The Effects of Anticipation of Motivationally Salient Outcomes on Attentional Bias

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

by

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This thesis is dedicated to my parents Aleksandra and Marek Jędras

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Abstract

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Attentional bias for substance-related cues could be a contributing factor in addiction and obesity. Current theoretical models implicate that attentional bias is a dynamic phenomenon that fluctuates over time within individuals; fluctuations in attentional bias may depend on the perceived availability of the substance such that attentional bias could be elevated when an imminent opportunity to consume the substance is anticipated. The goal of this PhD thesis was to investigate the effects of anticipation of substance-related motivationally salient outcomes (*i.e.*, gain and loss of those substances) on attentional bias for substance-related cues as well as other types of motivationally salient cues. The first four empirical studies used eye tracking methods to measure attentional bias; findings demonstrate that attentional bias for substance-related (alcohol and chocolate) cues is sensitive to anticipation of gain and loss of those substances. Importantly, these effects appear to be outcome-specific because anticipation of alcohol gain and loss influences attentional bias for alcohol but not chocolate pictures, and vice versa. These findings may also be dependent on the extent of participants' control over gain and loss outcomes during the task. The next empirical study used electroencaphalography (EEG) to measure attentional bias but this study revealed no effects of gain or loss anticipation on attentional bias. The final two studies explored if the effects of anticipated gain and loss of chocolate might also affect attentional biases for emotional stimuli (facial expressions), again using eye tracking methods. Findings from these studies demonstrate that anticipation of chocolate-related gains and losses influences attentional biases for facial expressions in a congruent manner: anticipation of chocolate gain increases attentional bias for happy faces, whereas anticipation of loss increases attentional bias for sad faces. These findings point to a broader role for anticipation of gain and loss in emotional regulation. The theoretical and applied implications of these findings for addiction, obesity and emotional disorders, in particular the role of attentional bias in those disorders, is discussed.

Table of contents

List of Figures

List of Tables

CHAPTER 1 - GENERAL INTRODUCTION

The first section of the introduction provides a definition of attentional bias, and briefly reviews available methods of its measurement. Subsequently, theoretical accounts of attentional bias are introduced and their predictions and limitations are evaluated in the context of available empirical evidence. This section emphasises the dynamic nature of attentional bias and its relationship with motivational states and goal relevance, concluding that changes in substance availability could be a contributing factor in the fluctuations of attentional bias. The second section demonstrates how substance availability could influence craving, attentional bias and substance use, even when availability is only anticipated. The evidence for the role of substance anticipation will be reviewed for both drugs (including alcohol) and food. The third section provides a different perspective on attentional bias and anticipation of motivationally salient outcomes. This section demonstrates how anticipation of motivationally salient outcomes such as reward or loss can influence the attentional processing of positively and negatively valenced information. The final section outlines the goals and aims of this thesis. Parts of this chapter were published as Jędras, Jones, and Field (2013).

1.1. Attentional Bias

1.1.1. Alcohol misuse, obesity and attentional bias

Alcohol misuse and obesity are a major public health problem. Although the age-standardised rate of alcohol-related deaths in the UK has decreased from 15.8 deaths per 100,000 people in 2008 to 14.3 per 100,000 in 2014, this rate is still considerably higher than 9.1 deaths per 100,000 recorded in 1994 (Office for National Statistics, 2016). It is predicted that by 2050, 60% of male and 50% of female UK population could become obese (Butland et al., 2007). The costs of alcohol harm to the society in the UK, were estimated at £21 billion a year while the costs to the National Health Service (NHS) were approximately £3.5 billion per year (Public Health England, 2014). Whereas the indirect costs of overweight and obesity in 2007 ranged between £2.6 billion and £15.8 billion, and the costs to the NHS were estimated at £4.2 billion (Morgan & Dent, 2010). The wide availability of alcohol and unhealthy food could be a contributing factor that drives alcohol misuse and obesity respectively (Rice & Drummond, 2012; Swinburn & Egger, 2002). Research suggests that substance use disorders tend to be associated with attentional preference for substance-related cues (Field & Cox, 2008), which could jeopardise attempts to maintain healthy life style in the environment where rewards such as alcohol and food are widely available. However, the relationship between attentional bias for substance-related cues and substance use is not clear (Field et al., 2016). Therefore, a better understanding of psychological mechanisms underlying alcohol misuse and obesity could be crucial for the development of effective treatment methods and policies.

1.1.2. Definition and methods of measurement

This section provides a definition of Attentional Bias (AB) as well as a brief overview of the research methods involved in AB. The methods of measurement in research on AB and motivated behaviour can be classified as indirect and direct. Indirect measures of AB infer bias through the analysis of response times. In comparison to indirect measures of AB, the direct measures allow for parallel and continuous recording of physiological and behavioural changes which occur during attentional processing of stimuli. The purpose of this overview is to introduce examples of the most popular methods of assessment of AB, highlighting their limitations and their psychometric properties.

Definition: *AB* is a tendency to prioritise the attentional processing of motivationally relevant cues over other information. Both appetitive cues (*e.g.*, cues related to rewarding stimuli such as sex, food or drugs) and aversive cues (*e.g.*, cues that signal danger such as threatening facial expressions) are able to capture and hold selective attention.

1.1.3. Indirect methods of AB inference

One of the most popular and widely used assessments of AB involves the measurement of the *Stroop* (1935) *effect*. The addiction Stroop task incorporates presentation of substance-related (*e.g.*, beer, cocktails, etc.) and matched emotionally neutral words (*e.g.*, water, lemonade, etc.). During the task, participants are required to quickly and accurately identify the colours of presented words while disregarding their semantic meaning. It is argued that in comparison to non-users, substance users automatically process the semantic content of substance-related words. These automatic processes could interfere with colour naming performance and hence cause greater response times. Therefore, the difference in mean colour naming reaction times between substance-related and neutral words is considered the index of AB. The main limitation of an addiction or a food Stroop effect is the speculative nature of its source. Both appetitive and aversive words are capable of eliciting the Stroop effect. The valence of substance-related words may depend on the individual evaluation of stimuli (Yiend, 2010) which could be affected by

substance use history. Hence, both positive and negative or even ambivalent evaluations could potentially evoke comparable Stroop effects.

Another group of indirect methods of assessment of AB involves a variety of cueing tasks. The dot-probe task is one of the most commonly used cuing tasks, which was originally developed by MacLeod, Mathews, and Tata (1986). In a typical dot-probe task participants are presented with pairs of pictures comprising of salient and neutral stimuli (*e.g.*, a glass of beer vs. a glass of water) simultaneously displayed on the left and the right side of a computer screen. A picture pair is presented for a predefined amount of time, and afterwards a probe (*e.g.*, a small dot) is displayed in place of one of the pictures. As reported by Field, Munafo, and Franken (2009) shorter presentation times (50 – 200 *ms*) are used to investigate the initial orientation but longer ones (500 *ms* or longer) are necessary to infer the biases in the maintenance of attention. Participants are requested to quickly and accurately indicate the location of the probe by pressing a keyboard button corresponding with the probe's location (left or right side). AB is inferred from the difference between mean reaction times to probes that replaced neutral pictures and mean reaction times to probes which replaced salient pictures. Therefore, the dot-probe task indicates to which neutral or substance-related cues, participants' attention was allocated before the stimulus was replaced by the probe. In comparison to the Stroop task, this method allows measuring AB *towards* and *away from* the salient stimuli (Yiend, 2010). Hence, it might be more suitable for capturing differences in attentional processing of positively and negatively valenced stimuli. AB *towards* stimuli is deduced from shorter reaction times to probes replacing the task-relevant pictures, and AB *away from* stimuli is associated with shorter reaction times to probes replacing neutral pictures. Despite this advantage over the Stroop task, it should be emphasised that problems with the internal and test-retest reliability of the dot-probe task have been reported (addiction research: Ataya et al. (2012); anxiety research: Schmukle (2005); *see also* Christiansen, Mansfield, Duckworth, Field, and Jones (2015)).

1.1.4. Direct methods of AB measurement

Electroencephalography (EEG) is a physiological measure widely utilised in the research on attentional processing of motivationally salient stimuli. EEG allows for the recording of electrophysiological neural changes related to unison activation of a group of neurones (Nunez & Srinivasan, 2006). During a typical EEG session, electrodes are placed on the scalp and event-related potentials (ERP) capturing a neural activity time-locked to a stimulus presentation are recorded. A capture of attention by motivationally relevant stimuli is argued to be reflected by P300 and the slow potential (SP, > 800 *ms*) components (Schupp et al., 2004). Therefore, the enhanced amplitude of these components observed during the presentation of motivationally salient stimuli in comparison to neutral stimuli is considered to be the index of biased cognitive processing (Littel, Euser, Munafo, & Franken, 2012). Unfortunately, the aforementioned components indicating AB can be triggered by both appetitive and aversive stimuli (Briggs & Martin, 2009; Littel et al., 2012; Polich, 2007). This introduces similar problems with the interpretation of results as in the case of the Stroop task (Yiend, 2010).

Currently, the assessment of eye movement with an eye tracker could serve as a gold standard for the research of AB. Eye-tracking is a direct method of measuring AB which allows for the continuous recording of eye movements as a probe of attention, which is a solution to the problems associated with indirect methods of assessment (Christiansen et al., 2015). Eye-tracking measurement of AB is generally used in the context of a visual probe task. AB scores are calculated by subtracting mean gaze dwell times on neutral pictures from the mean gaze dwell times on motivationally salient pictures. The movements allow for capturing AB *towards* and *away from* motivationally salient stimuli. Due to the constant recording of eye movements, more complex patterns of attentional processing like initial bias toward and subsequent bias away from a stimulus, can be registered. Therefore, this method allows for capturing patterns of AB which might be specific for the ambivalent evaluation of stimuli (Yiend, 2010).

1.1.5. Summary – measurement methods

One of the important aspects of research is the utilisation of research methods which aim at providing most unequivocal results. Eye-tracking fulfils these criteria better than the previously discussed methods, hence eye tracking is indicated as the primary tool in AB studies. When new aspects of attention are explored, eye-tracking studies are useful in defining research direction, particularly when supplemented with other direct or indirect measurements of AB.

1.1.6. AB in healthy functioning and in appetitive and aversive disorders

Motivationally salient (appetitive and aversive) environmental cues are able to capture and hold attention. For example, people who use addictive substances (including alcohol) have an AB for substance-related cues (Field & Cox, 2008), whereas AB for food cues appears to be present in everybody to some degree (Werthmann, Jansen, & Roefs, 2015). In the case of aversive motivation, AB for threat-related cues is present in anxiety disorders and individuals in the state of anxiety (Cisler, Bacon, & Williams, 2009; Cisler & Koster, 2010). Therefore, AB can be present in the non-clinical population as well as disorders characterised by either enhanced appetitive or aversive motivation. This section will provide a theoretical explanation of the development of AB for rewarding stimuli like drugs and food, as well as a brief discussion of the implications and limitations of the theoretical model.

1.1.7. The role of incentive sensitization theory in the development of AB

Incentive-sensitization theory (IST) presented in the influential publication by Robinson and Berridge (1993) provides an explanation for the development of AB in substance use disorders. IST was proposed to explain the development of addiction from the perspective of neuroadaptations in the mesolimbic dopamine system (especially nucleus accumbens) which is involved in the attribution of incentive salience to reward and reward-related cues. Repeated use of potentially addictive drugs enhancing dopaminergic activity could cause hypersensitisation of dopaminergic pathways, leading to abnormal levels of incentive salience being attributed to substance-related cues (Koob & Volkow, 2010). It is proposed that

these changes are mediated via associative learning processes. After repeated pairings of drug-induced dopamine releases with substance-related environmental cues (*e.g.*, an ashtray, a pack of cigarettes, etc.), the mere presence of the cues associated with substance availability could evoke a conditioned increase in dopamine release (Volkow et al., 2006). This indicates that mechanisms underlying craving may involve an element of anticipation of a further drug reward (Goldstein & Volkow, 2002), and it demonstrates that substance-related cues can acquire a powerful motivational value. It was proposed that it is this acquired incentive value that attracts attention, causing the experience of craving, and hence leads to drug-seeking behaviour (Robinson & Berridge, 1993).

There are similarities between drug and food reinforcers. Both drugs and food exert their reinforcing effects via an increase in the activity of dopaminergic pathways, and both drug abuse/addiction and obesity are associated with the overvaluation of the reinforcer (Volkow, Wang, Fowler, & Telang, 2008). Berridge, Robinson, and Aldridge (2009) suggested that a similar process could be involved in salience attribution and subsequent patterns of motivated behaviours for other types of reward apart from addictive drugs. This explains the understandable interest in the application of addiction theories for appetite research (Berridge, 2009; Havermans, 2013). Assuming that IST could explain patterns of behaviour responsible for obesity or at least its specific types, it could be expected that food-related cues should be capable of eliciting comparable motivational states and attract selective attention like addictive substances (Nijs & Franken, 2012).

The key concepts of IST implicate that both subjective experiences of craving and AB in response to reward-related cues are triggered by the incentive salience. Other theoretical models like the cognitive psychopharmacological model (CPM) proposed by Franken (2003) or the elaborated intrusion (EI) theory of desire introduced by Kavanagh, Andrade, and May (2005) further indicate that craving and AB are closely related expressions of the underlying appetitive motivational states. CPM posits that AB is a cognitive expression of a sensitised dopaminergic system; substance-related cues first evoke conditioned increase in dopamine and hence capture selective attention, and subsequently AB triggers craving. Once activated, craving further enhances AB, therefore operating in a reinforcing loop.

EI makes comparable predictions to CPM regarding the interaction of AB with craving. However, in contrast to CPM which defines craving as an emotion, EI provides a description of cognitive processes associated with the activation of craving (Kavanagh et al., 2005). EI suggests that AB for substance-related cues may trigger substance-related intrusive thoughts. Craving develops when these initial thoughts are elaborated upon within the working memory, through search of substance-related representations when accompanied by emotional states focused on the ability to satisfy substance-related desires. These consciously controlled elaborations may increase the salience of substance-related cues facilitating further attentional search. Hence, increasing AB and in turn facilitating intrusive thoughts and therefore reinforcing the entire process. Overall, these models demonstrate that AB is important because it may facilitate detection of substance-related cues. Once those cues are detected, AB may interact with craving. This may trigger drug-related expectancies and intrusive thoughts, and due to a limited capacity of attention affect processing of competing cues (Franken, 2003; Kavanagh et al., 2005). This suggests that reciprocal excitation between craving and AB could facilitate substance use behaviour.

1.1.8. AB predictions, limitations and the implications for research direction

The theories discussed in the previous section suggest some interesting predictions. It could be expected that due to an extensive history of substance use, AB should be more pronounced in addicted or obese individuals when compared to the healthy population. Finally, if AB has a causal role in addiction and obesity, then it should be a predictor of treatment success *i.e.*, reduction or cessation of drug use, and the likelihood of relapse to drug use after treatment (addiction) or changes in body weight (obesity).

A recent critical review of AB theories in addiction and obesity addressed these predictions, exposing the limitations in the current understanding of AB's role in motivated behaviour (Field et al., 2016). Overall, the following conclusions can be drawn: A variety of measurement methods including Stroop task, dot probe task, ERP measurements and eye-tracking provided solid empirical support for the presence or enhanced levels of AB in drug users when compared to non-users

(Cox, Fadardi, & Pothos, 2006; Field & Cox, 2008; Field, Marhe, & Franken, 2014; Littel et al., 2012). While addiction research provided rather unambiguous evidence for AB in substance users, research on AB in obesity provided mixed and inconclusive results, with studies reporting positive, negative and no association between AB and obesity. The opposite was implicated for the predictive value of AB in reward-seeking behaviour. AB appears to be a better predictor of food consumption than drug use or relapse (Field et al., 2016). Therefore, not all of the theoretical predictions are supported and the understanding of AB in substance seeking behaviour is limited.

What seems to be a significant hint for the current research are the results of a recent study investigating fluctuations of AB (Marhe, Waters, van de Wetering, & Franken, 2013). The observation of Stroop task performance recorded a few times a day over a period of one week in a group of heroin-dependent patients undergoing detoxification, revealed a peak Stroop interference before relapse. Although these findings await replication, they are of particular importance for the understanding of the predictive role of AB in substance use. The *intra-individual* temporal fluctuations of AB could be more important for the prediction of subsequent drug use or eating behaviour than overall intergroup differences in AB.

1.1.9. AB and appetitive motivation

The relationship between motivational states and AB proposed by some of the theoretical models (Field & Cox, 2008; Franken, 2003; Kavanagh et al., 2005) is generally supported by the empirical evidence. AB for substance-related cues is associated with the strength of substance, including alcohol, craving (Field et al., 2009; Rose, Brown, Field, & Hogarth, 2013) and AB for food cues was shown to be positively correlated with hunger (Werthmann et al., 2015). The relationship between AB and craving was supported by studies which experimentally manipulated drug deprivation or food fasting (*e.g.*, Field, Mogg, & Bradley, 2004; Lavy & Van den Hout, 1993), induced negative mood (*e.g.*, Bradley, Garner, Hudson, & Mogg, 2007; Hepworth, Mogg, Brignell, & Bradley, 2010) or measured craving and AB in response to food or drug related cues (*e.g.*, Field, Rush, Cole, & Goudie, 2007; Smeets, Roefs, & Jansen, 2009). These results indicate an association

between changes in AB and the fluctuations of motivational states, highlighting the dynamic nature of AB.

