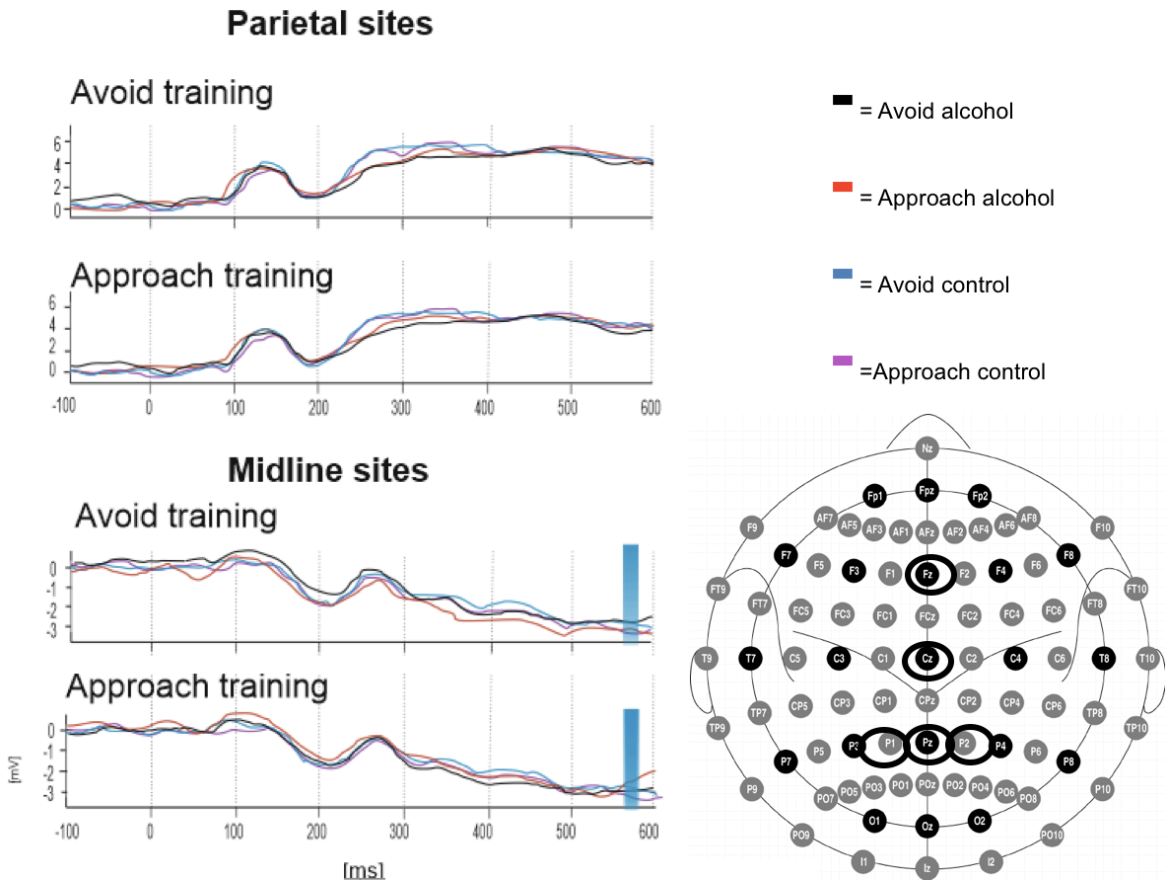
LPP (Figure 4.6)

The influence of cue avoidance training on the LPP at parietal (Pz, P2 and P1) and midline (Fz, Cz) electrode sites was investigated with a 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Picture type (2: alcohol, control), Movement (2: approach, avoidance) and Electrode site (parietal, midline), and a between-subject factor of Group (2: avoidance training, approach training). A significant main effect of Electrode site ($F(1,58) = 79.73$, $p < .01$), and a two-way interaction Electrode site × Picture type interaction ($F(1,58) = 5.26$, $p = .03$) were subsumed under the hypothesized four-way interaction Picture type × Movement × Electrode site × Group, which approached significance ($F(1,58) = 3.82$, $p = .06$). There were no other significant main effects or interactions ($Fs < 2.94$, $ps > .09$).

Separate ANOVAs on LPP amplitudes at each electrode site confirmed that group differences were driven by the midline electrodes, which evidenced a statistically significant three-way Picture type × Movement × Group interaction ($F(1,58) = 4.41$, $p = .04$). Data from the parietal electrodes revealed no significant main effects or interactions ($Fs < .44$, $ps > .51$).

Post-hoc t-tests were performed on LPP amplitudes at the midline electrodes. In the CAT group, LPP negativity was blunted when preparing to avoid alcohol pictures (M = -3.23, SD = 7.04) relative to control pictures (M = -4.41, SD = 6.33); $t(29) = -2.90$, $p = .01$, $d = .18$. No other differences were observed in this group ($ts < 1.77$, $ps > .09$). By contrast, the reverse pattern was seen in the approach training group, in whom LPP negativity was blunted when preparing to approach alcohol pictures (M = -1.82, SD = 3.98) relative to control pictures (M = -2.75, SD = 3.10); $t(29) = 2.17$, $p = .04$, $d = .26$. There were no other significant differences in this group ($ts < .97$, $ps > .34$).

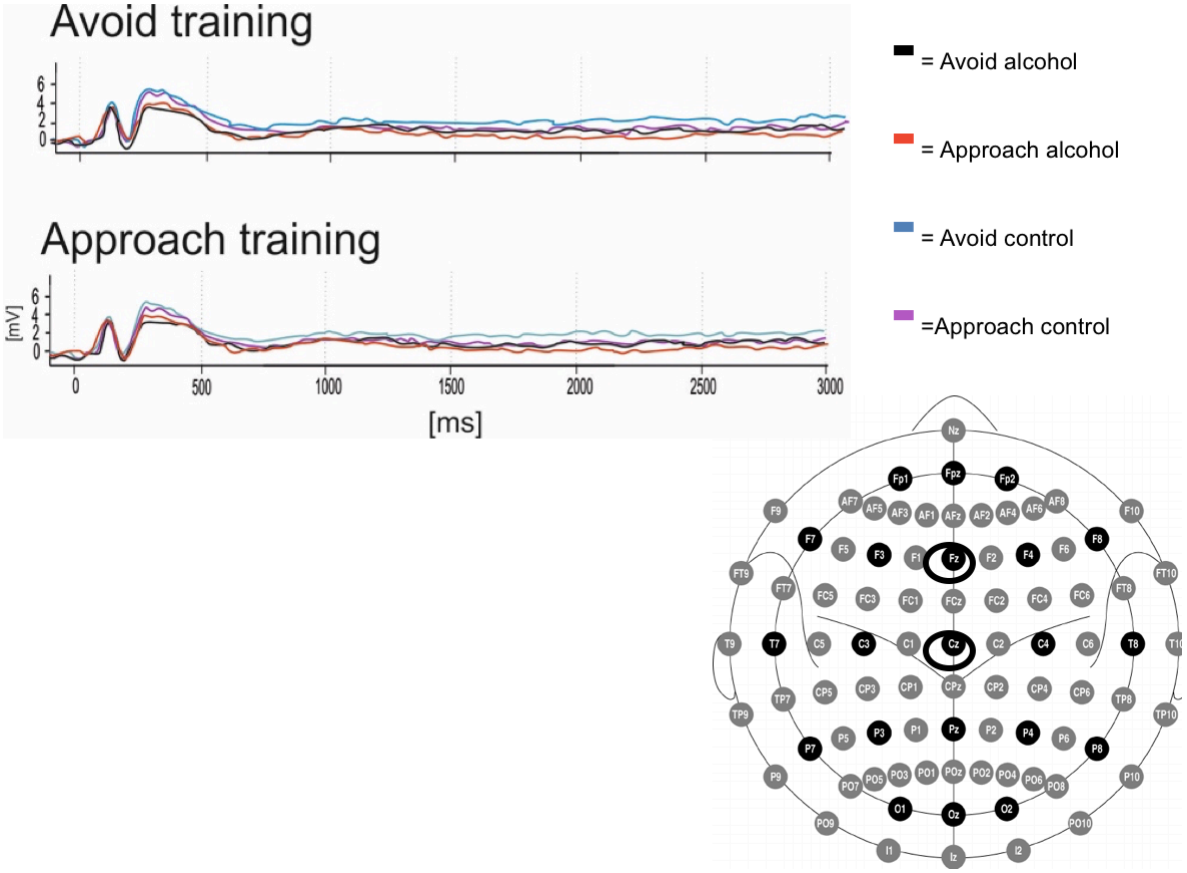
Figure 4.6 Grand average ERP responses to alcohol and control stimuli during the preparation to respond to the AAT. Latency component 570ms (LPP) at parietal (Pz, P1 and P2) and midline (Fz, Cz) electrode sites as shown below by the 64-channel sensor net layout.



Preparatory readiness potential intervals in the mid-line electrodes; Figure 4.7)

The amplitudes at the midline electrodes (Fz, Cz) were explored in four 500 ms intervals over time (3000ms). I was expecting to see greater readiness potential for trials congruent to movement learned in both groups, indicating preparation to motor activity. However, observations from the butterfly plot showed no further changes in brain activity until the preparatory period ended (S2). In order to validate these observed findings, I conducted a 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Picture type (2: alcohol, control), Movement (2: approach, avoidance) and Time (1000ms, 1500ms, 2000ms, 2500ms), and a between-subject factor of Training condition (2: avoidance training, approach training). Results showed no significant change over time between groups, as the critical four-way interaction was not significant ($F(3,174) = .03$, $p = .99$). Only a main effect of picture type was found ($F(1,58) = 4.17$, $p = .05$), indicating greater negativity for alcohol pictures ($M = -14.83$, $SD = 51.63$), relative to control pictures ($M = -19.38$, $SD = 47.45$), $t(29) = 2.05$, $p = .05$, $d = .65$. No other main effects or interactions were observed ($Fs < 3.00$, $ps > .09$), confirming observations from the butterfly plot.

Figure 4.7 Grand average preparatory readiness potential to approach and avoidance responses to alcohol and control stimuli during the preparation to respond to the AAT. Four 500ms intervals at midline (Fz, Cz) electrode sites as shown below by the 64-channel sensor net layout.



4.5 Discussion

Findings from the present study demonstrated stronger negativity of the N200 component in the CAT group when they were preparing to execute the motor movement that was incongruent with that which they had learned during the training block (i.e. when they were preparing to approach rather than avoid alcohol-related cues). Comparable incongruency effects were not seen in the approach alcohol group. However, in both groups of participants, blunted negativity of the LPP was observed at midline electrodes when participants were preparing to respond to alcohol-related pictures with a motor movement that was congruent with that which they had learned during the training block; i.e. blunted LPP negativity in the 'avoid alcohol' group when preparing to avoid alcohol pictures, but blunted LPP negativity in the 'approach alcohol' group when preparing to approach alcohol pictures. Contrary to expectations, no changes in preparatory readiness potential were observed in either group.

Regarding behavioural results, in line with the previous study 2.1 (see page 45) and some literature (Manning et al., 2016; Wiers, Stelzel, et al., 2015), I did not observe robust increases in the strength of alcohol-avoidance associations in participants who completed a single session of CAT. During pre-training the entire sample demonstrated a general bias to approach rather than avoid stimuli (e.g. faster to initiate approach rather than avoidance movements to both alcohol and control pictures), a pattern that has been observed in previous studies (Kersbergen et al., 2015; Watson, de Wit, Hommel, & Wiers, 2012). During the training block, participants in the CAT group were faster to avoid alcohol (often observed following training in literature: Wiers et al., 2010, 2011, Eberl et al., 2013, 2014; Sharbanee et al., 2014; Gladwin et al., 2015), whereas in the approach training group learning effects were observed in the opposite direction, as hypothesised. During the post-training block, in which participants had the opportunity to prepare their motor response before initiating it, these motor speeding effects reverted back to an overall approach bias in the CAT group. This suggests that effects of CAT on RTs are not robust and in fact are very sensitive to experimental factors, because these training effects disappear (and are actually reversed) if a delay is imposed between participants planning their response and actually initiating it. This issue may also be exacerbated by the previous stated methodological limitations of the irrelevant-feature AAT task (assessment version: poor internal reliability and predictive

validity) which may render it relatively insensitive for the purposes of assessing changes in alcohol approach-avoidance associations that are expected to arise after CAT (see Kersbergen et al. 2015).

The primary focus of the present study was the effects of CAT on components of the ERPs when participants were preparing to approach and avoid alcohol-related stimuli. Contrary to expectations and previous studies (e.g. Littel et al., 2012), I did not detect enhanced P300 during exposure to alcohol-related pictures compared to control pictures. However, these findings are consistent with those from other studies that also used the alcohol AAT (den Uyl, Gladwin, & Wiers, 2016) and the emotional AAT which failed to detect or observe changes in the P300 (Bamford et al., 2015; Ernst, Weidner, Ehlis, & Fallgatter, 2012). Furthermore, the P100 peak associated with early attentional and visual processing was observed bringing confidence to the protocol adopted, but contrary to expectations this component did not differentiate between alcohol-related and control pictures, and it was not affected by the training. However, P100 amplitude was larger for approach movements relative to avoidance, which could be related to the visual enlargement task feedback that followed successful approach movements.

Training effects were observed for the other two components analysed. As expected, a greater N200 amplitude was observed in the CAT group when they were preparing to approach alcohol cues rather avoid those cues. No differences were observed in the approach training group. Thus, training effects on N200 were found only for the CAT group (CBM intervention group) and only when preparing to approach alcohol cues, suggesting that preparing to approach alcohol cues when this is incongruent with the avoid-alcohol contingences that participants learned during the training block engages executive control. This interpretation of the N200 findings is consistent with other studies that suggest that enhanced N200 is an important ERP marker of the engagement of executive control in heavy drinkers. For example, a study showed larger amplitude of the N200 in heavy drinkers when they were actively inhibiting a motor response during a GNGT (Kreusch, Quertemont, Vilenne, & Hansenne, 2014). Findings are also consistent with a prior AAT study on emotional stimuli which showed enhanced N200 amplitudes during incongruent trials (e.g. when preparing to avoid rather than approach positive stimuli; Ernst et al., 2013).

I also observed the hypothesised congruency effects in the LPP. The amplitude of this component at midline electrodes was blunted when participants were preparing motor movements to alcohol stimuli that were congruent with associations learned the training block, and this was seen in both the CAT and the approach alcohol group. These effects are in line with our predictions of emotion-congruency effects in this EEG component, as previously reported in an AAT study with emotional stimuli (Bamford et al., 2015). Finally, these findings are compatible with findings from a meta-analysis demonstrating a medium effect-size for increments in the LPP amplitude when viewing substance-related cues relative to control cues in substance users (Littel et al., 2012b). It is fair to assume that these components were enhanced because those participants held an approach bias, rather than avoidance bias (because subjects were dependent users who had not received CAT). Our findings suggest that that these effects can be reversed after a brief session of CAT, although it is unclear how persistent these changes are.

This study has some limitations. The use of a 'preparatory AAT' (Korucuoglu et al., 2014, 2016) appears to have blunted some of the stimulus associations learned during the training block. This suggests that if participants are forced to wait before responding, they can quite easily resolve the conflict and reinstate the dominant motor response (which is to approach alcohol, i.e. approach bias). This is in line with a recent ICT study suggesting that time pressure is essential in order to observe training effects (Veling et al., 2017a); if there is no time pressure on responding, the effects of ICT on RTs disappear. Additionally, these results may be due to the fact that CAT may alter only the very early response to alcohol-related stimuli, which is why effects of CBM on RTs are often (but not always) detected when assessment tasks are suitable for measuring those early responses. Thus, the implication is that any beneficial effects of CAT on behaviour might be completely eliminated if participants have the opportunity to stop for a moment and think after they have been exposed to an alcohol-related stimulus. Additionally, future studies should investigate CAT pre- and post-changes in ERPs and should compare the present findings with a more appropriate control group (e.g. Sham training), because comparison with opposing trainings may inflate the effect size of the CBM intervention by increasing value of appetitive stimuli in these 'control' conditions (Schonberg et al., 2014).

Our study also has strengths. Most importantly, this is the first EEG study exploring ERPs and preparatory readiness potentials of motor states during the AAT, following a single session of CAT in a sample of heavy drinkers. Thus, the present findings are an important proof of concept of the mechanism underpinning CAT, which are necessary in order to optimise these training interventions in order to apply in real-world settings and clinical populations (see Cristea, Kok & Cuijpers, 2016).

To conclude, I demonstrated that a single brief session of CAT yielded behavioural learning effects only during training blocks and generated changes in neural activity when participants were preparing to respond to alcohol-related cues by making an approach or avoidance response. CAT resulted in increasing N200 amplitude when preparing to approach alcohol cues, which suggests recruitment and engagement of executive control when participants have to approach alcohol pictures immediately after having been trained to avoid those pictures. Additionally, in all participants the negativity of the LPP was blunted when participants were preparing to make a motor movement (approach or avoid alcohol, depending on the contingencies applied during training) that they had repeatedly practised during the training block.

Chapter Five

Do automatic affective associations underpin cognitive biases for appetitive stimuli? An investigation of affective and cognitive responses to chocolate pictures in chocolate consumers

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5.1 Abstract

Rationale: Appetitive pictures such as alcohol and chocolate evoke automatic cognitive processing biases, and these biases may be underpinned by positive automatic affective associations. However, the findings from study 2.1 did not support this hypothesis because two forms of CBM did not alter automatic affective associations. The aim of the cross-sectional studies described in this chapter was to investigate if cognitive biases for appetitive stimuli are reliably associated with automatic and self-reported affective responses to those stimuli.

Method: In two experiments, participants (regular consumers of chocolate) rated a set of chocolate-related pictures for attractiveness and palatability (only in study one), after completing AAT and GNGT with those same pictures. Participants also completed a pictorial IAT which assessed associations between chocolate pictures and valenced words (study 5.1, N = 60), or between chocolate pictures and approach and avoidance words (study 5.2, N = 30).

Results: Chocolate pictures, relative to control pictures, were rated as highly attractive and palatable, and on the IATs participants associated those pictures with

positively valenced words (study 5.1) and approach-related words (study 5.2). However, these positive self-reported and automatic affective responses to the chocolate stimuli were not accompanied by cognitive biases to automatically approach the stimuli in either study, or to robust biases in inhibitory control (the findings are inconsistent across studies). Most importantly, there was no evidence that individual differences in automatic or self-reported affective responses to the chocolate stimuli were associated with cognitive biases for those stimuli.

Conclusion: Chocolate-related stimuli that are evaluated positively and that evoke positive automatic affective associations do not reliably evoke automatic cognitive biases in approach or inhibition. These findings cast doubt on claims that cognitive biases are underpinned by automatic affective associations, which in turn suggest that the effects of CBM on behaviour may not be mediated by changes in automatic affective associations.

Keywords: approach, automatic affective associations, chocolate, cognitive bias, evaluation, inhibitory control.

5.2 Introduction

To date, there have been some parallel findings between appetite and addiction research that suggest links between a range of cognitive biases and the development and maintenance of certain risky behavioural outcomes, such as alcohol or eating pathologies (Brooks, Prince, Stahl, Campbell, & Treasure, 2011; Calitri, 2010; Field & Cox, 2008; Havermans et al., 2011; Kakoschke, Kemps, & Tiggemann, 2015; Littel et al., 2012; Nederkoorn et al., 2015; Smith, Hay, Campbell, & Trollor, 2011; Stacy & Weirs, 2012; Svaldi et al., 2014; Werthmann, Field, Roefs, Nederkoorn, & Jansen, 2014). In particular, previous research has shown that appetitive environmental cues (reward-associated stimuli, such as alcohol or chocolate) can trigger automatic cognitive processing biases, such as: automatic approach tendencies, failure to exert self-control and implicit positive evaluations associated to the cues.

As previously mentioned, by the term approach bias I indicate a fast, implicit drive to behaviourally approach (rather than avoid) appetitive cues measured by the AAT (Heuer, Rinck, & Becker, 2007) or the SRC task (De Houwer, 2001). Studies on approach biases found that individuals addicted to substances (e.g. smokers,

drinkers, cannabis users), restrained eaters, high-food cravers, over-weight individuals and high-external eaters (based on the Dutch Eating behaviour sub-scale) tend to show a significant greater approach bias towards relevant appealing environmental cues (Brignell, Griffiths, Bradley, & Mogg, 2009; Gladwin & Figner, 2014; Kersbergen et al., 2015; Korucuoglu, Gladwin, & Wiers, 2014; Piqueras-Fiszman, Kraus, & Spence, 2014; Veenstra & Jong, 2010; Watson et al., 2012; Wiers et al., 2013). In recent appetite studies, using an approach-avoidance Implicit Association task (IAT; food, non-food versus approach-avoidance words) results evidenced an approach bias for chocolate in normal-weight women, which correlated with self-report craving (Kemps et al., 2013) and in obese women for both high- and low-calorie food, when compared to normal-weight (Kemps & Tiggemann, 2016).

Studies on the (in)ability to suppress (or stop) a predominant response (Verbruggen & Logan, 2009; Verbruggen et al., 2014) found inhibitory control deficits over impulses when in the presence of appetitive cues, measured via either a SST (Logan & Cowan, 1984) or a GNGT (Patterson, Kosson, & Newman, 1987). Several studies adopting appetitive cues (reward associated stimuli such as alcohol) in substance abusers have consistently shown a poorer performance (an inability to successfully engage inhibitory control) in these tasks (Jentsch & Pennington, 2014; Petit et al., 2014; Smith, Mattick, Jamadar, & Iredale, 2014), with those cues temporarily increasing this deficit (Jones & Field, 2013, 2015; Monk et al., 2016). Similar findings have been observed in appetite literature in individuals who overeat, especially related to food stimuli (Adams, 2014; Schag, Schönleber, Teufel, Zipfel, & Giel, 2013).

As mentioned in chapter one, the evidence shows an overlap between the neurological pathways of addiction to substances, and overeating and obesity (Jentsch & Pennington, 2014; Volkow, Wang, Fowler, & Telang, 2008). For example, studies have demonstrated changes in the neural processing of appetitive stimuli, in both addiction and appetite research (Burger & Stice, 2011; Carnell et al., 2012; Courtney et al., 2016; Edward, 2001; Parvaz, 2012; Petit et al., 2014). Additionally, addiction and obesity are found to be associated with a tendency to over-value the appetitive stimuli (e.g. substance or food-related cues) as inferred from both subjective ratings and implicit evaluations (Hoefling & Strack, 2008; Stacy & Wiers, 2010). Affective associations of appetitive stimuli are commonly assessed by the Implicit Association task (IAT; Greenwald, McGhee, & Schwartz,

1998). The IAT measures the strength of automatic associations between a target category (e.g. alcohol or chocolate pictures and a neutral category) and an attribute category (e.g. positive or negative valance words). Findings in addiction research evidenced that heavy drinkers, compared to light drinkers, demonstrate stronger appetitive and arousal associations towards relevant stimuli; associations which predict unique variance in drinking (Houben & Wiers, 2008). Similar effects were observed for other substance and food-related stimuli especially when cognitive resources are limited (see Ayers et al., 2011; Hoffmann et al., 2010; Jansen, Houben, & Roefs, 2015; Roefs, Macleod, Jong, & Jansen, 2011; Stacy & Wiers, 2010;).

Furthermore, the Behaviour Stimulus Interaction Theory by Veling and colleagues (2008), argues that repeatedly inhibiting (or avoiding) an appetitive stimuli leads to a reduction of the hedonic value of the stimuli itself (stimuli-devaluation), which consequently weakens the potency of the impulse that is triggered (Veling et al., 2011; Veling et al., 2013a). Thus, for example once associations are established between a stopping (or avoidance) response and a palatable stimuli (or cue), the stop-goal may be automatically activated when the cue is encountered in the future (Verbruggen et al., 2014), and subsequently the perceived value of the stimuli would decrease in order to liberate the appetitive impulse towards the cue.

A recent model of action control (Guitart-Masip et al., 2014) is in line with this theory. This model depicts behavioural control as a bidirectional relationship between a system of action and a system of valence, arguing that appetitive stimuli are associated with the triggering of behavioural responses (action tendency). When, however, negative stimuli are encountered the automatic response becomes the suppression of the motor action and the active avoidance of the stimuli, due to the spontaneous devaluation of their valence. These two theories focus on stimulus devaluation, following the newly learned stimulus-pairing between the appetitive stimulus and either avoidance or inhibition.

This, implies that cognitive biases (approach tendencies or impaired control) are associated with automatic affective associations (i.e. positive evaluations and approach associations) towards these appetitive stimuli, suggesting a bidirectional casual relationship between these. A series of recent studies in different domains seem to support the stimuli-devaluation hypothesis by showing that subjective implicit or explicit values decreased in relation to the mapping with motor inhibition

or avoidance in: geometrical shapes (Wessel et al., 2014) in sexual stimuli (Ferrey et al., 2012), in appetite (Houben & Jansen, 2015; Kemps et al., 2013; Schonberg et al., 2014; Veling, Aarts, & Stroebe, 2013a) and addiction research (Gladwin et al., 2015; Houben et al., 2012; Wiers, Rinck, Kordts, Houben, & Strack, 2010).

However, it still remains unclear if these three automatic biases elicited by appetitive stimuli are independent of each other or if they all reflect a common underlying mechanism. It is of theoretical and practical importance to investigate these links between automatic biases in order to better understand the psychological processes underpinning these tasks which are crucial for the improvement of recent new interventions focusing on modifying these biases to alternative responses (CBM; Gladwin et al., 2016; Wiers et al., 2013), such as the CAT (Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011) or the ICT (Allom, Mullan & Hagger, 2015; Jones et al., 2016b), which seem to hold great clinical potential as effective treatments for behavioural change (Gladwin et al., 2016; Stice et al., 2016).

However, relatively little is known about the mechanism underpinning these interventions. Some studies have evidenced as a possible mechanism mediating CAT and ICT effectiveness, the previous suggested stimuli devaluation-hypothesis (Gladwin et al., 2015; Houben et al., 2012; Macy, Chassin, Presson, & Sherman, 2014; Veling, Aarts, & Stroebe, 2013a; Veling et al., 2017b; Woud et al., 2013) while other studies contradicted this hypothesis (Becker et al., 2015; Bowley et al., 2013; Wiers et al., 2014). For example, the recent ICT meta-analysis from our group suggests that findings on devaluation do not seem to be robust (Jones et al., 2016b). Findings which are consistent with study 2.1 (see page 42) in which both CAT and ICT interventions on heavy drinking students were equally effective in reducing alcohol consumption in the lab, nevertheless neither of the interventions led to changes in implicit alcohol associations. The failure to detect these changes in evaluation may be due to the unsuitability of the IAT as a measure (implicit measure dependent on RTs). In fact, in reviewing the literature most studies showing devaluation, even on different stimuli types, seem to be observed when adopting Likert scales and auction tasks as measures (Ferrey et al., 2012; Lawrence et al., 2015a; Veling, Aarts, & Stroebe, 2013a; Wessel et al., 2014); suggesting that in study 2.1 I may have utilised a measure that is not sensitive to devaluation effects.

Therefore, in two experiments I explore, for the first time in the literature, the independence or the existence of a common link between automatic approach

tendencies, inhibitory control, and both subjective evaluations and automatic affective responses to appetitive pictures (e.g. chocolate). Subjective evaluation measures were included in order to verify that participants evaluated the chocolate-related stimuli positively, and to investigate if these subjective ratings would be correlated with the aforementioned cognitive biases.

5.3 Experiment One methods

5.3.1 Participants

Sixty regular chocolate consumers (18 Males, mean age: 21.07, SD = 3.81 years) were recruited from the students and staff at the University of Liverpool via online and poster advertising.

I defined regular chocolate consumers as individuals consuming a minimum of one standard size chocolate bar (e.g. Mars, Snickers and Twix) per week. Inclusion criteria also included fluency in English, individuals aged between 18 and 30, and normal or corrected to normal vision.

Participant characteristics are shown in Table 5.1. All participants provided informed consent before taking part at the study, which was approved by the University of Liverpool Research Ethics Committee.

Table 5.1 Self-report measures showed separately for both experiments. Values are means ± SD.

	Experiment 5.1	**Experiment 5.2**
CUQ weekly consumption	1.16 (1.36)	1.16 (.83)
CUQ craving mean	4.82 (1.11)	4.71 (.99)
AtCQ Craving	47.63 (18.65)	50.70 (16.98)
AtCQ Guilt	43.53 (22.79)	35.97 (25.31)
AtCQ Functional Approach	37.57 (15.45)	35.74 (18.99)
DEBQ Restrained Eating	27.50 (8.74)	26.00 (9.36)
DEBQ Emotional Eating	33.72 (12.39)	32.33 (9.16)
DEBQ External Eating	33.37 (4.93)	35.63 (4.05)

CUQ chocolate consumption mean over the past week and chocolate craving score, rated on a 7-point Likert-scale. The *AtCQ* 3-factor structure questionnaire rated on a 10cm VAS scale. The *DEBQ* 3 sub-scale questionnaire rated on a 5-point Likert scale.

5.3.2 Materials and tasks

Self-report measures

Participants were asked to complete a Chocolate Use Questionnaire (CUQ), followed by the Attitudes to Chocolate Questionnaire (AtCQ) and the Dutch Eating Behaviour Questionnaire (DEBQ).

The CUQ (Tibboel et al., 2011) is a questionnaire formed by a diary that allows participants to recall and record retrospectively their chocolate consumption over the past week, deriving a frequency measure of their consumption. In addition, I derived an index of overall chocolate cravings by averaging participants' responses to five items (1. How much do you like to eat chocolate; 2. How often do you feel the urge to eat chocolate; 3. How strongly do you feel this urge; 4. To what extent do you feel you need to eat chocolate; 5. How difficult do you find it to stop eating chocolate once you have started). Participants responded to each item on a 7 point Likert-scale with anchors ranging from 'never' and to 'always'.

The AtCQ (Benton, Greenfield, & Morgan, 1998) is a 24 item self-report questionnaire. Respondents are asked to rate by putting a mark through a 10 cm visual analogue scale (VAS) representing how they are feeling at the moment. The scale has a three factor structure: Craving (weakness, preoccupation and acts of compulsions associated with chocolate), Guilt (negative emotions and experiences associated with body shape, after eating chocolate) and Functional Approach (pragmatic approach to chocolate, eaten for rational useful purposes). The Craving and Guilt subscales have been shown to have high validity and internal reliability (α = or above 0.88). Additionally, these two subscales are both related to chocolate consumption (Cramer and Hartleib, 2001).

The DEBQ (Strien & Frijters, JER, 1986) contains 33 five-point Likert items with anchors ranging from 'never' to 'very often'. It has a three factor structure: Emotional Eating (eating in response to emotional states), External eating (eating in

response to external food cues) and Restrained eating (measuring successful restraint over eating). The questionnaire has been shown to have good internal reliability and validity for all the subscales (α = above 0.80) (Strien & Frijters, JER, 1986; Wardle, 1987).

Experimental Tasks

All computer tasks were presented on a Dell desktop computer with a 15" monitor and participants responded by using a standard keyboard and a joystick. Tasks were programmed and administered using Inquisit version 3.0 software (Millisecond Software, 2008; Seattle, WA).

Chocolate stimuli consisted of 20 pairs of chocolate and matched control (neutral) pictures. The photographs adopted were used in a previous study (Jones et al., 2012). Chocolate pictures depicted a range of branded and non-branded chocolate snacks (e.g. Twix, Snickers, chocolate generic bar, muffin or cake) and they were matched for perceptual characteristics to control pictures depicting office stationery (e.g. pens, staplers, books) and daily life scenes using these objects (e.g. holding a pen, stapling a page). I chose to use this set of control pictures as I wanted to use objects that were as familiar and affectively neutral as possible, with no chocolate-related content. All pictures from both sets were presented in all three tasks.

The bipolar valence Implicit Association task was identical to the IAT previously described in the study 2.1 and was based on Houben et al. study (2012; see page 40). Similarly, the assessment versions of the AAT and the GNGT were identical to the tasks previously described for study 2.1 (see from page 38) and were respectively based on Wiers et al. (2011) and Houben et al. (2012).

Picture Rating Task (based on Veling et al., 2013a).

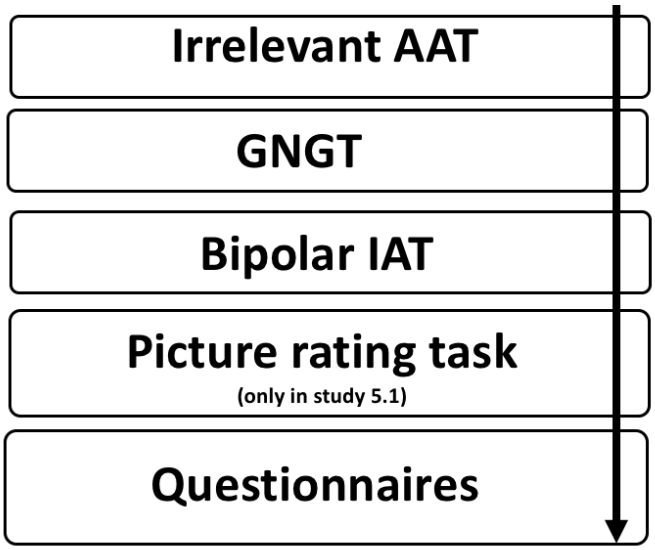
In this task participants rated each individual picture (both chocolate and control pictures) on dimensions of attractiveness and palatability using 7-point Likert scales with anchors 'not at all' to 'very'. In two separate blocks, participants rated each image in turn on "attractiveness" and palatability ("tastiness"). Before the beginning of each block instructions were presented, stating: "Please rate the attractiveness (or tastiness) of each of the following pictures on a scale from 1 to 7; where 1 is NOT at all attractive (or tasty) and 7 is VERY attractive (or tasty). In order to rate the picture, press the corresponding number on the keyboard". During

each trial, a picture was individually presented in the centre of the screen and the scale (a line with seven number points presented under the line) was presented below the picture. Items appeared together and remained on the computer screen until the participant responded by using the keyboard, and trials advanced automatically to the next page once the response was given. Block order (attractiveness or palatability ratings first) was counterbalanced across participants and the order of trials within each block was randomised. In a slight deviation from previous studies (Lawrence et al., 2015a; Veling et al., 2013a), I computed separate attractiveness and palatability ratings for both chocolate and control stimuli, in order to examine in detail, the relationships between these subjective ratings and cognitive biases, and in order to compare directly these ratings with implicit associations and to make the tasks more consistent between them. Additionally, in order to mask the aim of the study, all participants rated both appetitive and neutral stimuli after completing the other tasks.

5.3.3 Procedure

Participants were tested between 10:00 and 18:00 in a quiet laboratory in the Department of Psychological Sciences at the University of Liverpool. After providing informed consent, all participants completed the IAT, AAT, GNG in a counterbalanced order, followed by the picture rating task (see figure 5.1). Finally, they completed the questionnaire measures (CUQ, AtCQ, DEBQ). At the end of the study participants were debriefed and offered either course credit or £5 shopping vouchers as compensation for their time.

Figure 5.1 Schematic overview of the experimental procedure. For details see method section.