1.1.10. AB, aversive motivation and evaluative processes

Similarly to appetitive motivation, aversive motivation is also capable of affecting AB. For example, the induction of negative mood can lead to an increase in AB for negatively valenced cues (*e.g.*, Bradley, Mogg, & Lee, 1997; Mogg, Kentish, & Bradley, 1993). Aversive disorders are characterised by AB for negative information. AB for threat-related information is a robust phenomenon well documented across all types of anxiety disorders such as generalised anxiety disorder, social phobia, post-traumatic stress disorder, specific phobia, panic disorder and obsessive-compulsive disorder (Cisler & Koster, 2010). Similarly, empirical evidence suggests that depressive disorder is associated with AB for depression-relevant cues (Gotlib, Kasch, et al., 2004; Gotlib, Krasnoperova, Yue, & Joormann, 2004; Joormann & Gotlib, 2007). Both anxiety and depressive disorder are associated with mood congruent but qualitatively different negativity biases *i.e.*, vigilance towards threat in anxiety, and AB for dysphoric cues and stimuli connoting sadness in depression (Armstrong & Olatunji, 2012; Hankin, Gibb, Abela, & Flory, 2010). The different patterns of AB between anxiety and depression disorders suggest that self-relevance of cues could be one of the factors mediating AB. This is consistent with the theoretical models of aversive disorders that indicate that AB may be mediated via *evaluative processes* involved in the assessment of relevance (*see* Cisler & Koster, 2010; Yiend, 2010). The current perspective on mental health disorders indicates that normal and abnormal cognitive processes do not establish two independent entities. Therefore, the level of flexibility at which attention operates could vary on a continuum between normal and abnormal cognition. In the general population activation of selective attention may depend on cues reaching a certain level of intensity (*i.e.*, arousal - *see* Anderson, 2005). In the clinical population, this threshold level could be lower, leading to a wider range of negative information being *evaluated* as relevant and hence explaining greater AB (Yiend, 2010).

Taking into account the current evidence for AB in aversive disorders, it could be expected that AB for food-related cues should also be present in eating disorders where food could be evaluated as a threat. The results of a recent review of studies measuring AB in eating disorders indicated AB away from positive eating stimuli *i.e.*, healthy food, and AB toward negative eating stimuli *i.e.*, 'junk' food (Aspen, Darcy, & Lock, 2013). Therefore, it is possible that aversive motivation could be a moderator of AB in eating disorders, and certain types of food which could be evaluated as threatening can evoke AB. Although this concept was acknowledged, it must be treated with caution due to the a scarcity of available studies (Werthmann et al., 2015).

1.1.11. AB and goal relevance

The previous sections illustrated that both appetitive and aversive motivation can have an impact on AB. The roles of evaluation and relevance in AB are strongly implicated by theoretical models of aversive motivation. Similarly, relevance may also be a contributing factor in AB for positively valenced cues. For example when cues (*e.g.*, food) are relevant to a specific concern (*e.g.*, hunger) (*see* Pool, Brosch, Delplanque, & Sander, 2016). This is consistent with the argument that relevant stimuli, both positively and negatively, can capture selective attention (*e.g.*, Broeren & Lester, 2013; Muller, Rothermund, & Wentura, 2015; Van Dessel & Vogt, 2012; Wentura, Muller, & Rothermund, 2014). The moderating role of relevance in substance related AB can be demonstrated when substances become objects of contradictory goals (Field et al., 2016). Individuals attempting to control their substance use may perceive substance-related cues as a threat to the current goal of behaviour change (*i.e.*, selection of healthier alternatives, reduction or cessation of intake) and therefore these cues could evoke concerns about failing. Yet they may still be attracted by the goal of pursuing reward by substance use (Field et al., 2016). While the initial AB for substance-related cues found in individuals trying to control their substance use (Field, Mogg, Mann, Bennett, & Bradley, 2013; Lee, Cho, & Lee, 2014) could reflect the ambivalent motivational states, the subsequent AB away from the cues could be a consequence of the state of 'worry' where individuals overcome AB (*see* Koole, 2009). Overall, this evidence shows that goal relevance may moderate AB.

1.1.12. Summary and research directions

Motivationally salient (appetitive and aversive) environmental cues are able to capture and hold the attention (Cisler et al., 2009; Cisler & Koster, 2010; Field & Cox, 2008; Werthmann et al., 2015). IST provides an explanation for the development of AB in substance use disorders (Robinson & Berridge, 1993). It was proposed that comparable mechanisms could be involved in the development of AB and food cravings (Berridge, 2009; Havermans, 2013). Although, initial research aimed to explain substance use behaviour in terms of intergroup differences, comparing AB in non-users/non-problematic users vs. substance users/addicts, these attempts provided a limited understanding of the role of AB in the explanation of behaviour (Field et al., 2016). AB is a dynamic phenomenon which may reflect changes in the underlying motivational states like craving or hunger (Field et al., 2009; Rose et al., 2013; Werthmann et al., 2015). Temporal changes in AB appear to be a promising predictor of variability in substance use behaviour (Marhe et al., 2013). It is reasonable to posit that motivational states may affect perceived relevance of substance-related cues and vice versa – reflecting the reciprocal relationship between motivation and AB proposed by some of the theoretical accounts (Field et al., 2016). Positive, negative and ambivalent cues may receive selective attention due to their relevance to a goal of motivated behaviour. One of the factors which may determine substance relevance is current availability. Therefore, changes in substance availability could be a contributing factor in temporal changes of AB.

1.2. Substance availability

1.2.1. Introduction

Substance availability could be a contributing factor in substance-related problems (Gruenewald, 2011; Polivy, Herman, & Coelho, 2008). Living in an environment where alcohol and calorie-dense foods are widely available, can make the maintenance of a healthy lifestyle difficult (Bechara, 2005; Jansen, Houben, & Roefs, 2015; Papachristou, Nederkoorn, Corstjens, & Jansen, 2012; Wiers et al., 2007). This section will explore the results of naturalistic and laboratory studies on the effects of substance availability on motivation and substance use behaviour. Subsequently, the potential mechanisms responsible for the development and impact of availability on cue reactivity will be introduced and explained. Finally, the results of studies focused on the impact of availability on AB will be reviewed.

1.2.2. Drug availability and craving

Substance availability can affect motivational states which in turn can facilitate substance use. A naturalistic study conducted by Dar, Stronguin, Marouani, Krupsky, and Frenk (2005), investigated the effects of habitual abstinence on cigarette craving in a population of Orthodox Jewish smokers. Unavailability of smoking during the Sabbath (when Orthodox Jews are forbidden by faith to smoke) was accompanied by relatively lower craving experience in comparison to both a regular workday when they could smoke as usual and on a forced abstinence workday. However, there was no difference in craving levels between the regular workdays and the forced abstinence workdays. On one hand these findings may suggest that habitual abstinence from substance use for religious reasons could affect the perceived availability on those days, resulting in lower craving levels. On the other hand, the lack of difference in craving between regular workdays and forced abstinence workdays implicates that the reason behind substance unavailability could contribute to craving experience.

Alternatively, Dar et al. (2005) suggested that since the Sabbath is a day dedicated to rest, hypothetically lower levels of stress on that day could have contributed to the lower craving levels (*see review* Kassel, Stroud, & Paronis, 2003). In a follow-up study, Dar, Rosen-Korakin, Shapira, Gottlieb, and Frenk (2010) investigated the impact of smoking availability on craving in flight attendants. Craving was assessed during a 2-way short flight (each leg ranging from three to five and a half hours) and a one-way long flight (ranging from eight to thirteen hours). The results demonstrate that the strengths of craving were gradually increasing, during both short and long duration flights, to peak when landing approached. At the end of the first leg of the short flight (when an opportunity to smoke arose) cigarette craving was higher than at the equivalent point of the long flight (comparable nicotine deprivation) but comparable to craving strength assessed at the end of the long flight. Therefore, it is reasonable to interpret these results in terms of the impact of proximity to the opportunity to smoke, rather than nicotine deprivation associated with flight duration. This demonstrates that craving can be moderated by the anticipation of substance availability, and these effects can be seen when nicotine deprivation is controlled.

The presented naturalistic studies implicate that temporal changes in substance availability may affect substance-related motivational states (Dar et al., 2010; Dar et al., 2005). Appetitive motivation (*i.e.*, substance craving) can be triggered when drugs are expected to be available for consumption and attenuated when substance use is not allowed/ available. In line with these results, laboratory research provided empirical support for the impact of perceived drug availability on the strength of subjective craving. Research demonstrated that the strength of subjective craving in response to drug cue exposure was more pronounced in participants who expected to be able to subsequently consume the substance. Some of these studies captured the enhancing impact of substance availability on craving even among participants who were not exposed to substance-related cues (*e.g.*, Carter & Tiffany, 2001; Dols, van den Hout, Kindt, & Willems, 2002; Dols, Willems, van den Hout, & Bittoun, 2000; Droungas, Ehrman, Childress, & O'Brien, 1995; Hayashi, Ko, Strafella, & Dagher, 2013; Juliano & Brandon, 1998; Thewissen, Snijders, Havermans, van den Hout, & Jansen, 2006; Thewissen, van den Hout,

Havermans, & Jansen, 2005; Thewissen, van der Meijden, Havermans, van den Hout, & Jansen, 2008; *see review* Wertz & Sayette, 2001b). The majority of these studies were conducted with cigarette smokers, although one study demonstrated comparable findings in cocaine dependent individuals. Yamamoto, Karlsgodt, Rott, Lukas, and Elman (2007) manipulated beliefs about chances of cocaine administration. Although all participants received a dose of cocaine, one group believed that there was only a 33% chance of receiving the drug, whereas the second group was informed they would certainly receive the drug. In comparison to the uncertainty condition, participants who were certain of receiving cocaine reported significantly higher levels of craving immediately *before* drug administration. The current studies demonstrate that anticipation of drug availability is a sufficient condition for increasing the levels of subjective craving.

Research on alcohol availability provided a less clear pattern of results. Two studies reported no effect of alcohol availability on subjective craving in response to alcohol cues (Davidson, Tiffany, Johnston, Flury, & Li, 2003; Kruse et al., 2012). Conversely, Papachristou et al. (2012) reported greater craving levels in participants who expected to consume alcohol during a study in comparison to those who did not. On the contrary, MacKillop and Lisman (2005) showed that alcohol unavailability can actually increase cue-induced craving in participants who were explicitly informed they were not able to consume alcohol at the later stage of a study in comparison to those who were expecting to have an opportunity to consume alcohol (*see also* Mackillop & Lisman, 2007). The presented impact of unavailability information is consistent with Tiffany's (1990) theoretical model of addictive behaviour. Tiffany (1990) proposed that once drug use progresses to addiction, self-administration of drugs becomes a habitual automated process which can be triggered in the absence of strong cravings. The experience of craving emerges when the automatic process of drug administration is interrupted or ceased because of drug unavailability.

There are two possible explanations for the discrepancy between tobacco and alcohol findings. Firstly, the anticipation of tobacco and alcohol may have a differential effect on drug craving. Secondly, it is possible that apart from the presented effects of drug availability on craving, drug unavailability could

increase craving via a different mechanism, in which frustration, negative mood or the perspective of withdrawal symptom could contribute to craving-related experience.

1.2.3. Food availability, eating behaviour and craving

With respect to the drug availability studies discussed in the previous section, appetite research indicates that food availability can influence eating behaviour. Early research on external responsiveness to salient food cues (*i.e.*, nuts) and eating behaviour demonstrated that imminent food accessibility had an impact on food consumption of obese individuals (Costanzo & Woody, 1979; McArthur & Burstein, 1975; Schachter & Friedman, 1974). For example, in the study conducted by Costanzo and Woody (1979) normal weight and obese participants were assigned to one of two experimental conditions which could be interpreted in terms of availability. In the imminent availability group, participants were provided with a bowl of unshelled peanuts ready for consumption. The other group received a bowl of shelled peanuts – this can be considered as delayed availability condition. Overall, the results of the study demonstrate the main effect of *availability*, as participants who were provided with shelled peanuts consumed more peanuts than those who had to shell peanuts. The further analysis revealed that peanut availability had only significant impact on consumption in obese participants. This indicates that imminent food availability may facilitate eating behaviour in obese individuals.

It is reasonable to argue that the levels of convenience and visibility could contribute to the experience of perceived food availability. Studies showed that increased food (*e.g.*, chocolate) visibility and accessibility/distance can facilitate consumption (Maas, de Ridder, de Vet, & de Wit, 2012; Painter, Wansink, & Hieggelke, 2002; Wansink, Painter, & Lee, 2006). For example, increasing snack availability via placing them near the working area in which participants spend most of their time (*e.g.*, the top of an office desks), can lead to greater food consumption in comparison to more obscured (*e.g.*, placing a snack in a drawer) or more remote locations (*e.g.*, placing a snack on a shelf away from the desk) (Painter et al., 2002). It appears that the effects of availability are most pronounced when food is placed

within participants' reach (Maas et al., 2012), *i.e.*, when snacks are available for imminent consumption.

A recent study demonstrated that substance unavailability may decrease activation of neural circuits associated with craving (Frankort et al., 2014). Thirty-minute exposure to chocolate, without an ability to consume, elevated the levels of subjective craving relative to a control group which was exposed to neutral cues. This change was accompanied by an increased activation of the brain reward regions. After 60 minutes of exposure, the subjective ratings of craving began to drop, although they were not extinguished. Interestingly, at this point, the levels of activation of brain areas believed to reflect craving returned or dropped below the control group levels. It can be expected that longer exposure to chocolate cues would result in a further decrease in subjective craving. The results of this study indicate that the presence of chocolate cues may initially increase craving. However, when chocolate cues do not signal availability for an extended period of time, at least at the neural level, craving response is ceased. Such an interpretation is consistent with suggestions that mechanisms underlying craving may involve an element of anticipation of a further drug reward (Goldstein & Volkow, 2002). For example, a recent fMRI study which involved immediate food availability provided empirical support for the moderating role of food reward availability on cue reactivity (Blechert, Klackl, Miedl, & Wilhelm, 2016). During the experiment, participants viewed pictures of foods that were available for consumption during and after the study, and pictures of foods that were unavailable. Availability had an impact on palatability ratings ("How palatable is this food to you?" rated on a 7-point Likert scales (from "not at all" to "very palatable" or "very much")) with available foods being rated as more palatable than unavailable ones. Comparing to unavailable foods, the presentation of pictures of available foods caused stronger activation of brain circuits associated with reward, appetitive motivation and cognitive control.

1.2.4. Imminent availability

Some of studies suggest that availability should be imminent in order to have an impact on craving or behaviour (*e.g.*, Blechert et al., 2016; Costanzo & Woody,

1979; Maas et al., 2012; Painter et al., 2002; Wansink et al., 2006). The significance of the immediacy of a substance use opportunity has previously been emphasised by other research groups (*see* Blechert et al., 2016; Tiffany, Warthen, & Goedeker, 2009). It is possible that in the case of some studies the delay in substance delivery led to null results. For instance, Field and Duka (2004) observed no effects of smoking opportunity on craving and physiological measures of smoking cue reactivity. However, those authors noted that participants who expected to be able to smoke 'soon' still had to wait 20 minutes before they were able to smoke, and this delay may have reduced the impact of the expectancy information. Rejeski et al. (2010) found that delay in food availability interacted with state craving predicting negative affect during exposure to food cues. The highest negative affect was found in participants expecting a long delay in food availability (30 minutes vs. 6 hours) who reported high craving. Taking into account the potential importance of imminence of substance availability, the impact of availability information on positive affect could have been obscured due to relatively long food waiting time in the short delay condition. Therefore, it is possible that even a relatively small delay in substance availability may have an impact on the quantitative and qualitative aspects of availability information.

1.2.5. Cue reactivity and Pavlovian conditioning

Exposure to food and drug-related stimuli may trigger preparatory, consummatory, or both type of responses (Cardinal, Parkinson, Hall, & Everitt, 2002). Learned physiological (*e.g.*, increases in heart rate, activation of brain reward system), subjective (*i.e.*, particularly craving) and behavioural (such as substance-taking behaviour) reactions activated during exposure to substance-related cues are called cue reactivity. Increased responsiveness to drug-related cues in comparison to neutral ones is a common phenomenon found in substance use disorders, and could be a contributing factor to the maintenance of drug use behaviour (Carter & Tiffany, 1999; Drummond, 2000; Kuhn & Gallinat, 2011; Schacht, Anton, & Myrick, 2013). Food-related cues are capable of eliciting similar reactions in both normal weight and overweight individuals (Nederkoorn, Smulders, & Jansen, 2000; Wang et al., 2004). Studies indicate that overweight individuals might be more prone to the effects of exposure suggesting that enhanced cue reactivity could be

a contributing factor in obesity (Boswell & Kober, 2016; Ferriday & Brunstrom, 2011; Halford, Gillespie, Brown, Pontin, & Dovey, 2004; Havermans, 2013; Tetley, Brunstrom, & Griffiths, 2009).

According to conditioning accounts of cue reactivity, the substance acts as an unconditioned stimulus (US) that elicits unconditioned responses *e.g.*, experience of rewarding properties of a drug. With repeated substance use, the user learns the contingency between drug/food effects and cues associated with substance administration (*e.g.*, the sight and smell of a lit cigarette or food) such that those cues function as conditioned stimuli (CS) that are able to evoke conditioned responses (CRs). Once the CS-US contingency has been learned, the CS functions as a signal for the imminent availability of the substance, and, arguably, it is this anticipation that is responsible for the initial development of CRs such as changes in subjective state, physiological changes, and behavioural responses (Field & Cox, 2008; Havermans, 2013; Hogarth, Dickinson, Hutton, Bamborough, & Duka, 2006).

Awareness of CS-US contingencies may be a crucial condition for the initial development of CRs. A considerable number of human conditioning studies demonstrate that, during the formation of conditioned associations, participants show CRs only after they can verbalise the CS-US contingency, *i.e.*, when the presentation of the CS leads to the expectation that the US is imminent (Lovibond & Shanks, 2002). In a follow-up review, Shanks (2010) concluded that research failed to provide a robust and replicable empirical base for unconscious learning, implying that awareness is necessary for conditioning and other forms of learning (*see also* Lovibond, 2004; Vadillo, Konstantinidis, & Shanks, 2016).

An arbitrary cue that is paired with a substance reward is able to evoke an increase in craving (and other conditioned responses), but only after participants have learned the predictive significance of the cue, such that its presence elicits an expectation of the opportunity of substance use (Hogarth & Duka, 2006). For example, one study showed that a CS that had been paired with the opportunity to smoke (CS+) led to increased cigarette craving compared to a CS that had been explicitly unpaired with the opportunity to smoke (CS-) (Field & Duka, 2001). This CR (craving) was particularly pronounced in individuals who were aware of

the contingency between the CS and the US. Furthermore, the craving CR to the CS+ (versus the CS-) was completely abolished if participants were informed that smoking was unavailable. This study and several others reviewed by Hogarth and Duka (2006) reveal that drug expectancy in response to a CS that is paired with a drug use opportunity is an important determinant of other CRs in response to that cue (Field & Cox, 2008). To summarise, substance-related cues appear to able to evoke craving and physiological arousal only when individuals are aware of the predictive significance of those cues, such that their presence leads to an expectation that the substance is available.

Pavlovian to instrumental transfer (PIT) studies demonstrate how substance anticipation can influence behaviour. Conditioned cues predicting a reward are capable of influencing the rate of instrumental responding for that same reward, an effect known as PIT. For instance, Lovibond and Colagiuri (2013) used a differential-conditioning design to study PIT effects. During the instrumental-acquisition phase, participants were asked to respond by pressing a button in order to obtain M&M chocolate reward. The reward was dispensed on a variable ratio (VR 10) after the button was pressed 10 times on average (from 5 to 15). This stage ended after participants earned 12 chocolate rewards. During the Pavlovian-acquisition phase, one of the lights (red or blue - counterbalanced) was followed by the delivery of chocolate (CS+ trials) whereas the other light was followed by no outcome (CS- trials). Participants were asked to consume the obtained chocolate. In the final transfer-test phase participants were informed that they could press the button again. The final transfer test was conducted under extinction and neither instrumental response nor CS+ was followed by the delivery of chocolate reward. In the first stage of the transfer test, participants made instrumental responses under extinction and subsequently in the second stage CS+ and CS- were introduced for 10 *s* in random order. The responses were recorded from 30 *s* before to 60 *s* after the CS onset. Subsequently CS+ and CS- were presented again in random order. The results revealed that the presence of CS+ relative to CS- amplified instrumental responding during (10 *s*) and after (20 *s*) CS presentation. In the second experiment, CS presentation time was expanded from 10 *s* to 30 *s*. A similar pattern of instrumental facilitation lasting approximately 30 *s*

from the onset of CS was found. This implicates that the increase in the instrumental response was caused by the presentation of CS rather than frustration caused by lack of reward. These results demonstrate how expectation of substance availability can facilitate behaviour focused on obtaining the substance.

1.2.6. The effects of substance availability on AB

Field and Cox (2008) proposed that during conditioning, drug cues elicit an expectation of imminent drug availability and as a consequence of this, drug users preferentially shift their attention to the cue. This theory makes the prediction that AB for drug cues should be moderated by the perceived availability of the drug. Wertz and Sayette (2001a) showed that AB for smoking-related words was highest in nicotine-deprived smokers who expected to be able to smoke imminently compared to those who believed that they would not be able to smoke, or who were uncertain if they could smoke or not. These effects were replicated by McCarthy, Gloria, and Curtin (2009) who showed that anticipation of smoking increased AB for smoking-related words and other emotionally valenced words in smokers who were deprived of nicotine, but there were no effects of smoking expectancy in smokers who were nicotine sated at the time of testing. Using a within-subjects design, Field et al. (2011) informed social drinking (non-dependent) participants about the probability that they would receive beer (100%, 50%, 0%) before each trial of a visual-probe task with concurrent eye-tracking. During this task, alcohol-related and neutral pictures were presented on a computer screen while participants' eye movements were recorded. Results revealed that AB for alcohol cues was elevated when participants expected to be able to consume alcohol imminently, compared to when they knew that alcohol was not available. However, this sensitivity to availability information was only seen in relatively light drinkers. In heavier drinkers, AB for alcohol cues was seen regardless of availability information. This finding may suggest that AB can become decoupled from the anticipation of reward in those who drink more heavily or more frequently (*see also* Hogarth, Balleine, Corbit, & Killcross, 2013 for a broader discussion of this issue). In a follow-up study, Jones et al. (2012) used a similar methodology and replicated the basic demonstration of increased AB for alcohol cues when alcohol was anticipated imminently. However, unlike in the Field et al. (2011) study,

these effects were apparent in all participants regardless of whether they were a relatively heavy or light drinker. Overall, this evidence demonstrates that AB is sensitive to the perceived availability of reward.

Although, the comparable effects of food reward anticipation on AB for food-related cues have been reported by some studies (Jones et al., 2012) these findings have not always been replicated (Hardman, Scott, Field, & Jones, 2014; Werthmann, Roefs, Nederkoorn, & Jansen, 2013). In the study conducted by Werthmann, Roefs, Nederkoorn, and Jansen (2013) AB for chocolate-related cues was not moderated by perceived availability of chocolate. It is possible that in this study there was a fairly long interval (estimated at 15-20 minutes) between giving participants the availability information and the actual opportunity to consume chocolate, and this could have blunted the motivational impact of availability information. As in the case of other cue reactivity measures the impact of availability on AB could depend on close time and distance proximity of reward (*see* 1.2.4 Imminent availability, *p.* 17). To address this issue Hardman et al. (2014) manipulated the effects of food anticipation (*i.e.*, pizza points) on a trial by trial basis (*see also* Field et al., 2011; Jones et al., 2012). In line with the results reported by Werthmann, Roefs, Nederkoorn, and Jansen (2013), this study revealed that anticipation of food did not enhance AB neither for food or alcohol-related cues. However, a significant difference between probability conditions was revealed when mean gaze direction bias was averaged across food and alcohol pictures. Participants were more likely to initially direct their attention towards reward-related cues when food reward was anticipated (100% and 50% trials) in comparison to 0% likelihood of receiving reward. These results are partially consistent with studies which revealed that AB was enhanced when reward was anticipated. The available studies suggest that the effects of anticipation of drugs (and other rewards) on AB are readily detected when anticipation (expectancy) is manipulated on a within-subjects, trial-by-trial basis, which ensures that participants expect to receive the reward (or not receive it) at the exact moment that AB is measured (*e.g.*, Field et al., 2011; Jones et al., 2012), albeit these effects are less clear for food anticipation (*e.g.*, Hardman et al., 2014).

1.2.7. Are the effects of reward anticipation on attentional bias general or outcome specific?

It is unclear whether the effects of availability anticipation are dependent on congruency between the type of reward that is anticipated and the type of reward cue for which AB is measured. One account based on emotion regulation (broad-and-build theory; Fredrickson, 2001) suggests that effects of reward anticipation might be more generalised. According to this theory, positive emotions increase receptiveness to environmental signals that rewards are available. As predicted by the theory, induction of positive mood can facilitate AB for rewarding stimuli (Tamir & Robinson, 2007). It could be expected that reward anticipation may lead to comparable increases in AB. For instance, reward anticipation can increase positive mood as reflected by the correlation between the anticipatory increase of activation in the nucleus accumbens during reward anticipation and self-reported positive arousal (Knutson & Greer, 2008); and therefore, reward anticipation should also increase AB for a broad range of reward-related cues.

Interactions between Pavlovian and instrumental associative learning, specifically PIT, suggest an alternative mechanism through which anticipation of a specific reward might increase AB for reward-related stimuli in general. Outcome-specific PIT occurs when the presentation of a Pavlovian cue (*e.g.*, a discrete environmental cue previously paired with sucrose) increases instrumental responding for that reinforcer. However, that Pavlovian cue can also energise instrumental responding for other rewards as well, and this is known as General PIT (Cartoni, Puglisi-Allegra, & Baldassarre, 2013; Corbit & Balleine, 2005, 2011; Holmes, Marchand, & Coutureau, 2010). Given that attentional selection precedes action selection (Armel, Beaumel, & Rangel, 2008; Krajbich, Armel, & Rangel, 2010) we might expect that anticipation of a specific reward would increase AB for cues related to a range of rewarding stimuli. In the first test of this idea, Jones et al. (2012) investigated whether effects of reward anticipation could be attributed to an *outcome-specific* effect, or if they reflect a more *generalised* mechanism. In the Field et al. (2011) study participants received small amounts of alcohol on a trial-by-trial basis depending on the probability information and feedback, Jones et al. (2012) study involved secondary reinforcement (*i.e.*, points

that participants' believed would be exchanged for chocolate and beer at the end of the study). The lack of opportunity to consume rewards on the trial-by-trial basis suggests that Jones et al. (2012) was able to measure the effects of reward anticipation in isolation from the effects of satiety and intoxication. For example administration of alcohol reward could increase motivation to consume alcohol drinks (de Wit & Chutuape, 1993; Fillmore & Rush, 2001) and this could increase AB (Adams, Ataya, Attwood, & Munafo, 2012; Schoenmakers, Wiers, & Field, 2008). The risk here is alcohol intoxication could alter or even drive the effects of availability anticipation, thus creating difficulties in interpretation of results. Furthermore, the impairment of inhibitory control after alcohol use could increase consumption of food (*e.g.*, Christiansen, Rose, Randall-Smith, & Hardman, in press; Rose, Hardman, & Christiansen, 2015). Therefore, it is possible that the administration of alcohol reward could increase AB for food-related stimuli via changes in inhibition. At the same time, food intake could also affect food cravings and hence AB. Hence, the introduction of reward consumption during a reward anticipation task brings a new set of variables which could affect the clarity and interpretation of final results. Secondary reinforcement also allows for the simultaneous investigation of the impact of different substances on AB – actual consumption of chocolate and beer during the task could make participants nauseous affecting the value of anticipated reward as well as rising ethical concerns. The method introduced by Jones et al. (2012) showed that the anticipation of secondary reinforcers associated with the availability of actual rewards was sufficient to moderate AB.

In the study conducted by Jones et al. (2012), participants completed a computerised task whilst their eye movements were recorded. On each trial, participants were shown a picture that represented the type of reward (beer or chocolate) and a percentage that indicated the chances of reward (100%, 0% likelihood of reward) points that would later be exchanged for that reward. Subsequently, one of two types of pairs of pictures was displayed on the screen (chocolate–neutral pairs or alcohol-neutral pairs). The primary finding was an effect of reward anticipation on AB that was generalised rather than outcome-specific: AB for both alcohol and chocolate pictures (as inferred from longer maintenance of gaze

on those pictures rather than the neutral pictures) was larger on 100% probability trials compared to 0% trials, regardless of the type of reward (alcohol or chocolate) that was anticipated. This demonstration that the effects of reward anticipation on AB are general rather than specific to the reward that is anticipated is problematic for conditioning-based accounts of this effect (Field & Cox, 2008). It can be argued that the use of points could mean that participants did not actually anticipate different rewards on the different types of trials. However, it was proposed that the probability cues are sufficient to trigger the representations of substance-related reward and direct attention (Hogarth, Dickinson, Wright, Kouvaraki & Duka, 2007), which makes them a valid substitute of actual rewards in the examination of the effects of anticipation on AB. However, methodological issues in this study may account for these findings and suggest an alternative explanation for the results, as discussed in Jones et al. (2012).

1.2.8. Summary - Anticipation of reward

Increased food and alcohol availability could be a contributing factor in substance-related problems. Both naturalistic and laboratory-based studies demonstrated that perceived substance availability can increase craving and facilitate consumption. It should be emphasised that imminence of availability may be a crucial condition for revealing its effects on cue reactivity. Associative learning processes explain how drug and food-related cues can trigger conditioned responses, including craving and AB, via anticipation of substance availability. Research implicates that at least at the early stage, learning may depend on the awareness of *if-then* rules between substance-related cues and availability (Hogarth & Duka, 2006). Cues signalling imminent substance availability are capable of increasing AB (Field et al., 2011; Jones et al., 2012). Jones et al. (2012) demonstrated general effects of substance anticipation on AB – the anticipation of beer or chocolate can increase AB for both alcohol and chocolate cues regardless of the type of anticipated reward. However, it is fair to say that these findings are ambiguous, so one of the goals of the current research is to clarify whether effects of substance anticipation on AB are general or outcome specific.

1.3. AB and emotional regulation

1.3.1. Introduction

The anticipation of reward (substance) may have a moderating effect on AB. Apart from the presented effects of anticipation of motivationally salient outcomes like an alcohol or food reward on AB, research indicates that these moderating effects might generalise to a different type/category of motivationally salient stimuli. This section provides an overview of research related to the role of AB and anticipation of motivationally salient outcomes in emotional regulation focusing on the arguments provided by Rothermund and colleagues (Koole & Rothermund, 2011; Rothermund, Gast, & Wentura, 2011; Rothermund, Voss, & Wentura, 2008).

1.3.2. Positivity and negativity bias

AB may be a crucial mechanism in successful goal-directed behaviour whereby it highlights reward opportunities or potential threat, allowing for adequate response selection. As pointed out by Rothermund et al. (2011) there seem to be a dichotomous split among accounts regarding whether positive or negative information command more attention. This split is reflected by the results of research from various branches of cognitive processing (*e.g.*, selective attention, memory encoding or recall). Some evidence indicates that negative events are more salient than positive events and therefore they receive more attention (*e.g.*, Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Ohman, Lundqvist, & Esteves, 2001; Pinkham, Griffin, Baron, Sasson, & Gur, 2010; Pratto & John, 1991; Rozin & Royzman, 2001), while other research implicates the superiority of positive information over negative (*e.g.*, Kunda, 1990; Mata, Ferreira, & Sherman, 2013; Silvera, Krull, & Sassler, 2002; Svenson, 1981). Overall Rothermund et al. (2008) and Rothermund et al. (2011) concluded that both positivity and negativity biases are important from the perspective of goal-directed behaviour. For example, negativity bias might be crucial in threat detection (*see* Vaish, Grossmann, & Woodward, 2008) while positivity bias might be helpful in detection and tracking of rewarding stimuli, explaining an overall bias for rewards like food (*e.g.*, Hardman et al., 2014;

Werthmann, Roefs, Nederkoorn, Mogg, et al., 2013). Therefore, survival may depend on both negativity and positivity bias, making them equally important. However, none of accounts arguing superiority of one type of bias over the other one seems to provide a complete explanation of the role of cognitive bias in behaviour.

1.3.3. A rigid AB as a potential cause of 'disordered' goal behaviour

The rigid AB could distort the perception of the reality to the extent where everyday behaviour could be jeopardised. Rothermund et al. (2008) provided an example of mental health disorders to illustrate how persistent bias could be associated with maladaptive behaviour and play a role in their aetiology (*e.g.*, Everaert, Koster, & Derakshan, 2012; Field & Cox, 2008; Van Bockstaele et al., 2014). This seems to be true for both negativity and positivity AB. Anxiety disorders and mood disorders like depression tend to be accompanied by negativity bias. For anxiety disorders AB for some types of negative cues may lead to behavioural withdrawal and avoidance of certain situations (Perez-Edgar et al., 2010; Perez-Edgar et al., 2011) leading to failure in achieving goals. For example increased AB for threat-related stimuli could jeopardise a goal of having a successful social life. Some studies of AB in depression revealed an AB for negative stimuli (Gotlib, Krasnoperova, et al., 2004) and negativity AB being associated with the maintenance of depression (Beevers, Clasen, Enock, & Schnyer, 2015; Clasen, Wells, Ellis, & Beevers, 2013). At the same time, a failure to develop AB for reward-related stimuli (Brailean, Koster, Hoorelbeke, & De Raedt, 2014) may affect engagement in goal-directed behaviour. Research has also shown dysphoria and depression were associated with decreased positivity bias (Armstrong & Olatunji, 2012; Ellis, Beevers, & Wells, 2011; Sears, Thomas, LeHuquet, & Johnson, 2010). From the perspective of goal-directed behaviour, constant negativity bias and problems with maintaining attention on positive stimuli could be considered as a partial positivity blindness which could lead to further emotional distress and progression of a mental health disorder.