5.3.4 Data reduction

Data reduction prior to analysis was identical to that described for study 2.1 (for details see study 2.1, pages 42), with IAT effects calculated with the *D* measure (Greenwald et al., 2003) and corrected response latencies to chocolate and control pictures calculated for approach and avoidance movements in the AAT and for Go trials in the GNGT.

Furthermore, similarly to the previous studies reported in this thesis (study 2.1, page 42 and study 3.1, page 60) participants made very few commission errors, with half or more than half of the sample size never committing mistakes on the AAT and the GNGT blocks (see table 5.2). Given the limited amount of commission errors (with 55% or more of the individuals not making any errors) and the skewed distribution of error data, I only analysed commission errors (inhibition errors in No-Go trials) as these measures are used frequently in studies investigating impaired inhibitory control (Jones et al., 2016b), nevertheless these need to be interpreted with caution.

Regarding the picture rating task, I computed means of attractiveness and palatability ratings for each type of picture (chocolate and control). In order to compute the correlations between measures a final valence index was computed

separately for both 'attractiveness' and 'tastiness' as the difference score between the mean score of chocolate and control pictures (for example: mean attractiveness rating of chocolate pictures minus the mean attractive rating of the control stimuli; and the same was computed for tastiness ratings). However, as chocolate ratings were the only ratings used in previous studies (Lawrence et al., 2015a; Veling et al., 2013a) and are more salient to the purpose of the study, for the correlations analysis I also computed and correlated the two general means for chocolate attractiveness and palatability ratings (i.e., ratings for control pictures were not considered).

Table 5.2 Response errors to chocolate and control (neutral) stimuli shown separately for both experiments. Values are means ± SD.

	Experiment 5.1	**Experiment 5.2**
Approach chocolate	*.53 (.81)*	*.80 (1.13)*
Approach control	*.48 (.72)*	*.73 (1.31)*
Avoid chocolate	*.73 (1.07)*	*1.23 (3.64)*
Avoid control	*.77 (1.10)*	*1.63 (3.83)*
No-Go to chocolate	*.33 (.51)*	*.43 (.73)*
No-Go to control	*.12 (.42)*	*.27 (.52)*

5.4 Experiment one results

5.4.1 Task performance (see Table 5.3)

Approach and Avoidance task (AAT)

Data were analysed with a 2 × 2 ANOVA, with within-subject factors of Movement (2: Approach, Avoid) and Picture Type (2: Chocolate, Control). The main effect of Movement was statistically significant ($F(1,59) = 36.01$, $p < .01$), reflecting faster RTs to initiate approach rather than avoidance movements, but the main effect of Picture Type was not ($F(1,59) = .21$, $p = .65$). The hypothesised interaction Movement × Picture Type was not significant ($F(1,59) = 1.60$, $p = .21$). Therefore, in contrast to predictions, participants were not faster to approach rather than to avoid chocolate pictures in comparison to control pictures.

Go/No-Go task (GNGT)

A within-subject t-test confirmed no significant difference in the speed of Go RTs to chocolate-related and control stimuli t (59) = .81, p = .42. Therefore, in contrast to predictions, participants were not faster to 'Go' to chocolate stimuli.

Additionally, for the GNGT I calculated commission errors to both control and chocolate stimuli. Kolmogorov-Smirnov's test showed that inhibition errors to both stimuli were not normally distributed (D (60) <.15, ps > .01), therefore to analyse the data the Wilconxon test was used. Results showed that as expected participants made more commission errors towards chocolate pictures (M =.33, SD = .51) compared to neutral pictures (M =.12, SD = .42), z = -2.48, p = .01, d = .45.

Bipolar Valence Implicit Association Test (IAT)

A positive *D* measure would indicate that participants possess stronger associations between chocolate pictures and positive valence rather than negative valence, whereas a negative *D* measure would indicate the opposite. I used a one-sample t-test to compare *D* measures with zero. This revealed that *D* values were positive and significantly greater than zero, t (59) = 14.06, p < .01, d = .66. Therefore, participants had strong associations between chocolate pictures and positive words.

Picture Rating task

Picture ratings were analysed using a 2 × 2 ANOVA with within-subject factors of Rating type (2: Attractiveness, Palatability) and Picture Type (2: Chocolate, Control). There were significant main effects of Rating type (F (1,59) = 13.27, p < .01) and Picture Type (F (1,59) = 1823.57, p < .01), but these were subsumed under a significant interaction (F (1,59) = 59.83, p < .01). As expected, participants rated chocolate pictures as more palatable and attractive, than the control stimuli (see table 5.3). In order to untangle the significant interaction, I computed a paired sample t-test between the differences scores of chocolate and control stimuli (e.g. Valence index) for both Attractiveness and Tastiness ratings, which explained that the interaction arose because of greater chocolate palatability ratings, relative to attractiveness t (59) = -7.74, p < .01, d = .82.

Table 5.3 Task performance shown separately for both experiments. Values are reaction times (milliseconds) to approach and avoid responses in the AAT and to Go trials in the GNG, *D* measure scores for the IAT, and mean values of Attractiveness and Palatability picture ratings (only for experiment one). Values are shown separately for chocolate and control (neutral) stimuli respectively, except for the IAT as the measure is one score between the two stimuli type (positive values indicate stronger associations towards chocolate stimuli). Values are mean ± SD.

	Experiment 5.1	**Experiment 5.2**
Approach chocolate	756.*96 (125.98)*	*778.05 (129.06)*
Approach control	*765.42 (134.44)*	*788.33 (128.82)*
Avoid chocolate	804.*96 (134.88)*	*826.05 (139.45)*
Avoid control	*800.54 (137.30)*	*815.92 (153.31)*
Go to chocolate	*507.08 (58.63)*	*482.52 (40.89)*
Go to control	*509.16 (56.79)*	*490.93 (43.98)*
Attractiveness to chocolate	5.*46 (.77)*	/
Attractiveness to control	*1.54 (.57)*	/
Palatability to chocolate	*5.66 (.75)*	/
Palatability to control	*1.04 (.10)*	/
IAT	*.74 (.41)*	*.52 (.45)*

5.4.2 Inter-correlations between performance on the different tasks (Table 5.4)

In the correlation matrix, I included the IAT (*D* measure) and 'chocolate bias' scores derived from the AAT (speed of approach and avoidance), the Go/No-Go task (Go reaction times, and No-Go commission errors), and the Picture Rating Task (attractiveness and palatability ratings). For RT data, commission errors, and picture ratings, I subtracted values on neutral trials from chocolate trials. In some cases, bias scores were not normally distributed; in these cases, bias scores were log transformed before analysis. Additionally, I included mean ratings (not bias scores) of attractiveness and palatability for chocolate pictures only.

As can be seen in table 5.4, there were no significant correlations between performance on the different tasks. However, correlations within tasks confirmed the construct validity of those tasks: a bias to respond more rapidly to chocolate pictures during Go trials on the GNGT was associated with a bias to make more commission errors to chocolate pictures (r = - .28, p = .03). Robust inter-correlations were found for the rating task, for both valence indices of attractiveness and palatability (r = .67, p < .01) and for chocolate ratings of attractiveness and palatability (r = .89, p < .01), for details see table 5.4.

In addition, to the previous measures (differences scores and IAT *D* measure) I added to the matrix all the self-report measures (see table 5.5). The only correlations found were between the valence index of 'attractiveness' which related both positively to the AtCQ craving subscale (r = .26, p = .05) and to the DEBQ external eating subscale *(*r = .40, p < .01). Similarly, the mean 'attractiveness' chocolate ratings correlated to the DEBQ external eating subscale (r = .40, p < .01). Respectively, these indicated that participants who perceived chocolate pictures as more attractive, also possessed stronger cravings towards chocolate and ate more chocolate in response to external cues. For the details on the full correlation matrix see table 5.5.

Table 5.4 Correlation matrix between implicit measures: IAT *D measure*, AAT differences scores (dfs) and GNG difference scores, reported separately for both experiments. Valence indexes and chocolate means for 'attractiveness' and 'tastiness' are only in experiment one.

	Experiment 5.1								**Experiment 5.2**			
Variable	1.	2.	3.	4.	5.	6.	7.	8.	1.	2.	3.	4.
1. IAT D-measure	1								1			
2. AAT dfs.	-.06	1							.04	1		
3.Go dfs.	.09	.18	1						.19	.11	1	
4. Inhibition errors dfs.	-.07	.01	-.28*	1					-.27	-.02	-.18	1
5. 'Attractiveness' valence index	.18	.15	-.01	.07	1				\			
6. 'Palatability' valence index	.09	.06	-.01	.07	.67**	1			\			
7. Chocolate 'Attractiveness'	.13	.10	.01	.14	.80**	.87**	1		\			
8. Chocolate 'Palatability'	.10	.05	-.00	.07	.67**	.99**	.89**	1	\			

*Correlation is significant at the .05; ** Correlation is significant at the .01

5.5 Interim Discussion

In the present experiment I explored the inter-relationships between automatic approach tendencies, inhibitory control and self-reported and automatic positive evaluations elicited by chocolate pictures, and investigated if positive affective associations of hedonic chocolate stimuli would underpin the other two processing biases. Results indicated that participants possessed strong implicit positive associations towards chocolate and assigned more positive evaluation ratings to these pictures relative to control stimuli. Additionally, chocolate stimuli relative to control stimuli seem to have led to an increase of commission errors (e.g. impaired inhibitory control). However, cognitive biases based on speed of responding on Go trials and behavioural approach tendencies towards chocolate were not observed. Most importantly, the hypothesised correlation between the three cognitive processes (measured by the AAT, GNG and IAT) was not observed, indicating that these processes (and tasks) may be independent from each other.

To recapitulate, it can be said that participants possessed a positive bias towards chocolate (on both the IAT and the rating task), however this was not accompanied by (or correlated with) a robust bias in inhibitory control or automatic approach tendencies. As previously discussed (see study 2.1, page 49), these findings may be due to methodological limitations of the tasks used. For example, bias measures obtained from the irrelevant feature AAT have poor internal reliability (see Kersbergen et al., 2015), and both the AAT and GNGT assessment versions may not be sensitive enough to detect differential effects of chocolate versus matched neutral cues. Yet, this does not imply that the training versions of these tasks used in CBM (i.e. CAT and ICT) are not useful for behaviour change interventions. Furthermore, the IAT has been widely criticised in literature (see Stacy & Wiers, 2010) showing, as found in the present experiment, that IAT scores and subjective ratings are not consistently associated with each other, suggesting that subjective and behavioural measures of evaluations are not closely related to each other.

Taking into account findings from the present experiment (study 5.1) and from study 2.1, perhaps the predictions made by the BSI theory are incorrect: rather than underpinned by automatic associations between chocolate and positive valence (hedonic associations: positive and negative associations as used in experiment 5.1), cognitive biases may instead be underpinned by automatic approach associations. Thus, an alternative assumption may be that

approach-avoidance associations (and not hedonic associations) may be the mechanism underpinning automatic approach tendencies and deficits in inhibitory control.

A number of studies support this assumption. Firstly, two recent appetite studies measured automatic associations with an approach-avoidance IAT (using approach and avoidance words as an attribute category, unlike a Valence IAT) and confirmed that normal-weight women and obese women (Kemps & Tiggemann, 2016) were faster on approach-food trials. In addition, in a study that used a training version of the IAT, participants in the chocolate-approach association group reported as well stronger chocolate cravings, relative to the avoidance association group (Kemps et al., 2013). Furthermore, a number of studies successfully found that implicit approach and avoidance mediated the effectiveness of the CAT intervention (Gladwin et al., 2015; Wiers et al., 2010). Finally, a recent study (similar to the above study 5.1) investigated associations between drinking behaviour and three alcohol-related cognitive bias tasks, measured via an approach-avoidance IAT, irrelevant-feature AAT and a Dot Probe task (attentional bias), in alcohol dependent patients relative to healthy controls (Wiers et al., 2017). Results showed that alcohol dependent patients, relative to controls, held stronger alcohol implicit approach associations (IAT), but no other bias differences between groups were observed. However, in the patient group, alcohol approach tendencies (AAT) and attentional bias correlated positively, indicating that the stronger the approach bias the more participants attend to alcohol stimuli, but approach tendencies were negatively related to implicit approach associations (IAT), which instead were related positively with drinking behaviour.

Thus, in the following experiment (study 5.2), I explored this alternative hypothesis by modifying the IAT task used in study 5.1. In order to measure the strength of implicit associations between chocolate and approach-avoidance words, I administered a pictorial approach-avoidance IAT (Wiers, Rinck, Kordts, Houben, & Strack, 2010). Specifically, the aim of the study was to further test if these cognitive biases elicited by appetitive (chocolate) pictures are independent of each other, or if they all reflect approach associations as the common underlying mechanism. This was done in order to exclude completely any correlations with other types of automatic associations.

In the following study I restricted the sample size (N=30). Additionally, I adopted equivalent analysis and a similar protocol to that described above for study 5.1.

5.6 Experiment two methods

5.6.1 Participants

Thirty (9 Males, mean age: 25.07, SD = 3.84) regular chocolate consumers (as defined in experiment 5.1, see above page 102) were recruited from the local community and students and staff at the University of Liverpool via online and poster advertising. Inclusion criteria were identical to those described for the above experiment 5.1 (see page 102). Participant characteristics are shown in Table 5.1. Participants provided informed consent before taking part at the study, which was approved by the University of Liverpool Research Ethics Committee.

5.6.2 Materials and tasks

The present study was identical (in materials, tasks and in procedure adopted; see above figure 5.1) to the previous described 5.1 study (see page 103) with the important difference that participants completed the bipolar approach-avoidance version of the IAT (Wiers et al., 2010) instead of the bipolar Valence IAT (Houben et al., 2012).

The only difference in the task is that the bipolar approach-avoidance IAT, measures the strength of implicit associations between chocolate and approach vs. avoidance words. Therefore, during the task participants were asked to classify, as quickly as possible, stimuli into two target stimuli (chocolate or neutral stationary pictures, 10 pictures each, the same pictures used in experiment 5.1, see page 103) and two attribute categories (approach or avoidance words, 5 each; see Wiers, Rinck, Kordts, Houben, & Strack, 2010b), by using two different response keys on the keyboard (left and right).

Data reduction and analysis were identical as in the study 5.1 (see page 106), and in line with the previous study error rates for both stimuli type were very low and are reported in table 5.2.

5.7 Experiment two results

5.7.1 Task performance (see Table 5.3)

Approach Avoidance task (AAT)

A 2 × 2 ANOVA was carried out on approach and avoidance RTs, with within-subject factors of Movement (2: Approach, Avoid) and Picture Type (2: Chocolate, Control). A main

effect of Movement was statistically significant (F (1,28) = 8.34, p = .01), reflecting faster RTs to initiate approach rather than avoidance movements. The hypothesised interaction Movement × Picture Type was not significant (F (1,28) = 2.39, p = .13), and there were no other significant main effects or interactions (F (1,28) = .03, p = .86). Thus, the expected approach bias towards chocolate pictures was not observed.

Go/No-Go task (GNGT)

A within-subject t-test confirmed predictions, t (28) = 2.31, p = .03, d = .87. Participants were faster to respond to chocolate Go trials (M = 482.52, SD = 40.89) relative to control Go trials (M = 490.93, SD = 43.98). Additionally, Kolmogorov-Smirnov's test showed that commission (inhibition) errors in No-Go trials were not normally distributed (D (29) <.458, ps < .01), therefore the Wilcoxon test was used to analyse the data. Results showed no difference in the number of commission errors made to chocolate pictures (M =.43, SD =.73) compared to neutral pictures (M =.27, SD =.52), z = -1.03, p = .30.

Bipolar Approach and Avoidance Implicit association test (IAT)

The strength of automatic approach associations towards chocolate pictures, assessed with the IAT, was analysed with a one sample t-test, in which D measure-scores were compared to zero. Results showed that participants held associations between chocolate and approach words, as evidenced by the observation that D values were positive and significantly greater than zero, t (29) = 6.33, p <.01, d = .35.

5.7.2 Inter-correlations between performance on the different tasks (Table 5.4)

Similar to study 5.1, the correlation matrix included the IAT (D measure) and 'chocolate bias scores' (see details above in page 110) derived from the AAT (speed of approach and avoidance) and the Go/No-Go task (Go RTs, and No-Go commission errors). In some cases, bias scores were not normally distributed; in these cases, bias scores were log transformed before analysis. Contrary to expectations and similar to results from the study 5.1, no significant correlations were observed between bias scores from the different tasks.

Similarly, to the previous 5.1 study I added to the matrix self-report measures (Chocolate Use Questionnaire, CUQ; Attitudes to Chocolate Questionnaire, AtCQ; Dutch Eating Behavior, DEBQ). Approach bias scores correlated with both the craving subscale (r =

.43, p = .02) and the guilt subscale (r = .40, p = .02) of the AtCQ. Additionally, inhibition errors negatively correlated with the AtCQ guilt subscale (r = -.39, p = .03). Thus, is seems that the more the individuals possessed strong chocolate approach bias, the more they craved chocolate and the more they felt guilty of eating chocolate. On the other hand, the more participants felt guilty after eating chocolate, the more inhibition errors they performed in response to chocolate-related pictures. However, due to the low error rate in the GNGT these data should be interpreted cautiously. For the correlation matrix on self-report measures refer to table 5.5.

Table 5.5 Correlation matrix between explicit (shown in row) and implicit measures (shown in column): IAT *D measure*, AAT differences scores (dfs) and GNG difference scores, reported separately for both experiments. Valence indexes and chocolate means for 'attractiveness' and 'tastiness' are also added only in experiment one.

Experiment 5.1

Variable	CUQ	AtCQ Craving	AtCQ Guilt	AtCQ Function	DEBQ Restrained	DEBQ Emotional	DEBQ	
External								
IAT D-measure	.24	.01	-.04	.03	.07	.10	.20	
AAT dfs	-.02	.11	-.04	.06	-.02	-.05	.05	
Go dfs.	.11	-.15	-.21	-.03	-.25	-.15	-.22	
Inhibition errors dfs.	-.05	.12	.18	.09	.15	.23	.16	
'Attractiveness' valence index	-.10	.26*	.04	.13	.07	.06	.40**	
'Palatability' valence index		-.12	.09	-.03	.08	-.02	.02	.19
Chocolate 'Attractiveness'		-.12	.25	-.09	.21	-.07	.14	.40**
Chocolate 'Palatability'	-.12	.12	-.01	.09	.03	.04	.19	

Experiment 5.2

Variable	CUQ	AtCQ Craving	AtCQ Guilt	AtCQ Function	DEBQ Restrained	DEBQ Emotional	DEBQ
External							
IAT D-measure	-.16	.16	.13	.10	.11	-.15	-.12
AAT dfs	-.12	.43*	.40*	.28	.18	.19	.32
Go dfs.	-.01	.16	.18	-.16	.14	.13	.04
Inhibition errors dfs.	.01	-.18	-.39*	-.21	-.35	-.09	-.27

*Correlation is significant at the .05; ** Correlation is significant at the .01.

5.8 Discussion

In this experiment (study 5.2) I explored the inter-relationships between automatic approach tendencies, inhibitory control and automatic approach and avoidance associations elicited by chocolate pictures, and whether these approach associations of chocolate stimuli would underpin the other two processing biases. Similarly, to the study 5.1, effects on the IAT were observed, indicating that participants possessed strong implicit approach associations towards chocolate, relative to control stimuli. Additionally, similar to results from study 5.1 I observed no effects on behavioural approach tendencies towards chocolate (AAT), but again impaired inhibitory control for chocolate (GNGT). Yet, findings showed no effects on errors (as seen in study 5.1), but they did on RTs, with chocolate stimuli leading to an increase in response speed relative to control stimuli. Most importantly, the hypothesised correlation between the three cognitive processes (measured by the AAT, GNG and the approach-avoidance IAT) was again not observed, confirming previous results and suggesting that these processes may be independent from each other.

In the present chapter I examined the existence of a common underlying link between automatic approach tendencies, inhibitory control and automatic affective associations elicited by appetitive chocolate pictures. The main findings of the two studies were that implicit hedonic (positive) associations and approach associations of appetitive stimuli do not appear to underpin these processing biases (of approach or inhibitory control).

Recent literature suggests that successful CBM interventions may be mediated by reductions in the positive hedonic valence of appetitive stimuli (stimulus devaluation: Gladwin et al., 2015; Houben et al., 2012; Houben & Jansen, 2015; Veling et al., 2011, 2013a, 2017b; Wiers et al., 2011) and this claim seem to be corroborated by studies in different fields (Ferrey et al., 2012; Schonberg et al., 2014; Wessel et al., 2014) and by recent model of action-control, which depicts motivated behaviour as a bidirectional relationship between an action and valence system (Guitart-Masip et al., 2014). Yet, other CAT studies suggest that approach and avoidance associations mediate CBM effectiveness (Gladwin et al., 2015; Wiers et al., 2010). In this chapter I examined both these accounts, and showed no effects in both automatic hedonic or approach associations.

These claims need to be investigated as results in the literature are quite inconsistent (Bowley et al. 2013; study 2.1). Indeed, a recent meta-analysis suggests that findings of stimulus-devaluation on ICT are not so robust when measured by an IAT, relative to other

explicit measures (Jones et al., 2016b). Furthermore, the reported results from study 5.1 are consistent with findings from study 2.1 (see page 49; neither CAT or ICT, led to changes in implicit alcohol hedonic associations measured through a valence IAT) and corroborates Jones et al. (2016b) meta-analysis, as no correlations between automatic approach tendencies, inhibitory control, implicit hedonic evaluations and subjective ratings were observed.

Taking into consideration that appetitive pictures may elicit ambivalence, and the fact that some studies found that CBM effectiveness is mediated by approach-avoidance associations, measured via an approach-avoidance IAT (see Gladwin et al., 2015; Wiers et al., 2010), I further tested this hypothesis. I did so by replicating the protocol of study 5.1 and investigating the alternative option that approach-avoidance associations (rather than positive and negative associations) underpin these processing biases (implicit approach tendencies and inhibitory control). In the second experiment (5.2) I replicated results from the study 5.1; and found no significant correlations between automatic approach tendencies, inhibitory control and implicit approach-avoidance. These null findings on approach tendencies are not surprising as they replicate findings from study 2.1 (page 45) and from the literature (Kersbergen et al., 2015; Wiers et al., 2017). Additionally, these results may be due to the characteristics of the sample which did not in general possess strong cognitive processing biases towards chocolate, as observed from task performance in both experiments. In fact, in studies in which stimulus-devaluation have been found, individuals usually hold a strong bias towards the appetitive stimulus (Eberl et al., 2013; Kemps & Tiggemann, 2016; Kemps et al., 2013; Wiers et al., 2011) and usually the sample is made of individuals for which those cues create more vulnerability.

Therefore, there are some limitations to the studies presented in this chapter. Firstly, the sample does not represent individuals with risky habits (such as overweight or obese individuals, heavy drinkers or alcohol dependent patients) which instead are the population investigated in the other studies (Houben et al., 2012; Jones & Field, 2013; Wiers et al., 2011). A recent study on heavy drinkers supports this justification, by demonstrating that approach tendencies and inhibitory control deficit are linked when processing highly motivational salient stimuli, but only in individuals with specific characteristics, such as heavy drinkers with low sensitivity to alcohol (Fleming & Bartholow, 2014). In contrast, the samples in the present experiments were individuals with no specific characteristic apart from being regular chocolate consumers. Future studies should replicate these methods in samples

with different characteristics (e.g. BED, overweight individuals, etc.). Similarly, a recent paper that found positive correlations between alcohol approach tendencies and attentional bias, and negative correlations between these approach tendencies and implicit approach associations, was conducted on a sample of male alcohol dependent patients (Wiers et al., 2017).

Secondly, and more likely, it may be plausible that the tasks used to capture automatic responses towards chocolate (appetitive stimuli), may not be the best suited. De facto, the IAT is the subject of an ongoing methodological debate and has been criticized several times in literature (Stacy & Wiers, 2010). Additionally, by scrutinizing the devaluation literature I notice that the most robust effect in evaluation were measured through Likert ratings scales or auction tasks (Ferrey et al., 2012; Lawrence et al., 2015a; Veling et al., 2013a; Wessel et al., 2014; Wiers, Ludwig, et al., 2015). This is further justified by findings in the literature, and replicated in experiment 5.1 (IAT scores and chocolate ratings were not associated with each other), suggesting that subjective and behavioural measures of evaluations are not as closely related to each other (Stacy & Wiers, 2010). This issue will be investigated in the next chapter. Additionally, as discussed previously, the two assessment versions of the GNGT and especially the irrelevant feature AAT (see Kersbergen et al., 2015) may not be sensitive measures for the detection of these changes (see page 44).

To summarise, chocolate pictures elicited strong implicit positive and approach associations, and there was some inconsistent evidence of impaired inhibitory control. Yet, these effects did not translate into behavioural approach. Most importantly, there was no evidence of correlations between the three cognitive processes in either studies. Thus, suggesting that these processes may be independent from each other. These findings directly contradict Guitart-Masip et al. (2014) theoretical framework because they show that goal-directed behavioural actions (such as approach and inhibition) are not as closely associated to valence, as instead this model predicts. Consequently, stimulus devaluation may not be the mechanism that underlies the effects of CAT or ICT on behaviour.

Chapter Six

An investigation of the effects of Inhibitory Control Training on attention, evaluation and choice for chocolate-related stimuli paired with inhibition

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6.1 Abstract

Rationale: Considering failures to detect devaluation effects of 'Inhibitory Control Training' (ICT) when using implicit measures (study 2.1; Jones et al., 2016b; Veling et al., 2017b); in the present study I investigated this hypothesis by adopting an explicit measure of stimulus valuation and by administering ICT using a completely within-subjects design. In particular, I tested the hypothesis that chocolate-related pictures that had been paired with inhibition would be attended to less, chosen less frequently and evaluated more negatively compared to chocolate-related pictures that had been paired with responding.

Methods: Regular chocolate consumers (N=30) completed a single session of ICT in which chocolate pictures (half 'high value' and half 'low value', as identified in a separate online study) were paired with either rapid responding or inhibition in a GNGT. Evaluations of the pictures (VAS), attention to the pictures (as inferred from eye gaze), and behavioural choice (forced choice task), were assessed immediately before ICT and again immediately afterwards.

Results: Contrary to expectations, chocolate pictures that had been paired with inhibition were not evaluated more negatively after ICT. However, stimuli paired with inhibition were attended to less and chosen less frequently, relative to

stimuli paired with rapid responding. However, and again contrary to expectations, these effects of ICT were limited to low value stimuli, rather than high value stimuli.

Conclusions: The hypothesised effects of ICT on attention and behavioural choice were observed, but only for low-value stimuli. There was no evidence for subjective devaluation of stimuli paired with inhibition for either high value or low value stimuli. These findings build on other findings described in the thesis which also cast doubt on the role of stimulus devaluation as a mechanism of action of the effects of ICT on behaviour.

Keywords: attention, chocolate, choice, devaluation, inhibitory control training.

6.2 Introduction

To overcome unhealthy behaviours, such as excessive drinking or over-eating we must be able to exert self-control over impulses, especially when appetitive cues are present in our environment. As previously reported, meta-analyses have shown that a brief 'dose' of ICT, in which participants learn to associate appetitive cues (e.g. pictures of alcoholic drinks or chocolate) with inhibition, result in short-lived reduction in consumption (or influence on choice) in the laboratory (Allom, Mullan, & Hagger, 2015; Jones et al., 2016b, 2017). Yet, the mechanisms that underlie these ICT effects on behaviour are uncertain (Veling et al., 2017b)

As discussed in previous chapters a prominent explanation focuses on the link between action and valence and their effect on motivated behaviour (Guitart-Masip et al., 2014; Schonberg et al., 2014; Veling et al., 2017b; Wessel et al., 2014). Arguing that this reduction in health-harming behaviours via ICT is the result of the devaluation of appetitive stimuli, that were valued highly before being paired with motor inhibition (stimulus devaluation-hypothesis: Guitart-Masip et al., 2014; Veling et al. 2008, 2017b). Studies in many domains (especially in addiction and appetite research) have demonstrated that stimuli paired with inhibition are evaluated more negatively (e.g. implicit or explicit values decrease), compared to stimuli that have been paired with rapid behavioural responding (Ferrey et al., 2012; Houben et al., 2011, 2012; Houben & Jansen, 2015; Kemps et al., 2013; Schonberg et al., 2014; Veling et al., 2011, 2013a; Wessel et al., 2014).

A recent theoretical review paper summarizes these findings in the appetite literature and outlines three possible mechanisms (which are not mutually exclusive) that may underpin the effects of ICT on motivated behaviour (Veling et al., 2017b; see page 18 for details). The review claims that the formation of stimulus-stop associations appears to lead to stimulus devaluation, which ultimately leads to automatic inhibition when those cues are next encountered, hence leading to reductions in food intake and choices post-training. Importantly, the review concludes that these effects seem to be mostly linked to devaluation effects, with some evidence for stimulus-stop associations, suggesting overlaps and interactions between these mechanisms.

However, ICT devaluation effects do not appear to be robust, as recently demonstrated by a meta-analysis from our group, especially when measured by the IAT (Jones et al., 2016b). For example, study 5.1 in the previous chapter (page 112) found that implicit positive associations to chocolate pictures were not related to either approach or inhibitory control biases, suggesting that these processes are independent from one another. Additionally, results from study 2.1 (page 49) showed null effects of ICT on automatic alcohol implicit positive associations, measured with an IAT. Given that ICT leads to slowing of RTs to stimuli paired with inhibition (Bowditch et al., 2015; Verbruggen & Logan, 2008a), this might be expected to compromise the validity of tasks such as the IAT (Houben et al., 2012, 2011; Houben & Jansen, 2015; Kemps et al., 2013; Schonberg et al., 2014; Veling, et al. 2013a), particularly if participants' evaluations of the stimuli used during ICT are inferred from their RTs to respond to those target stimuli. Recent ICT reviews show that devaluation effects are more likely to be detected when adopting Likert or VAS and auction tasks as measures of devaluation (Jones, et al., 2016b; Veling et al., 2017b). Given this concern, it may be more appropriate to utilise measures that are not dependent on RTs to study devaluation effects via ICT, a feature that has not yet been investigated in the present thesis.

A recent series of studies demonstrated that it was possible to increase participants' positive evaluations of stimuli simply by training them to rapidly respond to those stimuli, and this behavioural response had consistent effects on attention and stimulus preference (Schonberg et al., 2014). The experimental protocol consisted of an initial auction task in which participants indicated how much they would be willing to pay for pictures of different snack foods; this was

used to distinguish relatively 'high value' from relatively 'low value' snack foods. Immediately following this task was a training phase in which half of the high value and half of the low value foods were paired consistently with a tone that signalled the requirement to make a rapid response ('Go' items) before the item disappeared. The remaining pictures were paired with absence of a tone and this signalled that participants should not respond ('No-Go' items). Immediately after the training phase, participants repeated the auction task, and they performed a forced choice task in which they had to choose between pairs of pictures (e.g. one that had been paired with 'Go' versus one that had been paired with 'No-Go' during the training phase), whilst their eye movements were recorded. Across studies, the consistent findings were that, at post-test, stimuli that were identified as highly valued at baseline and had been paired with rapid responding ('Go') during the training phase were chosen and attended to more frequently during forced choice, and participants were willing to pay more for them, compared to stimuli that were paired with not responding ('No-Go') during training. Weak, non-significant effects were observed on choices for low value stimuli paired with Go responses.

Similar procedures were adopted in recent experiments on food choices, with the addition of the manipulation of time pressure in order to investigate differences between impulsive and deliberative choices (Veling al., 2017a). Results replicated Schonberg et al.'s (2014) findings of increased selection of Go-paired stimuli post-training relative to No-Go-paired stimuli, but only when these choices were made impulsively. In addition, this devaluation effect disappeared when participants were required to direct their attention to the item that they did not want. This moderating effect of selective attention is consistent with earlier decision making literature (Izuma et al., 2010; Krajbich & Rangel, 2011; Lim et al., 2011; Sharot et al., 2009) which show that attention, behavioural choice and preference are strongly influenced by stimulus evaluations: people prefer, direct more attention to and are more likely to choose, items that they evaluate positively compared to items that they evaluate negatively.

In the present study, I adapted the methodology used in these recent studies in order to test the hypothesis that stimuli paired with inhibition during ICT would be devalued (as inferred from forced choice, selective attention, and subjective evaluations), compared to stimuli that had been paired with rapid responding. In order to identify relatively high value and low value chocolate-related pictures, I first

conducted a preliminary online study in which participants provided self-report ratings of attractiveness and palatability ('tastiness') for the chocolate-related pictures that were used in experiments described in chapter five (page 100). This enabled me to distinguish relatively 'high value' and 'low value' picture sets.

In line with the devaluation hypothesis, I predict that after ICT, relative to pre-training and in comparison to high value chocolate stimuli that have been paired with rapid responding ('Going'), high value chocolate stimuli that have been paired with inhibition (No-Go) will be: (1) evaluated less positively, (2) chosen less frequently during the forced choice task, and (3) attended to less. By contrast, relative to pre-training, stimuli paired with 'Going' will be evaluated more positively, chosen more frequently and attended to more, after ICT. In contrast to some previous studies (Schonberg et al., 2014; Veling et al., 2017a) measurement of choice and attention both before and after ICT should permit clearer identification of whether differences between Go-paired and No-Go-paired stimuli are attributable to increased valuation of Go-paired stimuli, devaluation of No-Go paired stimuli, or both.

6.3 Methods

6.3.1 Participants

In the initial online study, 67 healthy volunteers (25 Males, mean age: 29.15, SD = 10.99 years) were recruited from staff and students at the University of Liverpool via online advertising. The only criteria for inclusion was age between 18 and 35. In the laboratory study, 30 regular chocolate consumers (11 Males, mean age: 26.13, SD = 4.95 years) were recruited from staff and students at the University of Liverpool via online and poster advertising. As in previous studies in this thesis, I defined regular chocolate consumers as individuals who consumed a minimum of one standard size chocolate bar (e.g. Mars, Snickers and Twix) per week. Inclusion criteria also included fluency in English, aged between 18 and 35, and normal or corrected to normal vision. All participants provided informed consent before taking part in the studies, which were approved by the University of Liverpool Research Ethics Committee.

6.3.2 Materials and tasks

All computer tasks were presented on a Dell desktop computer with a 15" monitor and participants responded using a standard keyboard. All laboratory tasks were programmed and administered using Inquisit version 3.0 (Millisecond Software, 2008; Seattle, WA). The online survey was programmed and administered using Inquisit web 4.0 (Millisecond Software, 2015; Seattle, WA).

Chocolate stimuli consisted of 24 pairs of chocolate photographs, used in previous experiments described in chapter five (for details see page 103), which were employed in all the tasks for both the online and laboratory experiments. Matched neutral control pictures (for details see study 2.1, page 35) were used in the lab experiment, but only in the practice blocks of the probe task and ICT task.

Inhibitory Control Training (ICT, modified version based on Houben et al., 2012).

The ICT procedure and trials were similar to the 90:10 training contingency described in study 2.1 (see page 39). In contrast to the study 2.1, the ICT in the present experiment was comprised of only two blocks: a brief practice block (4 trials), and a training block (480 trials, with a short break half way through). Additionally, there were no pre-test and post-test assessment blocks that applied a 50% contingency. Within each block, trial order was randomized. Additionally, during the training block only chocolate stimuli were used, while only neutral control pictures were used during the practice block.