Conversely, a rigid AB for positive cues could make an individual underestimate warning signs, and lead to an excessive involvement in behaviour inconsistent with the achievement of long-term goals. Research has consistently

shown that addiction is characterised by AB for drug-related stimuli (Field & Cox, 2008). A study involving a spatial orienting task revealed that AB towards cues predicting general reward and non-punishment cues was associated with tobacco, alcohol and cannabis use three years after testing (van Hemel-Ruiter, de Jong, Ostafin, & Oldehinkel, 2015). A recent review provided support for AB for food-related cues in obesity (Hendrikse et al., 2015). Addiction and obesity, both of which could be characterised by positivity (reward-related) bias towards drug or food rewards respectively, illustrates how AB could distort perception of reality and lead to maladaptive behaviour. This explanation seems to be consistent with studies which have shown a link between impulsivity and substance misuse, obesity or binge eating disorder (Christiansen, Cole, Goudie, & Field, 2012; Fernie et al., 2013; Jentsch et al., 2014; Nederkoorn, Dassen, Franken, Resch, & Houben, 2015; Schag, Schonleber, Teufel, Zipfel, & Giel, 2013), and raises a question whether preference for instant gratification over achievement of long-term goals could be associated with being 'blinded' by the reward-related cues. Non-surprisingly a recent meta-analysis revealed a small but robust relationship between substance-related AB and impulsivity (Coskunpinar & Cyders, 2013); similar results were also shown for obesity (Hou et al., 2011).

The example of mental health disorders clearly shows that the avoidance of threat during reward pursuit could be as important as the ability to detect reward during threat avoidance behaviour. A rigid AB seems to be associated with the lack of ability to adjust or select behaviour, leading to behaviour preservation regardless of its consequences. While negativity and positivity bias might be beneficial and allow for survival, it is unlikely that in the long term successful goal-directed behaviour would depend on rigid cognitive mechanisms. Both of the groups of discussed mental health disorders characterised either by negativity and positivity bias demonstrate that goal achievement could be hindered by the formation of inflexible focus of attention. As pointed out by Rothermund et al. (2008) flexibility is an important concept in the successful goal-directed behaviour. Flexibility can help initiate, maintain and translate intentions into goal-directed behaviour (Brunstein, 1989; Gropel, Baumeister, & Beckmann, 2014; Kuhl, 1981, 1994, 2000) and can be a predictor of success (Diefendorff, 2004; Diefendorff, Hall,

Lord, & Strean, 2000). This shows that successful goal behaviour depends on response flexibility and implicates that a rigid or constant AB either for negative or positive information could be counterproductive in goal pursuit (Rothermund et al., 2008).

1.3.4. Counter-regulation principle (CRP)

As discussed before the experience of some negativity or positivity bias is a common trait cognitive characteristic. The reason behaviour is not sabotaged by AB allowing for goal achievement could lie in effective emotion regulation (Koole & Rothermund, 2011). The dual-process model of emotion regulation implicates that the regulatory processes take place at both explicit and implicit levels (Gyurak, Gross, & Etkin, 2011). Successful goal-directed behaviour depends on flexible and often quick decision making, where individuals can adjust their response while processing both negative and positive cues. The time restraint and the amount of information that has to be analysed during decision making suggest that some part of emotion regulation related to goal-directed behaviour must take place at the implicit (automatic) rather than the explicit (cognitively demanding) level (*see review* Koole & Rothermund, 2011). Rothermund et al. (2008) proposed CRP as one of the implicit processes which prevent emotional states from escalating, and supports the maintenance of emotional stability. CRP posits that attention is directed towards stimuli with valence that is incongruent with the goal-related motivational state. For example, the experience of loss should increase AB for positive (including reward-related cues) whereas the experience of reward should direct attention towards negative (including loss-related) stimuli. Rothermund et al. (2008) argues that this mechanism prevents us remaining in extreme emotional states and allows for flexible switching between motivational and emotional orientations.

Counter-regulation in attentional processing has received solid empirical support (*e.g.*, Rothermund, 2003; Rothermund et al., 2008; Schwager & Rothermund, 2013; Wentura, Voss, & Rothermund, 2009). For example in an innovative experiment conducted by Wentura et al. (2009), participants were asked to play a modified version of TETRIS game in order to study counter-regulation processes in motivational context. Participants were asked to respond

quickly and their response times and/or errors were recorded. The goal of the task was to either prevent the loss of high scores (negative outcome focus) or to gain high scores (positive outcome focus). The falling blocks were accompanied by positive (happy faces), negative (sad faces), neutral (neutral faces) distractor stimuli or none. During the negative outcome, focus participants experienced greater interference from positive distractors. In contrast, a positive outcome focus resulted in greater interference from negative distractors. These results are consistent with the predictions of CRP. However, incongruency effects could be explained in a more parsimonious way than emotion regulation. Incongruency in AB may reflect a mismatch between positively/negatively valenced stimuli and negative/positive motivational state or context. In comparison to a cue in which valence is consistent with a motivational context, presentation of valenced stimuli during a contrasting motivational context may enhance the cue's relative salience. This arguably increases its ability to attract attention (*see* Rothermund et al., 2011). Rothermund et al. (2011) addressed this issue and found that incongruency effects occurred only during the spatial search when affective-motivational states were induced by performance-related feedback presented at the end of each of the trials. In the second experiment, when participants were asked to memorise motivationally salient information (*i.e.*, the words: "good" or "bad"), the performance on the special search task revealed a congruency effect. Although this study suggests that counter-regulation is specific to goal-directed behaviour and provides further support for the role of incongruency effects in emotion regulation, it should be mentioned that the memory task did not include a neutral world as a control condition. These findings are consistent with theories which suggest that AB for positive stimuli under stress may support emotion regulation (Frenkel, Lamy, Algoma, & Bar-Haima, 2009; Wadlinger & Isaacowitz, 2008).

It was proposed that the anticipation of motivationally salient outcomes should be sufficient to trigger counter regulation processes. Using a flanker task Rothermund et al. (2008) found that introduction of positive or negative outcome focuses activated incongruency effects as would be predicted by CRP. The interference of stimuli signalling gain opportunities was stronger during negative outcome focus blocks of trials – when participants had to attain a certain

amount of points in order not to lose their reward; and the interference effects of stimuli signalling a risk of losing a point were stronger during positive outcome focus blocks of trials – when participants had to gain a certain amount of points in order to win a reward. Therefore, it was proposed that the anticipation of the possible motivationally relevant outcome - defined by the outcome focus - affected attentional preference during the task revealing counter regulation processes.

1.3.5. Congruency and incongruency in attentional processing

Research on emotion regulation and AB provides additional information on the effects of anticipation of motivationally salient outcomes. Apart from the previously discussed learned AB substance-related responses, attention can be selectively directed towards motivationally salient stimuli incongruent with a current motivational context. These incongruency effects can be triggered by anticipation of reward and loss, and could play a significant role in emotion regulation preventing affective states from escalation and allowing for flexible decision making. Contrarily, research which demonstrated that attention is allocated towards stimuli congruent with the content of working memory implicates the opposite predictions. For instance, Van Dessel and Vogt (2012) investigated the impact of affective context on AB for facial expressions of emotion. On a trial-by-trial basis, one group of participants was required to memorise either a positive, negative or neutral sound during a dot probe task whereas the other group was also expected to encode the valence of the sound. The results revealed the congruency effects in attentional processing of facial expressions of emotion. Attention was more likely to be directed towards faces congruent with the valence of affective context, albeit, these effects were only present in the group which was required to encode the sound. It was proposed that the content of working memory can moderate AB leading to the congruency effects when memorised information is task-relevant. Smith et al. (2006) demonstrated that priming with positive information can diminish negativity bias in affective processing. This demonstrates that, affective context, apart from increasing AB for congruent stimuli, can also diminish AB for incongruent stimuli. In general, research suggests that attentional selection of visual cues may depend on its match/relevance with the content of working memory (*see* Olivers, 2008; Soto, Hodsoll, Rotshtein, & Humphreys, 2008). Assuming that information about

the likelihood of motivationally salient outcomes is maintained in working memory, it can be expected that attention should be directed towards stimuli relevant to the current affective context.

1.3.6. AB and emotion regulation - Summary

Incongruency and congruency accounts of affective processing imply that anticipation of reward may have an impact on attentional processing of motivationally salient stimuli. While CRP based predictions suggest that anticipation of substance reward should increase AB for negatively valenced stimuli and anticipation of substance loss should increase AB for positively valenced cues, the congruency accounts suggest the opposite effects of anticipation of reward and loss on AB. The investigation of these hypotheses is important because the anticipation of drug or food reward or loss could have a more global impact on the attentional processing of surrounding stimuli. One of the goals of the current research is to explore whether the type of cues, comparable to those previously used by Jones et al. (2012) would be capable of triggering AB for motivationally salient stimuli congruent or incongruent with the anticipated outcome.

1.4. Aim and Outline of the Dissertation

The aim of the thesis is to extend previous research on AB and examine some fundamental issues regarding the link between anticipation of reward and loss and attention for motivationally-salient cues. The first specific aim is to investigate the psychological mechanisms that underlie the effects of anticipation of reward on AB for substance-related cues. The second aim is to extend this line of enquiry to examine the effects of loss anticipation on AB for substance-related cues. The third aim is to identify the neural mechanisms that underlie the effects of reward anticipation on AB for substance-related cues. The final aim is to investigate if the anticipation of substance reward and loss can influence AB for negatively and positively valenced cues (facial expressions) rather than pictures of substance-related rewards.

Chapter 2 reports the results of four empirical studies which investigate issues related to the effects of anticipation of motivationally salient outcomes on attentional bias for alcohol and chocolate-related stimuli. These studies utilise eye-tracking methods to measure AB for substance-related cues under different probabilities of winning or losing substance-related reward. The aim of the initial study was to explore whether the generalised effects of reward anticipation on AB reported by Jones et al. (2012) are demonstrated after controlling for a potential methodological confound in that earlier study. I tested the hypothesis that the anticipation of substance-related reward should increase AB for substance-related cues, and investigated whether this increase was: either outcome-specific *i.e.*, the effects of anticipation are specific to stimuli closely related to the anticipated substance, or general *i.e.*, anticipation of substance reward increases AB for the range of reward-related stimuli. This study clarifies the psychological mechanisms that underlie the effects reported previously (Field et al., 2011; Jones et al., 2012), and suggest avenues for follow-up studies.

A distinct, but related research question addressed in Chapter 2 concerns the anticipation of loss and its effects on AB. Two competing hypothesis regarding the direction of effects of loss anticipation on AB can be made: the anticipation of

loss should increase AB for a substance-related cues (Kavanagh et al., 2005) and these effects could be generalised (*see* Rothermund et al., 2008); or loss anticipation should decrease AB for substance-related cues (*e.g.*, Field et al., 2011; Jones et al., 2012) and these effects should be outcome specific (Field & Cox, 2008). These hypotheses are tested by the investigation of participants AB for substance-related cues (chocolate and alcohol) under different probabilities of substance loss (chocolate and beer) using a crossover design.

The effects of loss anticipation on AB may depend on the level of control over the outcomes of behaviour (*see* Brandtstädter & Rothermund, 2002; Rothermund, 2011). Therefore, in addition to the studies which investigate the impact of probabilistic cues indicating reward and loss, additional studies reported in Chapter 2 address the issue of outcome control as a potential moderator of AB and the effects of loss as well as reward anticipation. In these eye-tracking studies participants have behavioural control over reward and loss outcomes.

Chapter 3 expands upon the results of initial reward anticipation study, and aims to identify neurophysiological underpinnings of the effects of reward anticipation on the attentional processing of substance-related cues. This chapter provides a brief introduction to electroencephalography as a research method, explaining its' basic technical aspects and related terminology. Two components which can reflect changes in the attentional processing of substance-related cues during reward anticipation are discussed. It can be expected that increased attentional processing of substance-related stimuli should be reflected by a more pronounced P300 component which is considered an index of motivated attention (Littel et al., 2012; Schupp et al., 2004). Since the P300 component is sensitive to the motivational value of stimuli, its amplitudes should be further enhanced by the anticipation of substance-related reward. Alternatively, feedback relative negativity a component which is known to be associated with outcome evaluation processes (Holroyd & Coles, 2002; Nieuwenhuis, Holroyd, Mol, & Coles, 2004) is considered as likely to be affected by reward anticipation. This chapter reports the results of an electroencephalography study which investigates the amplitude of these ERP components in response to substance-related and neutral cues under different probabilities of reward.

Chapter 4 investigates the effects of anticipation of reward and loss on AB for positively and negatively valenced cues (*i.e.*, facial expression of emotions) rather than pictures of the substances (beer and chocolate) that participants are anticipating during the experimental tasks. Studies reported in this chapter examine the competing predictions based on research which reported congruency (*e.g.*, Smith et al., 2006; Van Dessel & Vogt, 2012) and incongruency (*e.g.*, Rothermund et al., 2008; Wentura et al., 2009) effects in attentional processing. Congruency based accounts suggest that attention is more likely to be directed towards stimuli matching the content of working memory (*see* Olivers, 2008; Soto et al., 2008). This implicates that reward anticipation should increase AB for positively valenced information whereas loss anticipation should increase AB for negatively valenced information. In contrast, the emotion regulation literature (*see* Rothermund, 2011; Rothermund et al., 2008) yield the opposite predictions *i.e.*, anticipation of reward should increase AB for negatively valenced cues and loss anticipation should increase AB for positively valenced cues. In order to investigate this issue, AB for facial expressions of emotion (happy, sad and neutral ones) is examined under different probabilities of substance reward and loss.

The thesis ends with a general discussion of the results reported in the empirical chapters. The first section of general discussion recalls the findings reported in the empirical chapters. Subsequently, these findings are discussed in the context of previous research and theoretical as well as clinical implications. Finally, the limitations of the research presented in this thesis and of the broader literature are discussed. This thesis provides important data regarding the link between motivation and attention which has implications for our understanding of biased attention in disorders such as addiction, obesity.

CHAPTER 2 - THE EFFECTS OF REWARD AND LOSS ANTICIPATION ON THE EYE MOVEMENT INDICES OF ATTENTIONAL BIAS FOR SUBSTANCE-RELATED CUES

ABes for substance-related cues are moderated by the expectation of imminent reward availability, but the psychological mechanisms that underlie this effect are unclear. This chapter reports a series of studies which investigated: (1) if effects of reward anticipation are specific to the type of reward that is anticipated; (2) if anticipation of loss has comparable effects to anticipation of reward; (3) the effects of uncertainty; and (4) how perceived control over rewards and losses moderates these effects. An eye tracking task was used to investigate the effects of anticipation of reward (Study 2.1) or loss (Study 2.2) of alcohol and chocolate on AB for alcohol and chocolate pictures using full crossover designs. Subsequently, the moderating role of perceived control on effects of loss anticipation (Study 2.3) and reward anticipation (Study 2.4) on AB was investigated. All of the studies investigated the effects of cues signalling certain (100% likelihood of outcome) and uncertain (50% likelihood of outcome) loss or reward. The results from Study 2.1 indicated outcome-specific effects of reward expectancy: anticipated alcohol reward increased AB for alcohol, but not chocolate, pictures, and the opposite pattern was seen for chocolate anticipation. The results from Study 2.2 revealed no effects of loss anticipation on AB. However, when participants perceived control over potential losses (Study 2.3), outcome-specific effects of loss anticipation on AB were observed, although the pattern differed for alcohol and chocolate pictures. Yet, when participants perceived control over potential rewards (Study 2.4), anticipation of reward did not influence AB. Across all studies, effects of uncertainty tended to mimic effects of anticipated reward or loss. Together, these findings demonstrate that anticipation of reward and prevention of loss lead to outcome-specific increases in AB for reward-related cues, but these effects are dependent on participants' perceived control over outcomes.

Introduction

Motivationally salient cues in the environment are able to capture and hold attention (Cisler et al., 2009; Field et al., 2014). For example, people who use addictive substances (including alcohol) have an AB for substance-related cues (Field & Cox, 2008), whereas AB for food cues appears to be present in everybody to some degree (Werthmann, Jansen, & Roefs, 2014). AB is a dynamic variable that fluctuates within individuals and it is closely related to the current underlying motivational state (*e.g.*, craving - Field et al., 2009; hunger - Werthmann et al., 2015). For example in both cases, experimental manipulations of the underlying motivational state by imposing a period of substance deprivation or fasting lead to increases in the strength of AB (Field et al., 2016).

Although previous research on AB highlighted the importance of between-group differences in AB (*e.g.*, addicts have a higher AB for drug-related cues in comparison to non-users), currently it appears to be agreed that the identification of variables responsible for the temporal changes in AB might be important in the prediction of substance-related behaviour. This has been emphasised for both food and addictive substances including alcohol (Field et al., 2016). One of the factors which may be responsible for the fluctuations of AB and related motivational states is substance availability. When food or drugs are anticipated imminently, this increases the strength of subjective craving and responses to reward-related cues, including AB. For instance, AB for substance-related cues can be potentiated if participants believe that they will have an opportunity to use the substance in the near future. Comparable effects of food anticipation on AB for food-related cues have been reported (*e.g.*, Field et al., 2011; Hardman et al., 2014; Jones et al., 2012), although these findings have not always been replicated (*see* Hardman et al., 2014; Werthmann, Roefs, Nederkoorn, & Jansen, 2013).

It is unclear if these effects are dependent on congruency between the type of reward that is anticipated and the type of reward cue for which AB is measured. Some of the emotion regulation accounts such as broaden-and-build theory (Fredrickson, 2001) suggest that effects of reward anticipation might be more generalised *i.e.*, the anticipation of reward should increase AB for reward-related

cues in a generalised fashion. Similar predictions are implicated by General PIT effects where Pavlovian cues associated with one reinforcer can also energise instrumental responses for other rewards as well (Corbit & Balleine, 2005, 2011; Holmes et al., 2010). Assuming that attentional selection precedes action selection (Armel et al., 2008; Krajbich et al., 2010) it might be expected that anticipation of a specific reward would increase AB for a variety of rewarding stimuli. The first study that addressed this issue conducted by Jones et al. (2012) provided empirical support for the general effects of reward anticipation on AB. AB for both alcohol and chocolate pictures was larger when participants expected to win a reward compared to no reward trials. These effects were present regardless of the type of substance reward (alcohol or chocolate) that was anticipated. However, a methodological confound could have obscured outcome-specific effects of reward anticipation.

The present chapter reports findings from four studies which attempted to clarify the psychological mechanisms that underlie the effects of substance anticipation on AB for reward-related cues. As a starting point, the generalised effects reported in the earlier study (Jones et al., 2012) were investigated to clarify whether these results could be replicated after considering a potential methodological confound. The role of uncertainty in comparison to the expectation of certain reward gains was also considered, as different theories of associative learning make competing predictions in this regard (Mackintosh, 1975; Pearce & Hall, 1980). Next, the effects of anticipation of loss on AB were investigated, because some theories (Rothermund et al., 2008) but not others (Carver, 2001; Gable & Harmon-Jones, 2010), suggested comparable effects of reward and loss anticipation on AB for reward-related cues. Finally, theoretical claims that the effects of reward and loss anticipation would be moderated by participants' perceived control over outcomes during the task (Rothermund, 2011) were tested.

Study 2.1. The effects of reward anticipation on AB

2.1.1. Introduction

Jones et al. (2012) demonstrated that the effects of anticipation of reward on AB were generalised rather than outcome-specific, because anticipation of alcohol or chocolate led to increased AB for both alcohol and chocolate pictures. However, some features of the experimental task could have contributed to these findings. The anticipation of alcohol and chocolate (points) reward was manipulated on a trial-by-trial basis and participants were instructed to make the same motor response (press the spacebar) on each trial, regardless of the type of reward that was available on that trial. Jones et al. (2012) acknowledged that this could have encouraged participants to focus on the probability information that was presented on each trial rather than the type of reward that was on offer. If this speculation is correct, this could explain the observed general effect of reward anticipation on AB rather than the hypothesised outcome-specific effects. The present study repeated the general methodology used in the earlier study, with one critical difference: participants were instructed to press one key on trials when alcohol expectancy was manipulated, and a different key when chocolate expectancy was manipulated. This should ensure that participants maintain awareness of the type of reward that is available throughout the trial, including, critically, whilst their eye movements are assessed.

This study investigated how AB would be affected when participants were uncertain about the likelihood of reward, *i.e.*, when they were informed that the probability of reward was 50%. This is important because the results for the effects of uncertainty were not reported by Jones et al. (2012). Associative learning theories make competing predictions about the nature of attention to conditioned stimuli during the formation of associations between conditioned and unconditioned stimuli, and after those associations have been established (*see* Hogarth, Dickinson, & Duka, 2010). One theory suggests that attention to conditioned stimuli should be maximal under conditions of uncertainty, *i.e.*, when the predictive significance of that cue is uncertain (Pearce & Hall, 1980).

A competing theory suggests that attention closely tracks the predictive significance of conditioned cues, such that maximal attention is directed toward cues that are reliable predictors of unconditioned stimuli (Mackintosh, 1975). Although these are not theories of AB to reward-related cues, they can be used to generate competing predictions about the effects of uncertainty in the current research paradigm. According to Pearce and Hall (1980), the incongruity between presentation of uncertainty information and a pictorial cue that is reliably associated with that reward should maximise attention to the cue; therefore, AB under conditions of uncertainty should be higher compared to AB when reward is anticipated with certainty. According to Mackintosh (1975), the congruence between anticipation of imminent reward and the presentation of a reward-related cue should increase AB for that cue. Therefore, AB should closely track probability information, and be maximal when reward is anticipated with certainty, lower under conditions of uncertainty, and lower still when the reward is not expected at all.

The aim of the first study was to investigate (1) whether the general effects of reward anticipation on AB would be demonstrated after controlling for the potential study artefact by using a crossover design with independent behavioural responses for chocolate and beer. The effects of probability were also investigated by testing if: (2) reliable reward predictors (100% probability of reward) have a greater impact on AB in comparison to uncertain ones (50% probability of reward); or if (3) the effects of uncertain loss predictors on AB are more pronounced than those of reliable predictors.

2.1.2. Method

Participants

Assuming that the general effects of anticipation demonstrated by Jones et al. (2012) were a study artefact, a-priori power analysis was based on the outcome specific effects sizes reported in the study (d = 1.22 for alcohol and d = 0.97 for chocolate anticipation effects). G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007) was used to conduct power analysis. This revealed that a total sample size of 9 participants would be required to detect the effects of alcohol anticipation, and a total sample size of 13 participants would be needed to detect the effects of chocolate

anticipation with 95% power at α = .05. To assure the current study was not underpowered thirty-four participants (27 female) were recruited from the staff and students at the University of Liverpool. For all studies, inclusion criteria were regular consumption of chocolate and beer (both at least once per week), aged above 18, fluency in English, and normal or corrected to normal vision (participants who wore glasses could not take part due to incompatibility with the eye tracker). Participants who had ever received treatment for alcohol problems could not take part. Study 2.1 was approved by the University of Liverpool Research Ethics committee (Ref. IPHS-1213-LB-024), and all participants provided informed consent before taking part. Participant characteristics are shown in Table 2.1.2-1.

Table 2.1.2-1 *Participant characteristics Study 2.1*

Recruited participants	34 (F = 27, M = 7)
Participants included in the analysis	30 (F = 23, M =7)
Age (years)	22.07 ± (3.85)
Alcohol consumption (in units per week)	15.59 ± (8.70)
AUDIT	10.43 ± (4.74)
Weekly chocolate consumption (in bars)	3.31 ± (2.43)
Chocolate bars usually kept at home	2.83 ± (3.50)
Chocolate use/craving - CUQ	20.13 ± (5.52)

AUDIT – Alcohol Use Disorders Identification Test, CUQ – Chocolate Use Questionnaire

Pictorial stimuli

The current study utilised the same pictorial stimuli reported in Jones et al. (2012). The alcohol-related stimuli consisted of 10 alcohol-related images (*e.g.*, a close-up of a model opening a bottle of beer, a can, and a glass of beer) each of which was paired with a neutral stationery-related picture (*e.g.*, a close-up of a model sharpening a pencil, pens in desktop organizers). For the chocolate-related stimuli, 10 chocolate-related images (*e.g.*, a chocolate bar, chocolate buttons) were paired with neutral stationery-related pictures (*e.g.*, a voice recorder, clothing buttons). Pictures within each pair were matched on complexity and brightness, and each individual picture was 130 *mm* wide by 90 *mm* high.

The expectancy AB task based on Jones et al. (2012)

At the beginning of each trial, a picture of a *Becks* beer bottle or a bar of *Cadbury's Diary Milk* chocolate (75 *mm* by 75 *mm*) determining the type of reward was displayed in the centre of the screen, directly above text that indicated the probability of winning a reward point on that trial (100%, 50%, or 0% - which reflected *certain reward*, *uncertain reward* and *no reward* respectively). These stimuli were presented for 1000 *ms* and were instantly replaced by a pair of either alcohol-neutral or chocolate-neutral pictures, with one picture to the left and one picture to the right of the central position, 120 *mm* apart, for 2000 *ms*. Immediately after the offset of pictures, the following text was displayed in the centre of the screen: '*press the left key to try to win chocolate*' on chocolate outcome trials, or '*press the right key to try to win beer*' on beer outcome trials. Text feedback was presented for 1000 *ms* as soon as participants pressed the appropriate key: '*you win a beer point!*' on all *certain reward* and half of *uncertain reward* beer outcome trials; 'you win a chocolate point' on all *certain reward* and half of *uncertain reward* chocolate outcome trials; and '*you win nothing*' on all *no reward* trials and the remaining *uncertain reward* trials. The inter-trial interval was 1500 *ms*.

Participants completed a practice block of 12 trials comprising equal numbers of trials in which *certain reward, uncertain reward* and *no reward* beer and chocolate probability information were presented before pairs of neutral pictures

(*e.g.*, household furniture); data from these trials were not analysed. The main block of 240 critical trials comprised 120 alcohol-neutral and 120 chocolate-neutral picture pairs. For each type of picture pair there were an equal number of alcohol and chocolate outcome trials (60 trials each); and within this an equal number of *certain reward*, *uncertain reward* or *no reward* probability trials (20 trials each). Participants had the opportunity to take a short break after every 60 trials, during which they received feedback about the number of beer and chocolate points that they had collected so far.

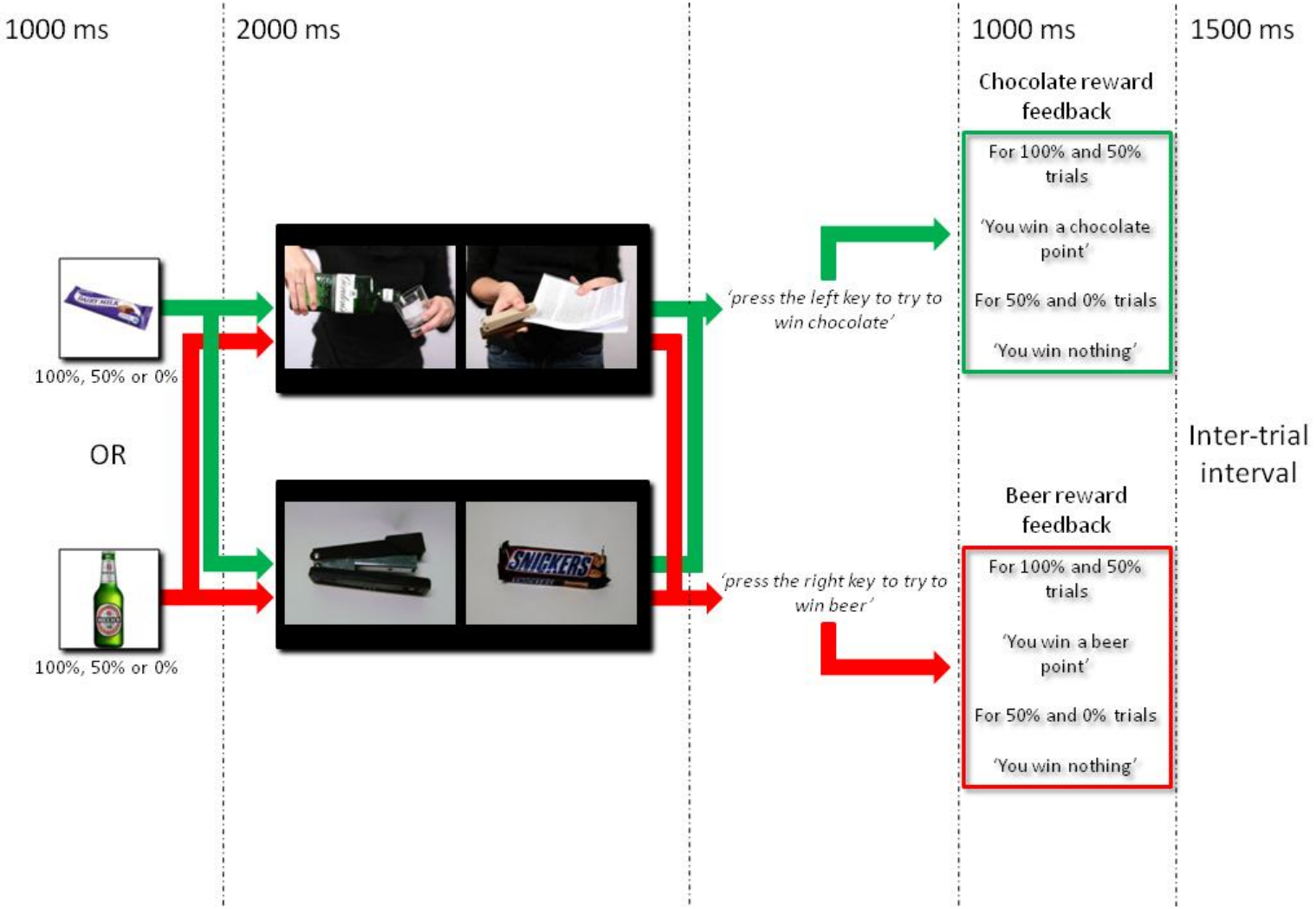

Figure 2.1.2.1. Flowchart of the experimental procedure Study 2.1.

Procedure

All testing took place between 1 pm and 6 pm in the eye movement laboratory in the Department of Psychological Sciences. Bottles of Becks beer and bars of Dairy Milk chocolate were placed around the laboratory so that they were visible to participants as they entered reinforcing the fact they would be competing for actual rewards, but these were out of view when participants completed the task. After providing informed consent participants completed three questionnaires: a two week Time-Line Followback alcohol consumption diary (Sobell & Sobell, 1992), *the Alcohol Use Disorders Identification Test (AUDIT - Babor, Higgins-Biddle, Saunders, & Monteiro, 2001)* and a chocolate use questionnaire (Tibboel et al., 2011).

Participants then completed the expectancy AB task. They were shown the beer and chocolate in the laboratory and were explicitly informed that the points that they accumulated during the task would be converted into actual rewards that they would receive at the end of the experiment. The beer and chocolate were then hidden from view before the eye tracker (Eye-Trac D6; Applied Science Laboratories, Bedford, MA) was calibrated and the task was explained. Participants were asked to pay close attention to the information about the type of outcome and the probability of winning that would be presented at the beginning of each trial, to rest their index fingers on two labelled keys ('c' for chocolate outcome trials and 'b' for beer outcome trials), and to respond by pressing the appropriate key when prompted to do so. As they completed the task, their eye-movement data was continuously recorded at a sampling frequency of 120 *Hz*. Participants were fully debriefed at the end of the experiment. Participants received course credit or a shopping voucher instead of the beer and chocolate, and the requirement for the deception was explained during debriefing.

Data reduction and analysis

Eye-movement data were recorded during the 2000 *ms* when alcohol-neutral or chocolate-neutral pictures were presented. The total duration of fixations upon each area of interest (reward picture or neutral picture) was used to calculate gaze 'dwell time' on each picture. Fixations were defined as the maintenance of gaze

within one degree of visual angle for 100 *ms*, as in previous AB research (Field et al., 2004; Jones et al., 2012; Mogg, Bradley, Field, & De Houwer, 2003). The analysis focused on mean gaze duration as the primary outcome measure of AB. This measure was selected taking into account the results of meta-analysis conducted by Field et al. (2009) which revealed a larger association between AB and craving for the measures of the disengagement of attention from substance-related cues (r = .20, 4% of shared variance) relative to the measures of the initial orientation bias (r = .08, less than 1% of shared variance). Skewness statistics for some dwell time variables were twice the standard error, so data were log transformed in order to normalise distribution before analysis. Data included in the analysis came from participants who had at least 500 *ms* gaze fixation time recorded per trial on average – which is more than 25% of stimulus presentation time. Four participants had incomplete data records (*i.e.*, no data recorded at all for certain trial types). Hence, all of their data was excluded from the analysis (N = 30).

2.1.3. Results

Gaze dwell times were analysed using a four-way repeated-measures ANOVA (*see* Figures 2.1.3.1-2), with factors of *Outcome Type* (2: alcohol points vs. chocolate points), *Probability* (3: *certain reward* vs. *uncertain reward* vs. *no reward*), *Picture Pair* (2: alcohol-neutral vs. chocolate-neutral) and *Picture Type* (2: alcohol/chocolate vs. neutral). This revealed a significant main effect of *Picture Type* ($F(1, 29) = 24.30$, $p < .001$, $\eta_p^2 = .46$) indicating the presence of AB: participants maintained their gaze for longer on chocolate and alcohol pictures in comparison to the matched neutral pictures. The *Probability* x *Picture Type* interaction was not significant ($F(2, 58) = 2.63$, $p = .081$, $\eta_p^2 = .08$); therefore, there was no generalised effect of *reward* anticipation on AB. However, the four-way interaction *Outcome Type* x *Probability* x *Picture Pair* x *Picture Type* was significant ($F(2, 58) = 3.33$, $p = .043$, $\eta_p^2 = .10$).