Chocolate pictures were divided into 'high value' and 'low value' subsets based on participants' responses during the online study. Creation of the two sub-sets of pictures were based on a 'Valence Index', which was the response mean from a 100mm VAS to both 'tastiness' and 'attractiveness' questions for each individual picture (see Veling, Aarts, & Stroebe, 2013a; Values ranged from 29% (SD = 10.99) to 62.5% (SD = 23.41)). I then performed a median split to allocate 12 pictures each, from the 24 available, to the two valence groups. Pictures with a valence index that was less than or equal to the median of 51.2% (SD = 24.44) were allocated to the low value picture set, and the remaining pictures were allocated to the high value picture set.

These two subsets of chocolate pictures were further randomly divided into two groups of six pictures each, so that half of the high value and half of the low

value pictures would be presented on 'Go' trials (with a 90% contingency), and the remaining pictures could be presented on No-Go trials (also with a 90% contingency). This established four stimulus categories for comparison before and after the ICT training block: (1) High value pictures paired with Go; (2) Low value pictures paired with Go; (3) High value pictures paired with No-Go; (4) Low value pictures paired with No-Go.

Furthermore, participants' RTs to respond to No-Go paired cues during the ICT training block on the 10% of trials in which those stimuli required a 'Go' response (catch trials), enabled me to investigate the anticipated slowing of reaction time to those cues over the course of the ICT training block.

Picture Rating Task (based on Lawrence et al., 2015a).

In this task participants rated each of the 24 individual chocolate pictures on dimensions of attractiveness and palatability ("tastiness") using a 100 mm VAS with two anchors at the extremes, ranging from 'not at all' to 'very much'. In two separate blocks, participants rated each image on attractiveness and palatability. Block order (attractiveness or palatability ratings first) was counterbalanced across participants and the order of trials within each block was randomised.

During each trial, a picture was individually presented in the centre of the screen, the question (attractiveness: "Indicate how attractive this food looks, independently of whether or not you like the taste of it"; or palatability: "Now imagine that this food is in your mouth, and rate how much you would like the taste of it") was presented above the picture, and the VAS was presented below the picture (with the cursor at the midpoint). These questions are worded differently to the ones used on study 5.1 (see page 104) because the present study is using a VAS based on Lawrence et al.'s recent task (2015a), while the previous study used a Likert scale based on Veling et al.'s task (2013a). These items remained on the computer screen until the participant responded by using the mouse to select a position on the VAS. Participants were instructed to respond quickly. In order to advance to the next trial, participants clicked a button labelled 'next'. Participants were given a short break between each block.

Forced Choice Probe (based on Schonberg et al., 2014).

On each trial of this task, a centrally presented fixation cross was presented for 500ms before a pair of pictures were presented to the left and right of the central position. Participants were instructed to choose their preferred item by pressing one of two keys, that were labelled left and right, as quickly as possible. The picture pair remained on screen until participants responded, and no feedback was provided. As they completed the task, participants' eye movements were recorded with an ASL Eye-Track D6 (Applied Science Laboratories, Bedford, MA) at a sampling rate of 120 Hz.

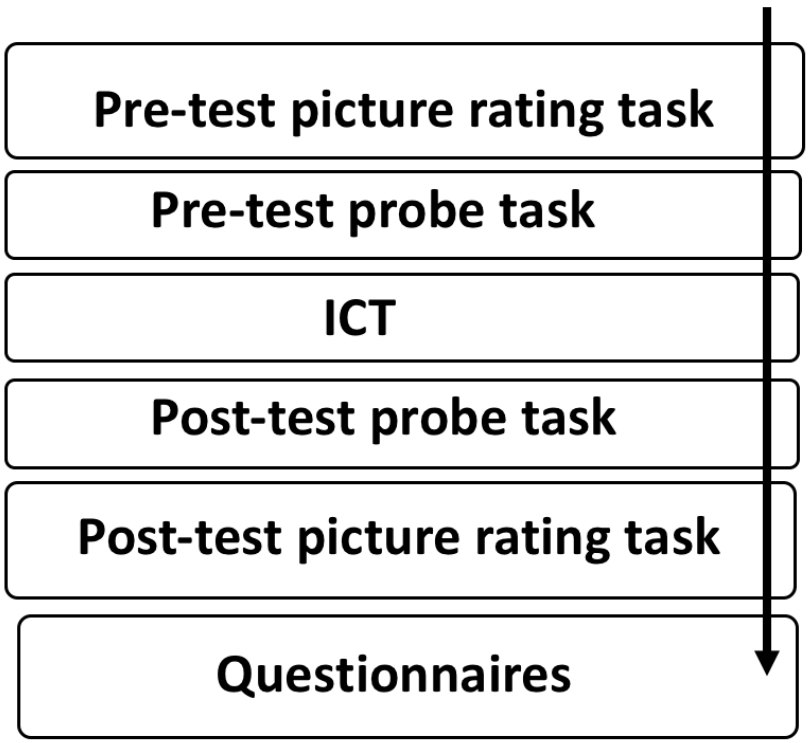
After calibration of the eye-tracker, eye tracking recordings started and a brief block of four practice trials followed (in which only control pictures were presented). Participants then started the main test block which was comprised of 96 trials, split into four sub-blocks of 24 trials each. Each sub-block required participants to choose between the following pairs of pictures: (1) High value pictures paired with Go vs. High value pictures paired with No-Go; (2) Low value pictures paired with Go vs. Low value pictures paired with No-Go; (3) High value pictures paired with Go vs. Low value pictures paired with Go; and (4) High value pictures paired with No-Go vs. Low value pictures paired with No-Go. Within each sub-block, pictures of each type appeared on the left of the screen on half of trials and on the right of the screen on the other half of trials. The trials within each sub-block were presented in a random order. However, the order of sub-blocks was kept constant between-subjects and within-subjects at pre-test and post-test as in Schonberg et al. study (2014).

6.3.3 Procedure

During recruitment and on the experimental day, participants were advised that the study was an investigation of the relationships between attention, categorisation speed and evaluations of branded and non-branded chocolate pictures (ICT was not mentioned). Participants were tested between 10:00 and 18:00 in the Eye-tracker laboratory in the Department of Psychological Sciences at the University of Liverpool. After providing informed consent, participants completed the picture rating task followed by the probe task (pre-test). They then completed the ICT training block, before immediately completing the picture rating and probe tasks once again (post-test). At the end of the study, participants provided general

demographic information, and they completed a brief chocolate use diary (Chocolate Use Questionnaire; CUQ; Tibboel et al., 2011; for details see study 5.1, page 102). Awareness of the aims of the study and hypotheses was assessed with two questions as used in previous studies (for details see study 2.1, page 40). Awareness was probed firstly by a general open-ended question about the overall aims of the experiment, followed by a 5-item multiple-choice question which assessed participants' awareness of the intended purpose of the ICT (the correct response was: "Teach me to control myself when I think of chocolate"). Finally, participants were debriefed about the aims and hypotheses of the study. The entire session lasted no longer than 40 minutes (for a schematic overview of the procedure see figure 6.1). At the end of the study, participants were debriefed and offered either course credit or £10 shopping vouchers as compensation for their time.

Figure 6.1 Schematic overview of the experimental procedure. For details see method section.



6.3.4 Data reduction and analysis

ICT

Similarly, to previous studies described in the thesis, regarding RTs on Go trials, trials with errors and then those with outlying reaction times (faster than 200ms or slower than 2000ms, then those that were more than 3 SDs above the mean) were removed. Then, mean reaction times on Go trials were calculated for each subset of chocolate pictures (high and low value pictures) at the beginning and the end of the training block. Regarding No-Go errors, participants made very few errors over the course of the ICT block (M=1.03, SD = 1.33); 47% of participants made no errors, 30% made one error and 20% made two or three; only one participant made more than three (errors n. = 5) No-Go errors, which is similar to the No-Go error rate reported in previous studies (see study 2.1, page 42; study 3.1, page 60; study 5.1 and 5.2, page 106). Thus, inhibition errors were not analysed.

Picture evaluations

Previous papers analysed evaluation data using either 'differences scores' (e.g. post-training scores minus pre-training scores separately for attractiveness and palatability ratings; see Lawrence et al., 2015a) or computed an index of food evaluations (e.g. overall mean of attractiveness and palatability ratings; see Veling et al., 2013a), in the present study I analysed mean evaluations for each of the four types of stimuli separately for attractiveness and palatability ratings at pre- and post-ICT. The following measure was adopted because unlike in Veling and colleges (2013a), attractiveness and palatability ratings were not consistently highly correlated at baseline (the average correlation was r = .17, p = .27; correlations ranged from r = .76, p < .01 to r = -.12, p = .53) and as more informative, by enabling the identification of differences between pre- and post-training.

Probe (forced choice) task

For each of the four types of pairings ((1) High value pictures paired with Go vs. High value picture paired with No-Go; (2) Low value pictures paired with Go vs. Low value pictures paired with No-Go; (3) High value pictures paired with Go vs. Low value pictures paired with Go; and (4) High value pictures paired with No-Go

vs. Low value pictures paired with No-Go), I computed the percentage of times that each stimulus was selected.

Eye tracking data

For each of the four types of pairing, I extracted and computed four variables: (1) total duration of gaze to each picture type, (2) number of fixations to each picture type, (3) duration of gaze to each picture type that was attended (fixated to) first (4) percentage of trials that each picture type was attended to first. Given that the display duration on each trial was controlled by the participant (the pictures were removed from view as soon as participants made their choice), total duration of gaze on each picture type was expressed as a proportion of display duration (which was equivalent to reaction time on that trial, as in Schonberg et al., 2014). Because all these variables were highly inter-correlated with each other, I report in the main analysis only proportions of time spent looking to each picture; analyses of the other eye movement variables, showed a similar pattern, and are reported in supplementary materials in Appendix C (page 228).

Furthermore, for the time spent looking at each stimulus, the eye tracking data for 3 participants at pre-test and 6 participants at post-test were excluded they had an excessive rate of missing data (eye movement data was missing on more than half of the trials for each pairing type). Finally, relative to most of the pairings analysed, eye data from the first pairing type (P1: high Go vs. high No-Go) was downsized due to missing data. This missing data may be due to the fact that this first pairing type sub-block (P1: high Go vs. high No-Go) was consistent for all participants, thus eye data loss might have been affected due to calibration adjustments.

6.4 Results

6.4.1 Participant characteristics

On average, participants reported consuming .99 (SD=.64) standard size bars of chocolate (e.g. Mars, Snickers or Twix) weekly. Additionally, they responded to the open question how many bars do you usually keep at home? by stating that they kept 3.77 (SD = 2.93) of these standard bars in the past week.

6.4.2 Equivalence of stimulus evaluations in the online study and the laboratory study (Table 6.1)

In order to confirm if picture ratings were equivalent in the preliminary online study and the laboratory study, I conducted a 2 × 2 × 2 ANOVA with a between-subject factor of Study (2: Online or Laboratory), and within-subject factors of Stimulus Type (2: High or Low value), and Question (2: Attractiveness or Palatability). Results showed a main effect of Study ($F(1, 29) = 4.43$, $p = .05$), reflecting higher overall scores in the Laboratory Study relative to the Online Study. Reassuringly, the main effect of Stimulus Type was statistically significant ($F(1, 29) = 56.18$, $p < .01$), and was not qualified by a significant Stimulus Type × Study interaction ($F(1, 29) = 1.08$, $p = .31$), indicating more positive evaluations for high value stimuli relative to the low value stimuli in both the Laboratory Study and the Online Study. However, the two-way interaction Study × Question was significant ($F(1, 29) = 6.5$, $p = .02$), which reflects higher palatability ratings in the Laboratory study compared to the Online study ($t(29) = 2.79$, $p = .01$, $d = .03$), but no difference in 'attractiveness' ratings ($t(29) = 1.08$, $p = .29$) were observed. There were no other significant interactions or main effects ($Fs < 2.74$, $ps > .11$).

Table 6.1. Stimulus evaluation ratings on a 100mm VAS for 'attractiveness' and 'palatability' questions for each for the two stimulus categories (e.g. high vs. low value stimuli), shown separately at pre-test in the Laboratory study and in the Online study. Values are mean ± SD.

	Lab. study	***Online study***
Attractiveness High	*58.85 (9.38)*	*57.57 (16.29)*
Attractiveness Low	*53.79 (10.54)*	*48.05 (17.51)*
Palatability High	*63.17 (9.47)*	*53.26 (15.08)*
Palatability Low	*57.00 (12.50)*	*47.19 (16.24)*

6.4.3 Performance during the ICT block (Table 6.2)

RTs on 'Go' trials during the ICT training block was analysed with a 2 × 2 ANOVA with within-subject factors of Stimulus Type (2: High or Low value pictures) and Cue associations (2: Paired with Go or with No-Go). The critical two-way interaction was not significant ($F (1, 29) = 1.95$, $p = .17$). However, main effects of Stimulus Type ($F (1, 29) = 13.40$, $p < .01$) and Cue associations were observed ($F (1, 29) = 4.04$, $p = .05$), indicating that overall participants were faster to respond to high value compared to low value stimuli, and to stimuli paired with Go compared to stimuli paired with No-Go.

In order to investigate if participants became slower to respond to pictures that were paired with No-Go over the course of the ICT training block (10% catch trials) I compared differences in Go RTs between the beginning and the end of the training (the first six and last six trials of each type). A 2 × 2 repeated measures ANOVA was conducted on Go RTs, with a within-subject factor of Time (2: Beginning of the training or End of the training) and Stimulus Type (2: High or Low value pictures). The critical Time × Stimulus interaction was not significant ($F (1, 29) = 1.44$, $p = .24$). However, a significant main effect of Time ($F (1, 29) = 7.56$, $p = .01$) and no main effect of Stimulus ($F (1, 29) = 3.49$, $p = .07$) were observed. The main effect of time indicates that, as hypothesized, participants became slower to respond to stimuli that were paired with No-Go on 90% of trials during the training block from the beginning towards the end of the training block (i.e. the development of associative inhibition: 'stop-learning effect'). Although this effect was not modified by Stimulus Type (High vs. Low value), planned contrasts indicated that RT slowing was only significant for high value pictures, ($t (29) = 3.36$, $p < .01$, $d = 1.25$), but not low value pictures ($t (29) = 1.14$, $p = .27$).

Regarding changes in RTs to Go-paired stimuli over time, a similar 2 × 2 repeated measures ANOVA was conducted on the first six and last six Go trials of each type, with, a within-subject factor of Time (2: Beginning of the training or End of the training) and Stimuli Type (2: High or Low value pictures). The critical Time × Stimulus interaction was not significant ($F (1, 29) = .78$, $p = .38$) and there were no significant main effects ($Fs < 2.12$, $ps > .16$). Therefore, the speed of responding on Go trials did not change over the course of the ICT training block.

Table 6.2. ICT performance over time: reaction times (milliseconds) for stimulus-cue pairings during the beginning and the end of the ICT training block. Values are mean ± SD.

RTs	**Beginning**	**End**
High value Go	*513.71 (46.37)*	*516.71 (46.96)*
Low value Go	*517.76 (50.91)*	*518.39 (47.94)*
High value No-Go	*509.33 (51.78)*	*530.72 (55.14)*
Low value No-Go	*524.43 (51.04)*	*533.99 (50.80)*

6.4.4 Stimulus evaluations (Table 6.3)

Ratings were analysed separately for attractiveness and palatability ratings using a 2 × 2 × 2 ANOVA, with within-subject factors of Time (2: Pre or Post-ICT) Stimulus Type (2: High or Low value), and Cue associations (2: paired with Go, paired with No-Go).

For palatability ratings, the critical Time × Stimulus Type × Cue associations interaction was not significant ($F(1, 29) = .03$, $p = .87$), likewise the two-way interactions between Time × Stimulus ($F(1, 29) = 2.97$, $p = .10$), Time × Cue associations ($F(1, 29) = .53$, $p = .47$) and Stimulus Type × Cue associations ($F(1, 29) = .49$, $p = .49$) were all non-significant. However, main effects for each of the within-subject factors were observed. Overall, chocolate pictures were rated as less palatable following ICT, relative to pre-training ($F(1, 29) = 4.65$, $p = .04$). Additionally, high value pictures were rated as more palatable than low value stimuli ($F(1, 29) = 9.84$, $p = .01$). Finally, pictures paired with No-Go were rated as more palatable, relative to those paired with 'Go' ($F(1, 29) = 6.73$, $p = .02$).

Similarly, for attractiveness ratings the critical Time × Stimulus Type × Cue associations interaction was not significant, ($F(1, 29) = 1.46$, $p = .24$) and none of the two way interactions ($Fs < 1.16$, $ps > .29$) were significant. The main effect of Time was not significant ($F(1, 29) = .18$, $p = .67$). However, again the main effects of Stimulus ($F(1, 29) = 10.59$, $p < .01$) and Cue associations ($F(1, 29) = 7.05$, $p = .01$) were significant. The pattern was similar to that for palatability ratings: participants rated high value stimuli as more attractive than low value stimuli, and

pictures paired with No-Go were rated as more attractive than stimuli paired with Go.

Thus, cues paired with inhibition (No-Go) were not devalued, and cues paired with rapid responding (Go) did not increase in value, after the ICT training block. However, interpretation of these findings is complicated by the observation that cues paired with No-Go were rated as more attractive than cues paired with Go before the ICT training block, and this difference did not change after the ICT training block.

Table 6.3. Evaluation ratings for each for the 4 stimulus-cue pairings (e.g. high vs. low value stimuli paired with either Go or No-Go) on a 100mm VAS. Values are shown separately for 'attractiveness' and 'palatability' ratings at pre- and post-ICT. Values are mean ± SD.

Attractiveness	**Pre**	**Post**
High Go	*55.20 (12.12)*	*55.35 (11.82)*
High No-Go	*62.50 (10.86)*	*62.25 (14.03)*
Low Go	*52.85 (13.52)*	*50.47 (15.44)*
Low No-Go	*54.73 (12.90)*	*54.55 (16.72)*
Palatability	**Pre**	**Post**
High Go	*59.97 (10.91)*	*55.91 (12.77)*
High No-Go	*66.37 (10.94)*	*61.21 (13.03)*
Low Go	*55.31 (13.97)*	*53.05 (13.09)*
Low No-Go	*58.70 (15.87)*	*55.78 (17.19)*

6.4.5 Forced choices during the probe task (Table 6.4)

I compared the percentage of choices for a stimulus, pre- and post-ICT training block, using paired samples t-tests separately for each pairing category (Pair 1: high Go vs. high No-Go, Pair 2: low Go vs. low No-Go, Pair 3: high Go vs. low Go and Pair 4: high No-Go vs. low No-Go). Results showed significant changes from pre- to post-ICT in the expected direction only for the second pairing (t (29) = -3.57, $p < .01$, $d = .29$): after the ICT training block, participants were more likely to

choose low value stimuli paired with Go, in favour of low value stimuli paired with No-Go. However, this difference was not significant for high value stimuli (Pair 1; t (29) = -.78, p = .44). Contrasts for the other two pairings were not statistically significant (Pair 3: t (29) = -1.21, p = .24, and Pair 4: t (29) = -.75, p = .46). These findings illustrate that, after ICT, participants are more likely to choose stimuli that were paired with Go over those that were paired with No-Go during the training block, albeit only for low value stimuli.

Table 6.4. Choices (percentage of selected stimuli) and proportion of the duration of gaze to each stimulus for the 4 different stimulus-cue pairings, during the probe task. Values are shown separately for time (pre or post-ICT). Values are mean ± SD.

P1 High Go vs. High No-Go	**Pre-test**	**Post-test**
% of choices of High Go	*39.86 (16.48)*	*42.22 (18.53)*
Proportion of time looking		
High Go	*.34 (.04)*	*.33 (.05)*
High No-Go	*.47 (.05)*	*.44 (.07)*
P2 Low Go vs. Low No-Go	**Pre-test**	**Post-test**
% of choices of Low Go	*43.06 (21.70)*	*49.31 (22.05)*
Proportion of time looking		
Low Go	*.38 (.03)*	*.39 (.09)*
Low No-Go	*.39 (.10)*	*.36 (.10)*
P3 High Go vs. Low Go	**Pre-test**	**Post-test**
% of choices of High Go	*51.95 (16.15)*	*49.17 (17.56)*
Proportion of time looking		
High Go	*.39 (.08)*	*.35 (.10)*
Low Go	*.40 (.09)*	*.39 (.09)*
P4 High No-Go vs. Low No-Go	**Pre-test**	**Post-test**
% of choices of High No-Go	*55.97 (22.18)*	*57.92 (25.15)*
Proportion of time looking		
High No-Go	*.38 (.12)*	*.40 (.10)*
Low No-Go	*.37 (.08)*	*.33 (.10)*

6.4.6 Eye movements (Table 6.4)

I analysed proportion of the time spent looking at each picture for each separate pairing (Pair 1: high Go vs. high No-Go, Pair 2: low Go vs. low No-Go, Pair 3: high Go vs. low Go and Pair 4: high No-Go vs. low No-Go) using 2 × 2 ANOVAs, with within-subject factors of Time (2: Pre or Post-ICT) and picture type.

Results from the first pairing (high Go vs. high No-Go) revealed no significant interaction between time and picture type ($F(1, 8) = .42$, $p = .54$), a non significant main effect of time ($F(1, 8) = 4.06$, $p = .08$) and a significant main effect of picture type ($F(1, 8) = 32.28$, $p < .01$). The effect of picture type reflects longer gaze times for high value pictures paired with No-Go cues relative to high value pictures paired with Go cues, both before ($t(9) = 6.04$, $p < .01$, $d = .02$), but not after ($t(22) = 1.85$, $p = .08$) the training block. However, these results need to be interpreted with caution due to the great amount of missing data.

For the second pairing (low Go vs. low No-Go) there were no main effects of time ($F(1, 16) = .73$, $p = .41$) or picture type ($F(1, 16) = .09$, $p = .77$), but the critical Time × Stimulus interaction was significant ($F(1, 16) = 5.71$, $p = .03$). Post-hoc paired t-tests showed that the interaction was underpinned by individuals spending less time looking at low value stimuli paired with No-Go cues after the ICT training block, compared to before ($t(19) = 2.09$, $p = .05$, $d = .95$). However, attention to low value cues paired with Go did not change from before the ICT training block to after the training block, and there were no differences between attention to cues paired with Go versus cues paired with No-Go either before or after the training block ($t < 1.02$, $p > .32$).

For the third pairing (high Go vs. low Go) there were no significant main effects (time ($F(1, 16) = 2.88$, $p = .11$); picture type ($F(1, 16) = .65$, $p = .43$)) and no significant interaction ($F(1, 16) = 1.93$, $p = .18$). For the fourth pairing (high No-Go vs. low No-Go), there were no significant main effects ($Fs < 2.17$, $ps > .16$), and no significant interaction ($F(1, 18) = 3.29$, $p = .09$).

6.4.7 Correlations between dependent variables after ICT (Table 6.5)

To assess the relationships between dependent variables after the ICT training block I analysed correlations between attractiveness and palatability ratings, forced choices and proportion of time spent looking at each picture, separately for each of the four pairings. Generally speaking, post-ICT attractiveness and

palatability ratings tended to be highly correlated with each other, as did the proportion of attention to a stimulus and the likelihood of selecting that stimulus during the probe task. Subjective ratings were never significantly correlated with attention to the stimuli, although more positive subjective ratings of stimuli were correlated with increased likelihood of choosing, a pattern that was inconsistent across pairings. For details see table 6.5.

Table 6.5 Correlation matrix between 'Attractiveness' and 'Palatability' ratings and behavioural (percentage of selected stimuli) and attentional measures (proportion of gaze to each stimulus) during the post-ICT probe task, shown separately for each stimulus and each pairing category.

Pairing 1 (High Go vs. High No-Go)

High Go	1.	2.	3.	4.
1. % of choices	1			
2. Proportion of time looking	.17	1		
3. Attractiveness	.41*	.03	1	
4. Palatability	.26	-.07	.76**	1
High No-Go				
1. % of choices	1			
2. Proportion of time looking	.49*	1		
3. Attractiveness	.03	-.11	1	
4. Palatability	.19	-.12	.74**	1

Pairing 2 (Low Go vs. Low No-Go)

Low Go	1.	2.	3.	4.
1. % of choices	1			
2. Proportion of time looking	.66**	1		
3. Attractiveness	.33	.17	1	
4. Palatability	.36	.22	.68**	1
Low No-Go				
1. % of choices	1			
2. Proportion of time looking	.12	1		
3. Attractiveness	-.54**	-.21	1	
4. Palatability	.60**	-.27	.86**	1

Pairing 3 (High Go vs. Low Go)

High Go	1.	2.	3.	4.
1. % of choices	1			
2. Proportion of time looking	.21	1		
3. Attractiveness	.06	.03	1	
4. Palatability	.34	-.03	.76**	1
Low Go				
2. % of choices	1			
5. Proportion of time looking	.56**	1		
6. Attractiveness	.40*	.12	1	
7. Palatability	.22	.19	.68**	1

Pairing 4 (High No-Go vs. Low No-Go)

High No-Go	1.	2.	3.	4.
1. % of choices	1			
2. Proportion of time looking	.37	1		
3. Attractiveness	.28	-.15	1	
4. Palatability	.33	-.25	.74	1
Low No-Go				
1. % of choices	1			
2. Proportion of time looking	.11	1		
3. Attractiveness	.64**	-.05	1	
4. Palatability	.57**	-.08	.86**	1

**Correlation is significant at the .05; ** Correlation is significant at the .01.*

6.4.8 Participants' awareness of the study aims and hypotheses (Table 6.6)

The first question in the funnelled debriefing required participants to identify what they thought was the main aim of the study (for details see study 2.1, page 40). Their responses revealed that the vast majority of participants (25; 83%) were unaware of the aims and hypotheses. Answers to this open-ended question were varied, but recurring themes were: how individual differences in packaging (branded versus non branded items) and chocolate preferences would influence choices, liking and cognitive performance during categorisation tasks.

Participants' responses to the next (multiple choice) question are shown in Table 6. These are consistent with results from previous experiments (see: study 2.1, page 49; study 3.1, page 64). Participants were led to believe that there was no experimental manipulation in the study, and the majority of participants believed the cover story that the study was an investigation of the relationship between speed of categorisation and behavioural control when evaluating appetitive stimuli. Only four participants (13%) indicated awareness of the intended purpose of ICT by stating that they believed that the purpose of the training task was to 'teach me to control myself when I think of chocolate'.

Table 6.6. Frequencies of participants' responses to the question that probes their awareness of the purpose of ICT.

a. *Train me to think more quickly*	0
b. *Measure how quickly I can categorise things*	11
c. *Measure my ability to control myself when I think of chocolate*	12
d. *Teach me to control myself when I think of chocolate*	4
e. *I do not know what this task was measuring*	3

6.5 Discussion

The aim of this study was to further test the devaluation hypothesis, by investigating if ICT would affect participants' self-report evaluations of chocolate stimuli that had been paired with inhibition of responding, and if ICT would additionally affect stimulus-choice selection and attentional processes. As expected, during ICT participants became slower over time to respond to high value stimuli that were paired with inhibition, indicating the formation of associations between those stimuli and inhibition. Most importantly, and contrary to hypotheses, ICT did not influence evaluations of attractiveness or palatability of stimuli that had been paired with inhibition. However, after ICT, participants were more likely to choose stimuli that had been paired with rapid responding (Go) over stimuli that had been paired with inhibition (Stop). Importantly, these effects were only observed for relatively low value chocolate stimuli, whereas I hypothesised that they would be seen for high value, rather than low value stimuli. Furthermore, ICT effects on attentional processes were observed, as participants spent less time looking at chocolate pictures that had been paired with inhibition, after the ICT training block. Again, these effects were only seen for relatively low value chocolate stimuli, whereas I hypothesised that these effects should have been more pronounced for high value stimuli.

In order to investigate effects of ICT, firstly I needed to check that stimulus-stopping associations developed over the course of the training block (Bowditch et al., 2015; Veling et al., 2017b; Verbruggen et al., 2014). Overall participants were faster to respond to high value stimuli, and as expected and in line with the literature

in the field (Jones & Field, 2013; Lenartowicz et al., 2011; Noël et al., 2016; Verbruggen & Logan, 2008a,b, 2009; Verbruggen et al., 2014) stimulus-stop learning effects were observed. Participants decreased their speed of response over time during the training block for high value stimuli paired with inhibition. This effect was not observed for low value stimuli, suggesting that inhibition does not affect RTs to these stimuli. Yet, studies in applied domains (see previous results in study 2.1, page 49) do not always demonstrate the predicted formation of stimulus-stop associations, in some cases even after multiple sessions of ICT (Houben et al., 2012; Lawrence et al., 2015a). As stated in previous chapters (see study 2.1, page 49 and study 5.1 and 5.2, page 119), the reasons for these mixed findings may be due to the fact that RTs may not be sufficiently reliable to detect these associations as they may be too sensitive to other external factors (e.g. instructions, executive settings or the stimuli used; Best et al., 2015; Chiu & Aron, 2014; Stice, Lawrence, Kemps, & Veling, 2016).

Recent studies demonstrate that successful ICT (following the formation of stimulus-response associations) may be accompanied by devaluation of appetitive stimuli paired with stopping (stimulus-devaluation hypothesis: Houben et al., 2012; Houben & Jansen, 2015; Veling et al., 2011, 2013a; Veling et al., 2017b). However, these findings of stimulus devaluation after ICT are not so robust, especially when measured by implicit measures (Jones, et al., 2016b; Veling et al., 2017b). In the present study I investigated if post-ICT devaluation effects would be detected in high value stimuli when adopting self-report evaluation ratings, and by contrast if high value stimuli paired with 'Going' would be evaluated more positively compared to baseline, effects which were not expected for low value stimuli.

Contrary to expectations, results indicated no effect of ICT on evaluations. Participants showed an overall tendency to value high value stimuli relative to low value ones, and showed a general decrease in palatability ratings post-ICT which cannot be attributed to ICT. Additionally, general baseline differences were present, with participants rating overall higher stimuli paired with-No-Go, making the overall null-effect of ICT difficult to interpret.

These results contrast with other research that used a similar experimental protocol, which shows repeated devaluation effects for highly attractive stimuli (Chen et al., 2016; Lawrence, et al., 2015a; Veling et al., 2017a). An explanation for the present results may be due to this pre-existing baseline difference, which might

have prevented the ability to investigate effectively the study hypothesis, as ideally pre-training Go and No-Go stimuli categories were meant to have similar value. Additionally, most of the studies that found an effect controlled for hunger, by either asking participants to attend the experimental session at a certain specific time (before or after lunch) and by refraining from eating for example for at least 4 hours before the experiment or by splitting participant in two groups (high versus low appetite condition) (Lawrence et al., 2015a,b; Veling, Chen, et al., 2017; Veling et al., 2013a). This criteria was not applied in our study and should be accounted for in future studies, because motivated behaviour and the valence of food stimuli are sensitive to food deprivation (Blundell, 1996; Seibt, Häfner, & Deutsch, 2007; Veltkamp, Aarts, & Custers, 2008). Therefore, between-subject differences in hunger may partially account for the failure to detect ICT effect in the present study.

During the probe task, contrary to our predictions I did not observe ICT effects on forced choices of high value chocolate stimuli as has been reported in other studies (Schonberg et al., 2014; Veling, Aarts, & Stroebe, 2013a). However, I did observe the hypothesised effects for low value stimuli, with increases in the selection of low value stimuli paired with rapid responding and decreases in the selection when low value stimuli were paired with inhibition. Furthermore, during the probe task eye movements were recorded in order to investigate effects of ICT on attentional processes. Attentional results, inferred from eye movements, are consistent with findings from forced choice, with individuals spending less time looking at low value stimuli paired with inhibition post-ICT relative to pre-training, suggesting that ICT made these stimuli less appealing.

These results are in line with findings on attentional processes and motivated behaviour (Schonberg et al., 2014). However, this interpretation needs to be considered with caution. Firstly, null effects of ICT were observed in subjective evaluations, which instead would be expected if ICT made these stimuli less appealing. Moreover, contrary to Schonberg and colleagues (2014) I did not observe post-ICT effects for high value stimuli, this may be due to pre-existing baseline differences between Go and No-Go stimuli and a significant number of missing eye-data for high No-Go trials. Thus, future studies should counterbalance sub-blocks between subjects in order to compensate for missing data due to calibration adjustments. Additionally, these effects may have been more disrupted for gaze

times as measured as a proportion of stimulus display time (dependent on reaction time on that trial) which may have been affected by ICT learning effects on RTs.

Moreover, post-ICT correlations between these attentional measures and the behavioural measure of choice suggest that choice and attentional processes tend to co-vary with each other. Additionally, positive correlations between the percentage of forced choices and evaluation ratings were observed. Results which are in line with the decision making literature (Izuma et al., 2010; Krajbich & Rangel, 2011; Lim et al., 2011; Sharot et al., 2009) and Schonberg et al. findings (2014), showing that post-ICT greater evaluations and longer gazes to stimuli were related to greater selection of the stimuli during forced choice.

The present study has some limitations. As already mentioned, the failure to control for hunger and BMI may have impacted our findings. Additionally, the use of a probe task in which trial duration terminated when participants made a response is a limitation of the present study, because it complicates interpretation of the choice data. Firstly, because recent experiments have shown that food choice can be manipulated by ICT but only if the choice is impulsive (with time pressure); and that the effect of ICT on choice disappeared when participants received more time or when their choice required them to direct their attention to alternatives (Veling et al., 2017a). In the present study, although participants were instructed to respond as quickly as they could, the absence of a timeout may have minimised the pressure on performance. In fact, relative to the mean RT in the time pressure (and also in the no time pressure) condition in the Veling and colleagues (2017a) study, in the present probe choice task mean overall RTs were longer both pre- (M = 927.63, SD = 240.86) and post-ICT (M = 784.08, SD = 198.76). Future studies should further investigate these hypotheses by using trials with a fixed response time. It would also be interesting to incorporate more neutral stimuli (Stice et al., 2016) during the forced choice probe task, in order to compare them to appetitive stimuli and exacerbate the differences in cognitive, attentional and choice processes, which could help in the interpretation of these complex interactions.

To conclude, I demonstrated that a single brief session of ICT in the laboratory yielded effects on choice and attentional processes, but only for low value stimuli. Furthermore, over time ICT led to slower responses for high value stimuli paired with inhibition, yet the the formation of these stimulus-stop associations unexpectedly did not affect stimulus evaluations. Thus, these results build on

previous findings reported in the thesis which also cast doubt on the role of stimulus devaluation as a mechanism underlying the effects of ICT on behaviour. This suggests that other mechanisms may be involved, and these will be investigated in the next and final experimental chapter.

Chapter Seven

What is learned during inhibitory control training? An experimental test of the roles of associative inhibition and signal-detection.

7.1 Abstract

Introduction: ICT is a behaviour change intervention that trains participants to form associations between appetitive cues (e.g. alcohol pictures) and engagement of inhibitory control (Allom, Mullan & Hagger, 2015; Jones et al., 2016b). However, the associative learning mechanisms that mediate the effects of ICT are ambiguous. In the present study I investigated two candidate mechanisms (Verbruggen et al., 2014): 'associative-inhibition' (ICT leads to the formation of automatic associations between target cues and behavioural inhibition, that are independent of context) and 'signal detection' (ICT improves the ability to detect inhibition signals after target cues, but effects of target cues on behavioural inhibition will only manifest in an 'executive setting' in which inhibition might be required).