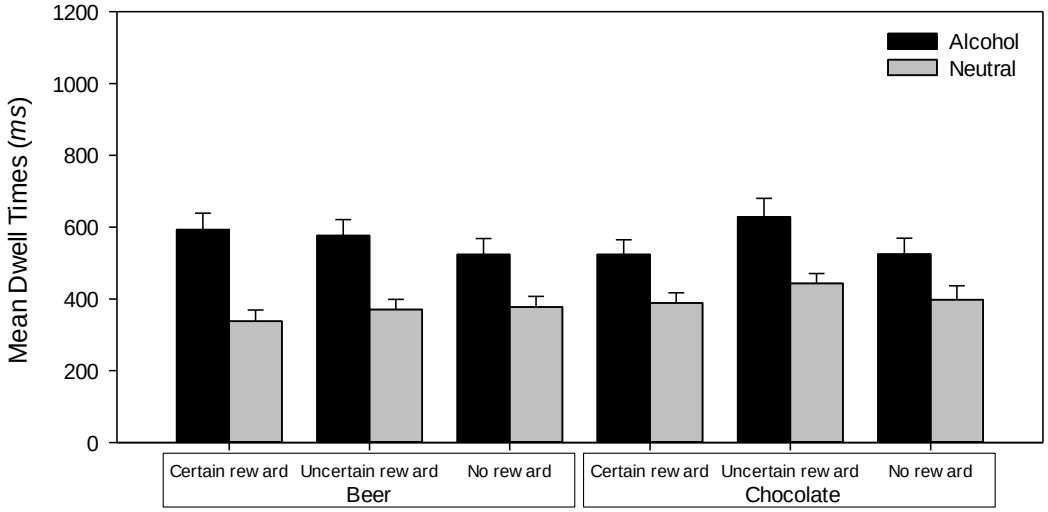

Figure 2.1.3.1. The effects of beer and chocolate reward anticipation on mean dwell times (*ms*) for alcohol-related and matched neutral pictures.

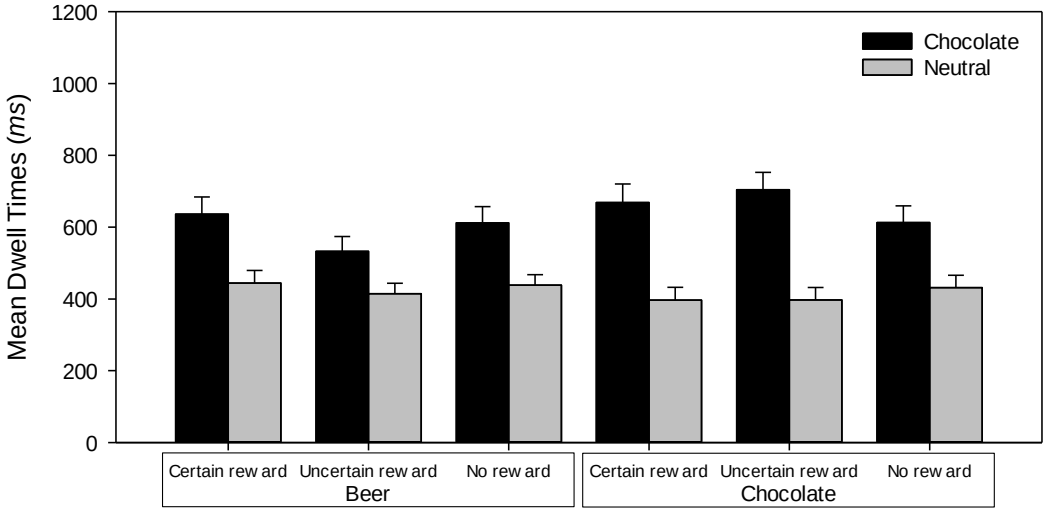

Figure 2.1.3.2. The effects of beer and chocolate reward anticipation on mean dwell times (*ms*) for chocolate-related and matched neutral pictures.

To deconstruct the four-way interaction, AB scores were calculated by subtracting gaze dwell time on neutral pictures from gaze dwell time on the corresponding alcohol and chocolate pictures. One-way ANOVAs were conducted to determine if AB for alcohol and chocolate pictures was reliably affected by expectation of different reward outcomes. The effect of alcohol expectancy on AB for alcohol cues was reliable ($F(2, 58) = 4.57$, $p = .014$, $\eta_p^2 = .14$) but the effect of alcohol expectancy on AB for chocolate pictures was not ($F(2, 58) = 0.62$, $p = .488$, $\eta_p^2 = .02$) (*see* Figure 2.1.3.3). Conversely, chocolate expectancy had a reliable effect on AB for chocolate pictures ($F(2, 58) = 3.79$, $p = .028$, $\eta_p^2 = .12$), but the effect of chocolate expectancy on AB for alcohol pictures was not significant ($F(2, 58) = 0.30$, $p = .686$, $\eta_p^2 = .01$) (*see* Figure 2.1.3.4). Two-way ANOVAs were run on the bias scores with factors of *Outcome Type* and *Picture Pair*, separately at each level of *Probability* (*certain reward*, *uncertain reward*, and *no reward*). The two-way *Outcome Type* x *Picture Pair* interactions were significant for *certain reward* ($F(1, 29) = 8.87$, $p = .006$, $\eta_p^2 = .23$) and *uncertain reward* trials ($F(1, 29) = 8.57$, $p = .007$, $\eta_p^2 = .23$), but not *no reward* trials ($F(1, 29) = 0.14$, $p = .709$, $\eta_p^2 = .01$).

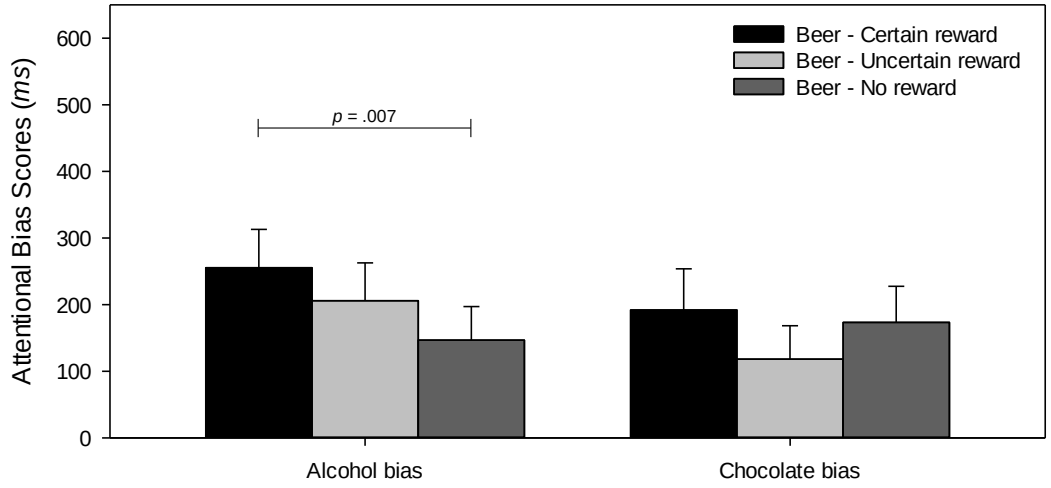

Figure 2.1.3.3. The effects of alcohol reward anticipation on AB (*ms*) for alcohol and chocolate-related pictures.

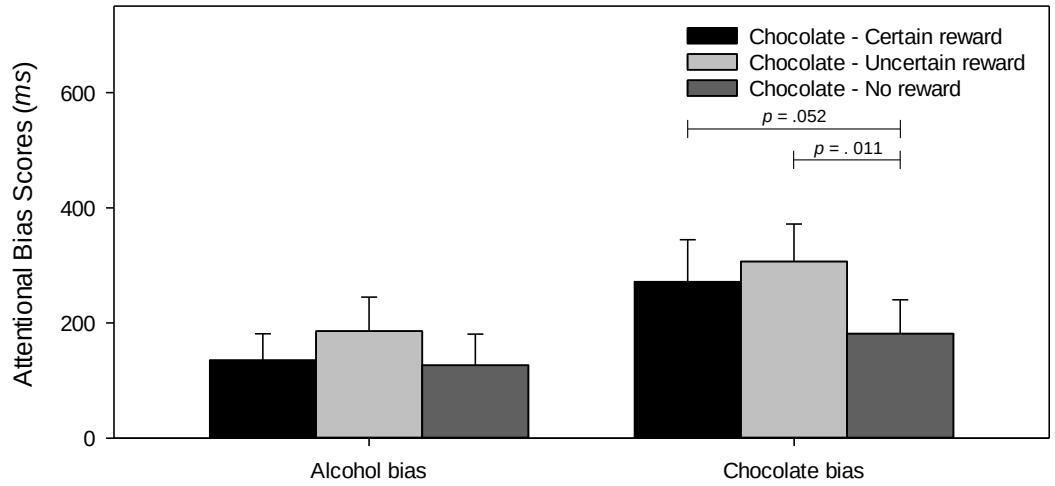

Figure 2.1.3.4. The effects of chocolate reward anticipation on AB (*ms*) for alcohol and chocolate-related pictures.

Next, within-subject *t*-tests were performed to follow-up these main effects and interactions. When alcohol expectancy was manipulated, AB for alcohol pictures was larger on *certain reward* trials compared to *no reward* trials ($t(29) = 2.89$, $p = .007$, $d = 0.39$), although AB on *uncertain reward* trials did not reliably differ from AB on *certain reward* ($t(29) = 1.56$, $p = .129$, $d = 0.18$) or *no reward* trials ($t(29) = 1.54$, $p = .135$, $d = 0.21$). When chocolate expectancy was manipulated, none of the contrasts on alcohol AB were significant (*certain reward* vs. *no reward*, $t(29) = 0.12$, $p = .906$, $d = 0.02$; *certain reward* vs. *uncertain reward*, $t(29) = 0.67$, $p = .511$, $d = 0.12$; *uncertain reward* vs. *no reward*, $t(29) = 0.58$, $p = .565$, $d = 0.13$). A similar pattern was seen for AB for chocolate pictures. When chocolate expectancy was manipulated, chocolate AB was larger on *certain reward* compared to *no reward* trials and this difference approached significance ($t(29) = 2.02$, $p = .052$, $d = 0.26$). Similarly chocolate AB was larger on *uncertain reward* compared to *no reward* trials ($t(29) = 2.71$, $p = .011$, $d = 0.38$). Although, the contrast between *certain reward* and *uncertain reward* trials was not significant ($t(29) = 0.70$, $p = .488$, $d = 0.10$). When alcohol expectancy was manipulated, none of the contrasts on chocolate AB were significant (*certain reward* vs. *no reward* ($t(29) = 0.49$, $p = .627$, $d = 0.06$); *certain reward* vs. *uncertain reward* ($t(29) = 0.89$, $p = .383$, $d = 0.23$); *uncertain reward* vs. *no reward* ($t(29) = 0.73$, $p = .470$, $d = 0.18$)).

2.1.4. Discussion

The results of this study confirmed that AB is sensitive to anticipated reward: AB was larger on *certain reward* trials compared to *no reward*. This replicates previous findings (*e.g.*, Field et al., 2011; Jones et al., 2012), but importantly it goes beyond them by demonstrating that these effects are outcome-specific rather than generalised. That is, the anticipation of alcohol reward increased AB for alcohol, but not chocolate pictures, whereas anticipation of chocolate reward increased AB for chocolate, but not alcohol pictures. This observation contrasts with the generalised effect of reward anticipation on AB demonstrated by Jones et al. (2012). Methodological differences between the two studies can account for these conflicting findings. In the present study, throughout each trial participants had to maintain a representation of both the type of anticipated reward (alcohol or chocolate points) and the probability of receiving it, and an outcome-specific effect was seen. In the earlier study, participants were likely to have focussed on the probability of receiving the reward rather than the type of reward that was available, and there a more generalised effect of reward anticipation was seen.

The effects of uncertainty on AB were also observed, and these effects were also outcome-specific. On uncertain reward trials, AB was larger compared to no reward trials, although this contrast was only statistically significant on chocolate trials. No significant difference was observed between AB on certain reward and uncertain reward trials for both alcohol and chocolate pictures. Overall, these findings are not consistent with the proposed interpretation of predictions made by either Mackintosh (1975) or Pearce and Hall (1980), because the former would predict a linear relationship between probability and AB whereas the latter would predict that AB should be maximal under conditions of uncertainty.

Study 2.2. The effects of loss anticipation on AB

2.2.1. Introduction

The second experiment investigated the effects of loss anticipation on AB. Despite emerging evidence for the role of reward anticipation on AB, little is known about the effects of loss anticipation. The impact of loss anticipation can also be approached from the reward anticipation perspective. Loss could be considered as a specific case of substance availability *i.e.*, an expectation of no loss is a condition comparable with reward availability. Aforementioned studies on reward anticipation (*i.e.*, Field et al., 2011; Jones et al., 2012) could suggest that while attention should be directed towards reward-related stimuli when individuals are able to keep their rewards, so they are perceived as imminently available, AB for rewarding cues should be attenuated when individuals expect to lose their rewards (reward becomes unavailable). As implied by the results of Study 2.1 and conditioning based accounts of the effects of reward anticipation on AB (Field & Cox, 2008) these effects should be outcome specific. The potential decrease in AB associated with anticipation of loss could also be explained in a different way. The anticipation of loss is likely to be an unpleasant event and therefore trigger negative affect. This could lead to attentional avoidance or withdrawal behaviour to prevent further distress reflected by the allocation of attention away from stimuli associated with loss (*see* Carver, 2001; Gable & Harmon-Jones, 2010; Koole, 2009).

Some theoretical accounts implicate that the anticipation of substance loss could increase AB. For instance, the anticipation of substance loss could activate negative thoughts associated with previous situations when substance-related urges could not be satisfied. This negative experience could initiate substance seeking and increase AB for substance-related cues (Kavanagh et al., 2005). Alternatively, CRP (Rothermund et al., 2011; Rothermund et al., 2008) indicates that attention is allocated towards stimuli incongruent with the anticipated motivationally salient outcome. The incongruency effects in attentional processing, experienced during goal-directed behaviour, are argued to prevent individuals from reaching extreme emotional states allowing for better flexibility during decision making (Rothermund,

2003; Wentura et al., 2009). It can be expected that loss anticipation relative to *no loss* condition should direct attention towards substance-related cues to counterbalance negative emotions associated with loss. This has been demonstrated in the task where reward and loss depended on the detection of valenced stimuli as well as for valenced stimuli which were not crucial for the success of goal-directed behaviour (Rothermund et al., 2008). Although the incongruency effects for goal-irrelevant valenced information were only present for negative stimuli during reward outcome focus, the authors suggested that the non-significant effects of loss anticipation could have been a consequence of the research method used or the lack of statistical power (*see* Rothermund et al., 2008). Therefore, general effects of loss anticipation on AB cannot be ruled out.

The aim of Study 2.2 was to investigate issues related to the effects of loss anticipation on AB by using a crossover design in order to test competing hypotheses: (1) anticipation of loss increases AB for rewarding stimuli, and (2) anticipation of loss decreases AB for rewarding stimuli. (3) Anticipation of a specific loss has an outcome-specific effect on AB for rewarding stimuli, and (4) anticipation of loss has a generalised effect on AB for rewarding stimuli. Similarly to Study 2.1, the effects of probability were examined: (5) reliable loss predictors (100% chance of loss) have a greater impact on AB in comparison to uncertain ones (50% chance of loss), and (6) the effects of uncertain loss predictors on AB are more pronounced than those of reliable predictors.

2.2.2. Method

Participants

Thirty-six participants were recruited from the staff and students at the University of Liverpool. Study 2.2 was approved by the University of Liverpool Research Ethics committee (Ref. IPHS-1213-LB-024), and all participants provided informed consent before taking part. Participant characteristics are shown in Table 2.2.2-1.

Table 2.2.2-1 *Participant characteristics Study 2.2*

Recruited participants	36 (F = 32, M = 4)
Participants included in the analysis	34 (F = 30, M =4)
Age (years)	20.59 ± (3.35)
Alcohol consumption (in units per week)	19.90 ± (13.12)
AUDIT	10.29 ± (4.78)
Weekly chocolate consumption (in bars)	3.29 ± (1.70)
Chocolate bars usually kept at home	4.03 ± (5.11)
Chocolate use/craving - CUQ	19.15 ± (4.20)

AUDIT – Alcohol Use Disorders Identification Test, CUQ – Chocolate Use Questionnaire

Procedure

The experimental procedure, pictures and stimulus timings were identical to those used in Study 2.1. To reinforce the fact they would be competing for actual rewards, participants were shown the beer and chocolate in the laboratory and were informed at the beginning of the study that they had 120 chocolate and 120 beer points. They were explicitly informed that these points represented three chocolate bars and three bottles of beer and they would lose some of their points as they completed the task. However, at the end of the experiment their remaining points would be converted into actual beer and chocolate that they could take with them. On each trial, the probability information indicated which type of outcome point they could lose or keep on that trial (alcohol or chocolate), and the probability that they would lose (100%, 50%, or 0% which indicated *certain loss*, *uncertain loss* and *no loss* respectively). After presentation and offset of the alcohol-neutral or chocolate-neutral image pair, the following text was displayed in the centre of the screen: '*press the left key to check if you lost chocolate*' on chocolate outcome trials, or '*press the right key to check if you lost beer*' on beer outcome trials. Text feedback was presented as soon as participants pressed the appropriate key: '*you lose a beer point!*' on all *certain loss* and half of *uncertain loss* alcohol outcome trials; '*you lose a chocolate point*' on all *certain loss* and half of *uncertain loss* chocolate outcome trials; and '*you lose nothing*' on all *no loss* trials and the remaining *uncertain loss* trials. Participants completed a total of 240 trials, and at the end of the study participants had 60 beer points and 60 chocolate points remaining - exactly the same number of points that participants had at the end of the experiment in Study 2.1.

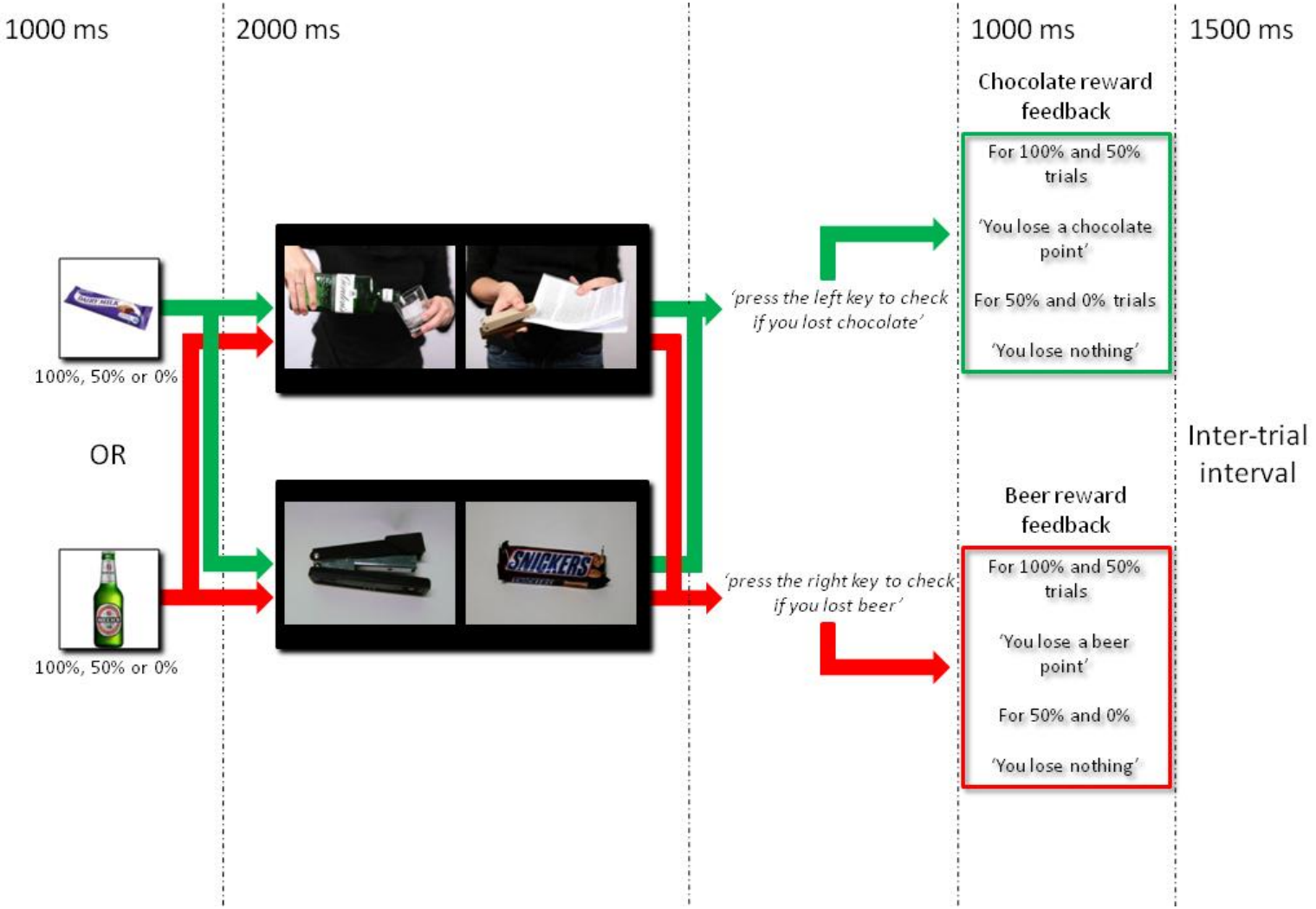

Figure 2.2.2.1. Flowchart of the experimental procedure Study 2.2.

Data reduction and analysis

Skewness statistics for some dwell time variables were twice the standard error, so data were log transformed in order to normalise distribution before analysis. Two participants were excluded from the analysis as their mean gaze fixation time per trial was less than 500 *ms* (N = 34).

2.2.3. Results

Gaze dwell times were analysed using a four-way repeated-measures ANOVA (*see* Figures 2.2.3.1-2), with factors of *Outcome Type* (2: alcohol points vs. chocolate points), *Probability* (3: *certain loss* vs. *uncertain loss* vs. *no loss*), *Picture Pair* (2: alcohol-neutral vs. chocolate-neutral) and *Picture Type* (2: alcohol/chocolate vs. neutral). This revealed a significant main effect of *Picture Type* ($F(1, 33) = 11.41$, $p = .003$, $\eta_p^2 = .24$) indicating that participants maintained their gaze on reward pictures for longer than on matched neutral pictures. Neither the *Probability* x *Picture Type* interaction that would suggest general effects of loss anticipation on AB ($F(2, 66) = 0.71$, $p = .495$, $\eta_p^2 = .02$), nor the four-way *Outcome Type* x *Probability* x *Picture Pair* x *Picture Type* interaction which would indicate outcome specific effects ($F(2, 66) = 0.38$, $p = .683$, $\eta_p^2 = .01$) were significant.

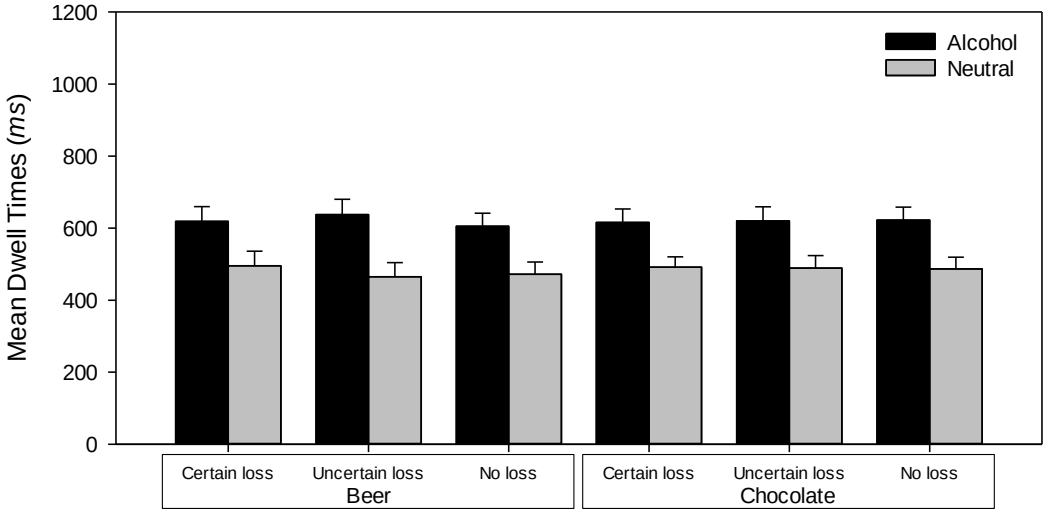

Figure 2.2.3.1. The effects of beer and chocolate loss anticipation on mean dwell times (*ms*) for alcohol-related and matched neutral pictures.

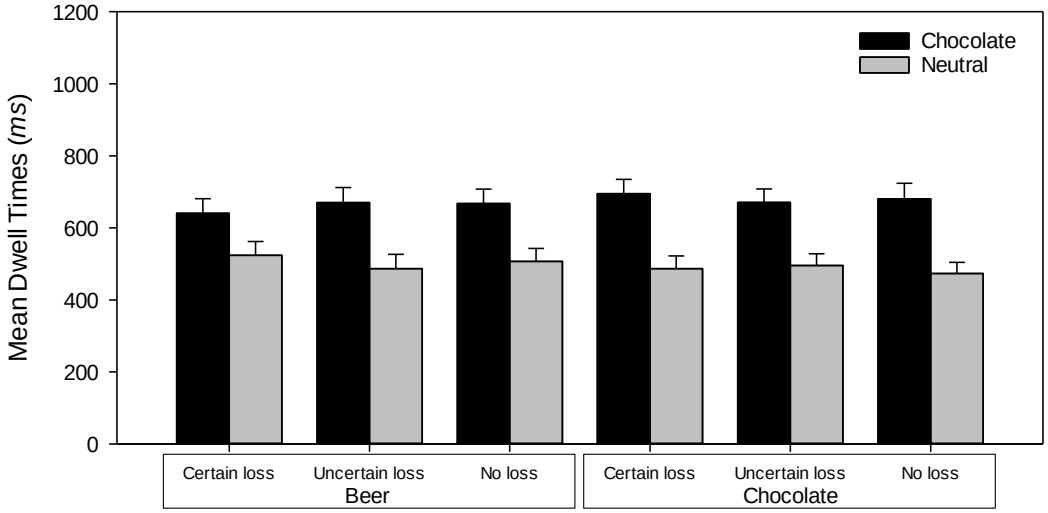

Figure 2.2.3.2. The effects of beer and chocolate loss anticipation on mean dwell times (*ms*) for chocolate-related and matched neutral pictures.

2.2.4. Discussion

In this experiment, a general AB was found for substance-related cues when compared with neutral pictures. The current results did not support predictions about the influence of chocolate or beer loss expectancy manipulation on AB. Therefore, the anticipation of *reward* and *loss* do not have the same effect, and they might not have opposing effects on AB.

One of the initial hypotheses proposed that the anticipation of loss would direct attention away from the stimuli associated with loss. This would reflect withdrawal behaviour to prevent negative affect from escalation. This hypothesis was made under the assumption that otherwise rewarding substances could trigger a negative affect when presented in the context of loss anticipation. However, it is possible that the lack of control over the loss outcomes prevented participants from becoming involved in the task. This could suggest that the withdrawal behaviour was not expressed on a trial-by-trial basis depending on loss anticipation, but was a general response to the task. Rothermund (2011) proposed that the involvement in motivated behaviour may depend on the level of control over its outcomes. When individuals experience problems during goal pursuit, they may respond in two ways depending on perceived efficacy and level of control. They can either increase their commitment and face the difficulties trying to resolve a problem, or they may disengage from a blocked goal, preserve their resources, and achieve emotional relief (*see* Brandtstädter & Rothermund, 2002). The withdrawal behaviour in the face of unavoidable loss could be reflected by a decrease in sensitivity to danger (*i.e.*, loss) signals (Brandtstädter, Voss, & Rothermund, 2004). Thus, it is possible that fixed probability cues which signal inevitable loss can lead to disengagement from goal pursuit, and this could explain their lack of impact on AB.

Study 2.3. The effects of reward loss anticipation on AB under behavioural control over the outcomes

2.3.1. Introduction

The third experiment was adapted to address the possible explanation for the null effects of loss anticipation on AB, and re-test the Study 2.2 hypotheses. A modified version of loss anticipation task addressed the issue of lack of control over the outcomes. Taking into consideration the potential role of behavioural control in engagement in behaviour (Brandtstädter & Rothermund, 2002; Rothermund, 2011), it could be expected that introduction of control over loss outcomes should allow for revealing the effects of loss anticipation on AB. For example, Brandtstädter et al. (2004) have shown that participants paid more attention to cues signalling a danger of losing a point if they could prevent its' loss by identifying the location of the cue. Therefore, in comparison to fixed probability information, the introduction of control over the outcomes should enhance the processing of cues signalling likelihood of loss, and hence, facilitate their impact on AB.

2.3.2. Method

Participants

Thirty-three participants (23 female) were recruited from the staff and students at the University of Liverpool. Study 2.3 was approved by the University of Liverpool Research Ethics committee (IPHS-1415-012 (Generic approval IPHS-1213-LB-024)), and all participants provided informed consent before taking part. Participant characteristics are shown in Table 2.3.2-1.

Table 2.3.2-1 *Participant characteristics Study 2.3*

Recruited participants	33 (F = 23, M = 10)
Participants included in the analysis	30 (F =22, M = 8)
Age (years)	24.10 ± (7.70)
Alcohol consumption (in units per week)	17.94 ± (12.87)
AUDIT	11.27 ± (6.02)
Weekly chocolate consumption (in bars)	3.73 ± (2.27)
Chocolate bars usually kept at home	3.82 ± (4.34)
Chocolate use/craving - CUQ	22.33 ± (6.09)

AUDIT – Alcohol Use Disorders Identification Test, CUQ – Chocolate Use Questionnaire

Procedure

The experimental procedure, pictures and stimulus timings were identical to those used in Studies 2.1-2. To reinforce the fact they would be preventing the loss of actual rewards, participants were shown three bottles of beer and three chocolate bars in the laboratory and were informed at the beginning of the study that they had 120 chocolate and 120 beer points. They were explicitly informed that these points represented three chocolate bars and three bottles of beer. They would lose some of their points as they completed the task, but at the end of the experiment their remaining points would be converted into actual rewards that they could take with them.

Some important modifications to the task were made in order to increase participants' perceived control over avoidance of loss on each trial and increase their involvement in the task. At the beginning of each trial two identical pictures were presented in the centre of the screen (5.92 *mm* wide by 4.49 *mm* high each), one directly above the central position and one directly below it. The pictures represented chocolate blocks with Cadbury's logo on chocolate outcome trials and beer in a glass with Beck's logo on beer outcome trials. This modification was made so participants could see the actual content of rewards that they were trying to maintain during a trial. Hence, their engagement in the task could be further increased. Information about the probability of losing on that trial was superimposed over the pictures. On beer reward *certain loss prevention* trials, the text '*100% chance of keeping a beer point'* was superimposed over the top (or bottom; fully counterbalanced) beer picture, and the text '*0% chance of keeping a beer point'* was superimposed on the other beer picture. On beer reward *uncertain loss prevention* trials, identical text (*'50% chance of keeping a beer point'*) was superimposed on both beer pictures. On *unlikely loss prevention* beer trials, the text *'100% chance of keeping a beer point'* was superimposed on one beer picture and the text *'0% chance of keeping a point'* was superimposed on the other. These trials differed from the *certain loss prevention* trials because the location of the text rapidly switched between the top and bottom boxes at a rate of one switch per 100 *ms,* therefore the text appeared to 'flicker'. Chocolate anticipation trials used the same probability conditions but information about winning referred to chocolate

points (*e.g., '100% chance of keeping a chocolate point'* vs. *'0% chance of keeping a chocolate point'* etc.) and probability information was superimposed on the top of chocolate pictures. Probability pictures disappeared after participants pressed one of the trial specific buttons, as detailed below.

On each trial, participants responded on a Sony PlayStation 3 gamepad by pressing the left and right upper and lower shoulder (trigger) buttons. They were instructed to press the left sided buttons on chocolate outcome trials and the right sided buttons on beer outcome trials, and to attempt to minimise the number of beer and chocolate points that they lost over the course of the experiment. On *certain loss prevention* trials, it was easy for participants to select the button that corresponded to the location of '100% chance of keeping a chocolate/beer point' text. On *uncertain loss prevention* trials ('50% chance of keeping a chocolate/beer point'), participants were aware that they had to guess and choose between pressing either the top or the bottom reward specific button. On *unlikely loss prevention* trials, participants were informed that avoidance of losses on these trials depended on precise synchronisation of their response, but the rapidly oscillating display would make this very difficult. In addition, participants were penalised for pressing an incorrect trigger (*e.g.*, if they pressed one of the chocolate buttons during beer anticipation trials) and received feedback 'you lose a beer and a chocolate point'.

On *certain loss prevention* trials, if participants pressed the correct button the feedback stated *'you keep a chocolate point'* or *'you keep a beer point'* depending on the substance type on a given trial. The incorrect response resulted in 'you lose a chocolate point' or 'you lose a beer point' for chocolate and beer trials respectively. On *uncertain loss prevention* chocolate trials, top and bottom buttons were fully counterbalanced – on half of chocolate trials pressing the top left button resulted in the *'you keep a chocolate point'* feedback and pressing the left bottom button resulted in the '*you lose a chocolate point'* feedback and vice versa for remaining half. The *uncertain loss prevention* beer trials were counterbalanced in the same manner but were followed by beer-specific feedback *i.e., 'you keep a beer point'* or *you lose a beer point'*. On *unlikely loss prevention* chocolate trials, 10% of trials had the *'you keep a chocolate point'* feedback and 90% of trials had the *'you lose a chocolate point'*. The same feedback ratio was used for *unlikely loss*

prevention beer trials during which participants received beer specific feedback. For *unlikely loss prevention* trials, the feedback presented was selected randomly according to the contingencies described above. This modification to the experimental procedure gave participants a perception of control over the outcome, but in the case of *unlikely loss prevention* trials they did not actually control whether they retained or lost points on any individual trial.

To further enhance participants' involvement in the task, successful loss prevention was accompanied by cha-ching-like sound effects (similar to sound effects used in some of the vintage video games when a point is earned which remind of a cash register ringing sound) - one sound effect was specific for beer and one for chocolate outcome. The loss feedback was accompanied by a dissonant unpleasant sound effect based on an *ascending minor second* interval (Cousineau, McDermott, & Peretz, 2012; McDermott, Lehr, & Oxenham, 2010) one for the beer and one for the chocolate outcome. The incorrect response feedback was accompanied by an unpleasant buzzer sound effect. Each of the sound effects used was volume and length (600 *ms*) matched.