Methods: Non-dependent heavy drinkers (N=80) were tested individually in laboratories. In order to train associations between alcohol cues and inhibition (No-Go training group) or alcohol cues and rapid responding (Go training group), participants completed an alcohol-related GNGT in which alcohol pictures were consistently paired either with a signal to inhibit (the letter 'f'; No-Go trials) or a signal to respond rapidly (the letter 'p'; Go trials), respectively. During a subsequent test phase, participants completed a speeded categorization task that required them to rapidly respond to the letters 'p' and 'f' that were preceded by the alcohol and control pictures (used during the training phase) or by additional novel pictures

(pictures of boats and birds). Critically, half of the participants in each group completed the test phase in a context that favoured inhibition (they expected to have to inhibit occasionally, whenever they saw pictures of boats; inhibition context) or a context that favoured speed (in which they knew that they would never have to inhibit; speed context).

Results: During the test phase, RTs were significantly slower among participants who completed the task in the inhibition context versus those who completed the task in the speed context. However, contrary to predictions, there was no strong evidence that participants had formed associations between alcohol cues and behavioural inhibition (or alcohol cues and rapid responding), regardless of group allocation. Instead, regardless of the testing context, all participants were slower to respond to the letter 'f' (that had been the No-Go cue during the training phase) compared to the letter 'p' (that had been the Go cue during the training phase).

Conclusions: These findings do not support either 'associative inhibition' or 'signal detection' accounts of the associative learning effects that underlie ICT. Instead, the findings suggest that participants formed neither direct nor indirect associations between alcohol cues and behavioural inhibition during the training phase, and therefore these data are unable to distinguish between the two accounts.

Keywords: alcohol, automatic associative-inhibition, inhibitory control, signal detection.

7.2 Introduction

During ICT, participants repeatedly inhibit responding to certain types of pictures (e.g. alcohol), and this should lead to the formation of direct 'stimulus-stop' associations, which can be inferred from slowing of RTs or reduced rate of commission errors (Verbruggen & Logan, 2008a, 2009; Chiu & Aron, 2014; Best et al., 2015; Bowditch, Verbruggen & Mclaren, 2016; Houben & Jansen, 2015). Subsequently, these learned associations may be automatically retrieved from memory and should manifest as automatic inhibition when these alcohol cues are next encountered (Verbruggen et al., 2014). In a meta-analysis of applied studies from our group, we demonstrated that ICT effectiveness on eating and drinking behaviour in the laboratory was inversely related to the number of inhibition failures,

presumably because each inhibition failure weakens the association between the target cues and successful inhibition (Jones et al., 2016b). Hence, higher training effectiveness for individuals with fewer inhibition-errors suggest that individuals must learn to form associations between cues and the behavioural response ('associative inhibition hypothesis').

A series of studies lend support to this claim. For example, Verbruggen and Logan (2008a) presented a set of experiments formed by a training phase where stimuli (living and non-living words) were paired with behavioural response or inhibition, followed by a test-phase in which reversed stimulus-responses pairings were administered. Results showed that inhibition became an automatic learned process because, during the test-phase, individuals were slower to respond to stimuli that had previously been paired with stopping compared to novel stimuli or stimuli that had previously been inconsistently paired with responding or stopping. These implicit stop-learning effects have been replicated in other laboratory studies that used arbitrary stimuli (Bowditch, Verbruggen & McLaren, 2015; Verbruggen & Logan, 2009; Lenartowicz et al., 2011; Verbruggen et al., 2014), in studies that used alcohol-related stimuli (Jones & Field, 2013; Noël et al., 2016) and in appetite studies using tempting food stimuli (Houben & Jansen, 2015; Lawrence et al., 2015a).

Nonetheless, these post-training effects on RTs are not consistently found. For example, null effects on RTs have been reported in ICT laboratory studies with hazardous drinking students (Houben et al., 2012, and see study 2.1, page 47). Similarly, RT effects were not consistently observed in the experiments reported in the present thesis, with increases in RTs for stimuli paired with response shown in study 3.1 (page 62) and stop-learning effects shown in study 6.1 (page 134). As previously mentioned (see page 49) these inconsistencies may be explained by recent laboratory findings suggesting that effects on RTs may be sensitive to a number of factors (Best et al., 2015; Stice et al., 2016). For example, a study found stop-learning effects only in the presence of an executive setting / inhibition context (i.e. a setting / context in which participants might be required to inhibit; Chiu & Aron, 2014).

In a recent theoretical paper, an alternative account has been proposed in order to explain the mechanisms that underpin action-control, arguing that the detection of (stop)-signals is an essential cognitive process for successful inhibition

('signal-detection' hypothesis; Verbruggen et al., 2014). As applied to ICT, the proposal is that cues paired with stop signals (e.g. alcohol cues) may be indirectly priming the representation of learned associations, which may lead to improvements in the ability to detect these signals and indirectly to improvements in general behavioural inhibition. Experiment number two in the paper supports this claim, by demonstrating that during the training phase the learning of the pairings (stimulus mappings), influenced the probability of responding on signal trials, but did not influence Go RTs. Participants showed no differences in RTs between consistent-old and inconsistent-novel stimuli pairings, but learned associations affected their probability of response, with lower probability of response for consistent stop stimuli pairings rather than for inconsistent pairings. Furthermore, this view is supported by another study showing RTs impairments only when irrelevant perceptual distractors are introduced in a SST (Logan et al., 2014). Thus, these findings suggest that a proportion of stopping latency is occupied by perceptual processes, which become more substantial when distracters are introduced as they increase the difficulty of the task.

Importantly, these 'associative inhibition' and 'signal-detection' hypotheses make competing predictions about the effectiveness of ICT in the 'real world': the 'Associative Inhibition' account predicts that after associative pairings between alcohol cues and inhibition of behaviour, alcohol cues will automatically evoke inhibitory control when they are subsequently encountered, even if they are encountered in a context in which inhibition is not required (speed context). On the other hand, the competing 'Signal detection' hypothesis predicts that during alcohol inhibition training, alcohol cues improve the ability to detect signals to inhibit. An implication is that if alcohol cues are encountered after training in a setting in which inhibition is not required (non-executive context; speed context), they should improve the efficiency of detection of signals to inhibit, but they will not evoke inhibitory control. Therefore, the 'Associative Inhibition' hypothesis predicts that alcohol cues will automatically result in inhibition of behaviour whenever they are encountered, whereas the 'Signal detection' hypothesis predicts that they will only do so in a setting in which inhibition may be required (an executive inhibition context; Chiu & Aron, 2015).

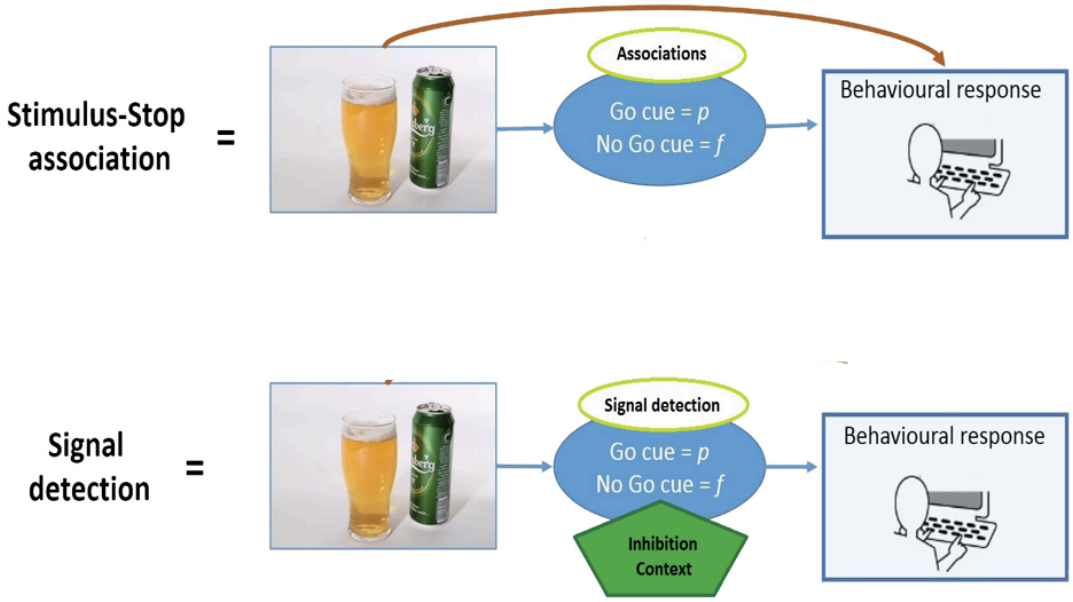
The present study seeks to test these competing explanations (see figure 7.1 for a schematic overview) by randomly assigning participants to one of four groups

which differ in the stimulus-stop associations that are learned during ICT (No-Go training: alcohol-stop & stationery-go, or vice versa in the Go training condition), and in the context in which stimulus-stopping associations are assessed after ICT (either an 'inhibition context' in which participants have to inhibit some of the time, or a 'speed context' in which inhibition is never required). The two alcohol interventions are exactly opposite; in one condition (No-Go training) individuals exerted self-control in the presence of appetitive stimuli, while in the other condition (Go training) individuals enhanced their appetitive bias towards alcohol. Alcohol-Go ICT was employed as a control condition instead of a Sham training condition (50% contingency), as these types of control conditions inflate the effect of the training by increasing the subjective value of the trained appetitive stimuli (Schonberg et al., 2014) and helping to disentangle and detect more effectively ICT effects on RTs.

According to the 'associative inhibition' hypothesis, participants should be slower to respond to alcohol cues during the test phase if they had previously been paired with stopping during the training phase, and this pattern should be seen regardless of the inhibition context during the test phase (Bowditch, Verbruggen & McLaren, 2015; Verbruggen et al., 2014). By contrast, the 'signal detection' hypothesis yields the following predictions: if the test phase is conducted in an inhibition context, stop-learning effects should be apparent (e.g. participants should be slower to respond to alcohol pictures if those pictures had been paired with stopping during the training phase). However, if the test phase is conducted in a speed context (in which participants are never required to inhibit), then stop-learning effects should not be apparent, but instead participants should be faster to respond when the congruency between target letters ('p' or 'f') and pictures (alcohol-related or stationery) matches the pairings that were applied during the training phase, because the pictures should facilitate rapid detection and categorization of the letter. As a manipulation check, I also investigated stop-learning effects during the training block; e.g., participants in whom alcohol pictures were consistently paired with No-Go trials should be slower to respond on the minority of alcohol 'Go trials' during the training block.

Figure 7.1. Schematic overview of the architecture of the 'Associative inhibition' hypothesis and the 'Signal detection' hypothesis tested in the present study, which may not be mutually exclusive. The first hypothesis predicts that alcohol stimuli

previously paired with inhibition (letter 'f') will automatically directly result in inhibition, regardless of the context. While the 'Signal detection' predicts that whenever these stimuli are encountered automatic behavioural inhibition will be activated only when encountered in a context in which inhibition may be required (executive inhibition context) because of the improved ability to detect the signals to inhibit. One implication is that if alcohol cues are encountered after training in a setting in which inhibition is not required (non-executive context; speed context), they should improve the efficiency of detection of signals to inhibit, but they will not evoke inhibitory control, possibly leading back to risky behaviours.



7.3 Methods

7.3.1 Participants

Eighty (40 males; mean age 21.25, SD 4.62 years) heavy drinkers were recruited from the student and staff population at the University of Liverpool via posters, social media and the University online announcements system. I defined heavy drinkers as individuals who regularly consume alcohol over the recommend UK government guidelines at the time of the study (for details see study 2.1, page 35). Inclusion criteria included fluency in English, aged between 18 and 35 years, normal or corrected to normal vision (contact lenses) and a breath alcohol concentration of zero. Exclusion criteria included any history of treatment of alcohol

problems or currently seeking such treatment. All participants provided informed consent before taking part in the study, which was approved by the University of Liverpool Research Ethics Committee.

7.3.2 Materials and tasks

All computer tasks were presented on a Dell desktop computer with a 15" monitor and participants responded using a standard keyboard. Tasks were programmed and administered in Inquisit version 3.0 (Millisecond Software, 2009).

Eight pairs of alcohol-related pictures and matched neutral pictures were selected randomly from the pictures used in the study 2.1 (see page 35 for description of stimuli) and were used during both the training and test phases. Two additional categories of control pictures (pictures of birds and boats, obtained online) were created and used during the test phase. I chose these categories as they should not hold strong motivational properties and because they are distinctive from the other picture categories used (alcohol and stationery pictures).

Participants completed a computerized task that comprised a training phase (ICT; either Alcohol No-Go or Alcohol Go training, 480 trials) followed by a test phase (256 trials, either Inhibition Context or Speed Context). Participants completed 10 practice trials before each phase, and were given a short break halfway through the training phase, and in between the training and test phases. In both phases, trial onset was signalled by a centrally presented fixation cross for 500 ms, which was replaced by the simultaneous presentation of the picture stimulus and the letter cue, both of which remained on the computer screen until participants responded (2500 ms timeout). Error feedback was provided at the end of each trial (a green circle for a correct response or a red cross for an incorrect response).

Inhibitory Control Training (ICT) phase (based on Houben et al., 2012)

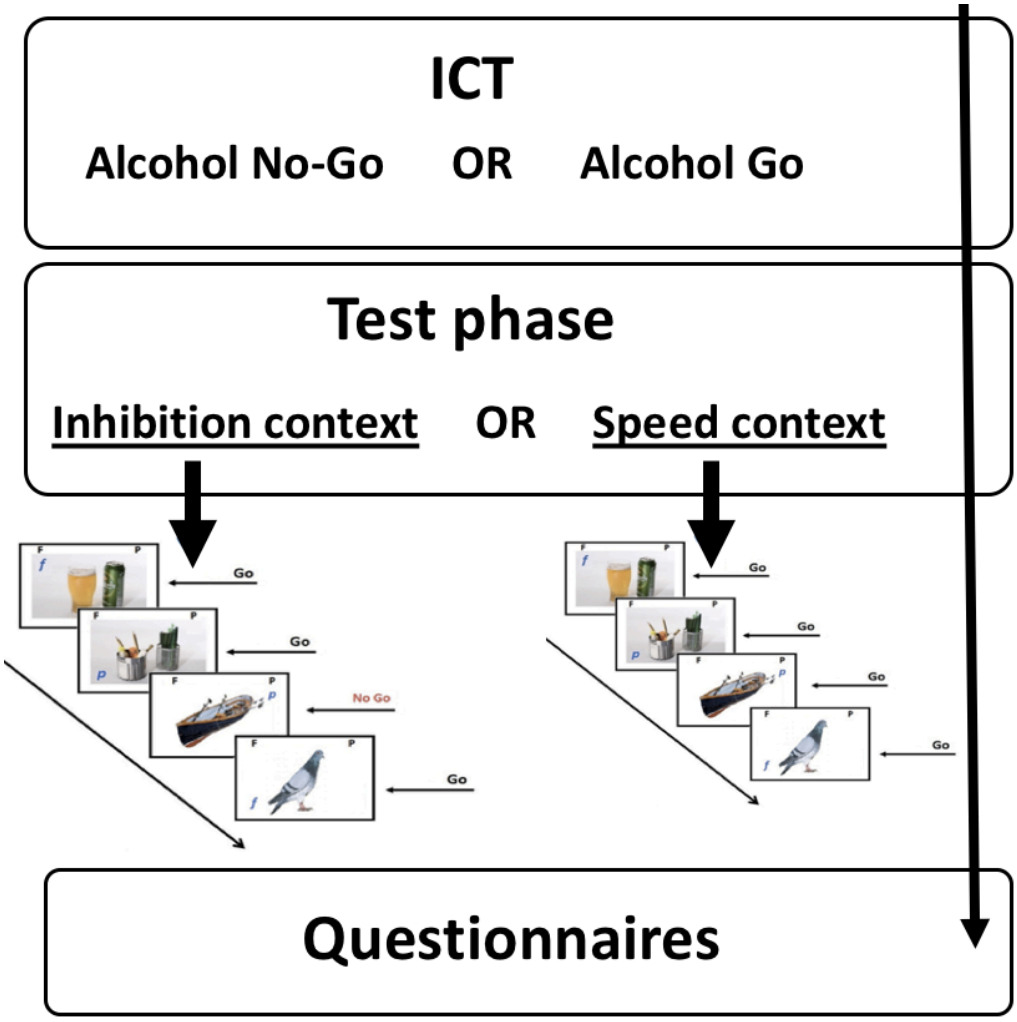
Participants were instructed to rapidly categorise letters that were superimposed on alcohol-related or stationery-related (control) pictures by pressing the space bar if the letter 'p' (Go cue) was presented, but to withhold their response if the letter 'f' (No-Go cue) was presented (for details see study 2.1, page 39). For participants in the Alcohol No-Go group, the majority of alcohol pictures were accompanied by the No-Go cue and the majority of stationery pictures were paired

with the Go cue (90% contingency). These contingencies were reversed for participants in the Alcohol Go group.

Test phase (based on Chiu and Aron, 2015 and Best et al., 2015)

During this phase, on each trial a picture (alcohol-related, stationery, birds or boats) was presented with the letter 'f' or 'p' superimposed, and participants were instructed to quickly categorise the letter by pressing an appropriately labelled response key ('z' or 'm'). Allocation of the letters 'f' and 'p' to left and right response keys was counterbalanced across participants within groups, and a reminder of this stimulus-response mapping remained at the top of the screen for the duration of the test phase. There were 256 trials in total: each picture type was presented equally often (64 trials each), and was accompanied by the letters 'f' and 'p' equally often. Inhibition context was experimentally manipulated as follows: participants in the inhibition context groups were instructed to categorise letters as normal, but to inhibit responding whenever a boat picture was presented (see figure 7.2). Participants in the speed context groups were instructed to categorise pictures as rapidly as possible, irrespective of the type of picture that was presented. Therefore, in the inhibition context groups, boat pictures functioned as a stop-signal, and the ratio of 'go' to stop signal trials was 3:1.

Figure 7.2. Schematic overview of the study procedure. Participants are randomised to one of four conditions (N=20 per group): Alcohol No-Go ICT with an Inhibition Context Test-phase, Alcohol No- Go ICT with a Speed Context (control) Test-phase, Alcohol Go ICT with an Inhibition Context Test-phase, Alcohol Go ICT with a Speed Context Test-phase.



7.3.3 Procedure

Participants attended the laboratory between 10:00 and 18:00 for a single experimental session. They were informed that the aim of the study was to investigate whether cognitive performance changes over time, and whether this is linked to the categorisation and processing of alcohol stimuli. After providing

informed consent and giving a breathalyser reading, participants completed the training phase followed by the test phase of the computer task (see figure 7.2). They then provided general demographic information and completed some self-report measures of their alcohol consumption and their motivation to cut down drinking (the Timeline Follow-Back, TLFB, Sobell & Sobell, 1992; the Alcohol Use Disorders Identification Test, AUDIT, Saunders et al., 1993; and the Contemplation Ladder, CL, Amodei & Lamb, 2004; equivalent to those used in study 2.1, page 39 and study 3.1, page 56; for details see page 35). No measure of awareness was administered. After completing the study, participants were debriefed and offered either course credit or a £10 shopping voucher as compensation for their time. The entire study took approximately 50 minutes to complete.

7.3.4 Data reduction and analysis

In order to investigate the development of cue-inhibition associations, I analysed response latencies on 'Go' trials' (during training) and all trials during test phases. Similar to previous described studies before analysing RTs data, trials with errors were excluded, and then outliers were excluded (for details see study 2.1, page 42 and study 3.1, page 60).

During the training phase, to investigate the differential development of associations between alcohol cues and behavioural inhibition (vs. rapid responding), RTs on Go trials were analysed using a mixed design ANOVA with a between-subjects factor of Training Type (Alcohol Go vs. Alcohol No-Go), and within-subjects' factors of Picture Type (alcohol-related vs. stationery) and time (first 8 trials of the training block vs. last 8 trials of the training block).

During the test phase, RTs were analysed using a mixed design ANOVA with between-subject factors of Training Type (Alcohol Go vs. Alcohol No-Go) and Inhibition Context (Inhibition Context vs. Speed Context), and within-subject factors of Picture Type (alcohol-related, stationery, birds) and Target Type ('f', the letter that had been the No-Go cue during the training phase, vs. 'p', the letter that had been the Go cue during the training phase). RTs to boat pictures were not included in this analysis because only half of participants (the speed context groups) were required to respond to these stimuli, and the inhibition context groups were instructed to refrain from responding when they saw the boat pictures.

Furthermore, similarly to previous studies reported in the thesis (study 2.1, page 42; study 3.1, page 60; study 5.1 and 5.2, page 106; study 6, page 131) participants made very few errors, with 44% of the sample making no errors to Go trials during the training (M = 2.81, SD = 8.54) and 55% of the sample making eight errors to Go trials during test phase (M = 10.58, SD = 10.21). Similarly, participants made very few commission errors (inhibition errors to No-Go trials, with 58% of the sample not making any errors during the training task and with 55% of the individuals in the Inhibition Context group making four errors to boat pictures during the test phase). Given the limited number of errors, error data were not formally analysed. Yet, given that commission errors (inhibition errors to No-Go trials) are a frequently reported measure in studies using GNGT paradigms and in CBM research (Jones et al., 2016b), inhibition errors are reported in detail in table 7.1.

Table 7.1. Summary of commission errors to No-Go trials split by picture type during the Training phase and during the Test-phase (only for the Inhibition Context condition, as boat pictures were the stop-signal), shown separately for the Alcohol No-Go and the Alcohol Go ICT. Values are mean ± SD.

	Alcohol No-Go ICT	**Alcohol Go ICT**
Training phase		
Alcohol No-Go	1.83 (1.96)	1.08 (1.46)
Stationary No-Go	.48 (.72)	1.95 (2.30)
Test phase *(Inhibition Context)*		
Boat + ***p***	2.65 (2.06)	3.20 (3.40)
Boat + ***f***	2.60 (2.30)	3.05 (3.17)

* Test phase learned associations: No-Go cue = *f* and Go cue = *p*.

7.4 Results

7.4.1 Group characteristics

Table 7.2 shows the summary data for the self-report measures separately for the two groups. A 2 × 2 MANOVA with Training Type (2: Alcohol No-Go ICT or Alcohol Go ICT) and Inhibition Context (2: Inhibition Context or Speed Context) showed that there were no significant main effects of Training Type ($F(5, 72) = .38$, $p = .86$), Inhibition Context ($F(5, 72) = .59$, $p = .71$), and no interaction ($F(5, 72) = .35$, $p = .88$) on participant age, units of alcohol consumed in the last two weeks, AUDIT scores, and the Contemplation ladder. Therefore, groups were well matched. Groups were also well-balanced for gender ($\chi 2\ (3) = .00$, $p = 1.00$).

Table 7.2. Characteristics of participants allocated to the Alcohol No-Go ICT with an Inhibition Context and with a Speed Context during the Test-phase and respective control group (Alcohol Go ICT with either Inhibition or Speed Context). Values are mean ± SD.

	Alcohol *No-Go* ICT		**Alcohol *Go* ICT**	
	Inhibition Context	*Speed Context*	*Inhibition Context*	*Speed Context*
Age (years)	21.90 (5.22)	21.25 (5.29)	21.40 (4.11)	20.45 (3.94)
Gender ratio (M/F)	10:10	10:10	10:10	10:10
Consumption	30.15 (15.40)	27.36 (9.87)	26.56 (10.62)	28.04 (11.61)
AUDIT	13.65 (6.70)	12.05 (4.48)	14.25 (5.35)	13.10 (5.08)
CL	3.50 (2.76)	2.85 (2.64)	3.30 (2.68)	3.80 (2.46)

Weekly alcohol consumption self-reported average weekly alcohol intake, in UK units. *AUDIT* score on the alcohol use disorders identification test, possible range of scores 0 to 40, score from 8 are associated with hazardous drinking. *CL,* Contemplation Ladder with a 10-point Likert scale measuring different stages of motivation to change their drinking behaviour (10 indicating taking action to change).

7.4.2 Reaction times during the training phase (Table 7.3)

In order to measure if cognitive biases changed in the expected direction of the training I analysed differences in Go RTs to alcohol and neutral pictures at the beginning (the first eight trials of each type) and at the end of the training block (the last eight trials of each type). I analysed Go RTs during ICT using a 2 × 2 × 2 mixed design ANOVA, with a within-subject factors of Time (2: beginning of the training, end of the training) and Picture Type (2: alcohol, stationary) and between-subject factor of Training Type (2: Alcohol No-Go ICT, Alcohol Go ICT).

The critical Time × Picture Type × Training type interaction was not significant ($F (1, 78) = .00$, $p = .96$), suggesting that, contrary to expectations, ICT did not cause the development of robust stimulus-stop associations. However, a statistically significant two-way Picture Type × Training Type interaction ($F (1, 78) = 7.46$, $p = .01$) was observed. Additionally, the two-way interaction between Time × Training Type was not significant ($F (1, 78) = 3.54$, $p = .06$). Yet, no main effects of Time ($F (1, 78) = .31$, $p = .58$) or two-way interaction Time × Picture Type interaction ($F (1, 78) = .04$, $p = .85$) were found.

Post-hoc t-tests across RTs on the whole training block, evidenced some kind of learning in line with predictions, showing a non significant trend of slower responses to alcohol pictures for the Alcohol No-Go training group (M = 535.69, SD = 69.89) compared to the Alcohol Go group (M = 511.98, SD = 49.47), $t (78) = -1.75$, $p = .08$, $d = .22$. However, no between group differences in RTs to stationery pictures were observed, $t (78) = -.16$, $p = .88$.

Table 7.3. Summary of RTs (in ms) shown separately for the Alcohol No-Go and the Alcohol G ICT. Values are RTs to Go trials during the Training phase (beginning and end of the trainin block) and RTs for each pairing of stimuli and cue during the Test-phase, respectively fc inhibition conditions (Inhibition context, Speed Context). Values are mean ± SD.

Training phase	**Alcohol No-Go ICT**	**Alcohol Go ICT**
Alcohol Go (start)	523.31 (71.41)	520.53 (58.77)
Alcohol Go (end)	536.27 (74.39)	511.97 (56.64)
Stationary Go (start)	516.41 (52.51)	523.37 (58.85)
Stationary Go (end)	521.09 (67.34)	516.61 (61.02)

Test phase	*Inhibition Context*	*Speed Context*	*Inhibition Context*	*Speed Context*
Alcohol + ***p***	701.33 (84.39)	602.97 (74.36)	684.92 (79.50)	559.46 (83.12)
Alcohol + ***f***	721.78 (68.57)	609.93 (70.86)	716.31 (83.66)	582.04 (85.23)
Stationery + ***p***	678.96 (75.00)	582.36 (72.41)	674.75 (70.43)	557.79 (76.72)
Stationery + ***f***	702.92 (71.63)	594.46 (64.65)	698.30 (81.77)	567.29 (73.81)
Birds + ***p***	685. 54 (83.74)	579.13 (69.88)	679.19 (76.93)	547.67 (69.81)
Birds + ***f***	701.58 (93.72)	585.98 (74.70)	684.38 (87.84)	552.07 (79.64)
Boat + ***p***	/	576.09 (83.02)	/	545.88 (81.71)
Boat + ***f***	/	584.06 (60.02)	/	555.25 (72.82)

* Test phase learned associations: No-Go cue = *f* and Go cue = *p*.

7.4.3 Reaction times during the test phase (Table 7.3)

RTs were analysed using a 3 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Picture Type (3: alcohol, stationery, birds) Target Type (2: 'p', that had been the Go cue during the training phase, or 'f', that had been the No-Go cue during the training phase) and between-subject factors of Training Type (2: Alcohol No-Go ICT or Alcohol Go ICT) and Inhibition Context (2: Inhibition Context or Speed Context).

Most importantly, the hypothesized interactions between Picture Type × Training Type ($F(2, 152) = 1.25$, $p = .29$), Picture Type × Training Type × Inhibition Context ($F(2, 152) = .07$, $p = .94$), and Training Type × Inhibition Context × Picture Type × Target Type ($F(2, 152) = .18$, $p = .84$) were not statistically significant. Therefore, there was no evidence of slowing of RTs to alcohol cues in the Alcohol No-Go group compared to the Alcohol Go group during the test phase (regardless of the inhibition context), and also no evidence that participants became faster to detect target letters that had been paired with specific picture types (alcohol-related or stationery-related) during the training phase, in a test phase setting that emphasized speed.

However, there were a number of statistically significant main effects and interactions. Firstly, there were significant main effects of Inhibition Context ($F(1, 76) = 49.91$, $p < .01$), Picture Type ($F(2, 152) = 29.83$, $p < .01$), and Target Type ($F(1, 76) = 39.56$, $p < .01$), which were qualified by significant interactions between Picture Type × Target Type ($F(2, 152) = 3.48$, $p = .03$), and between Inhibition Context × Target Type ($F(1, 76) = 4.13$, $p = .05$). There were no other significant main effects or interactions ($Fs < 2.35$, $ps > .1$).

The main effect of Inhibition Context reflects the observation that participants who completed the test phase in an inhibition context were significantly slower than participants who completed the test phase in a speed context. Main effects of Picture Type and Target Type reflect the observations that RTs were slower on trials with alcohol pictures compared to trials with stationery or bird pictures, and on trials in which the letter 'f' (the letter that had been the No-Go cue during the training phase) was the target, compared to trials on which the letter 'p' (the letter that had been the Go cue during training phase) was the target. The interactions arose because (a) the slowing effect associated with responding to the letter 'f' compared to the letter 'p' was more pronounced among participants who

completed the test phase in the inhibition context compared to participants who completed the test phase in the speed context, and (b) participants were slower to respond on trials with bird pictures (novel item) compared to trials with stationery pictures, but only on trials in which the target letter was 'f' ($p < .01$); this contrast was not significant on trials in which the target letter was 'p' ($p > .1$). Detailed post-hoc statistics are not reported because these interactions are not relevant to the primary hypotheses.

7.5 Discussion

In the present study I aimed to investigate two competing hypotheses which have implications for the mechanisms of action of ICT and its likely effectiveness outside of the laboratory. I tested if associative pairings between alcohol cues and inhibition of behaviour during ICT would lead to the formation of 'stimulus-stop associations' which in the future would either automatically activate behavioural inhibition ('associative inhibition hypothesis'; Chiu & Aron; 2015; Verbruggen & Logan, 2008a,b, 2009) or would lead to the ability to the detect the inhibition-signal after target cues more effectively, thereby only leading to behavioural inhibition when in an environment in which inhibition might be required ('signal-detection hypothesis'; Verbruggen et al., 2014). Thus, according to the 'associative inhibition' hypothesis I would expect to find in the test-phase particularly slower RTs to alcohol cues previously paired with inhibition, regardless of the inhibition context. Whereas according to the 'signal detection' hypothesis individuals when exposed to a Speed context setting should have in general faster responses to the signals/cues congruent to the learned associations, as they learned to detect signals more effectively, but should evoke automatic inhibition only in a context where inhibition is required.

In order to investigate these hypothesis, firstly I needed to test if the ICT developed the predicted stimulus-stop associations over the course of the training blocks (Bowditch et al., 2015; Veling et al., 2017b; Verbruggen et al., 2014). Results showed that over time, in both groups participants seemed overall not to have formed strong associations. However, a trend in the expected direction was observed in the Alcohol No-Go ICT group, with individuals showing slower responses to alcohol stimuli relative to the Alcohol Go group. However, no corresponding difference was seen for control stationery stimuli.

This slowing in RTs to target stimuli (formation of stimulus-stop associations) is consistent with most literature in the field (Jones & Field, 2013; Lenartowicz et al., 2011; Noël et al., 2016; Verbruggen & Logan, 2008a,b, 2009; Verbruggen et al., 2014), although there are exceptions, particularly when motivationally salient stimuli are used (see study 2.1, page 44; Houben et al., 2012; Lawrence et al., 2015a). As argued previously in the thesis (see study 2.1, page 49 and study 5.1 and 5.2, page 119, study 6.1, page 141), reasons for this ambiguity may be due to the task used, which might not be sufficiently reliable to detect these changes (Best et al., 2015; Chiu & Aron, 2014; Stice et al., 2016).

In regard to the test-phase, to investigate the two competing hypotheses, I employed two conditions (Inhibition context vs. Speed context) following the learning of stimulus-stop associations during the training block. Results showed that overall: (1) participants in the Inhibition Context were slower relative to participants in the Speed context, showing that the manipulation was effective; (2) in both contexts RTs were slower for alcohol pictures compared to either novel or trained control stimuli (e.g. stationery or bird pictures). These results are in line with studies showing slower responses to alcohol cues following ICT (Jones and Field 2013; Noël et al. 2016). However, due to the lack of the critical interaction these effects can not be robustly related to the interventions. A possible explanation can be due to the lack of strong learning effects during the training; (3) RTs were slower for the Target Letter (letter 'f') that had been paired during the training block with behavioural inhibition ('No-Go cue'), relative to the Target Letter (letter 'p') that had been paired with responding ('Go cue'), replicating previous work on stop-learning (Verbruggen & Logan, 2008a, 2009; Chiu & Aron, 2015; Best et al., 2015; Bowditch, Verbruggen & Mclaren, 2016; Houben & Jansen, 2015). Furthermore, these slowing effects to the No-Go cue (letter 'f'), were prominent among: (a) participants in the Inhibition context, compared to those in the Speed context, replicating Chiu & Aron's work (2014); and (b) in trials with novel control stimuli (bird pictures) compared to trials with trained control stimuli (stationery pictures). This specific reduction to novel control stimuli paired with inhibition (No-Go cue) may be due to a number of factors, including task instructions (Best et al., 2015), or individual differences in the motivational response to the stimuli used (Stice et al., 2016). Most likely, the effect is related to the introduction of irrelevant perceptual

task distractors (novel control stimuli) which have been shown to influence performance (Logan et al., 2014; Verbruggen et al., 2014).

To sum up, these results do not support the predictions made prior to the study. The present study corroborates Verbruggen and colleagues' findings (Best et al., 2015; Bowditch, Verbruggen & McLaren, 2016; Verbruggen & Logan, 2008b, 2009; Verbruggen et al., 2014), suggesting that during ICT individuals do learn to associate the No-Go cue (letter 'f') with stopping. Critically, they do not seem to learn to associate alcohol pictures with either the No-Go cue ('f') or behavioural stopping. However, contrary to our hypothesis (and findings in literature) these effects seemed not to be induced by the ICT received. Most importantly, neither stimulus-stop or stimulus-signal associations were observed because participants formed neither direct nor indirect associations between alcohol cues and behavioural inhibition during the training phase, and therefore these data are unable to distinguish between the two accounts. These null effects may be explained by the introduction post-ICT of a new task with new irrelevant stimuli, which may have reduced the effects of the training inferred from 'Go' RTs, or due to confounds (mentioned above). These confounds may complicate the interpretation of changes in latencies.

The present findings also agree with the expectancy and learning literature (McLaren et al., 2014). For example, when an in individual is aware that a cue/signal is likely to occur on a subsequent trial, participants actively increase their response thresholds (increase in RTs) and adjust their strategies. This may suggest that if an individual is aware that they might have to 'stop', this makes them more cautious, slowing down their responses in order to perform at their best. Hence, why RTs may be slower in an active Inhibition context, as a greater proactive control and a cognitive load (influenced by expectancies and attentional efforts) are applied during their performance. Evidence on the role of expectancies on stimulus-stop learning has shown that these effects are partly mediated via explicit contingency knowledge by the adoption of task relevant features (Best et al., 2015; Van Dessel, De Houwer, & Gast, 2016). This suggest that the implementation of task relevant features in ICT should strengthen ICT effectiveness by producing stronger associations. The lack of a measure of contingency awareness, unlike previous studies presented in the thesis, is a limitation of the present study and does not allow me to investigate this issue.

The present study contributes to the theoretical understanding of associative learning and contributes to applied CBM research. For example, if an Inhibition context (necessity of a constant remainder of the action to take) may be required in order to influence behaviour (as suggested by Chiu & Aron; 2015), thus ICT is less effective when it is most needed (e.g. in a real-world setting, such as when visiting a pub with friends; see Cristea, Kok & Hagger, 2016).

To conclude, the present study supports and builds on the findings that cues paired with motor inhibition (and executive inhibition context) are successful in reducing the speed of behavioural responses. However, these findings do not support either 'associative inhibition' or 'signal detection' accounts.

Chapter Eight

General discussion

8.1 Summary of main findings

The main aim of the current thesis was to increase the scientific knowledge about the effectiveness and mechanisms of action of CBM interventions for appetitive behaviours and disorders by using laboratory experimental manipulations with appetitive stimuli, particularly alcohol and chocolate.

Chapter One examined the theoretical evidence which developed and supports CBM interventions. The examination of this evidence revealed two main interventions that have been demonstrated to be successful in changing behaviours: CAT and the ICT, which became the focus of this thesis. Additionally, a review of the literature revealed two main unresolved questions in CBM research. The first question related to their effectiveness in changing risky behaviours (Cristea, Kok, Cuijpers, 2016): Are both interventions equally effective? Are these interventions still effective in 'real-world' situations, outside of the laboratory? The second question related to the mechanisms underpinning their effectiveness: what, for example, are their physiological and psychological mechanisms of action?

This thesis, therefore, conducted two lines of research. The first (see Chapters Two and Three) aimed to compare the effectiveness of CAT and ICT interventions in reducing alcohol consumption, and to expand this investigation to an ecologically valid setting with 'real-word' environmental triggers. The second line of research (see Chapters Four to Seven) sought to shed light on the neuro-correlates by focusing on ERPs and on the proposed psychological mechanisms that actually explain the effects of CBM on behaviour. In particular, the thesis examined three main hypotheses: the formation of stimulus-response (stimulus-stop or avoidance) associations (associative inhibition hypothesis); the devaluation of stimuli paired with avoidance and stopping (the devaluation hypothesis); and an alternative hypothesis (the signal detection hypothesis).

These research questions are relevant for a number of reasons. Firstly, by both providing evidence of their effectiveness and clarifying their mechanisms it will help to optimise these interventions as potential treatments for addiction and other compulsive behaviours such as overeating, prior to their translation to real-world clinical investigations with RCTs. Secondly, these investigations develop and increase the theoretical knowledge of CBM models of appetitive behaviours and disorders, and specifically the cognitive processes which may contribute to these goal-directed behaviours.

These research questions were investigated with university students (young adults, who were either heavy drinkers or chocolate consumers), as these individuals often fit the criteria of a number of risky behaviours, especially hazardous drinking or unhealthy eating. The examination of both risky behaviours is justified by studies in different domains (Allom, Mullan & Hagger, 2015; Burger & Stice, 2011; Carnell et al., 2012; Jones et al., 2016b, 2017; Kakoschke et al., 2017a; Parvaz, 2012) and by theoretical models which posit overlaps between the brain and psychological mechanisms which underlie addiction and obesity (see Volkow et al., 2008).

In this general discussion, the main findings from the previous chapters will be summarized. Firstly, I will discuss CAT and ICT training effectiveness. Then, I will review the results in the light of the main proposed physiological and psychological mechanisms of action underpinning these interventions and will follow up with a discussion of the findings and how they relate to previously discussed models of goal directed behaviour and addiction. Finally, implications, methodological limitations, and suggestions for future research will be discussed.

8.1.1 The effects of CBM on drinking behaviour

More than 2.5 million people in Britain drink alcohol over the recommended daily limits (i.e., 14 alcohol units, one UK unit = 10ml /8g of pure alcohol). Alcohol plays a casual role in various medical conditions (e.g. cirrhosis of the liver, high blood pressure, liver and breast cancers, etc.), thus making alcohol the third biggest risk factor for disease and death in the UK, and also worldwide, after smoking and obesity (Statistics on Alcohol, England - 2016).

Hazardous drinking and increased alcohol cravings can be triggered by alcohol related cues (Gauggel et al., 2010; Thomas et al., 2005; Witteman et al., 2015). De facto, alcohol advertising is a prominent aspect of the world we live in

('alco-genic' environment), and promotes the culture of heavy drinking. Systematic reviews on alcohol advertising have shown that alcohol adverts, are potent cues that contribute to immediate and sustained alcohol consumption (and consequent harm) in young adults (Anderson, De Bruijn, Angus, Gordon, & Hastings, 2009; de Bruijn et al., 2016; Koordeman, Anschutz, & Engels, 2011; Koordeman, Kuntsche, Anschutz, van Baaren, & Engels, 2011; Smith & Foxcroft, 2009; Siegel et al., 2016; Stautz et al., 2016). More broadly, there is ample empirical support regarding the role of alcohol-related stimuli (and other motivationally-relevant cues) on goal directed behaviours (Gauggel et al., 2010; Jones & Field, 2015; Kreusch, Vilenne, & Quertemont, 2013; Littel et al., 2012; Stacy & Wiers, 2010; Wilson et al., 2004).

Dual process models argue that goal directed behaviours are guided by two competing systems, an automatic and a more reflective controlled system (Gladwin & Figner, 2014). These theories predict that biases deriving from automatic cognitive and control processes can be modified through CBM. Two CBM interventions have been demonstrated to be successful in reducing alcohol consumption and other appetitive behaviours: CAT interventions which reverse alcohol approach tendencies (Wiers et al., 2011) and inhibitory control training (ICT; Houben et al., 2012). Laboratory findings support the effectiveness of these interventions (Allom, Mullan & Hagger, 2015; Jones, et al., 2016b; 2017; Kakoschke et al., 2017a), also with clinical evidence (reduction in relapse rates) for multiple sessions of CAT in alcohol-dependent patients (Eberl et al., 2013; Wiers et al., 2011).

Study 2.1 (Chapter Two, page 30) was the first study in the CBM literature to compare the effectiveness of a single session of CAT and ICT on alcohol consumption in the laboratory. The mixed design involved four groups who were exposed to either intervention (2: CAT or ICT) and either training condition (2: active training, 90:10 contingency or 'sham control', 50:50 contingency). Following these interventions participants completed an alcohol taste-test (measure of their motivation to drink alcohol). Results demonstrated that participants in the active training conditions, relative to the control, reduced their alcohol consumption in both interventions, evidencing a medium effect size. The difference was not observed for soft-drinks. Most importantly, both CAT and ICT were equally effective. These findings replicate recent reviews that demonstrate small but robust effects in changing drinking behaviour and unhealthy snacking, following ICT (see Allom,

Mullan & Hagger, 2015; Jones et al., 2016b) and CAT, especially if the training reversed the approach bias (Kakoschke et al., 2017a).

However, a recent meta-analysis argued that the effects of CBM on addictive behaviour are not robust, and that most studies in the field are susceptible to bias (Cristea, Kok & Cuijpers, 2016). It is therefore important to investigate if the effects of CBM on drinking behaviour are robust, and if they persist outside of traditional laboratory settings, and are robust even after exposure to alcohol-related cues. In study 3.1 (Chapter Three, page 53) I investigated the effectiveness of ICT by analysing if reductions in alcohol consumption could be replicated in a more valid ecological setting (e.g. lounge laboratory) even after exposure to alcohol advertising. Similarly, to the previous study a mixed design was adopted. Participants were randomly assigned to one of four groups that were exposed to one single session of either ICT or control (2: active training, 90:10 contingency or 'sham control', 50:50 contingency) and two TV advert conditions (2: alcohol or neutral adverts), which were shown during a popular TV comedy show. Following these conditions, a taste-test, equivalent to the one used in the previous study, was administered. Results replicated previous studies showing that participants in the active training condition consumed less alcohol relative to participants in the sham training even in a 'lounge lab'. Again no differences in consumption of soft drinks were observed. More importantly, alcohol adverts did not increase alcohol consumption and ICT effect was only robust for individuals exposed to neutral adverts.

These findings are in line with results from the existing ICT literature (Allom, Mullan & Hagger, 2015; Jones et al., 2016b) and show that ICT does have an effect in consumption in a more ecologically valid setting (i.e., context effect). To the best of my knowledge this study is the first in the literature that was conducted in an ecologically valid setting. However, ICT effects were abolished when participants were exposed to environmental triggers (i.e. alcohol adverts; advertising effect). These findings have important implications, as they suggest that the beneficial effects of ICT (typically found in neutral laboratory settings) may not be robust in an 'alco-genic' environment, and support the conclusions of Cristea et al. (2016) that this effectiveness may not persist outside of the laboratory. Thus, these findings shed doubt on the feasibility of these interventions in the real word, and suggest that more 'real-world studies' and clinical trials are needed in order to test the behavioural effects of ICT and other forms of CBM (Cristea, Kok & Cuijpers, 2016).

Additionally, exposure to alcohol advertisements did not increase alcohol consumption. These results contrast with those from a recent review demonstrating a robust but small effect of alcohol adverts on alcohol intake in the laboratory (see Stautz et al., 2016). These findings (and previous ICT studies) may be attributed to the lack of statistical power to detect these small effects sizes (sample N = 80, 20 participants per group), or the ad-lib consumption measured used (Stautz et al., 2016), or and most importantly to participants' awareness of both the alcohol advertising condition and the taste-test manipulation. Study awareness (e.g. demand effects) might have modulated consumption effects, even though re-analysis of results controlling for taste-test awareness seemed not to suggest its influence on the primary findings (see Jones et al., 2016a).

Furthermore, study 6.1 (Chapter Six, page 122) investigated pre- and post-effects of ICT on behavioural choice (via a forced choice probe task) in regular chocolate consumers. Compared to the above studies this was a within-subject experiment and only appetitive stimuli of different value were used (i.e. high or low value chocolate stimuli), but no control stimuli. Results were in line with previous literature showing increases in selection for stimuli paired with motor response and decreases for stimuli paired with inhibition (Schonberg et al., 2014; Veling, Aarts, & Stroebe, 2013a). However, contrary to expectations, this effect was found only for low value stimuli and not the predicted high value stimuli. This inconsistency with literature (Schonberg et al., 2014; Veling et al., 2017a) may be due to baseline differences in the evaluations of stimuli (for details refer to page 136).

To sum up, findings from these two studies suggest that CAT and ICT successfully change drinking behaviour and choice preferences of appetitive stimuli in the laboratory. These findings are in line with other research in the field (see reviews: Allom, Mullan & Hagger, 2015; Gladwin et al., 2016; Jones et al., 2016b, 2017; Kakoschke et al., 2017a), thus suggesting that these interventions have the potential to be cost-effective add-ons to existing behavioural interventions. However, their effectiveness after exposure to real-world environmental triggers (such as TV adverts) seems to be abolished, suggesting that more work is required to refine these interventions to ensure that the effects persist even in real-world environments.

8.1.2 Mechanism underpinning the effectiveness of CBM

8.1.2.1 Neural correlates

Previous results showed behavioural effects of both CAT and ICT. However, the neural mechanisms underpinning these interventions are still unclear. To date there are no ERPs studies investigating direct effects of CAT in heavy drinkers (see review: Wiers & Wiers, 2016). Neuroimaging studies on approach and avoidance tendencies (measured by an AAT) in response to emotional stimuli showed increased amplitudes for congruency effects (e.g. when approaching emotional stimuli vs. when avoiding them) in a range of ERPs (P150, P300, LPP; see Bamford et al., 2015; Van Peer et al., 2007), while increased N200 was observed during emotion-incongruent trials (e.g. when preparing to avoid rather than approach positive stimuli; Ernst et al., 2013).

Study 4.1 (Chapter Four, page 69) aimed to identify the brain mechanisms that underlie the effects of a single brief session of alcohol-CAT in the laboratory, during preparation to approach or avoid alcohol cues. To the best of my knowledge, this study is the first attempt in literature to focus on the direct effects of CAT on ERPs. Contingent negative variation (CNV) readiness potentials were also measured during the 'Preparatory AAT', as preparatory motor states seem to play a key role in the task (see Korucuoglu et al., 2014; Korucuoglu et al., 2016). A between-subjects design was adopted: heavy drinking young adults were assigned to complete either Cue Avoidance Training (CAT; avoidance movements to alcohol pictures) or Cue Approach Training (opposite training: approach movements to alcohol pictures). Following training, adopting a CNV paradigm, participants' ERPs and preparatory readiness potentials were measured during preparation to approach or avoid alcohol and to control pictures.

Behavioural effects (inferred from changes in RTs in the expected directions) during the training block were found in both training groups (see next section for details, page 171). These alcohol-approach or alcohol-avoidance learning effects were accompanied by changes in some ERPs but not on CNV preparatory readiness potentials. These null effects may due to the use of a 'preparatory AAT', which forced participants to wait before responding, thus resolving the conflict and reinstating the dominant response, as suggested by recent studies showing ICT effects only under time pressure (impulsive responses; Veling et al., 2017a).

Moreover, the CAT group showed increased amplitude of the N200 component when preparing to approach alcohol, the motor movement that was incongruent with that which they had learned during the training block. These

incongruency effects on N200 are consistent with previous AAT studies with emotional stimuli (Ernst et al., 2013). These findings suggest that engaging an action that is incongruent with associations learned during CAT activates a goal conflict which requires engagement of executive control to resolve. This hypothesis is validated by various studies demonstrating that N200 is a bio-marker for the engagement of executive control in heavy drinkers (Kreusch, Quertemont, Vilenne, & Hansenne, 2014; Petit, Kornreich, Verbanck, & Campanella, 2013).

Congruency effects in the LPP were also observed in both groups, with blunted negativity at midline electrodes when preparing to respond to alcohol stimuli with motor movements that were congruent with associations learned during training (in the 'avoid alcohol' group when preparing to avoid alcohol pictures and in the 'approach alcohol' group when approaching alcohol). These effects were in line with my predictions and with the AAT study on emotional stimuli (Bamford et al., 2015). These findings are also compatible with findings from meta-analysis demonstrating increments in the LPP amplitude when viewing substance-related cues (Littel et al., 2012). They, therefore, suggest that these components are enhanced in individuals who hold an approach bias, but these can be reversed after a brief session of CAT, although it is unclear how persistent these changes are.

The present findings are an important proof of the concept for the brain mechanisms underpinning CAT that are necessary to optimise these interventions (see Cristea, Kok and Cuijpers, 2016). New studies incorporating pre-training and post-training changes on brain activation, and a more neutral control group (e.g. Sham training; see Schonberg et al., 2014), should be conducted.

8.1.2.2 Stimulus-Response associations

It is suggested that CBM influences behaviour because it changes underlying stimulus-response associations (stimulus association hypothesis), in such a way that repeatedly avoiding or refraining from responding to target motivationally-salient cues (e.g. alcohol or chocolate) leads to the formation, respectively, of stimulus-avoidance (CAT) or stimulus-stop associations (ICT). Consequently, these learned associations should be manifested as automatic avoidance or inhibition when those target stimuli are next encountered (Verbruggen et al., 2014; For a schematic overview see figure 1.4 page 21).

Findings from both CAT (Gladwin, Wiers & Wiers, 2016; Kakoschke et al., 2017a) and ICT (Verbruggen & Logan, 2008a, 2009; Chiu & Aron, 2014; Best et al., 2015; Bowditch, Verbruggen & Mclaren, 2016; Houben & Jansen, 2015) laboratory studies corroborate this view. These findings demonstrate that, in drinkers, a single session of these interventions strengthens alcohol-avoidance associations after CAT (Wiers et al., 2010, 2011; Eberl et al., 2013; Sharbanee et al., 2014; Gladwin et al., 2015; Manning et al., 2016) and strengthens inhibitory control to specific cues after ICT, as inferred from the slowing of RTs to cues that were previously paired with behavioural inhibition (Jones et al., 2016b, 2017; Allom, Mullan & Hagger, 2015). This hypothesis was investigated in most of the experiments in the thesis, but findings were inconsistent across studies and also across type of CBM (CAT vs. ICT).

In study 2.1 (page 30), even though behavioural effects on consumption were found, I did not observe robust formation of stimulus-response associations, between pre- and post-training interventions. Specifically, ICT did not lead to the expected slowing in RTs for alcohol stimuli paired with inhibition. Regarding CAT, alcohol-approach bias (faster RTs to approach alcohol rather than avoid) was found, following training, in the control group (Sham CAT) but it was absent in the active CAT group.

The following study 3.1 (page 53), showed post-ICT consumption effects in a lounge laboratory, especially if participants were exposed to non-alcohol related TV adverts. Nevertheless, participants during the training block, again, did not show the expected slowing in RTs to alcohol cues following the ICT. But in the ICT group, I observed faster RTs for control cues paired, relative to the Sham control group.

In the EEG study (study 4.1, page 69) examining alcohol CAT neuro correlates, results showed a similar pattern to the study described in study 2.1. During pre-training, the sample demonstrated an overall approach bias (similar to: Kersbergen et al., 2015; Watson, de Wit, Hommel, & Wiers, 2012), while during the training block as hypothesised, and as seen in the literature, learning effects were observed. Participants in the active CAT group became faster to avoid alcohol (Wiers et al., 2010, 2011, Eberl et al., 2013, 2014; Sharbanee et al., 2014; Gladwin et al., 2015). Whereas in the approach training group, learning effects were observed in the opposite direction. Following training, when participants had the opportunity to prepare their motor response before initiating it (Preparatory AAT), training effects

reverted back to an overall approach bias in the CAT group. These findings show that training effects disappear if a delay is imposed between the planning of the motor response and the actual initiation of the motor action. Therefore, this suggests that effects of CAT on RTs are very sensitive to experimental factors.

In study 6.1 (Chapter Six, page 122) the primary aims were to investigate if ICT affected stimulus evaluation, behavioural choice and attention, in chocolate consumers (for details see next section, page 174). As predicted, over the course of the training block, participants became slower to respond to chocolate stimuli that were paired with inhibition, although only if those chocolate stimuli were highly valued before training.

In the final study, (study 7.1, Chapter Seven, page 146) ICT was administered to heavy drinkers, with half of the sample inhibiting to alcohol and responding to neutral control stimuli (No-Go training group) and the other half being trained in the opposite direction (Go training group). Following that, participants completed a test phase consisting of a speeded categorization task that required them to rapidly respond to both cues (letters 'p' and 'f') used during the training phase pairings, with alcohol and control pictures. Novel neutral control pictures (pictures of boats and birds) were also added and importantly half of the participants in each training group completed the test phase in either a context that favoured inhibition (executive inhibition context; inhibit to boats pictures) or that never required inhibition (speed context). Results showed that over time during the training blocks weak cue-inhibition associations were found for the Alcohol No-Go ICT group, with individuals showing slower responses to alcohol stimuli. A comparable difference was not observed for control stimuli (e.g. stationery) or the Alcohol Go group. Despite the emergence of these alcohol-inhibition associations during the training block, the important finding is that these effects were completely abolished during the test block, when both groups of participants completed a different stop-signal task with alcohol-related cues embedded into it.

Taken together all of these results show some development of stimulus-response associations, as often seen in literature for both CAT (Wiers et al., 2010, 2011, Eberl et al., 2013, 2014; Sharbanee et al., 2014; Gladwin et al., 2015) and ICT (Jones & Field, 2013; Allom, Mullan & Hagger, 2015; Jones et al., 2016b, 2017; Noël et al., 2016). However, these effects seem rather weak. This is in line with conspicuous exceptions found in literature which do not always demonstrate the

predicted formation of stimulus-stop associations, for both CAT (Wiers, Stelzel, et al., 2015; Manning et al., 2016) and ICT (Houben et al., 2012; Lawrence et al., 2015a). As stated in previous chapters, the reasons for these mixed findings may be due to the fact that RTs may not be sufficiently reliable to detect these associations (see study 2.1, page 49): it is possible that latencies to 'Go' trials are not sufficiently sensitive to detect these changes. This issue may also be exacerbated by the methodological limitations of the assessment version of the irrelevant-feature AAT task, which is characterised by poor internal reliability and predictive validity which may render it insensitive for the purposes of assessing changes in associations following CAT (see Kersbergen et al., 2015). Furthermore, overall learning effects seem to be found, yet these are very sensitive to even minor changes to experimental procedures (see: Stice, Lawrence, Kemps, & Veling, 2016). For example, the type of stimuli used seems to have an affect because as shown in study 6.1, ICT seemed to affect only high value appetitive stimuli but not low value stimuli. More importantly, even when these learning effects are evident over the course of training, they tend to disappear when there are slight changes to the task, such as seen is study 2.1 changing into an assessment version AAT, in study 4.1 changing into a 'Preparatory AAT' and in study 7.1 changing into a speeded categorisation task, or as seen in literature due to changes in task instructions (Best et al., 2015), or the presence of an executive setting (Chiu & Aron, 2015). These findings are informative as they suggest that associative learning processes are in operation, but they are not at all robust. This has really important implication as further research is required to identify a measure that is sensitive and reliable to detect these changes in RTs, and more sophisticated CBM procedures may be needed to strengthen the formation of cue-avoidance or cue-inhibition associations.

To sum up, overall this thesis found mixed results regarding the claim that CBM leads to the formation of cue-avoidance (CAT) or cue-inhibition (ICT) associations. Specifically, for the two CAT studies (Chapters Two and Four) weak evidence for formation of stimulus-avoidance associations was observed, although even these weak effects were only seen during the training block, not at post-test. Whereas for ICT, study 2.1 (Chapter Two) found null effects either during training or post-test, and the remaining three studies found weak evidence for the hypothesis, showing some stop-learning effects mainly during the training block (Chapter Three, Six and Seven). Therefore, overall the findings described in this thesis suggest that

learning effects are inconsistent. The reasons for these discrepant findings are unclear and corroborate the mixed findings described above in the literature.

8.1.2.3 Devaluation hypothesis

An influential account of CBM, and ICT in particular, argues that the effects of training on behaviour can be attributed to changes in the positive evaluations of appetitive stimuli (as appetitive stimuli are hyper-valued). This devaluation hypothesis refers to the BSI theory (Veling et al., 2008), which claims that appetitive stimuli automatically evoke appetitive tendencies, and repeatedly inhibiting (or avoiding) the stimulus leads to the spontaneous devaluation of the stimulus itself, thus weakening the potency of the impulse triggered by the stimulus (Veling et al., 2008, 2013a; Havermans & Jansen, 2003; see figure 1.5 in page 23). This theory is also supported by Guitart-Masip and colleagues' (2014) recent model which describes motivated behaviour as the result of interaction between valence (positive or negative) and action execution (behavioural responding or approach versus inhibition or avoidance). An implication of the account is that the "stimulus-response" associations account discussed in the previous section, and the devaluation account, may not be mutually exclusive: the formation of automatic associations may lead to changes in behaviour via the devaluation of target stimuli which, in turn, weakens the initial appetitive tendencies of those stimuli to influence behaviour (Guitart-Masip et al., 2014; Veling, Holland, & van Knippenberg, 2008). Therefore, changes in hedonic evaluations of appetitive stimuli may be a shared mechanism that underpins the mechanisms of action of diverse forms of CBM, including both CAT and ICT.

Several studies support the devaluation hypothesis and demonstrate that stimuli paired with inhibition of behaviour (Ferrey, Frischen, & Fenske, 2012; Houben & Jansen, 2015; Houben et al., 2011, 2012; Kemps et al., 2013; Schonberg et al., 2014; Veling, et al., 2017a; Veling, Aarts, & Papies, 2011; Veling, Aarts, & Stroebe, 2013a; Veling et al., 2017b; Wessel, Doherty, Berkebile, Linderman, & Aron, 2014) or overt avoidance responses (Kemps et al., 2013; Schonberg et al., 2014; Woud et al., 2013b) are evaluated more negatively than stimuli paired with behavioural responding or approach. Nevertheless, the findings are still uncertain following a meta-analysis of applied studies which failed to demonstrate robust effects of ICT on stimulus devaluation across studies of both eating and drinking

behaviour in the laboratory, particularly when measured by the IAT (Jones et al., 2016b).

In study 2.1 (page 30) a secondary aim was to investigate if the formation of associations during training would lead to changes in automatic positive evaluations of alcohol pictures following CBM interventions. I predicted that implicit evaluations, inferred from a pictorial bipolar valence IAT measured pre- and post-CBM, would became more negative after CAT or ICT (as seen in Houben et al., 2011, 2012). Contrary to hypotheses, neither form of CBM led to the devaluation of alcohol-related cues (e.g. no IAT changes between pre- and post- CBM were observed). This finding suggests that the reduction in alcohol consumption that was observed following both interventions cannot be attributed to changes in automatic evaluations of alcohol pictures. Therefore, I failed to replicate Houben and colleagues (2011, 2012) earlier findings, yet these findings are in line with the meta-analysis from the group of which this study was part (see Jones et al., 2016b).

In two cross-sectional experiments (see Chapter Five) I investigated the independence or the existence of a common link between automatic approach tendencies, inhibitory control, and affective associations and self-reported valence of chocolate-related pictures. Both experiments consisted in the performance of the three cognitive bias assessment tasks: the AAT, the GNGT and the bipolar IAT (see next section for study 5.2, page 178). In experiment 5.1 (page 102) participants were administered a valence IAT (positive vs. negative words) and rated the stimuli on attractiveness and palatability (subjective explicit evaluations), in order to verify if participants perceived the stimulus pictures as attractive and palatable, and if these ratings would be correlated with the aforementioned cognitive tasks. Results from experiment 5.1 showed that automatic evaluation of hedonic stimuli (positive hyper-valuation) does not appear to underpin these cognitive biases (of approach or inhibitory self-control).

Even though chocolate pictures were rated (evaluated) positively and participants possessed implicit positive associations (valence IAT) towards them, neither of these measures were correlated with either cognitive bias, suggesting that these processes may be independent of each other. These findings are in line with the inconsistency found in the relevant literature (Bowley et al. 2013; Jones et al., 2016b, 2017). Furthermore, approach tendencies were not detected by the AAT, whereas some evidence of impaired inhibitory control (inferred by commission

errors to No-Go trials) was seen in the GNGT. Thus, maybe these findings may be due to our sample. The sample did not represent individuals with risky habits (excessive drinking or eating) which are often the population investigated that hold strong biases (see Houben et al., 2012; Jones & Field, 2013; Wiers et al., 2011). De facto the absence from our sample of strong cognitive biases towards chocolate, as usually seen in literature (Eberl et al., 2013; Kemps & Tiggemann, 2016; Kemps et al., 2013; Wiers et al., 2011), might have driven our results, because of the absence of biases to correlate the hyper-evaluation.

In the light of failures to detect devaluation effects when using an IAT and, on the contrary, in the light of robust devaluation effects when measured through Likert or rating scales or auction tasks (Ferrey et al., 2012; Lawrence et al., 2015a; Veling et al., 2013; Wessel et al., 2014; Wiers, Ludwig, et al., 2015) I adopted an explicit measure of stimulus valuation, a VAS, to further examine the devaluation hypothesis, in study 6.1 (page 121). Additionally, I examined if in regular chocolate consumers a single session of ICT influenced both attention (inferred from eye-gaze) and behavioural choice (preference, measured by a forced-choice task), as shown in previous CBM studies (Schonberg et al., 2014; Veling et al., 2017a). As described above, the ICT was administered to all participants and was formed only by high value and low value chocolate pictures, paired with either behavioural response or inhibition, and changes in outcome variables were observed pre- and post-training.

Following the formation of stimulus-stop associations, it was shown that ICT leads to changes in attention and overt choice, although these effects were limited to low value stimuli, rather than high value stimuli. However, contrary to expectations these were not accompanied by changes in subjective evaluation. Chocolate pictures that had been paired with inhibition were not evaluated more negatively following ICT. As previously argued, the explanation for these results may be due to either the tasks used, or to pre-existing baseline differences in ratings or in the sample (see Lawrence et al., 2015a; Veling et al., 2017a; Veling et al., 2013a).

Overall, this thesis casts doubt on the role of stimulus devaluation as a mechanism of action for the effectiveness of CBM (Jones et al., 2016b). Specifically, null findings were observed in all the three studies discussed in this section: no devaluation effects were found on alcohol implicit evaluations after CBM (Chapter Two); no effects of ICT were found on explicit subjective ratings measured via a VAS scale (Chapter Six); and study 5.1 showed that neither implicit positive

associations (via a valence IAT) or subjective ratings were associated with cognitive biases of automatic approach or impaired inhibitory control (Chapter Five).

8.1.2.4 Alternative hypotheses

Approach-avoidance associations

Findings from this thesis pose serious problems for the devaluation hypothesis of CBM effects, because no link was found between cognitive processing bias and affective responses to appetitive stimuli, regardless of how assessed. Therefore, an alternative explanation may be that approach tendencies and inhibitory control are not determined by valence (hyper-valuation of appetitive stimuli) but by strong implicit approach and avoidance associations, as shown by some studies (Gladwin et al., 2015b; Kemps & Tiggemann, 2016; Kemps et al., 2013; Wiers et al., 2017; Wiers et al., 2010).

In the second cross-sectional experiment of Chapter Five (study 5.2, page 112) I investigated this hypothesis, by examining the independence (or the existence of a common link) between automatic approach tendencies (AAT), inhibitory control (GNGT) and approach and avoidance associations (approach-avoidance IAT) of chocolate-related pictures. Results were consistent with those from study 5.1, showing that automatic approach-avoidance associations did not appear to underpin these cognitive biases (of approach or inhibitory self-control). Individuals possessed strong implicit approach associations (IAT) towards chocolate, however these did not correlate with either of the cognitive biases (approach tendencies or impaired inhibitory control), suggesting again that these processes may be independent of each other. Therefore, the mechanism of action remains unclear.

Signal Detection hypothesis

In the last experimental chapter (Chapter Seven, study 7.1, page 146) of the thesis I examined signal detection as an alternative theoretical explanation for the effects of ICT (Veling et al., 2017b; Verbruggen et al., 2014). It has been proposed that ICT may train people to more efficiently detect the cues (signals), but should evoke automatic inhibition only in a context where inhibition is required. Experiments show that a proportion of stopping latency can be accounted for by perceptual processes (Logan et al., 2014; Verbruggen et al., 2014), thus the detection of the signal (No-Go cues), primed by the learned associations, leads to

improvements in the ability of detection that then affect successful inhibition (action control).

As described above, study 7.1 examines this signal detection hypothesis by comparing it to the associative hypothesis, because both accounts make different behavioural predictions about the effects of ICT on RT speeding and slowing. The associative hypothesis proposes that ICT leads to formation of automatic associations between alcohol cues and behavioural inhibition (slowing in RTs) that are independent of context (effect that should not be modulated by inhibition context). The competing hypothesis proposes that ICT improves the ability to detect inhibition signals after alcohol stimuli, but the effects of alcohol stimuli on behavioural inhibition (slowing in RTs) will only become manifest in an 'executive setting' in which inhibition might be required (Chiu & Aron, 2015), while in a non-executive setting (i.e., 'speed context'), participants should be faster to respond when the congruency between target cues (Go and No-Go cues: such as the letters: 'p' or 'f') and stimuli (alcohol-related or stationery pictures) matches the pairings that were learned during ICT, because the stimuli (alcohol pictures) should facilitate rapid detection and categorization of the letter.

Heavy drinkers completed an ICT training phase in which alcohol stimuli were paired with No-Go signals (No-Go training group) or with Go signals (Go training group). Following this, a speeded categorization task was administered (test phase), in which participants were required to respond to cues (the letters 'p' and 'f') that had functioned as the Go and No-Go stimuli during the training phase, alongside alcohol-related, neutral, and additional novel pictures (pictures of boats and birds). Half of the participants in each group completed the test phase either in an inhibition context (i.e. occasionally inhibit to boat pictures) or in a speed context (i.e. never inhibit).

Unfortunately, the results were unable to distinguish between the two accounts. Specifically, during the test-phase RTs were significantly slower among participants who completed the task in the inhibition context versus those who completed the task in the speed context, showing that the manipulation was effective. In both contexts, RTs were slower for alcohol pictures compared to either control novel or trained stimuli (e.g. stationery or bird pictures). However, these effects cannot be attributable to ICT because they did not differ across groups. Most importantly, regardless of group allocation, participants were slower to respond to

the letter ‘f’ (that had been the No-Go cue during the training phase) compared to the letter ‘p’ (that had been the Go cue during the training phase). These specific ‘No-Go cue’ effects were prominent among participants in the Inhibition context, compared to those in the Speed context, replicating Chiu & Aron’s work (2014).

These findings suggest that ICT leads to weak stop learning effects during training, between the ‘No-Go cue’ and behavioural stopping (as seen in: Verbruggen and Logan, 2008a, 2009; Chiu & Aron, 2015; Best et al., 2015; Bowditch, Verbruggen and Mclaren, 2016; Houben & Jansen, 2015), but it does not evidence the formation of any associations between alcohol stimuli and stopping (or alcohol cues and rapid responding). Furthermore, this study casts doubt on the applicability of ICT in the ‘real world’, as the fact that a reminder of inhibition (Inhibition context) may be required in order for ICT to be effective makes this intervention less useful when more needed (Cristea, Kok, Cuijpers, 2016).

Attention

A final alternative hypothesis considered a posteriori in the present thesis focuses on how CBM (mostly ICT) may train individuals to attend more to stimuli paired with inhibition (or avoidance, see: Anderson, Laurent, & Yantis, 2011; Stice et al., 2016). This account is consistent with research on decision-making, arguing that evaluations affect preference (choice) and attention (Izuma et al., 2010; Krajbich & Rangel, 2011; Lim et al., 2011; Sharot et al., 2009).

Recent studies show that individuals exposed to ICT reduced their body fat, palatability and monetary ratings and attention towards high-calorie foods that had been paired with inhibition, relative to the control group (Stice et al., 2016; Veling et al., 2017a). Similarly, another study showed that training motor approach towards specific high-calorie snack increased the approach behaviour, choice and attention towards these snacks (Schonberg et al., 2014). Therefore, both studies showed that ICT affected attentional processes, which seems to be related to the devaluation hypothesis.

In study 6.1 (Chapter Six, page 122) my aim was to investigate this hypothesis, by examining if a single session of ICT affected stimulus evaluation, behavioural choice and attention, in regular chocolate consumers. As mentioned previously, ICT was administered to all participants and was formed only by high value and low value chocolate pictures, paired with either behavioural response or

inhibition, and pre- and post-ICT changes in evaluation (measured by a VAS scale), attention (inferred from eye-gaze) and behavioural choice (measured by a forced-choice task) were analysed.

As predicted, the formation of stimulus-stop associations over the course of the training block (although only in chocolate stimuli that were highly valued before training), lead to changes in attention and choice, but not evaluation ratings. Chocolate pictures that had been paired with inhibition were chosen and attended to less, whereas chocolate pictures paired with responding were chosen and attended to more, replicating previous findings in the literature (Schonberg et al., 2014; Stice et al., 2016; Veling et al., 2017a). However, unexpectedly these effects were observed only for low value chocolate pictures (instead of high value pictures).

Overall these findings suggest that ICT does affect preferences and attentional process, but these do not seem to be linked to the hyper-valuation of appetitive stimuli (as argued by the devaluation hypothesis). However, these claims require confirmation in future research.

8.2. Theoretical implications

Now that a brief overview of the different findings reported in this thesis has been provided, in this section I wish to consider how these findings fit in with the theoretical models discussed in the literature review (Chapter One), particularly the Dual processes models, associative inhibition theories and models of stimulus hyper-valuation.

As discussed in Chapter One, the essence of Dual process models of addiction is that addictive behaviours are the result of automatic appetitive processes (e.g. approach tendencies) that compete with controlled processes (e.g. inhibitory control) (Gladwin & Figner, 2014). These models account for motivational and individual differences in the determinants of the substance misuse and propose that automatic processes reflect incentive learning processes (Stacy & Wiers, 2010). According to these claims, CBM interventions should modify unhealthy behaviours by weakening/reversing the automatic processes or strengthening the controlled processes.

These key predictions of Dual process models are supported by the findings in this thesis, that show effects in drinking behaviour (reduction in consumption, as seen in study 2.1 and 3.1) and choice (as seen in study 6.1) after modification of

cognitive biases. However, these effects may be context-dependent. Results from study 3.1 suggest that these interventions are effective in a more ecologically valid setting, but that these effects are abolished when exposed to environmental triggers. Therefore, these findings cast doubt on the generalizability of these interventions to the 'real world', as argued by a recent review in the field (Cristea, Kok & Cuijpers, 2016).

Moreover, Dual process model claim that CBM effects should be mediated by changes in underlying automatic associations (Stacy & Wiers, 2010). In the present thesis, this claim of associative effects was the most consistently supported: with study 2.1 and 4.1 showing a trend in reversing approach biases and study 3.1, 6.1 and 7.1 showing some improvement in inhibitory control performance (but not in study 2.1). Overall these findings seem to suggest that during the training participants develop new associative links between appetitive stimuli and behavioural responses (Houben & Jansen, 2015; Houben et al., 2012; Lawrence et al., 2015b), which consequently modify automatic and controlled processes thus impacting on unhealthy behaviours. Therefore, these findings are consistent with the Dual process model predictions, but also support the 'stimulus-association' hypothesis as a mechanism underpinning CBM effectiveness as argued in recent reviews (see Jones et al. 2016b; Veling et al., 2017b; Verbruggen et al., 2014).

Furthermore, findings from study 4.1 corroborate and strengthen these claims by evidencing that CBM interventions affect not only cognitive processes but also brain activity. Results showed that the amplitude of components of the event-related potentials were modified following alcohol-CAT during the processing of alcohol-related stimuli, when preparing a motor approach and avoidance actions. Of particular interest are the findings in the N200 component, suggesting that in addition to strengthening automatic associations between stimulus and response, participants recruit executive control in order to supress the dominant response (i.e. to approach alcohol-related cues). These findings are in line with fMRI studies showing CBM leads to reductions in neural regions associated with the processing of motivationally salient stimuli (e.g. mPFC, nucleus accumbens, amygdala), reductions which correlated with the behavioural modification of alcohol related biases (e.g. the reversing of alcohol approach biases via the learning of new associations) (see Verdejo-Garcia, 2016; Wiers, Ludwig, et al., 2015; Wiers, Stelzel, et al., 2015; Wiers & Wiers, 2016).

Finally, results from the present thesis cast doubt on the idea that 'hyper-valuation' of appetitive stimuli determines cognitive biases. This account is supported by models focusing on the link between stimulus valence and actions of behavioural regulation (Guitart-Masip et al., 2014; Veling et al., 2008). The key prediction of these models is that reductions in positive evaluations (devaluation) of appetitive stimuli should underpin and explain changes in behaviour (Veling, Aarts, & Stroebe, 2013a; Veling et al., 2017b). In accordance with a recent meta-analysis in the field from our group (Jones et al., 2016b), this explanation was not supported by the studies presented in this thesis, even when using different measures of evaluation such as the valence IAT in study 2.1 (implicit measure) or VAS scale in study 6.1 (explicit measure). Further evidence against the 'hyper-valuation' models was suggested by study 5.1, showing that cognitive bias and implicit positive evaluations of chocolate-related pictures are independent from each other.

8.3 Clinical applications of these findings

CBM interventions hold great potential for the modification of appetitive behaviours and associated disorders, because they are easy to administer alongside existing treatments, and they can be administered to a large number of individuals, and at a very low economic cost. Relative to traditional medicine an advantage of CBM lies in fact that can be administered via a computer, or any mobile device, leading to the development of new multi-disciplinary treatments that can be carried out before episodes of temptation, such as a night out in a bar or pub (Boffo, Pronk, Wiers, & Mannarini, 2015).

Multiple sessions of CAT have replicated laboratory findings in clinical settings on alcohol-dependent patients, demonstrating a reduced likelihood of relapse following the intervention compared to a control intervention (Wiers et al., 2011; Eberl et al., 2013; Gladwin et al., 2015; Manning et al., 2016). Similar clinical trials targeting specific populations have not yet been published for ICT.

Considering the findings on CBM effectiveness reported in the present thesis (study 2.1 and 3.1), these interventions seem to be successful in reducing alcohol consumption in the laboratory. However, in terms of translating this effect to the 'real world' (an 'alco-genic/obeso-genic' environment) these outcomes may be less realistic (Cristea, Kok & Cuijpers, 2016). As mentioned above, study 3.1 showed that after exposure to environmental triggers (alcohol-related TV adverts) ICT

effects were abolished. Thereby suggesting that the beneficial effects of ICT may be very context-dependent, making the intervention less useful when it is most needed (e.g. during tempting episodes, such as when visiting the pub/bar with friends).

These findings cast doubt on the longevity of CBM effects outside of the laboratory, because optimistic conclusions are almost exclusively based on lab. studies (Allom, Mullan & Hagger, 2015; Jones et al., 2016b, 2017; Kakoschke et al., 2017a) and this thesis suggest that behaviour in the lab might not generalize (Cristea, Kok & Cuijpers, 2016). Yet, recent studies seem to suggest that ICT may be more beneficial for specific populations, such as clinical populations or individuals with higher BMI (Jones et al., 2017; Veling et al., 2014).

Overall, there is mounting evidence that suggests that researchers should remain optimistic in CBM interventions. However, in the light of my findings, more pre-registered RCTs and 'real world' experiments are deemed necessary in order to clarify inconsistent findings in literature and shed light on their real long-term effectiveness.

8.4 Limitations and strengths

The studies described in this thesis present a number of limitations and strengths. The lack of power in study 3.1 is a first limitation and we know that if a study has inadequate statistical power it has reduced sensitivity to detect small effect sizes, as discussed previously in study 3.1 (for details see page 66). Secondly, in each of the studies described in the experimental chapters the sample size was not determined on the basis of formal power calculations. However, the choice was made on the basis of previous studies with similar designs (see Wiers et al.2011; Houben et al., 2012). Additionally, in study 5.1, 5.2 and 6.1 I did not apply corrections to control for multiple comparison. I opted to do this because none of the hypothesised correlations were significant even at the .05 level, therefore a correction for multiple comparison would have made no difference. in the main variables were not close to $p = .05$. However, future research should apply such corrections as good practice. Three main methodological issues that could have influenced the reported findings will be reviewed below: (1) Task and stimulus properties; (2) Participant characteristics; (3) Demand effects.

8.4.1 Task and stimulus properties

I believe that a primary limitation in the present thesis, that also applies to much of the published literature, relates to methodological features of the tasks that are used to assess cognitive biases (the AAT, the GNGT and the IAT), all of which are based on response latencies (manual RTs). These tasks may not be sufficiently reliable or sensitive to detect changes in RTs (especially bias scores) following a single session of CBM (e.g. measures of alcohol-avoidance/inhibition associations). This may be especially true for tasks that have already been criticised in the current literature, such as the IAT (see Stacy & Wiers, 2010) and the irrelevant version of the AAT (in comparison to alternative tasks such as the relevant-feature AAT or the SRCT, see Kersbergen et al., 2015). However, the poor sensitivity of assessment tasks does not imply that the training versions of these tasks are incapable of changing stimulus-response associations or behaviour.

Moreover, recent laboratory studies have suggested that RT changes following CBM may be sensitive to a number of factors (Best et al., 2015). One factor may be the presence of an executive setting (i.e. a setting in which participants might be required to inhibit), which may be necessary to consistently detect ICT effects (Chiu & Aron, 2015). Secondly, task instructions may be an important confound. This is a feature that was not investigated in the present thesis, yet recently different studies found greater CBM effects when instructions were explicit and relevant to the task (e.g. avoid alcohol; Best et al., 2015; Van Dessel, De Houwer, & Gast, 2016; Van Dessel, De Houwer, Gast, & Smith, 2015; Van Dessel Promotor, De Houwer, & Gast, 2016).

Thirdly, recent findings showed that behavioural choice can be manipulated by ICT but only if the choice is impulsive (with time pressure), while the effect of ICT on choice disappears when participants received more time, or when their choice required them to direct their attention to alternatives (Veling et al., 2017a). In the present thesis although participants were mostly instructed to respond as quickly as they could, the absence of a timeout in some trial tasks may have minimized the pressure on performance, as found in study 6.1. Thus, it is possible that similar time pressure may be essential in order to detect other behavioural effects.

A fourth factor perhaps influencing RTs may be individual differences in motivational responses to the stimuli used (Stice et al., 2016), as seen in study 6.1.

Although efforts were made to keep these tasks as consistent as possible across studies and consistent with the reported literature (Allom, Mullan & Hagger, 2015; Jones et al., 2016b, 2017; Kakoschke et al., 2017a), there are still variations in the present thesis and in the available literature according to different task parameters including the arbitrary use of the stimuli presented (e.g. complexity, palatability, branded and non-branded items, arousal and valence), the number of trials or images within each stimulus category (e.g. trained, novel, picture pairing, picture category). Nevertheless, the exploration of all these confounds is essential, because by investigating these factors on outcomes it should contribute to creating training procedures that are more effective and standardized.

Regarding stimulus devaluation, similar failure to detect these effects in the present thesis may be related to the use of the tasks adopted. As I mentioned earlier, most robust effects in evaluation are measured through Likert ratings scales or auction tasks (Ferrey et al., 2012; Lawrence et al., 2015a; Veling et al., 2013a; Wessel et al., 2014; Wiers, Ludwig, et al., 2015) and results from study 5.1 confirm that subjective and behavioural measures of evaluations are not closely related to each other. However, even when measuring devaluation effects with a VAS scale (in study 6.1) null effects were found. However, as mentioned previously these effects may have been related to the baseline differences in stimuli ratings or either to changes in the ICT task adopted in the study. Thus, further work is required to identify a reliable measure that is sensitive to the detection of stimulus devaluation, and of stimulus associations, following CBM.

8.4.2 Participant characteristics

The characteristics of participants who took part in these studies might also reflect a limitation of the thesis. The majority of the participants were students or staff recruited from various departments at Liverpool University, via the University's announcement page. All the participants were 'paid' (either in course credit or shopping vouchers), and so were a population that might have an increased knowledge of research methods due to involvement in multiple studies (such as psychology undergraduates or 'professional' participants) and may perhaps be suspicious of deception, consequently altering their behaviour accordingly (or discordantly; Bentley & Thacker, 2004; Conner, Godin, Norman, & Sheeran, 2011; Dickert, 2013; Devine, et al., 2013; 2015; Kypri et al., 2011; McCambridge, de

Bruin, & Witton, 2012; McCann et al., 2015), as found in study 3.1 (invalidating the advertisement manipulation). Efforts were made to recruit from a wider population via online and social media advertising, however the recruitment from this method was low. As in most psychology studies, this is a limitation that has implications for the generalizability of the findings, because these results are based on a Western-educated sample.

Furthermore, the motivation of the present population is a factor that needs to be considered. All participants were young adults (aged 18 to 30, a population known to have increased risk taking behaviours), and either heavy drinkers or regular chocolate consumers, who were not motivated to change behaviour as measured by self-report questionnaires reported in some chapters (e.g. Readiness to change questionnaire or Contemplation ladder). These questionnaires were adopted in order to control for group differences in this measure, which is known to influence behaviour, such as drinking. In fact, adolescents and young adults generally have little motivation to reduce their drinking, as drinking is considered a normative behaviour (Faulkner et al. 2006; Littlefield et al. 2009). Consequently, if the motivation to change is not there, the effects of CBM on drinking behaviour may under- or over-estimate the likely effect in a different population who are motivated to change their drinking (see Chapter One, page 2). Future studies, should investigate these moderating effects in CBM studies.

Moreover, another limitation was that in most of the experiments described above the samples were predominantly female, despite great efforts during recruitment to equally match groups. Gender differences are known to play a role in drinking and eating behaviour (Jones et al., 2016a; Siegel, Ayers, DeJong, Naimi, & Jernigan, 2015). For example, women are more worried about food and score higher in dietary restraint than men (Tapper & Pothos, 2010). Additionally, some ICT studies found training effects on consumption only in female restrained eaters (Houben & Jansen, 2011b; Veling et al., 2011). However, analyses on participant gender or group allocation were conducted in all studies, and showed that these factors did not moderate results.

A final limitation related to the participants, involves time dependent factors. These refer to state changes in the person examined. For example, these changes include increases or decreases in craving, hunger, attention and boredom. All these variables create biases, and efforts were made to reduce or control for these factors.

For example, the high number of trials in both CBM tasks adopted in the present thesis made the interventions quite demanding and boring. I, therefore, introduced breaks in order to control for loss of attention and boredom. Additionally, a number of self-report questionnaires were administered in order to control other state variables. However, a posteriori, I noticed that most appetite studies that found devaluation effects controlled for hunger and BMI (see Lawrence et al., 2015a,b; Veling et al., 2017a; Veling et al., 2013a). Unfortunately, these criteria were not applied in the studies for this thesis, and may partially account for the failure to detect devaluation effects.

8.4.3 Demand effects

Behavioural and self-report measures are sensitive to a number of demand effects, which are effects related to when a participant recognise the aim of the study and subconsciously (or consciously) modifies his or her behaviour. Firstly, in common with most of the CBM laboratory studies, group allocation was single rather than double blinded. Therefore, the experimenter was aware of group allocations, but not participants. This factor is known to increase the risk of bias in such studies (see Cristea, Kok & Cuijpers, 2016). However, a cover story for each study was given in order to lead participants to believe that there was no experimental manipulation. Additionally, I measured participants' awareness of the aims, hypotheses and task contingencies during debriefing at the end of most studies. Indeed, the vast majority of the sample (50% of participants or more) across all studies indicated that they believed the cover story, while usually only a small minority developed awareness of the intended overall purpose of study or of the CBM intervention (contingency awareness). Therefore, it seems unlikely that these demand characteristics affected the findings, however contingency awareness was only inferred from these responses.

Furthermore, the vast majority of the participants across both studies that adopted a taste-test (study 2.1 and 3.1) developed awareness of the real purpose of the test, identifying that this task was a measure of their motivation to drink alcohol. To explore the influence of this factor supplementary analyses were conducted showing that awareness did not influence primary findings (see Appendix A, page 215). These findings are not surprising in light of results from a recent meta-analysis (of which some of this thesis data is part) confirming that awareness was not related

to ad-libitum alcohol consumption (see Jones, et al., 2016a). However, contrary to previous awareness factors, a risk of bias that may have affected our primary findings was awareness of the advertising manipulation (either neutral or alcohol TV adverts) in study 3.1 (Cristea, Kok & Cuijpers, 2016). Future studies should address this issue with a modified procedure that is able to mask effectively the aims of the manipulation.

Some ICT studies, moreover, have demonstrated that participants become aware of the contingency between appetitive stimuli and the requirement to inhibit (Lawrence et al., 2015a), as inferred from expectations of having to stop when those cues are encountered (Best et al., 2015). De facto, some recent studies have shown that ICT (Best et al., 2015) and CAT (Van Dessel et al., 2015, 2016; Van Dessel, De Houwer and Gast, 2016) stimulus-response learning effects are partly mediated via explicit contingency knowledge to task relevant features. In the light of these recent findings and in relation to the associative-learning literature (McLaren et al., 2014), showing that when an in individual is aware that a cue/signal is likely to occur and expects it, participants actively adjust their strategies in order to improve performance. Future studies should investigate contingency awareness with specific direct questions (unlike in the studies presented in this thesis). However, it seems unlikely that awareness of experimental contingencies could account for the findings of the present thesis as participants were led to believe that there was no experimental manipulation and mostly because the majority believed the cover story.

8.4.4 Strengths

The present thesis also has some notable strengths. As previously discussed, efforts were made to recruit from external sources, match groups on variables (e.g. gender), and control for time dependent variables (e.g. attention) and trait variables (e.g. motivation measured via self-report questionnaires). Additionally, I kept tasks as consistent as possible across studies (and with the reported literature at the time that the study was designed) in order to compare these more effectively.

Furthermore, in order to control for study awareness (known to increase the risk of bias; see Cristea, Kok & Cuijpers, 2016) all of the studies in this thesis possessed a cover study that led participants to believe that there was no experimental manipulation, and more importantly in most of the experiments described in this thesis (except for study 5.1, 5.2 and 7.1), I collected awareness data

before formal debriefing. Data that revealed that the majority of the participants across all studies believed the cover stories.

Most importantly, the use of appropriate control groups in all between-subject studies is a strength compared to much of the existing literature. This type of control manipulation helps to resolve ambiguity regarding interpretation of CBM findings, because opposite control interventions (e.g. Cue Approach training, ICT Go training) attempt to increase (rather than extinguish or reverse) cognitive biases (Houben et al., 2012; Kakoschke et al., 2017a; Wiers et al., 2010b) and by doing so they inflate CBM effect sizes (Schonberg et al., 2014).

Finally, this thesis thoroughly explored the same questions (e.g. stimulus devaluation) by using a range of different methods. For example, with the adoption of different measures (e.g. for devaluation: IAT, Likert scale or VAS), the adoption of different experimental tools (e.g. EEG, eye movements), the adoption of different appetitive stimuli (e.g. alcohol and chocolate) and the use of both between-groups and within-subjects' experimental designs.

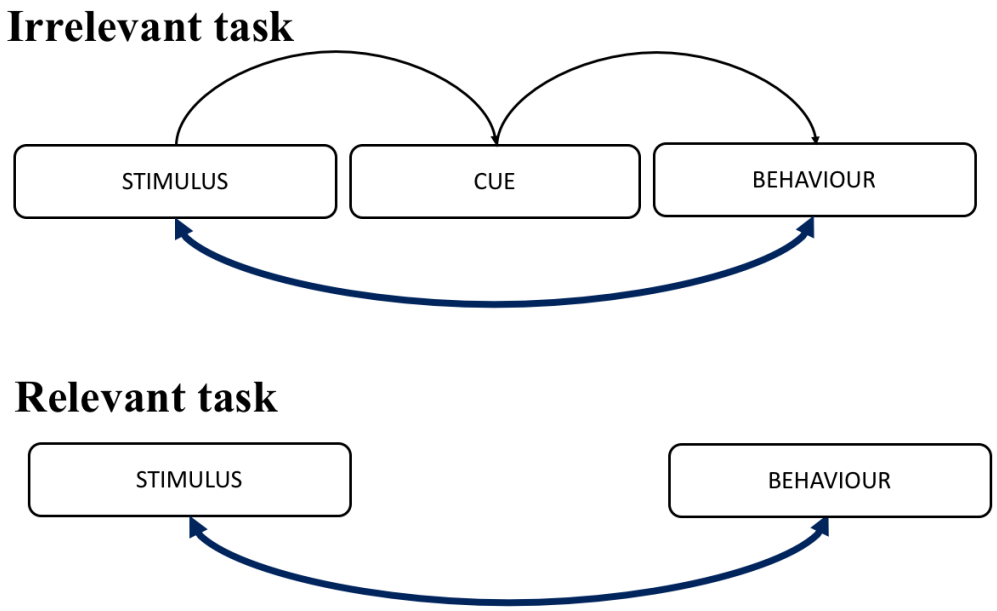
8.5 Future research

More research is needed to formulate a comprehensive theory with clear testable predictions about the mechanisms of action of CBM interventions and their lasting effects on behaviour. On the basis of my findings, my primary suggestion is to examine CBM effects by using relevant features tasks, as opposed to the irrelevant-feature tasks that were used in the present thesis. Irrelevant feature tasks instruct participants to focus on 'irrelevant' features of the stimulus (such as the format of the picture or a specific cue/signal to inhibit), for example to avoid landscape pictures and approach portrait pictures (irrelevant AAT). Whereas, relevant feature versions of these tasks instruct participants to make their response based on the alcohol-relatedness of the pictures, for example to avoid alcohol pictures and approach control pictures (e.g. relevant AAT). In the light of recent findings showing that task relevant (explicit) instructions show greater learning effects following training (Best et al., 2015; Van Dessel, De Houwer, & Gast, 2016; Van Dessel et al., 2015; Van Dessel Promotor et al., 2016) and especially with respect of the findings in this thesis (showing associative effects across most studies), this would seem to be a promising research avenue. And especially so, because it directly supports the associative hypothesis, implying that perhaps to

strengthen stimulus-response associations these need to be more 'direct'. For example, in a relevant ICT individuals would directly learn to inhibit to alcohol cues; whereas in an irrelevant ICT participant would first inhibit to the No-Go cue (as seen in study 7.1), which with repeated pairing with alcohol stimuli, would lead consequently to automatic inhibition to alcohol pictures (see figure 8.1). Thus, would removing the 'irrelevant' associations from the process, and encouraging instead the development of 'relevant' associations ("avoid alcohol or stop eating chocolate biscuits") make CBM more effective?

Figure 8.1 Schematic overview of the irrelevant versus relevant associative hypothesis.

The irrelevant tasks, by repeatedly avoiding or inhibiting to appetitive stimuli (e.g. alcohol), that had been paired with a cue (or signal), lead to the formation respectively of stimulus-avoidance or stimulus-stop associations. Consequently, these learned associations become manifest as automatic avoidance or inhibition when those stimuli (e.g. alcohol) are next encountered. Whereas, the relevant tasks by repeatedly avoiding or inhibiting to appetitive stimuli (e.g. alcohol) that had been paired with the trained response (e.g. avoidance or inhibition), lead to the direct formation respectively of stimulus-avoidance or stimulus-stop associations.



Additionally, future studies should evaluate CBM interventions on specific populations who are most likely to benefit from them (e.g. individuals who possess strong implicit appetitive biases, individuals with SUDs, obese or overweight individuals, individuals with a genetic/neurologic propensity to dopamine, etc.), rather than on healthy students. Finally, it is important to state that if CBM interventions are to be effective in the real world, they are likely to require multiple sessions if they are to alter automatic appetitive responses that have been acquired and strengthened over a long period of time, and laboratory studies that investigate the effects of only a single session of CBM should be interpreted with caution because they are unlikely to detect the changes that occur after multiple sessions of CBM.

8.6 Concluding Comments

I conclude that CAT and ICT are successful interventions that affect appetitive behaviours in the laboratory. However, their effectiveness in more naturalistic settings require further investigation.

Additionally, I carefully assert that devaluation effects following CBM, previously reported in the literature, do not seem to be robust, and I advance the doubt over the claim that this is the mechanism underpinning the CBM effectiveness. Most importantly, I conclude that the formation of stimulus-response associations seems to be the most plausible explanation for the mechanism of action of CBM on appetitive behaviour.

Finally, findings reported in this thesis support the theoretical predictions of the Dual process models and associative learning (Wiers et al., 2007). However, these findings are difficult to reconcile with alternative accounts that centre around hyper-valuation of appetitive stimuli (Guitart-Masip et al., 2014; Veling et al., 2008).

References

Adams, R. C. (2014). Training Response Inhibition to Reduce Food Consumption.

Ayres, K., Prestwich, A., Conner, M., & Smith, P. (2011). Emotional eating moderates the relationship between implicit measures of attitudes and chocolate consumption. *European Journal of Personality, 25*(5), 317-325.

Allom, V., Mullan, B., & Hagger, M. (2015). Does inhibitory control training improve health behaviour? A meta-analysis. *Health Psychology Review*, *7199*, 1–38.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.). Washington, DC: Author.

Anderson, B. A, Laurent, P. A, & Yantis, S. (2011). Value-driven attentional capture. *Proceedings of the National Academy of Sciences*, *108*(25), 10367–10371.

Anderson, P., De Bruijn, A., Angus, K., Gordon, R., & Hastings, G. (2009). Special issue: The message and the media: Impact of alcohol advertising and media exposure on adolescent alcohol use: A systematic review of longitudinal studies. *Alcohol and Alcoholism*, *44*(3), 229–243.

Bamford, S., Broyd, S. J., Benikos, N., Ward, R., Wiersema, J. R., & Sonuga-Barke, E. (2015). The late positive potential: A neural marker of the regulation of emotion-based approach-avoidance actions? *Biological Psychology*, *105*, 115–123.

Barkby, H., Dickson, J. M., Roper, L., & Field, M. (2012). To Approach or Avoid Alcohol ? Automatic and Self-Reported Motivational Tendencies in Alcohol Dependence, *36*(2), 361–368. http://doi.org/10.1111/j.1530-0277.2011.01620.x

Becker, D., Jostmann, N. B., Wiers, R. W., & Holland, R. W. (2015). Approach avoidance training in the eating domain : Testing the effectiveness across three single session studies. *Appetite*, *85*(266408), 58–65.

Bentley, J. P., & Thacker, P. G. (2004). The influence of risk and monetary payment on the research participation decision making process. Journal of medical ethics, 30(3), 293-298.

Benton, D., Greenfield, K., & Morgan, M. (1998). The development of the Attitudes

to chocolate questionnaire. *Persoality and Individual Differences*, *24*(4), 513–520.

Berkman, E. T., Kahn, L. E., & Merchant, J. S. (2014). Training-Induced Changes in Inhibitory Control Network Activity. *The Journal of Neuroscience*, *34*(1), 149–157.

Best, M., Lawrence, N. S., Logan, G. D., Mclaren, I. P. L., & Verbruggen, F. (2015). Should I Stop or Should I Go? The Role of Associations and Expectancies. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(1), 115–137.

Bickel, W. K., Jarmolowicz, D. P., Mueller, E. T., Gatchalian, K. M., & McClure, S. M. (2012). Are executive function and impulsivity antipodes? A conceptual reconstruction with special reference to addiction. *Psychopharmacology*, *221*(3), 361–387.

Biener, L., & Abrams, D. B. (1991). The Contemplation Ladder: validation of a measure of readiness to consider smoking cessation. *Health Psychology*, *10*(5), 360–5.

BioSemi, B. V. (2011). BioSemi ActiveTwo. [EEG system]. Amsterdam: BioSemi.

Blanton, H., Jaccard, J., Klick, J., Mellers, B., Mitchell, G., & Tetlock, P. E. (2009). Strong claims and weak evidence: Reassessing the predictive validity of the IAT. *Journal of Applied Psychology*, *94*(3), 567–582.

Blundell, J. E. (1996). Control of Human Appetite: Implications for the Intake of Dietary Fat. *Annual Review of Nutrition*, *16*(1), 285–319.

Boffo, M., Pronk, T., Wiers, R. W., & Mannarini, S. (2015). Combining cognitive bias modification training with motivational support in alcohol dependent outpatients : study protocol for a randomised controlled trial, 1–15.

Bowditch, W. A., Verbruggen, F., & Mclaren, I. P. L. (2015). Associatively mediated stopping : Training stimulus-specific inhibitory control.

Bowley, C., Faricy, C., Hegarty, B., Johnstone, S. J., Smith, J. L., Kelly, P. J., & Rushby, J. A. (2013). The effects of inhibitory control training on alcohol consumption, implicit alcohol-related cognitions and brain electrical activity. *International Journal of Psychophysiology*, *89*(3), 342–348.

Brignell, C., Griffiths, T., Bradley, B. P., & Mogg, K. (2009). Attentional and approach biases for pictorial food cues. Influence of external eating. *Appetite*, *52*(2), 299–306. http://doi.org/10.1016/j.appet.2008.10.007

Brockmeyer, T., Hahn, C., Reetz, C., Schmidt, U., & Friederich, H.-C. (2015). Approach Bias Modification in Food Craving—A Proof-of-Concept Study. *European Eating Disorders Review, 23*(5), 352-360.

Brooks, S., Prince, A., Stahl, D., Campbell, I. C., & Treasure, J. (2011). Clinical Psychology Review A systematic review and meta-analysis of cognitive bias to food stimuli in people with disordered eating behaviour. *Clinical Psychology Review*, *31*(1), 37–51.

Brunia, C. H., & van Boxtel, G. J. (2001). Wait and see. *International Journal of Psychophysiology*, *43*(1), 59–75.

Burger, K. S., & Stice, E. (2011). Variability in reward responsivity and obesity: evidence from brain imaging studies. *Current Drug Abuse Reviews*, *4*(3), 182–9.

Cabrera, E. A., Wiers, C. E., Lindgren, E., Miller, G., Volkow, N. D., & Wang, G. J. (2016). Neuroimaging the Effectiveness of Substance Use Disorder Treatments. *Journal of Neuroimmune Pharmacology*, *11*(3), 408–433.

Calitri, O. Pothos, E. M., Taper, K., Brunstrom, J. M., & Rogers, P. J. (2010). Cognitive Biases to healthy and unhealthy food words predict change in BMI. *Obesity society*, City Research Online, *18*, 2282–2287.

Carnell, S., Gibson, C., Benson, L., Ochner, C. N., & Geliebter, A. (2012). Neuroimaging and obesity: Current knowledge and future directions. *Obesity Reviews*, *13*(1), 43–56.

Carter, B. L., & Tiffany, S. T. (1999). Meta-analysis of cue-reactivity in addiction research. *Addiction*, *94*(3), 327–340.

Chen, Z., Veling, H., Dijksterhuis, A., Holland, R. W., Chen, Z., Veling, H., Holland, R. W. (2016). Journal of Experimental Psychology : General How Does Not Responding to Appetitive Stimuli Cause Devaluation : Evaluative Conditioning or Response Inhibition ? How Does Not Responding to Appetitive Stimuli Cause Devaluation : Evaluative Conditioning or Re, *145*(12), 1687–1701.

Chiu, Y.-C., & Aron, A. R. (2014). Unconsciously triggered response inhibition requires an executive setting. *Journal of Experimental Psychology. General*, *143*(1), 56–61.

Clayson, P. E., & Larson, M. J. (2011). Neuropsychologia Conflict adaptation and sequential trial effects : Support for the conflict monitoring theory.

Neuropsychologia, *49*(7), 1953–1961.

Collins, R., & Lapp, W. (1992). The temptation and restraint inventory for measuring drinking restraint. *British Journal of Addiction*, *87*(4), 625–633.

Conner, M., Godin, G., Norman, P., & Sheeran, P. (2011). Using the question-behavior effect to promote disease prevention behaviors: two randomized controlled trials. *Health Psychology : Official Journal of the Division of Health Psychology, American Psychological Association*, *30*(3), 300–9.

Conrey, F. R., Sherman, J. W., Gawronski, B., Hugenberg, K., & Groom, C. J. (2005). Separating Multiple Processes in Implicit Social Cognition: The Quad Model of Implicit Task Performance. *Journal of Personality and Social Psychology*, *89*(4), 469–487.

Courtney, K. E., Schacht, J. P., Hutchison, K., Roche, D. J. O., & Ray, L. A. (2016). Neural substrates of cue reactivity: Association with treatment outcomes and relapse. *Addiction Biology*, *21*(1), 3–22.

Cramer, K. M., & Hartleib, M. (2001). The attitudes to chocolate questionnaire: a psychometric evaluation. P*ersonality and Individual Differences, 31*(6), 931-942.

Cristea, I. A., Kok, R. N., & Cuijpers, P. (2016). The effectiveness of cognitive bias modification interventions for substance addictions: A meta-analysis. *PloS One*, *18*, 1–19.

Davis, C. G., Thake, J., & Vilhena, N. (2010). Social desirability biases in self-reported alcohol consumption and harms. *Addictive Behaviors*, *35*(4), 302–311.

Department of Health (January 2016) UK Chief Medical Officers' Alcohol Guidelines Review: Summary of the proposed new guidelines. Available via: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/489795/summary.pdf

Devine, E. G., Waters, M. E., Putnam, M., Surprise, C., O'Malley, K., Richambault, C., & Streeter, C. (2013). Concealment and fabrication by experienced research subjects. *Clinical Trials*, 10(6), 935-948.

Devine, E. G., Knapp, C. M., Sarid-Segal, O., O'Keefe, S. M., Wardell, C., Baskett, M., & Ciraulo, D. A. (2015). Payment expectations for research participation among subjects who tell the truth, subjects who conceal information, and subjects who fabricate information. *Contemporary clinical trials*, 41, 55-61.

Dickert, N. W. (2013). Concealment and fabrication: The hidden price of payment

for research participation?. *Clinical Trials*, 10(6), 840-841.

de Bruijn, A., Tanghe, J., de Leeuw, R., Engels, R., Anderson, P., Beccaria, F., … van Dalen, W. (2016). European longitudinal study on the relationship between adolescents' alcohol marketing exposure and alcohol use. *Addiction*, *111*(10), 1774–1783.

De Houwer, J. (2001). A structural and process analysis of the Implicit Association Test. *Journal of Experimental Social Psychology*, *37*, 443–451.

De Houwer, J., Crombez, G., Baeyens, F., & Hermans, D. (2001). On the generality of the affective Simon effect. *Cognition & Emotion*, *15*(May 2013), 189–206.

den Uyl, T. E., Gladwin, T. E., Rinck, M., Lindenmeyer, J., & Wiers, R. W. (2016). A clinical trial with combined transcranial direct current stimulation and alcohol approach bias retraining. *Addiction Biology*, 1–9.

den Uyl, T. E., Gladwin, T. E., & Wiers, R. W. (2016). Electrophysiological and Behavioral Effects of Combined Transcranial Direct Current Stimulation and Alcohol Approach Bias Retraining in Hazardous Drinkers. *Alcoholism: Clinical and Experimental Research*, *40*(10), 1–10.

Di Lemma, L. C. G., & Field, M. (2017). Cue avoidance training and inhibitory control training for the reduction of alcohol consumption: a comparison of effectiveness and investigation of their mechanisms of action. *Psychopharmacology,* 1-10.

Drummond, D. C., Cooper, T., & Glautier, S. P. (1990). Conditioned learning in alcohol dependence: implications for cue exposure treatment. *British Journal of Addiction*, *85*(6), 725–743.

Eberl, C., Wiers, R. W., Pawelczack, S., Rinck, M., Becker, E. S., & Lindenmeyer, J. (2013). Approach bias modification in alcohol dependence: Do clinical effects replicate and for whom does it work best? *Developmental Cognitive Neuroscience*, *4*, 38–51.

Eberl, C., Wiers, R. W., Pawelczack, S., Rinck, M., Becker, E. S., & Lindenmeyer, J. (2014). Implementation of Approach Bias Re-Training in Alcoholism-How Many Sessions are Needed? *Alcoholism: Clinical and Experimental Research*, *38*(2), 587–594.

Edward, M. (2001). Addiction and the brain: the role of neurotransmitters in the cause and treatment of drug dependence, *164*(6), 817–821.

Ernst, L. H., Ehlis, A. C., Dresler, T., Tupak, S. V., Weidner, A., & Fallgatter, A. J.

(2013). N1 and N2 ERPs reflect the regulation of automatic approach tendencies to positive stimuli. *Neuroscience Research*, *75*(3), 239–249.

Ernst, L. H., Plichta, M. M., Dresler, T., Zesewitz, A. K., Tupak, S. V., Haeussinger, F. B., Ehlis, A. C. (2014). Prefrontal correlates of approach preferences for alcohol stimuli in alcohol dependence. *Addiction Biology,* 19 (3), 497-508.

Ernst, L. H., Weidner, A., Ehlis, A. C., & Fallgatter, A. J. (2012). Controlled attention allocation mediates the relation between goal-oriented pursuit and approach-avoidance reactions to negative stimuli. *Biological Psychology*, *91*(2), 312–320.

Euser, A. S., & Franken, I. H. A. (2012). Alcohol affects the emotional mod ulation of cognitive control: An event-related brain potential study. *Psychopharmacology*, *222*(3), 459–476.

Ferrey, A. E., Frischen, A., & Fenske, M. J. (2012). Hot or not: Response inhibition reduces the hedonic value and motivational incentive of sexual stimuli. *Frontiers in Psychology*, *3*, 1–7.

Field, M., & Cartwright-Hatton, S. (2015). Essential Abnormal and Clinical Psychology. SAGE.

Field, M., & Cox, W. M. (2008). Attentional bias in addictive behaviors : A review of its development, causes, and consequences, *Drug and alcohol dependence, 97*, 1–20.

Field, M., Duka, T., Eastwood, B., Child, R., Santarcangelo, M., & Gayton, M. (2007). Experimental manipulation of attentional biases in heavy drinkers: Do the effects generalise? *Psychopharmacology*, *192*(4), 593–608.

Field, M., Kiernan, A., Eastwood, B., & Child, R. (2008). Rapid approach responses to alcohol cues in heavy drinkers. *Journal of Behavior Therapy and Experimental Psychiatry*, *39*(3), 209–218.

Field, M., Mogg, K., & Bradley, B. P. (2005). Craving and cognitive biases for alcohol cues in social drinkers, *Alcohol and Alcoholism, 40*(6), 504–510.

Field, M., Mogg, K., Zetteler, J., & Bradley, B. P. (2004). Attentional biases for alcohol cues in heavy and light social drinkers: The roles of initial orienting and maintained attention. *Psychopharmacology*, *176*(1), 88–93.

Field, M., Werthmann, J., Franken, I., & Hofmann, W. (2016). The role of attentional bias in obesity and addiction. *Health Psycholog, 35*(8)*,* 767, 1–45.

Fishbach, A., & Shah, J. Y. (2006). Self-control in action: implicit dispositions

toward goals and away from temptations. *Journal of Personality and Social Psychology*, *90*(5), 820–32.

Fleming, K. A., & Bartholow, B. D. (2014). Alcohol Cues , Approach Bias , and Inhibitory Control : Applying a Dual Process Model of Addiction to Alcohol Sensitivity, *Psychology of Addictive Behaviours, 28*(1), 85–96.

Franken, I. H. A. (2003). Drug craving and addiction: Integrating psychological and neuropsychopharmacological approaches. *Progress in Neuro-Psychopharmacology and Biological Psychiatry*, *27*(4), 563–579.

Friese, M., Hofmann, W., & Wiers, R. W. (2011). On taming horses and strengthening riders: Recent developments in research on interventions to improve self-control in health behaviors. *Self and Identity*, *10*(3), 336–351.

Gauggel, S., Heusinger, A., Forkmann, T., Boecker, M., Lindenmeyer, J., Miles Cox, W., & Staedtgen, M. (2010). Effects of Alcohol Cue Exposure on Response Inhibition in Detoxified Alcohol-Dependent Patients. *Alcoholism: Clinical and Experimental Research*, *34*(9), 1584–1589.

Geelkopf, M., Levitt, S., & Bleich, A. (2002). An integration of three approaches to addiction and methadone maintenance treatment: the self-medication hypothesis, the disease model and social criticism. *The Israel journal of psychiatry and related sciences*, 39(2), 140.

Gladwin, T. E., & Figner, B. (2014). "Hot" cognition and dual systems: Introduction, criticism, and ways forward. *Neuroeconomics, judgment, and decision making,*157-180.

Gladwin, T. E., Figner, B., Crone, E. A., & Wiers, R. W. (2011). Addiction, adolescence, and the integration of control and motivation. *Developmental Cognitive Neuroscience*, *1*(4), 364–376.

Gladwin, T. E., Rinck, M., Eberl, C., Becker, E. S., Lindenmeyer, J., & Wiers, R. W. (2015). Mediation of Cognitive Bias Modification for Alcohol Addiction via Stimulus-Specific Alcohol Avoidance Association. *Alcoholism: Clinical and Experimental Research,* 39(1), 101-107.

Gladwin, T. E., Wiers, C. E., & Wiers, R. W. (2016). Cognitive neuroscience of cognitive retraining for addiction medicine: From mediating mechanisms to questions of efficacy. *Progress in brain research,* 224. 323-344.

Gladwin, T. E., Wiers, C. E., & Wiers, R. W. (2017). Interventions aimed at automatic processes in addiction: considering necessary conditions for efficacy.

Current Opinion in Behavioral Sciences, *13*, 19–24.

Goldstein, R. Z., & Volkow, N. D. (2002). Drug addiction and its underlying neurobiological basis: Neuroimaging evidence for the involvement of the frontal cortex. *American Journal of Psychiatry*, *159*(10), 1642–1652.

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. (1998). Measuring individual differences in implicit cognition: the implicit association test. *Journal of Personality and Social Psychology*, *74*(6), 1464–1480.

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and using the Implicit Association Test: I. An improved scoring algorith. *Journal of Personality and Social Psychology*, *85*(2), 197–216.

Guerrieri, R., Nederkoorn, C., & Jansen, A. (2012). Disinhibition is easier learned than inhibition. The effects of (dis)inhibition training on food intake. *Appetite*, *59*(1), 96–99.

Guerrieri, R., Nederkoorn, C., Schrooten, M., Martijn, C., & Jansen, A. (2009). Inducing impulsivity leads high and low restrained eaters into overeating , whereas current dieters stick to their diet, *53*, 93–100.

Guitart-Masip, M., Duzel, E., Dolan, R., & Dayan, P. (2014). Action versus valence in decision making. *Trends in Cognitive Sciences*, *18*(4), 194–202.

Hajcak, G., MacNamara, A., & Olvet, D. M. (2010). Event-Related Potentials, Emotion, and Emotion Regulation: An Integrative Review. *Developmental Neuropsychology*, *35*(2), 129–155.

Health and Social Care Information Centre (June 2016) Statistics on Alcohol, England - 2016 Ref: ISBN 978-1-78386-7417, Available at: http://www.hscic.gov.uk/pubs/alcohol16

Havermans, R. C., Giesen, J. C. A. H., Houben, K., & Jansen, A. (2011). Eating Behaviors Weight , gender , and snack appeal. *Eating Behaviors*, *12*(2), 126–130.

Heim, D., & Monk, R. (2017). Commentary on Thrul *et al* . (2017): A welcome step towards a more context-aware addiction science. *Addiction*, *112*(3), 440–441.

Heuer, K., Rinck, M., & Becker, E. S. (2007). Avoidance of emotional facial expressions in social anxiety: The Approach-Avoidance Task. *Behaviour Research and Therapy*, *45*(12), 2990–3001.

Hofmann, W., Deutsch, R., Lancaster, K., & Banaji, M. R. (2010). Cooling the heat of temptation: Mental self-control and the automatic evaluation of tempting

stimuli. *European Journal of Social Psychology, 40*(1), 17-25.

Hofmann, W., Friese, M., & Roefs, A. (2009). Three ways to resist temptation : The independent contributions of executive attention , inhibitory control , and affect regulation to the impulse control of eating behavior. *Journal of Experimental Social Psychology*, *45*(2), 431–435.

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and Self-Control From a Dual-Systems Perspective. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *4*(2), 162–176.

Hogarth, L., Balleine, B. W., Corbit, L. H., & Killcross, S. (2013). Associative learning mechanisms underpinning the transition from recreational drug use to addiction. *Annals of the New York Academy of Sciences*, *1282*(1), 12–24.

Hogue, A., Dauber, S., & Morgenstern, J. (2010). Validation of a contemplation ladder in an adult substance use disorder sample. *Psychology of Addictive Behaviors : Journal of the Society of Psychologists in Addictive Behaviors*, *24*(1), 137–144.

Hopf, J., Vogel, E., Woodman, G., Heinze, H., Luck, S. J., Heinze, J., & Luck, S. J. (2002). Localizing Visual Discrimination Processes in Time and Space, 2088–2095.

Houben, K., Havermans, R. C., Nederkoorn, C., & Jansen, A. (2012). Beer ? no-go: Learning to stop responding to alcohol cues reduces alcohol intake via reduced affective associations rather than increased response inhibition. *Addiction*, *107*(7), 1280–1287.

Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite,* 56 (2), 345-349.

Houben, K., & Jansen, A. (2015). Chocolate equals stop . Chocolate-specific inhibition training reduces chocolate intake and go associations with chocolate. *Appetite*, *87*, 318–323.

Houben, K., Nederkoorn, C., Wiers, R. W., & Jansen, A. (2011). Resisting temptation: Decreasing alcohol-related affect and drinking behavior by training response inhibition. *Drug and Alcohol Dependence*, *116*(1–3), 132–136.

Houben, K., & Wiers, R. W. (2007a). Are drinkers implicitly positive about drinking alcohol ? personalizing the alcohol-iat to reduce negative extrapersonal contamination, *Alcohol and Alcoholism, 42*(4), 301–307.

Houben, K., & Wiers, R. W. (2007b). Personalizing the alcohol-IAT with

individualized stimuli: Relationship with drinking behavior and drinking-related problems. *Addictive Behaviors*, *32*(12), 2852–2864.

Houben, K., & Wiers, R. W. (2008). Addictive Behaviors Implicitly positive about alcohol ? Implicit positive associations predict drinking behavior, *Addictive behaviours, 33*, 979–986.

Houben, K., & Wiers, R. W. (2009). Response inhibition moderates the relationship between implicit associations and drinking behavior. *Alcoholism: Clinical and Experimental Research*, *33*(4), 626–633.

Inquisit 3.0 [Millisecond Computer software]. (2009). Retrieved from http://www.millisecond.com

Inquisit 4.0 Web [Millisecond Computer software]. (2015). Retrieved from http://www.millisecond.com

Izuma, K., Matsumoto, M., Murayama, K., Samejima, K., Sadato, N., & Matsumoto, K. (2010). Neural correlates of cognitive dissonance and choice-induced preference change. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(51), 22014–9.

Jansen, A., Houben, K., & Roefs, A. (2015). A cognitive profile of obesity and its translation into new interventions. *Frontiers in psychology*, 6, 1807.

Jasinska, A. J., Yasuda, M., Burant, C. F., Gregor, N., Khatri, S., Sweet, M., & Falk, E. B. (2012). Impulsivity and inhibitory control deficits are associated with unhealthy eating in young adults q. *Appetite*, *59*(3), 738–747.

Jentsch, J. D., & Pennington, Z. T. (2014). Reward, interrupted: Inhibitory control and its relevance to addictions. *Neuropharmacology*, *76*, 479–486.

Jones, A., Button, E., Rose, A. K., Robinson, E., Christiansen, P., Di Lemma, L., & Field, M. (2016a). The ad-libitum alcohol "taste test": Secondary analyses of potential confounds and construct validity. *Psychopharmacology*.

Jones, A., Di Lemma, L. C. G., Robinson, E., Christiansen, P., Nolan, S., Tudur-Smith, C., & Field, M. (2016b). Inhibitory control training for appetitive behaviour change: A meta-analytic investigation of mechanisms of action and moderators of effectiveness. *Appetite*, *97*, 16–28.

Jones, A., & Field, M. (2013). The effects of cue-specific inhibition training on alcohol consumption in heavy social drinkers. *Experimental and Clinical*

Psychopharmacology, *21*(1), 8–16.

Jones, A., & Field, M. (2015). Alcohol-related and negatively valenced cues increase motor and oculomotor disinhibition in social drinkers. *Experimental and Cinical Psychopharmacology*, *23*(2), 122–129.

Jones, A., Guerrieri, R., Fernie, G., Cole, J., Goudie, A., & Field, M. (2011). The effects of priming restrained versus disinhibited behaviour on alcohol-seeking in social drinkers. *Drug and Alcohol Dependence*, *113*(1), 55–61.

Jones, A., Hardman, C. A., Lawrence, N., & Field, M. (2017). Cognitive training as a potential treatment for overweight and obesity: A critical review of the evidence. *Appetite*.

Jones, A., Hogarth, L., Christiansen, P., Rose, A. K., Martinovic, J., & Field, M. (2012). Reward expectancy promotes generalized increases in attentional bias for rewarding stimuli. *The Quarterly Journal of Experimental Psychology*, *218*, 1–10.

Kahneman, D. (2011). Thinking, fast and slow. Macmillan.

Kakoschke, N., Kemps, E., & Tiggemann, M. (2015). Physiology & Behavior External eating mediates the relationship between impulsivity and unhealthy food intake. *Physiology & Behavior*, *147*, 117–121.

Kakoschke, N., Kemps, E., & Tiggemann, M. (2017a). Approach bias modification training and consumption: A review of the literature. *Addictive Behaviors*, *64*, 21–28.

Kakoschke, N., Kemps, E., & Tiggemann, M. (2017b). The effect of combined avoidance and control training on implicit food evaluation and choice. *Journal of Behavior Therapy and Experimental Psychiatry*, *55*, 99–105.

Keil, A., Bradley, M. M., Hauk, O., Rockstroh, B., Elbert, T., & Lang P. J. (2002). Large-scale neural correlates of affective picture processing, *Psychophysiology, 39* (5), 641-649.

Kemps, E., & Tiggemann, M. (2016). Approach bias for food cues in obese individuals, *Psychology & Health,* 30(3), 370-380.

Kemps, E., Tiggemann, M., Martin, R., & Elliott, M. (2013). Implicit approach – avoidance associations for craved food cues. *Journal of Experimental Psychology: Applied, 19*(1), 30–38.

Keren, G., & Schul, Y. (2009). Two is not better than one: A critical evaluation of two-system theories, *Perspective on psychological science, 4*(6), 533–551.

Kersbergen, I., Woud, M. L., & Field, M. (2015). The validity of different measures of automatic alcohol action tendencies. *Psychology of Addictive Behaviors : Journal of the Society of Psychologists in Addictive Behaviors*, *29*(1), 225–30.

Kok, A., Ramautar, J. R., De Ruiter, M. B., Band, G. P. H., & Ridderinkhof, K. R. (2004). ERP components associated with successful and unsuccessful stopping in a stop-signal task. *Psychophysiology*, *41*(1), 9–20.

Koob, G. F., & Volkow, N. D. (2010). Neurocircuitry of Addiction. *Neuropsychopharmacology*, *35*(1), 217–238.

Koordeman, R., Anschutz, D. J., & Engels, R. C. M. E. (2011). Exposure to alcohol commercials in movie theaters affects actual alcohol consumption in young adult high weekly drinkers: An experimental study. *American Journal on Addictions*, *20*(3), 285–291.

Koordeman, R., Kuntsche, E., Anschutz, D. J., van Baaren, R. B., & Engels, R. C. M. E. (2011). Do we act upon what we see? Direct effects of alcohol cues in movies on young adults' alcohol drinking. *Alcohol and Alcoholism*, *46*(4), 393–398.

Korucuoglu, O., Gladwin, T. E., & Wiers, R. W. (2014). Preparing to approach or avoid alcohol: EEG correlates, and acute alcohol effects. *Neuroscience Letters*, *559*, 199–204.

Korucuoglu, O., Gladwin, T. E., & Wiers, R. W. (2016). The effect of acute alcohol on motor-related EEG asymmetries during preparation of approach or avoid alcohol responses. *Biological Psychology,* 114, 81-92.

Krajbich, I., & Rangel, A. (2011). Multialternative drift-diffusion model predicts the relationship between visual fixations and choice in value-based decisions. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(33), 13852–7.

Kreusch, F., Quertemont, E., Vilenne, A., & Hansenne, M. (2014). Alcohol abuse and ERP components in Go/No-go tasks using alcohol-related stimuli: Impact of alcohol avoidance. *International Journal of Psychophysiology*, *94*(1), 92–99.

Kreusch, F., Vilenne, A., & Quertemont, E. (2013). Response inhibition toward alcohol-related cues using an alcohol go/no-go task in problem and non-problem drinkers. *Addictive Behaviors*, *38*(10), 2520–2528.

Kypri, K., McCambridge, J., Wilson, a., Attia, J., Sheeran, P., Bowe, S., & Vater, T. (2011). Effects of study design and allocation on participant behaviour-ESDA:

study protocol for a randomized controlled trial, 1–9.

Lapenta, O. M., Sierve, K. Di, de Macedo, E. C., Fregni, F., & Boggio, P. S. (2014). Transcranial direct current stimulation modulates ERP-indexed inhibitory control and reduces food consumption. *Appetite*, *83*, 42–48.

Lawrence, N. S., Hinton, E. C., Parkinson, J. A., & Lawrence, A. D. (2012). Nucleus accumbens response to food cues predicts subsequent snack consumption in women and increased body mass index in those with reduced self-control. *NeuroImage*, *63*(1), 415–422.

Lawrence, N. S., O'Sullivan, J., Parslow, D., Javaid, M., Adams, R. C., Chambers, C. D., Verbruggen, F. (2015a). Training response inhibition to food is associated with weight loss and reduced energy intake. *Appetite*, *95*, 17–28.

Lawrence, N. S., Verbruggen, F., Morrison, S., Adams, R. C., & Chambers, C. D. (2015b). Stopping to food can reduce intake. Effects of stimulus-specificity and individual differences in dietary restraint. *Appetite,* 85: 91-103.

Lehmann, D. (1984). EEG assessment of brain activity: Spatial aspects, segmentation and imaging. *International Journal of Psychophysiology*, *1*(3), 267–276.

Lenartowicz, A., Verbruggen, F., Logan, G. D., & Poldrack, R. a. (2011). Inhibition-related activation in the right inferior frontal gyrus in the absence of inhibitory cues. *Journal of Cognitive Neuroscience*, *23*(11), 3388–99.

Lim, S.-L., O'Doherty, J. P., & Rangel, A. (2011). The decision value computations in the vmPFC and striatum use a relative value code that is guided by visual attention. *The Journal of Neuroscience : The Official Journal of the Society for Neuroscience*, *31*(37), 13214–23.

Littel, M., Euser, A. S., Munafò, M. R., & Franken, I. H. A. (2012). Electrophysiological indices of biased cognitive processing of substance-related cues: A meta-analysis. *Neuroscience and Biobehavioral Reviews*, *36*(8), 1803–1816.

Logan, G. D., & Cowan, W. B. (1984). On the ability to inhibit thought and action: A theory of an act of control. *Psychological Review*, *91*(3), 295–327.

López-Caneda, E., Rodríguez Holguín, S., Cadaveira, F., Corral, M., & Doallo, S. (2014). Impact of alcohol use on inhibitory control (and vice versa) during adolescence and young adulthood: A review. *Alcohol and Alcoholism*, *49*(2), 173–181.

Lowe, M. R., van Steenburgh, J., Ochner, C., & Coletta, M. (2009). Neural correlates of individual differences related to appetite. *Physiology and Behavior*, *97*(5), 561–571.

Luck, S. J., & Kappenman, E. S. (Eds.). (2011). The Oxford handbook of event-related potential components. Oxford university press.

MacLeod, C., Mathews, A. M., & Tata, P. (1986). Attentional bias in emotional disorders. *Journal of Abnormal Psychology*, *95*, 15–20.

Macnamara, A., Foti, D., & Hajcak, G. (2009). Tell me about it : neural activity elicited by emotional pictures and preceding descriptions. *Emotion, 9*(4), 531–543.

Macy, J. T., Chassin, L., Presson, C. C., & Sherman, J. W. (2014). Changing implicit attitudes toward smoking: results from a web-based approach-avoidance practice intervention. *Journal of Behavioral Medicine*, *38*(1), 143–152.

Manning, V., Staiger, P., Hall, K., Garfield, J., Flaks, G., Leung, D., … Verdejo-García, A. (2016). Cognitive Bias Modification Training During Inpatient Alcohol Detoxification Reduces Early Relapse: A Randomized Controlled Trial. *Alcoholism: Clinical & Experimental Research*, *In press*, 1–9.

McCambridge, J., de Bruin, M., & Witton, J. (2012). The effects of demand characteristics on research participant behaviours in non-laboratory settings: A systematic review. *PLoS ONE*, *7*(6), 1–6.

McCann, D. J., Petry, N. M., Bresell, A., Isacsson, E., Wilson, E., & Alexander, R. C. (2015). Medication Nonadherence," Professional Subjects," and Apparent Placebo Responders: Overlapping Challenges for Medications Development. *Journal of clinical psychopharmacology*, 35(5), 566-573.

Mcclure, S. M., & Bickel, W. K. (2014). A dual-systems perspective on addiction: Contributions from neuroimaging and cognitive training. *Annals of the New York Academy of Sciences*, *1327*(1), 62–78.

Melson, A. J., Monk, R. L., & Heim, D. (2016). Self–Other Differences in Student Drinking Norms Research: The Role of Impression Management, Self-Deception, and Measurement Methodology. *Alcoholism: Clinical and Experimental Research*, *40*(12), 2639–2647.

Miller, W. R. (1996). Motivational interviewing: research, practice, and puzzles. *Addictive Behaviors*, *21*(6), 835–842.

Monk, R. L., & Heim, D. (2014). A real-time examination of context effects on

alcohol cognitions. *Alcoholism: Clinical and Experimental Research*, *38*(9), 2454–2459.

Monk, R. L., Pennington, C. R., Campbell, C., Price, A., & Heim, D. (2016). Implicit Alcohol-Related Expectancies and the Effect of Context. *Journal of Studies on Alcohol and Drugs*.

Monk, R. L., Sunley, J., Qureshi, A. W., & Heim, D. (2016). Smells like inhibition: The effects of olfactory and visual alcohol cues on inhibitory control. *Psychopharmacology*, *233*(8), 1331–1337.

Nederkoorn, C., Braet, C., Van Eijs, Y., Tanghe, A., & Jansen, A. (2006). Why obese children cannot resist food: The role of impulsivity. *Eating Behaviors*, *7*(4), 315–322.

Nederkoorn, C., Coelho, J. S., Guerrieri, R., Houben, K., & Jansen, A. (2012). Specificity of the failure to inhibit responses in overweight children. *Appetite*, *59*(2), 409–413.

Nederkoorn, C., Dassen, F. C. M., Franken, L., Resch, C., & Houben, K. (2015). Impulsivity and overeating in children in the absence and presence of hunger. *Appetite*, *93*, 57–61.

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2008). Food cue-elicited brain potentials in obese and healthy-weight individuals. *Eating Behaviors*, *9*(4), 462–470.

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2009). Enhanced processing of food-related pictures in female external eaters. *Appetite*, *53*(3), 376–383.

Noël, X., Brevers, D., Hanak, C., Kornreich, C., Verbanck, P., & Verbruggen, F. (2016). On the automaticity of response inhibition in individuals with alcoholism. *Journal of Behavior Therapy and Experimental Psychiatry*, *51*, 84–91.

Oddy, B. W., & Barry, R. J. (2009). The relationship of N2 and P3 to inhibitory processing of social drinkers in a Go/NoGo task. *International Journal of Psychophysiology*, *72*(3), 323–330.

Parvaz, M. A., Alia-Klein, N., Woicik, A. P., Volkow, N. D., Goldstein, R. Z. (2012). Neuroimaging for drug addiction and related behaviors. NIH Public Access. *Rev Neurosci*, *22*(6), 609–624.

Patel, S. H., & Azzam, P. N. (2005). Characterization of N200 and P300: Selected studies of the Event-Related Potential. *International Journal of Medical*

Sciences, *2*(4), 147–154.

Patterson, C. M., Kosson, D. S., & Newman, J. P. (1987). Reaction to punishment, reflectivity, and passive avoidance learning in extraverts. *Journal of Personality and Social Psychology*, *52*(3), 565–575.

Pennington, C. R., Qureshi, A., Monk, R. L., & Heim, D. (2016). The effects of stereotype threat and contextual cues on alcohol users' inhibitory control. *Addictive Behaviors*, *54*, 12–17.

Petit, G., Cimochowska, A., Kornreich, C., Hanak, C., Verbanck, P., & Campanella, S. (2014). Neurophysiological correlates of response inhibition predict relapse in detoxified alcoholic patients: Some preliminary evidence from event-related potentials. *Neuropsychiatric Disease and Treatment*, *10*, 1025–1037.

Petit, G., Kornreich, C., Noël, X., Verbanck, P., & Campanella, S. (2012). Alcohol-related context modulates performance of social drinkers in a visual go/no-go task: A preliminary assessment of event-related potentials. *PLoS ONE*, *7*(5), 1–11.

Petit, G., Maurage, P., Kornreich, C., Verbanck, P., & Campanella, S. (2014). Binge drinking in adolescents: A review of neurophysiological and neuroimaging research. *Alcohol and Alcoholism*, *49*(2), 198–206.

Piqueras-Fiszman, B., Kraus, A. A., & Spence, C. (2014). "Yummy" versus "Yucky"! Explicit and implicit approach-avoidance motivations towards appealing and disgusting foods. *Appetite,* 78, 193-202.

Prochaska, J. O., DiClemente, C. C., & Norcross, J. C. (1993). In Search of How People Change: Applications to Addictive Behaviors. *Journal of Addictions Nursing*, *5*(1), 2–16.

Robinson, T. E., & Berridge, K. C. (1993). The neural basis of drug craving: An incentive-sensitization theory of addiction. *Brain Research Reviews*, *18*(3), 247–291.

Roefs, A., Macleod, C. M., Jong, P. J. De, & Jansen, A. T. M. (2011). Implicit Measures of Association in Psychopathology Research, *137*(1), 149–193.

Rollnick, S., Heather, N., Gold, R., & Hall, W. (1992). Development of a short "readiness to change" questionnaire for use in brief, opportunistic interventions among excessive drinkers. *British Journal of Addiction*, *87*(5), 743–754.

Rooke, S. E., Hine, D. W., & Thorsteinsson, E. B. (2008). Implicit cognition and substance use : A meta-analysis. *Addictive Behaviors, 33*(10), 1314–1328.

Ruchsow, M., Groen, G., Kiefer, M., Beschoner, P., Hermle, L., Ebert, D., & Falkenstein, M. (2008). Electrophysiological evidence for reduced inhibitory control in depressed patients in partial remission: A Go/Nogo study. *International Journal of Psychophysiology*, *68*(3), 209–218.

Saunders, J. B., & Babor, T. F. (1993). AUDIT questionnaire : screen for. *Addiction*, *88*(791–803), 1–2.

Schacht, J. P., Anton, R. F., & Myrick, H. (2013). Functional neuroimaging studies of alcohol cue reactivity: A quantitative meta-analysis and systematic review. *Addiction Biology*, *18*(1), 121–133.

Schag, K., Schonleber, J., Teufel, M., Zipfel, S., & Giel, K. E. (2013). Food-related impulsivity in obesity and Binge Eating Disorder - a systematic review. *Obesity Reviews*, *14*(6), 477–495.

Scherg, M., & Berg, P. (1990). BESA—Brain electric source analysis handbook. Munich: Max-Planck Institute for Psychiatry.

Schonberg, T., Bakkour, A., Hover, A. M., Mumford, J. A., Nagar, L., Perez, J., & Poldrack, R. A. (2014). Changing value through cued approach : an automatic mechanism of behavior change, *Nature neuroscience*, *17*(4), 625-630.

Schumacher, S. E., Kemps, E., & Tiggemann, M. (2016). Bias modi fi cation training can alter approach bias and chocolate consumption. *Appetite*, *96*, 219–224.

Seibt, B., Häfner, M., & Deutsch, R. (2007). Prepared to eat: How immediate affective and motivational responses to food cues are influenced by food deprivation. *European Journal of Social Psychology*, *37*(2), 359–379.

Sharbanee, J. M., Hu, L., Stritzke, W. G. K., Wiers, R. W., Rinck, M., & MacLeod, C. (2014). The effect of approach/avoidance training on alcohol consumption is mediated by change in alcohol action tendency. *PLoS ONE*, *9*(1).

Sharot, T., De Martino, B., & Dolan, R. J. (2009). How Choice Reveals and Shapes Expected Hedonic Outcome. *Journal of Neuroscience*, *29*(12), 3760–3765.

Siegel, M., Ayers, A. J., DeJong, W., Naimi, T. S., & Jernigan, D. H. (2015). Differences in alcohol brand consumption among underage youth by age, gender, and race/ethnicity—United States, 2012. *Journal of Substance Use*, *20*(6), 430–438.

Siegel, M., Ross, C. S., Albers, A. B., DeJong, W., King Iii, C., Naimi, T. S., & Jernigan, D. H. (2016). The relationship between exposure to brand-specific

alcohol advertising and brand-specific consumption among underage drinkers - United States, 2011-2012. *The American Journal of Drug and Alcohol Abuse*, *42*(1), 4–14.

Smith, A., & Foxcroft, R. (2009). The effect of alcohol advertising, marketing and portrayal on drinking behaviour in young people: systematic review of prospective cohort studies. *BMC Public Health*, *9*, 51.

Smith, E., Hay, P., Campbell, L., & Trollor, J. N. (2011). A review of the association between obesity and cognitive function across the lifespan: implications for novel approaches to prevention and treatment. *Obesity reviews, 12*(9), 740–755.

Smith, J. L., Mattick, R. P., Jamadar, S. D., & Iredale, J. M. (2014). Deficits in behavioural inhibition in substance abuse and addiction: A meta-analysis. *Drug and Alcohol Dependence*, *145*, 1–33.

Sobell, L., & Sobell, M. (1992). Timeline follow-back: A technique for assessing self-reported alcohol consumption. In J. Allen & R. Z. Litten (Eds.), *Measuring Alcohol Consumption Psychosocial and Biochemical Methods*, Humana Press, 41-72.

Spierer, L., Chavan, C. F., & Manuel, A. L. (2013). Training-induced behavioral and brain plasticity in inhibitory control. *Frontiers in Human Neuroscience*, *7*, 427.

Stacy, A. W., & Wiers, R. W. (2010). Implicit Cognition and Addiction: A Tool for Explaining Paradoxical Behavior. *Annual Review of Clinical Psychology*, *6*(1), 551–575.

Stautz, K., Brown, K. G., King, S. E., Shemilt, I., Marteau, T. M., Murphy, A., … Kaplan, D. (2016). Immediate effects of alcohol marketing communications and media portrayals on consumption and cognition: a systematic review and meta-analysis of experimental studies. *BMC Public Health*, *16*(1), 465.

Stautz, K., Frings, D., Albery, I. P., Moss, A. C., & Marteau, T. M. (2017). Impact of alcohol-promoting and alcohol-warning advertisements on alcohol consumption, affect, and implicit cognition in heavy-drinking young adults: A laboratory-based randomized controlled trial. *British journal of health psychology, 22*(1), 128-150.

Stice, E., Lawrence, N., Kemps, E., & Veling, H. (2016). Training motor responses to food: A novel treatment for obesity targeting implicit processes. *Clinical Psychology Review,* 49, 16-27.

Strien, T. Van, & Frijters, JER, Bergers G. & Deafares P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating disorders*, *5*(2), 295–315.

Svaldi, J., Naumann, E., Trentowska, M., & Schmitz, F.. (2014). General and Food-Specific Inhibitory Deficits in Binge Eating Disorder. *International Journal of Eating Disorders*, 47(5), 534-542.

Tapper, K., & Pothos, E. M. (2010). Development and validation of a Food Preoccupation Questionnaire. *Eating Behaviors*, *11*(1), 45–53.

Tecce, J. J. (1972). Contingent negative variation (CNV) and psychological processes in man. *Psychological Bulletin*, *77*(2), 73–108.

Thanos, P. K., Volkow, N. D., Freimuth, P., Umegaki, H., Ikari, H., Roth, G., … Hitzemann, R. (2001). Overexpression of dopamine D2 receptors reduces alcohol self-administration. *Journal of Neurochemistry*, *78*(5), 1094–1103.

Thomas, S. E., Drobes, D. J., & Deas, D. (2005). Alcohol cue reactivity in alcohol-dependent adolescents. *Journal of Studies on Alcohol, 66*(3), 354-360.

Tibboel, H., De Houwer, J., Spruyt, A., Field, M., Kemps, E., & Crombez, G. (2011). Testing the validity of implicit measures of wanting and liking. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(3), 284–292.

Tiffany, S. T. (1990). A cognitive model of drug urges and drug-use behavior: role of automatic and non automatic processes. *Psychological review*, 97(2), 147.

Van Dessel, P., De Houwer, J., & Gast, A. (2016). Approach–Avoidance Training Effects Are Moderated by Awareness of Stimulus–Action Contingencies. *Personality and Social Psychology Bulletin*, *42*(1), 81–93.

Van Dessel, P., De Houwer, J., Gast, A., & Smith, C. T. (2015). Instruction-based approach-avoidance effects: Changing stimulus evaluation via the mere instruction to approach or avoid stimuli. *Experimental Psychology*, *62*(3), 161–169.

Van Dessel, P., De Houwer, J., Gast, A., Smith, C. T., & De Schryver, M. (2016). Instructing implicit processes: When instructions to approach or avoid influence implicit but not explicit evaluation. *Journal of Experimental Social Psychology*, *63*, 1–9.

Van Dessel, P., De Houwer, J., & Gast, A. (2016). Approach-avoidance instructions and training as a method for changing implicit evaluations. Doctoral

dissertation, Ghent University.

Van Peer, J. M., Roelofs, K., Rotteveel, M., van Dijk, J. G., Spinhoven, P., & Ridderinkhof, K. R. (2007). The effects of cortisol administration on approach-avoidance behavior: An event-related potential study. *Biological Psychology*, *76*(3), 135–146.

Veenstra, E. M., & de Jong, P. J. (2010). Restrained eaters show enhanced automatic approach tendencies towards food. *Appetite,* 55(1): 30-36.

Veling, H., Aarts, H., & Papies, E. K. (2011). Behaviour Research and Therapy Using stop signals to inhibit chronic dieters ' responses toward palatable foods. *Behaviour Research and Therapy*, *49*(11), 771–780.

Veling, H., Aarts, H., & Stroebe, W. (2013a). Stop signals decrease choices for palatable foods through decreased food evaluation. *Frontiers in Psychology*.4, 1-7.

Veling, H., Aarts, H., & Stroebe, W. (2013b). Using stop signals to reduce impulsive choices for palatable unhealthy foods. *British journal of health psychology,* 18(2): 354–368.

Veling, H., Chen, Z., Tombrock, M. C., Verpaalen, I. A. M., Schmitz, L. I., Dijksterhuis, A., & Holland, R. W. (2017a). Training Impulsive Choices for Healthy and Sustainable Food. *Journal of Experimental Psychology: Applied*, *23*(1), 1–14.

Veling, H., Holland, R. W., & van Knippenberg, A. (2008). When approach motivation and behavioral inhibition collide: Behavior regulation through stimulus devaluation. *Journal of Experimental Social Psychology*, *44*(4), 1013–1019.

Veling, H., Lawrence, N. S., Chen, Z., van Koningsbruggen, G. M., & Holland, R. W. (2017b). What Is Trained During Food Go/No-Go Training? A Review Focusing on Mechanisms and a Research Agenda. *Current Addiction Reports,* 4(1): 35-41.

Veling, H., van Koningsbruggen, G. M., Aarts, H., & Stroebe, W. (2014). Targeting impulsive processes of eating behavior via the internet. Effects on body weight. *Appetite*, 78, 102-109.

Veltkamp, M., Aarts, H., & Custers, R. (2008). On the emergence of deprivation-reducing behaviors: Subliminal priming of behavior representations turns deprivation into motivation. *Journal of Experimental Social Psychology*, *44*(3),

866–873.

Verbruggen, F., & Logan, G. D. (2008a). Automatic and Controlled Response Inhibition : Associative Learning in the Go / No-Go and Stop-Signal Paradigms. *Journal of Experimental Psychology: General*, *137*(4), 649–672.

Verbruggen, F., & Logan, G. D. (2008b). Response inhibition in the stop-signal paradigm. *Trends in Cognitive Sciences*, *12*(11), 418-424.

Verbruggen, F., & Logan, G. D. (2009). Automaticity of Cognitive Control : Goal Priming in Response-Inhibition Paradigms. *Joural of Experimental Psychology, Memory, and Cognition 35*(5), 1381–1388.

Verbruggen, F., McLaren, I. P. L., & Chambers, C. D. (2014). Banishing the Control Homunculi in Studies of Action Control and Behavior Change. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *9*(5), 497–524.

Verdejo-Garcia, A. (2016). Cognitive training for substance use disorders: Neuroscientific mechanisms. *Neuroscience and Biobehavioral Reviews*, *68*, 270–281.

Version, M. A. T. L. A. B. (2002). The MathWorks Inc. Natick, Mass, USA.

Volkow, N. D., Wang, G.-J., Fowler, J. S., & Telang, F. (2008). Overlapping neuronal circuits in addiction and obesity: evidence of systems pathology. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *363*(1507), 3191–200.

Walter, W. G., Cooper, R., Aldridge, V. J., McCallum, W. C., Winter, & A. L. (1964). Contingent Negative Variation : An Electric Sign of Sensori-Motor Association and Expectancy in the Human Brain. *Nature*, *203*(4943), 380–384.

Wang, G. J., Volkow, N. D., Telang, F., Jayne, M., Ma, J., Rao, M., … Fowler, J. S. (2004). Exposure to appetitive food stimuli markedly activates the human brain. *NeuroImage*, *21*(4), 1790–1797.

Wardle, J. (1987). Eating style: A validation study of the Dutch eating behaviour questionnaire in normal subjects and women with eating disorders. *Journal of Psychosomatic Research*, *31*(2), 161–169.

Watson, P., de Wit, S., Hommel, B., & Wiers, R. W. (2012). Motivational mechanisms and outcome expectancies underlying the approach bias toward addictive substances. *Frontiers in Psychology*, *3*, 1–12.

Watson, T. D., & Garvey, K. T. (2013). Neurocognitive correlates of processing

food-related stimuli in a Go/No-go paradigm. *Appetite*, *71*, 40–47.

Werthmann, J., Field, M., Roefs, A., Nederkoorn, C., & Jansen, A. (2014). Journal of Behavior Therapy and Attention bias for chocolate increases chocolate consumption e An attention bias modi fi cation study. *Journal of Behavior Therapy and Experimental Psychiatry*, *45*(1), 136–143.

Wessel, J. R., Doherty, J. P. O., Berkebile, M. M., Linderman, D., & Aron, A. R. (2014). Stimulus Devaluation Induced by Stopping Action, *143*(6), 2316–2329.

West, R., & Hardy, A. (2006). Theory of Addiction. *Alcohol and Alcoholism,* Oxford press (Vol. 42).

Wiers, C. E., Gladwin, T. E., Ludwig, V. U., Gröpper, S., Stuke, H., Gawron, C. K., Bermpohl, F. (2017). Comparing three cognitive biases for alcohol cues in alcohol dependence. *Alcohol and Alcoholism*, *52*(2), 242–248.

Wiers, C. E., Këhn, S., Javadi, A. H., Korucuoglu, O., Wiers, R. W., Walter, H., Bermpohl, F. (2013). Automatic approach bias towards smoking cues is present in smokers but not in ex-smokers. *Psychopharmacology*, *229*(1), 187–197.

Wiers, C. E., Ludwig, V. U., Gladwin, T. E., Park, S. Q., Heinz, A., Wiers, R. W., Bermpohl, F. (2015). Effects of cognitive bias modification training on neural signatures of alcohol approach tendencies in male alcohol-dependent patients. *Addiction Biology,* 20(5), 990-999.

Wiers, C. E., Stelzel, C., Gladwin, T. E., Park, S. Q., Pawelczack, S., Gawron, C. K., Bermpohl, F. (2015). Effects of cognitivebias modification training on neural alcohol cue reactivity in alcohol dependence. *American Journal of Psychiatry,* 172(4), 335-343.

Wiers, C. E., Stelzel, C., Park, S. Q., Gawron, C. K., Ludwig, V. U., Gutwinski, S., Bermpohl, F. (2014). Neural correlates of alcohol-approach bias in alcohol addiction: the spirit is willing but the flesh is weak for spirits. *Neuropsychopharmacology : Official Publication of the American College of Neuropsychopharmacology*, *39*(3), 688–97.

Wiers, C. E., & Wiers, R. W. (2016). Imaging the neural effects of cognitive bias modification training. *NeuroImage,* 151: 81-91.

Wiers, R. W., Bartholow, B. D., van den Wildenberg, E., Thush, C., Engels, R. C. M. E., Sher, K. J., Stacy, A. W. (2007). Automatic and controlled processes and the development of addictive behaviors in adolescents: A review and a model. *Pharmacology Biochemistry and Behavior*, *86*(2), 263–283.

Wiers, R. W., Eberl, C., Rinck, M., Becker, E. S., & Lindenmeyer, J. (2011). Retraining automatic action tendencies changes alcoholic patients' approach bias for alcohol and improves treatment outcome. *Psychological Science,* 22 (4), 490-497.

Wiers, R. W., Gladwin, T. E., Hofmann, W., Salemink, E., & Ridderinkhof, K. R. (2013). Cognitive Bias Modification and Cognitive Control Training in Addiction and Related Psychopathology: Mechanisms, Clinical Perspectives, and Ways Forward. *Clinical Psychological Science*, *1*, 192–212.

Wiers, R. W., Rinck, M., Dictus, M., & Van Den Wildenberg, E. (2009). Relatively strong automatic appetitive action-tendencies in male carriers of the OPRM1 G-allele. *Genes, Brain and Behavior*, *8*(1), 101–106.

Wiers, R. W., Rinck, M., Kordts, R., Houben, K., & Strack, F. (2010). Retraining automatic action-tendencies to approach, *Addiction*, *105*(2), 279–287.

Williams, J. M., Mathews, a, & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, *120*(1), 3–24.

Wilson, S. J., Sayette, M. A., & Fiez, J. A. (2004). Prefrontal responses to drug cues: a neurocognitive analysis. *Nature Neuroscience*, *7*(3), 211–214.

Witteman, J., Post, H., Tarvainen, M., De Bruijn, A., Perna, E. D. S. F., Ramaekers, J. G., & Wiers, R. W. (2015). Cue reactivity and its relation to craving and relapse in alcohol dependence: A combined laboratory and field study. *Psychopharmacology, 232*(20), 3685-3696.

Woud, M. L., Becker, E. S., Lange, W.-G., & Rinck, M. (2013a). Effects of approach-avoidance training on implicit and explicit evaluations of neutral, angry, and smiling face stimuli. *Psychological Reports*, *113*(1), 199–216.

Woud, M. L., Maas, J., Becker, E. S., & Rinck, M. (2013b). Make the manikin move: Symbolic approach-avoidance responses affect implicit and explicit face evaluations. *Journal of Cognitive Psychology*, *25*(6), 738–744.

Zilverstand, A., Parvaz, M. A., Moeller, S. J., & Goldstein, R. Z. (2016). Cognitive interventions for addiction medicine: Understanding the underlying neurobiological mechanisms. *Progress in Brain Research, 224*, 285-304.

Appendix A

Supplementary materials to study 2.1

A.1 Introduction

I report a detailed description of the implicit association test (IAT). I also report findings related to a number of secondary hypotheses that were not covered in the primary manuscript. In particular, I investigated (a) whether effects of CAT and ICT on alcohol-approach and alcohol-inhibition associations would generalize to novel stimuli that were not used during training blocks (see Wiers et al., 2010); (b) if participants' awareness of the purpose of CAT or ICT, or their awareness of the experimental hypotheses, would moderate the effects of CAT or ICT on alcohol consumption during the taste test (see Field et al., 2007); (c) if post-training performance on any of the cognitive tasks was associated with individual differences in beer or soda consumption during the taste test; and (d) if any of the analyses reported in the main manuscript were moderated by participant sex. I also report participants' accuracy on the tasks during training and test blocks.

A.2 Methods

Description of the Bipolar Alcohol Valence IAT

Participants were instructed to classify stimuli into two target categories (alcohol or stationery pictures, 10 pictures each) and two attribute categories (positive or negative words, 6 each), by responding on one of two different response keys (left and right) as quickly as possible. The modified version used in the present study was adapted from Houben et al. (2012), the only differences regarded the use of different neutral stimuli (instead of empty glasses I adopted photographs of stationery items), and I included 10 (rather than 6) alcohol and stationery pictures in

order to match the number of pictures used in the assessment blocks of the two CBM interventions. The attribute words were the same as those used in the earlier study.

The underlying idea is that the simultaneous classification of targets and attributes is easier and faster when the target and the attribute are strongly associated. If a participant is faster to respond when alcohol pictures and positive words share a response key compared to when alcohol pictures and negative words share a response key, this indicates that alcohol-positive associations are stronger than alcohol-negative associations for that participant.

The IAT comprised seven blocks. In the first two blocks (practice blocks, 24 trials each) participants were asked to practice the target (alcohol vs. stationery) categorization and then the attribute (pleasant vs. unpleasant words) categorization using two response keys (left and right). The third block (also 24 trials) was a practice combination block in which participants pressed one key for one target category or one attribute category (e.g. alcohol pictures or positive words), and a different key for the other target or attribute category (e.g. stationery pictures or negative words). The fourth block (48 trials) was the test combination block in which participants continued to categorize the pictures and words using the same keys as in block 3. Block 5 (48 trials) was another practice categorisation block, with the key difference that the mapping of response keys to alcohol and neutral stimuli was reversed from that applied during block 1. Block 6 (24 trials) was a reversed practice combination block in which participants practiced the opposite combination of target and attribute categories present in block four (e.g. responding on one key for alcohol or unpleasant words and a different key for neutral or pleasant words). Finally, block 7 tested the combination they just practiced (reversed test block, 48 trials). Response key assignment and the order of the combined sorting conditions (in blocks 3, 4, 6 and 7) were counterbalanced across participants.

IAT effects were calculated with the d measure (Greenwald et al., 2003). Response latencies less than 300ms or more than 10000ms were discarded. Error latencies were replaced by the block mean + 2 standard deviations. Mean RTs were calculated separately for both sub-blocks of the combination task (block 3 and 6 and block 4 and 7). The d measure was then calculated as the standardized difference between these two RTs divided by the standard deviation of RTs in both blocks. A stronger positive d score indicates stronger associations between alcohol cues and positive valence.

CAT and ICT generalization effects: Trained versus novel picture sets

In order to test if effects of CAT and ICT would generalize from the specific stimuli used during training to novel alcohol-related stimuli (that were not used during training), the pre-test and post-test assessment blocks contained 10 additional pairs of alcohol-related and control stimuli that were not used during the training block. To investigate generalization effects, I repeated the analysis of reaction time data (as reported in the manuscript), but with an additional within-subjects factor of picture set (trained vs. novel).

Participants' awareness of the study aims and hypotheses

I probed participants' awareness of the intended purpose of CAT and ICT and of the taste test, in addition to their awareness of the overall aims of the study. To achieve this I used a combination of open-ended and multiple choice questions based on those used in previous research (Field et al., 2007; Jones & Field, 2013). First, participants provided a written response to an open-ended question 'What was the general purpose of the experiment'? The second question was a multiple choice question which assessed participants' awareness of the intended purpose of the CAT or ICT training. The question was phrased as 'The computer task where you had to respond by… moving the joystick (CAT groups only)… (or) pressing the space bar to letters p or f (ICT groups only)…, was designed to…..'? There were five response options: a. Train me to think more quickly; b. Measure how quickly I can categorise things; c. Measure my ability to control myself when I think of alcohol; d. Teach me to control myself when I think of alcohol; e. I do not know what this task was measuring. The final question assessed participants' awareness of the purpose of the bogus taste test, and was worded: 'The purpose of the Taste-Test was to….': There were five response options: a. Measure my liking for each drink; b. Measure how much I wanted to drink alcohol (participants who selected this option were classed as aware of the purpose of the taste test); c. Measure my thirst; d. Find out which drink I preferred; e. I do not know the purpose of this task).

A.3 Results

Do effects of CBM generalize to pictures that were not used during the training block?

Effects of CAT on trained vs. novel pictures (Table A.1a)

Reaction times were subjected to a 2 × 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Time (2: pre-test, post-test), Picture type (2: alcohol, control), Movement (2: approach, avoidance), Picture Set (2: trained pictures, novel pictures) and a between-subject factor of Condition (2: active training, sham training). To avoid duplication with the primary results section, only significant main effects or interactions that involve Picture Set are reported here.

There was a significant main effect of Picture Set ($F(1, 58) = 23.20$, $p < .01$), a significant Time × Picture Set interaction ($F(1, 58) = 4.35$, $p = .04$), and a Time × Movement × Picture Set × Condition ($F(1, 58) = 3.83$, $p = .05$) interaction. These main effects and interactions reflect the observation that participants were generally faster to respond to trained pictures rather than novel pictures, and this difference was particularly noticeable (1) at post-test, compared to pre-test, (2) for approach movements rather than avoidance movements, and (3) both of these differences were slightly more pronounced in the active training group compared to the sham training group. Details of these post-hoc tests are available on request. Importantly, the five-way interaction Time × Movement × Picture Set × Picture Type × Condition interaction was not statistically significant ($F(1, 58 = .63$, $p = .43$). This demonstrates that, although there were noticeable differences between reaction times to trained and novel pictures, this pattern did not differ for alcohol and control pictures by experimental group and therefore the effects of CAT on reaction times to alcohol and control pictures (as reported in the main manuscript) were not different for stimuli that were used during training, or novel stimuli.

Table A.1a. Reaction times (milliseconds) to approach and avoid alcohol and control pictures during the approach-avoidance task (AAT). Values are shown separately for active training and sham training groups, and at pre-test (before cue avoidance training) and post-test (after cue avoidance training), respectively for trained and untrained picture sets. Values are mean ± SD.

	Active Training	**Sham Control**
Pre-test		
Approach Alcohol Trained	*739.49 (126.64)*	*745.26 (137.59)*
Avoid Alcohol Trained	*803.62 (155.96)*	*754.27 (118.53)*
Approach Alcohol Novel	*775.32 (171.80)*	*741.54 (128.32)*
Avoid Alcohol Novel	*793.58 (173.44)*	*773.88 (125.15)*
Approach Control Trained	*758.60 (161.68)*	*768.29 (143. 59)*
Avoid Control Trained	*794.49 (177.56)*	*768.70 (134.28)*
Approach Control Novel	*784.86 (190.52)*	*770.63 (153.19)*
Avoid Control Novel	*784.20 (163.01)*	*774.17 (142.46)*
Post-test		
Approach Alcohol Trained	*743.46 (145.59)*	*733.36 (165. 36)*
Avoid Alcohol Trained	*752.12 (142.25)*	*786.50 (180.77)*
Approach Alcohol Novel	*773.81 (160.94)*	*762.87 (138.61)*
Avoid Alcohol Novel	*783.53 (147.25)*	*808.67 (196.06)*
Approach Control Trained	*728.10 (129.10)*	*748.86 (174.65)*
Avoid Control Trained	*772.37 (166.16)*	*772.35 (176.58)*
Approach Control Novel	*770.07 (149.43)*	*780.76 (188.98)*
Avoid Control Novel	*795.29 (163.78)*	*792.35 (190.40)*

Effects of ICT on trained vs. novel pictures (Table A.1b)

Reaction times on Go trials were analysed with a 2 × 2 × 2 × 2 mixed design ANOVA, with within-subject factors of Time (2: pre-test, post-test), Picture type (2: alcohol, control), Picture set (2: trained pictures, novel pictures) and a between-subjects factor of Condition (2: active training, sham training). To avoid duplication with the primary results section, only main effects or interactions that involve Picture Set are reported here.

The main effect of Picture Set was statistically significant, ($F(1, 58) = 4.02$, $p = .05$) and it was subsumed under interactions between Time × Picture set ($F(1, 58) = 5.57$, $p = .02$) and Time × Picture type × Picture Set ($F(1, 58) = 4.66$, $p = .04$) were significant. These main effects and interactions arose because participants were generally faster to respond to trained pictures rather than novel pictures, a difference that was particularly evident (1) at post-test compared to pre-test; (2) for alcohol pictures compared to control pictures, and (3) for participants in the active training group compared to participants in the sham training group. Details of these post-hoc tests are available on request. Importantly, there were no other significant main effects or interactions involving Picture Set (Picture Type × Picture Set × Condition, $F(1, 58) = .18$, $p = .68$; Picture Type × Picture Set × Condition × Time, ($F(1, 58) = .37$, $p = .54$).

In response to a helpful suggestion from an anonymous reviewer that participants may rapidly habituate to No-Go paired stimuli during test blocks, and this effect may have been obscured by the incorporation of novel stimuli, I performed an additional analysis to investigate reaction times on Go trials, but I limited this analysis to trained stimuli during the first half of trials in the pre- and post-test blocks. These reaction times were analysed with a 2 × 2 × 2 ANOVA, with within-subject factors of Time (2: pre-test, post-test), Picture type (2: alcohol, control) and a between-subjects factor of Condition (2: active training, sham training). The three-way interaction was not statistically significant ($F(1,58) = 1.31$, $p = .26$) and there were no other significant main effects or interactions ($F < 1.86$, $p > .18$). These analyses demonstrate that, although there were noticeable differences between reaction times to trained and novel pictures, this pattern did not differ for alcohol and control pictures by experimental group, and this was also the case when analysis was restricted to the first half of trials in each test block.

Table A.1b. Reaction times (milliseconds) on 'Go' trials with alcohol and control pictures during the Go / No-Go (GNG) task. Values are shown separately for active training and sham training groups, and at pre-test (before inhibitory control training) and post-test (after inhibitory control training), respectively for trained and untrained picture sets. Values are mean ± SD.

	Active Training	**Sham Control**
Pre-test		
Alcohol Trained	*515.99 (55.27)*	*497.95 (50.91)*
Control Trained	*520.43 (53.70)*	*498.98 (50.16)*
Alcohol Novel	*525.15 (61. 95)*	*502.16 (52.81)*
Control Novel	*514.71 (55.40)*	*490.35 (53.78)*
Post-test		
Alcohol Trained	*521.24 (62.17)*	*469.35 (50.66)*
Control Trained	*505.29 (52.59)*	*488.89 (56.39)*
Alcohol Novel	*522.25 (68.48)*	*509.17 (53.97)*
Control Novel	*515.33 (61.26)*	*502.75 (55.06)*

Participants' awareness of the study aims and hypotheses (Table A.2)

The first question in the funnelled debriefing required participants to identify what they thought was the main aim of the study. Their responses revealed that the vast majority of participants (116; 97 %) were unaware of the aims and hypotheses. Answers to this open-ended question were varied, but recurring themes were advertising, individual differences in liking of tastes of different drinks, and how individual differences in alcohol consumption may influence cognitive performance.

Participants' responses to the next (multiple choice) question are shown in Table A.2. It is evident that the majority of participants believed the cover story that the study was an investigation of the relationship between cognitive performance and

individual differences in drinking habits, because the majority thought that the purpose of the training task was to 'measure my ability to control myself when I think of alcohol' (46%) or 'measure how quickly I can categorise things' (36%). Only six participants (5%; 5 in active training groups, 1 in sham training group) thought that the purpose of the training task was to 'teach me to control myself when I think of alcohol'. Although it appears that participants in the active training groups were more likely to select this option than participants in the sham training groups, a Chi Square test confirmed that there was no significant relationship between group allocation and the response option selected ($\chi 2(12) = 14.49$, $p = .27$).

Participants' responses to the final question revealed that the majority were aware of the real purpose of the Taste-Test, with 63 participants (53 % of the sample) correctly identifying that this task was a measure of their motivation to drink alcohol. To explore the influence of this factor, I repeated the analysis of taste test data (see figure 2.2 in the main manuscript, page 51) with the addition of awareness (2: aware, unaware) as an additional between-subjects factor. This analysis revealed that the main effect of drink type ($F(1,112) = 11.91$, $p < .01$) and the two-way interaction drink type × condition ($F(1,112) = 20.45$, $p < .01$) that were reported in the main manuscript, remained statistically significant. Importantly, the three-way interaction drink type × condition × awareness was not significant ($F(1, 112) = .26$, $p = .61$) and there were no other significant interactions or main effects ($Fs < 2.56$, $ps > .11$). Therefore, participants' awareness of the purpose of the taste test did not influence the primary findings.

Table A.2. Frequencies of participants' responses to the question that probes their awareness of the purpose of CBM.

	CAT	**Sham CAT**	**ICT**	**Sham ICT**
a. *Train me to think more quickly*	1	1	1	2
b. *Measure how quickly I can categorise things*	10	13	10	10
c. *Measure my ability to control myself when I think of alcohol*	14	14	16	11
d. *Teach me to control myself when I think of alcohol*	3	1	2	0
e. *I do not know what this task was measuring*	2	1	1	7

Response errors (Table A.3)

Participants made very few errors on the Go/No-Go and Approach Avoidance tasks during pre-test, training and post-test blocks. Given the skewed distribution of error data, these were not formally analysed.

Table A.3. Response errors. Values are shown separately for active training and sham training groups, and at pre-test (before training), during training and post-test (after training), respectively. Values are means (SD in brackets).

	Active Training	**Sham Control**
Pre-test (80 trials)		
AAT errors	*4.53 (8.08)*	*2.83 (2.48)*
No-Go errors (from 40 No-Go trials)	*.40 (.89)*	*.77 (.94)*
Training (480 trials)		
AAT errors	*19.73 (28.76)*	*13.03 (12.34)*
No-Go errors (from 240 No-Go trials)	*2.77 (2.30)*	*4.10 (4.41)*
Post-test (80 trials)		
AAT errors	*4.37 (6.85)*	*2.53 (2.64)*
No-Go errors (from 40 No-Go trials)	*.90 (1.09)*	*.77 (1.19)*

Correlations between task performance and consumption during the taste test (Table A.4)

To investigate if individual differences in performance on the cognitive tasks at post-test were associated with individual differences in beer or soda consumption, I correlated drink consumption (as a percentage of fluid available) with the IAT *D* measure, and with alcohol approach bias (CAT groups only) and alcohol inhibition bias (ICT groups only). The latter bias scores were computed on the basis of both reaction time and error data. These correlations are reported in Table A.4, initially for the sample as a whole and then separately for each of the four experimental groups. After correction for multiple comparisons, none of these correlations were statistically significant.

Table A.4. Correlation matrix between alcohol (1.) and soda (2.) consumption during the taste test and post-training bias scores for the sample as a whole and stratified by each experimental group. Values are D-measure, RTs, errors and bias scores.

	Whole sample		CAT		Sham CAT		ICT		Sham ICT	
Variables	**1.**	**2.**	**1.**	**2.**	**1.**	**2.**	**1.**	**2.**	**1.**	**2.**
IAT D-measure	*.01*	*.10*	*- .05*	*-.01*	*.03*	*.05*	*.02*	*.29*	*.02*	*.15*
AAT bias (RTs)	*.14*	*.08*	*.16*	*.06*	*-.04*	*.18*	*/*	*/*	*/*	*/*
AAT bias (Errors)	*.20*	*-.03*	*.07*	*-.06*	*.26*	*.10*	*/*	*/*	*/*	*/*
Go / No-Go Go RT bias	*.07*	*.08*	*/*	*/*	*/*	*/*	*.14*	*.11*	*.00*	*.07*
Go/ No-Go No-Go error bias	*.16*	*.22*	*/*	*/*	*/*	*/*	*.26*	*-.07*	*-.09*	*-.36*

Sex differences

In order to investigate if participant sex moderated any of the primary findings reported in the main manuscript, I repeated all primary analyses after adding sex as an additional between-subjects factor. These analyses confirmed that sex did not moderate the effects reported here: there were no interactions involving sex and either condition or training type, and the findings reported in the manuscript were unaffected.

A.4 Supplementary discussion

In line with previous CBM work, I demonstrated that effects of CBM on reaction times to alcohol cues were not noticeably different for stimuli that were used during training compared to novel alcohol stimuli (Wiers et al., 2010). In general, reaction times for pictures that had been used during CBM were faster than reaction times to novel pictures, however the absence of interactions with experimental condition, picture type and time suggests that this did not affect generalization of effects of CBM from trained to novel stimuli. Furthermore, in line with findings from previous studies (Houben & Jansen, 2011; Wiers et al., 2010) participants were not aware of the overall aim of the study. In general, it seemed that most participants believed the cover story that they were provided with. Additionally, I observed no significant correlations between individual differences on the cognitive tasks at post-test, and beer or soda consumption.

A limitation is that I can only indirectly infer that individuals in the active training groups were not aware of the contingencies that were applied during CBM, because our awareness questions assessed their awareness of the purpose of CBM

rather than the contingencies that were applied during training. Some previous ICT studies have demonstrated that most participants become aware of the contingency between appetitive cues and the requirement to inhibit (Lawrence et al., 2015a; Lawrence et al., 2015b), as inferred from expectations of having to stop when those cues are encountered (Best et al., 2015). In the light of some recent findings, future studies could investigate the effects of providing participants with explicit information about training contingencies before they receive CBM (Van Dessel et al., 2015, 2016; Van Dessel, De Houwer and Gast, 2016).

Finally, approximately half of our participants were aware of the real purpose of the taste test. However, participant awareness did not affect our primary findings, because participants who received active CBM drank less alcohol than participants who received sham (control) CBM, regardless of their awareness of the purpose of the taste test (see Jones et al., 2016a).

Appendix B

Supplementary materials to study 3.1

The TV-show used was extracted by the following link: https://www.youtube.com/watch?v=E1qC6XvO7nc

Category	Adverts links
Headphones	Beats: https://www.youtube.com/watch?v=CemKcjh9_m8 Ministry of Sound: https://www.youtube.com/watch?v=ZKmjeN9NZRQ Sony: https://www.youtube.com/watch?v=rfTU6HdE8Fg
Car	Smart: https://www.youtube.com/watch?v=IAJBtPz6sZE Toyota Hybrid: https://www.youtube.com/watch?v=U-cHYhx-_ro Toyota Yaris: https://www.youtube.com/watch?v=YEBQnuL7QFU
Smart phones and watches	Apple smart watch: https://www.youtube.com/watch?v=a8GtyB3cees Galaxy S7: https://www.youtube.com/user/SAMSUNGMOBILEUK?v=75qc16axg_E Microsoft Lumia 950: https://www.youtube.com/watch?v=snEIjWR4lQw
Alcohol	Magners (Target cider used in the study) Fosters (Target beer used in the study) Coors (Generic beer not used in the study) Blumers (Generic cider not used in the study) Bacardi rum (Generic liquor not used in the study) Smirnoff vodka(Generic liquor not used in the study) https://www.youtube.com/watch?v=PgHhE8gMFT8&index=86&list=PLlDunEJdBtJqt8DcPuVLjELOXGZujwr2d All of the other ads are in the following Google drive: https://drive.google.com/folderview?id=0B6GhQrS77d5jdzIxamV0bGl3Ulk&usp=sharing

Appendix C

Supplementary materials to study 6.1

C.1 Introduction

To further investigate the role of attention on choice behaviour of appetitive-valued stimuli I additionally measured differences pre and post-ICT manipulation, for each of the four chocolate pairings, on the overall number of fixations, on the duration of the first fixation and on the percentage of times of this first fixation, to each picture presented during the probe task (see table C.1).

C.2 Results

I analysed the overall average number of fixations for each separate pairing (P1: high Go vs. high No-Go, P2: low Go vs. low No-Go, P3: high Go vs. low Go and P4: high No-Go vs. low No-Go) using a 2 × 2 ANOVA, with a within-subject factor of Time (2: Before or After the training) and Stimulus (Left or Right picture).

For the first pairing, results showed only a main effect of time ($F(1, 27) = 16.83$, $p < .01$), indicating a tendency of the participants at fixating slightly less times post-ICT, relative to pre-training. No other main effect or interaction on the number of fixations were observed ($Fs < .33$, $ps > .57$). For the second pairing again a main effect of time was observed ($F(1, 26) = 18.54$, $p < .01$), which was underpinned by Time × Stimulus interaction ($F(1, 26) = 4.99$, $p = .03$). No main effect of stimuli was observed ($F(1, 26) = .06$, $p = .81$). Post-hoc T-test showed that these effects were driven by individuals fixating significantly less to low valence pictures associated to No-Go cues (e.g. inhibition) post-ICT, rather than pre-training ($t(26) = 4.43$, $p < .01$). No pre-post differences were observed for low valence stimuli associated to Go cues ($t(26) = 1.62$, $p = .12$). For the third pairing, again a reduction in the averaged number of fixations was found ($F(1, 26) = 20.41$, $p < .01$) and no other main effect or interaction were observed ($Fs < 2.15$, $ps > .15$). Similarly, for the last pairing, a reduction in the averaged number of fixations was

observed post-ICT (F (1, 27) = 13.98, $p < .01$) and no other main effect or interaction were found (Fs < 1.33, ps > .26). Thus, overall I observed less fixations post-ICT on the averaged number of fixations and most importantly I found effects of ICT in the second pairing, suggesting that the association learned during the training between low value stimuli and inhibition reduced the average number of fixations to those specific stimuli.

Moreover, the mean duration of first fixations to each pairing type was also analysed by a 2 × 2 ANOVA, with a within-subject factor of Time (2: Before or After the training) and Stimulus (Left or Right picture). For the first pairing only the 2-way interaction was significant (F (1, 5) = 13.32, $p = .02$). No other main effect was found (Fs < 3.91, ps > .11). Post-hoc showed no significant difference between these pairings ($t < 1.21$, $p > .24$). For the second pairing (Fs < 1. 88, ps > .24), third (Fs < 1. 76, ps > .23) and fourth pairing (Fs < 1. 09, ps > .34) null effect were observed. Thus, suggesting that overall ICT did not affect the duration of the first fixations.

Finally, the percentage of number of first fixations to each pairing type was also analysed by a 2 × 2 ANOVA, with a within-subject factor of Time (2: Before or After the training) and Stimulus (Left or Right picture). For the first pairing no main effects or interaction were observed (Fs < 2.71, ps > .16). Similar null effects were observed for the second (Fs < 3.37, ps > .10), the third (Fs < 2.15, ps > .19) and forth pairing category (Fs < 1.71, ps > .25), which suggest that overall ICT did not affect the percentage of times the first fixated on a stimulus.

Table C.1. Eye movement data (overall number of fixations, duration of first fixations, and percentage of first fixations) to each stimuli, for the 4 different stimulus-cue pairings, during the probe task. Values are shown separately for time pre or post-ICT. Values are mean ± SD.

P1 **High Go vs. High No-Go**	**Pre-test**	**Post-test**
N. of fixations		
High Go	*1.25 (.68)*	*.92 (.55)*
High No-Go	*1.21 (.89)*	*.96 (.77)*

1st fixation duration		
High Go	*.34 (.04)*	*.33 (.05)*
High No-Go	*.47 (.05)*	*.44 (.07)*
% of 1st fixation		
High Go	*54.17 (27.40)*	*31.88 (29.13)*
High No-Go	*42.67 (31.21)*	*38.26 (33.10)*

P2 Low Go vs. Low No-Go	**Pre-test**	**Post-test**
N. of fixations		
Low Go	*1.14 (.89)*	*.98 (.73)*
Low No-Go	*1.34 (.69)*	*.87 (.59)*
1st fixation duration		
Low Go	*.34 (.04)*	*.33 (.05)*
Low No-Go	*.47 (.05)*	*.44 (.07)*
% of 1st fixation		
Low Go	*50.70 (28.81)*	*52.08 (29.50)*
Low No-Go	*50.69 (28.81)*	*30.16 (28.29)*

P3 High Go vs. Low Go	**Pre-test**	**Post-test**
N. of fixations		
High Go	*1.34 (.67)*	*.93 (.54)*
Low Go	*1.18 (.90)*	*.96 (.73)*
1st fixation duration		
High Go	*.34 (.04)*	*.33 (.05)*
Low Go	*.47 (.05)*	*.44 (.07)*
% of 1st fixation		
High Go	*43.18 (33.35)*	*30.48 (30.11)*
Low Go	*42.26 (33.55)*	*52.08 (29.50)*

P4 High No-Go vs. Low No-Go	**Pre-test**	**Post-test**
N. of fixations		
High No-Go	*1.19 (.93)*	*.99 (.70)*
Low No-Go	*1.27 (.65)*	*.91 (.54)*
1st fixation duration		
High No-Go	*.34 (.04)*	*.33 (.05)*
Low No-Go	*.47 (.05)*	*.44 (.07)*
% of 1st fixation		
High No-Go	*45.83 (32.84)*	*44.96 (29.97)*
Low No-Go	*45.00 (32.29)*	*30.16 (28.29)*

C.3 Supplementary discussion

In line with the previously reported gaze data (proportion of time spent looking to each stimulus presented), the overall number of fixations decreased post-ICT relative to pre-training, as RTs during the probe task became faster post-ICT. Furthermore, in line with gaze and forced choice results, especially the average number of fixations for low valence stimuli associated with inhibition decreased post-ICT. These results confirm the suggested ICT effect for low valence stimuli, previously described. Yet, null effects were found on the duration mean and on the percentage of first fixation to each stimulus.