Participants completed a practice block of 12 trials comprising equal numbers of trials in which *certain loss prevention*, *uncertain loss prevention* and *unlikely loss prevention* beer and chocolate probability information were presented before pairs of neutral pictures (*e.g.*, household furniture); data from these trials were not analysed. The main block of 240 critical trials comprised 120 alcohol-neutral and 120 chocolate-neutral picture pairs. For each type of picture pair there were an equal number of alcohol and chocolate outcome trials (60 trials each) and within this an equal number of *certain loss prevention*, *uncertain loss prevention* or *unlikely loss prevention* probability trials (20 trials each). Participants had the opportunity to take a short break after every 30 trials.

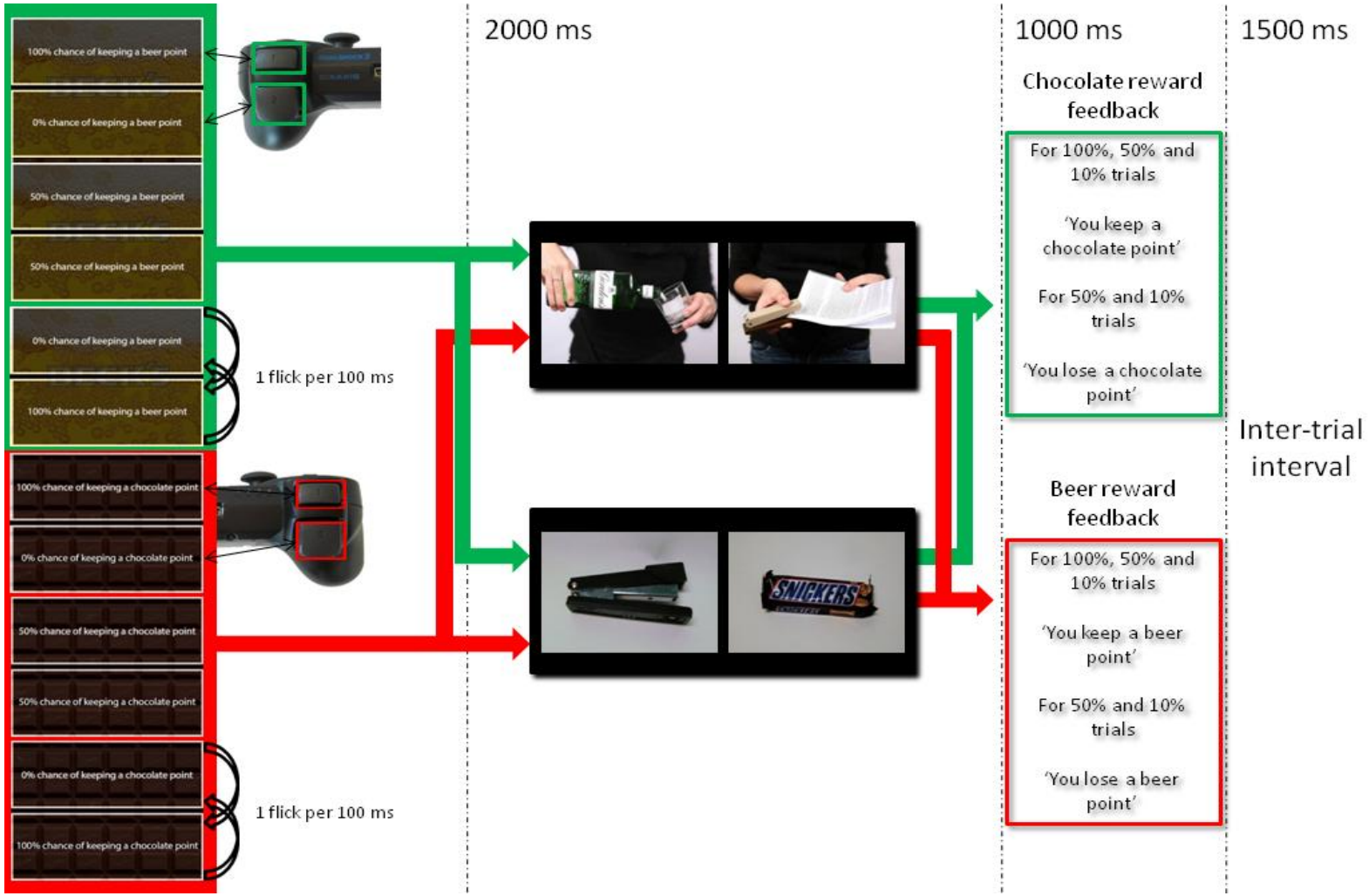

Figure 2.3.2.1. Flowchart of the experimental procedure Study 2.3.

Data reduction and analysis

Skewness statistics for some dwell time variables were twice the standard error, so data were log transformed in order to normalise distribution before analysis. Data of participants with at least 500 *ms* average total gaze fixation time per trial (more 25% of stimulus presentation time) was included in the analysis. Therefore, one participant was excluded. Two participants did not complete the experiment, hence, their data was also not included in the analysis (N = 30).

2.3.3. Results

Gaze dwell times were analysed using a four-way repeated-measures ANOVA (*see* Figures 2.3.3.1-2), with factors of *Outcome Type* (2: alcohol points vs. chocolate points), *Probability* (3: *certain loss prevention* vs. *uncertain loss prevention* vs. *unlikely loss prevention*), *Picture Pair* (2: alcohol-neutral vs. chocolate-neutral) and *Picture Type* (2: alcohol/chocolate vs. neutral). This revealed a significant main effect of *Picture Type* ($F(1, 29) = 41.87$, $p < .001$, $\eta_p^2 = .59$) indicating an overall AB: participants maintained their gaze for longer on chocolate and alcohol pictures in comparison to the matched neutral pictures. The *Probability* x *Picture Type* interaction was not significant ($F(2, 58) = 0.22$, $p = .801$, $\eta_p^2 = .01$); therefore, there was no generalised effect of reward loss anticipation on AB. The four-way *Outcome type* x *Probability* x *Picture pair* x *Picture type* interaction was significant ($F(2, 58) = 4.18$, $p = .020$, $\eta_p^2 = .13$).

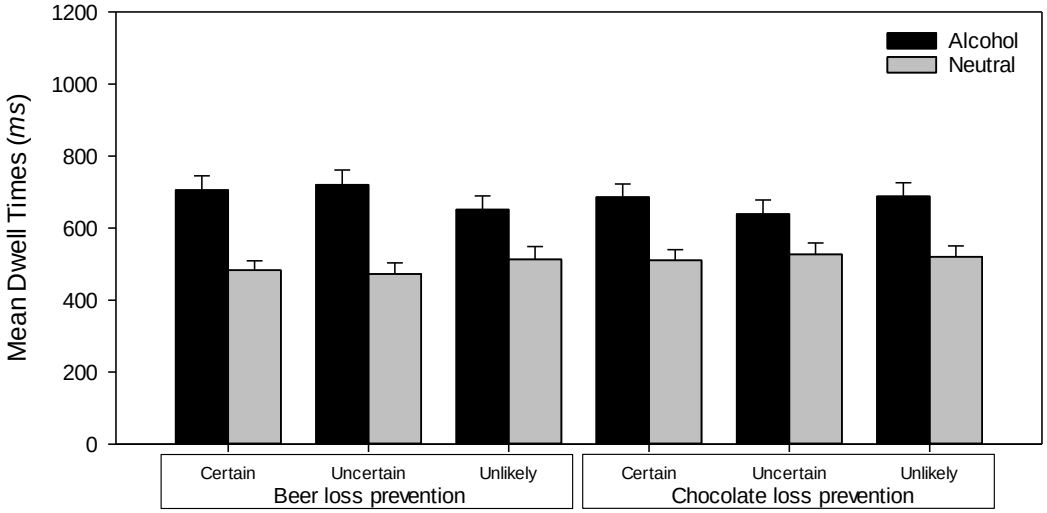

Figure 2.3.3.1. The effects of beer and chocolate loss anticipation on mean dwell times (*ms*) for alcohol-related and matched neutral pictures under behavioural control over the outcomes.

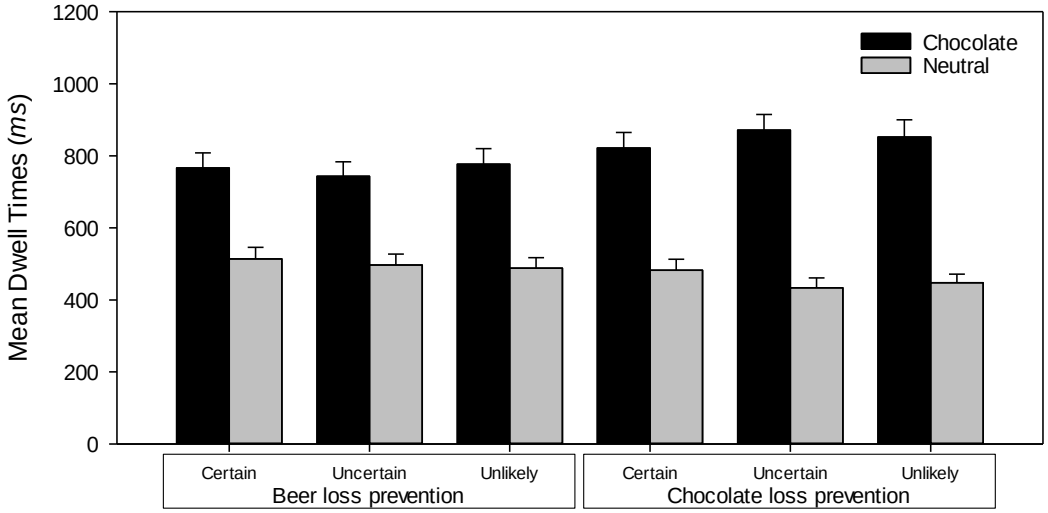

Figure 2.3.3.2. The effects of beer and chocolate loss anticipation on mean dwell times (*ms*) for chocolate-related and matched neutral pictures under behavioural control over the outcomes.

To deconstruct the four-way interaction, AB scores were first calculated by subtracting gaze dwell time on neutral pictures from gaze dwell time on the corresponding alcohol and chocolate pictures. Then one-way ANOVAs were run to determine if AB for alcohol and chocolate pictures was reliably affected by anticipation of loss of different outcomes. A significant effect of alcohol loss anticipation on AB for alcohol pictures was found ($F(2, 58) = 4.01$, $p = .023$, $\eta_p^2 = .12$), but alcohol loss anticipation had no effect on AB for chocolate pictures ($F(2, 58) = 0.45$, $p = .643$, $\eta_p^2 = .02$) (*see* Figure 2.3.3.3). The effect of chocolate loss anticipation on AB for chocolate pictures did not reach significance ($F(2, 58) = 2.47$, $p = .094$, $\eta_p^2 = .08$), chocolate loss anticipation had no effect on AB for alcohol pictures ($F(2, 58) = 1.83$, $p = .170$, $\eta_p^2 = .06$) (*see* Figure 2.3.3.4). Also, two-way ANOVAs were run on the bias scores with factors of *Outcome Type* and *Picture Pair*, separately at each level of *Probability* (*certain loss prevention*, *uncertain loss prevention* and *unlikely loss prevention*). The two-way *Outcome Type* x *Picture Pair* interaction was significant for *uncertain loss prevention* ($F(1, 29) = 19.14$, $p < .001$, $\eta_p^2 = .40$) but not for *certain loss prevention* ($F(1, 29) = 3.03$, $p = .092$, $\eta_p^2 = .10$) and *unlikely loss prevention* trials ($F(1, 29) = 2.71$, $p = .111$, $\eta_p^2 = .09$).

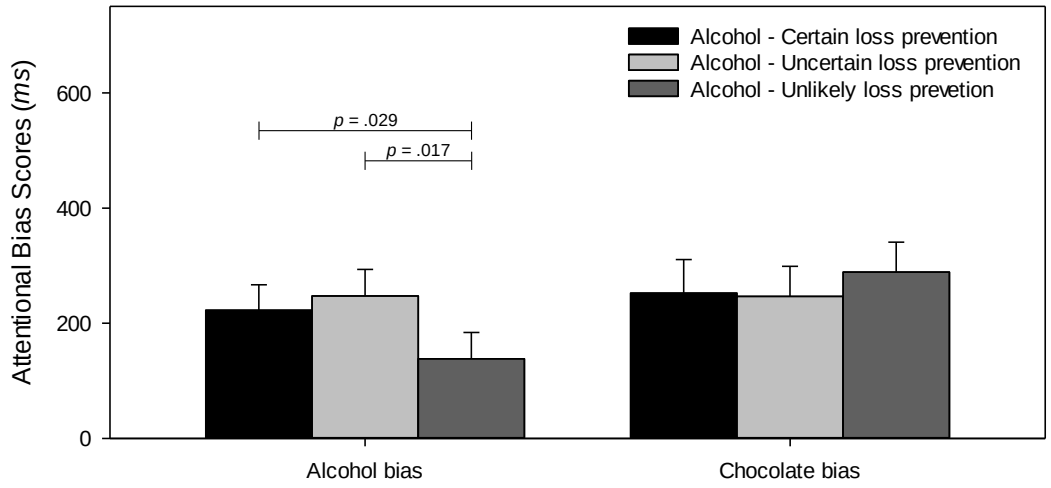

Figure 2.3.3.3. The effects of beer loss anticipation on AB (*ms*) for alcohol and chocolate-related pictures under behavioural control over the outcomes.

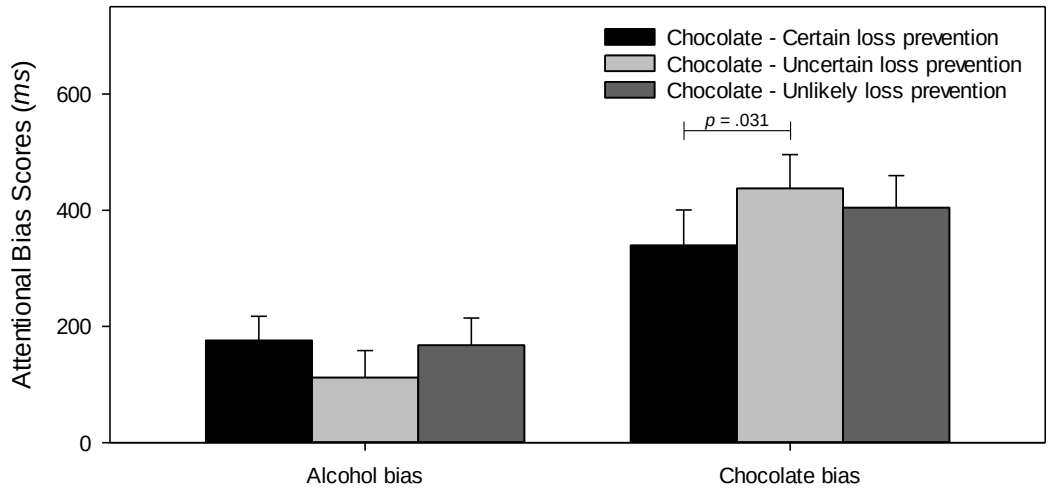

Figure 2.3.3.4. The effects of chocolate loss anticipation on AB (*ms*) for alcohol and chocolate related pictures under behavioural control over the outcomes.

Finally, within-subject *t*-tests were performed to analyse these findings. When alcohol loss was manipulated, AB for alcohol pictures was larger in the *certain loss prevention* ($t(29) = 2.29$, $p = .029$, $d = 0.33$) and *uncertain loss prevention* ($t(29) = 2.54$, $p = .017$, $d = 0.43$) compared to the *unlikely loss prevention* condition. Although bias in the *certain loss prevention* condition did not reliably differ from the *uncertain loss prevention* condition ($t(29) = 0.67$, $p = .510$, $d = 0.11$). When chocolate expectancy was manipulated, none of the contrasts on alcohol AB were significant (*certain loss prevention* vs. *unlikely loss prevention*, ($t(29) = 0.24$, $p = .813$, $d = 0.04$); *certain loss prevention* vs. *uncertain loss prevention*, ($t(29) = 1.73$, $p = .095$, $d = 0.27$); *uncertain loss prevention* vs. *unlikely loss prevention*, ($t(29) = 1.73$, $p = .094$, $d = 0.22$)).

A different pattern of results was seen for AB for chocolate pictures. When chocolate loss was manipulated, the bias was smaller on *certain loss prevention* compared to *uncertain loss prevention* trials ($t(29) = 2.27$, $p = .031$, $d = 0.30$). However, *uncertain loss prevention* were not different from *unlikely loss prevention* expectancy trials ($t(29) = 0.99$, $p = .329$, $d = 0.12$). Furthermore, *certain loss prevention* compared to *unlikely loss prevention* expectancy trials ($t(29) = 1.18$, $p = .249$, $d = 0.19$) did not differ from each other. When alcohol loss expectancy was manipulated, none of the contrasts on chocolate AB were significant (*certain loss prevention* vs. *unlikely loss prevention* ($t(29) = 0.85$, $p = .401$, $d = 0.12$); *certain loss prevention* vs. *uncertain loss prevention* ($t(29) = 0.06$, $p = .956$, $d = 0.01$); *uncertain loss prevention* vs. *unlikely loss prevention* ($t(29) = 0.92$, $p = .363$, $d = 0.13$)).

2.3.4. Discussion

Study 2.3 revealed an overall AB for reward-related pictures. This bias was influenced in the outcome specific manner by loss anticipation. A greater chance of keeping an alcohol point increased AB for alcohol-related pictures. Similarly, an opportunity to avoid the loss of chocolate points only influenced AB for chocolate-related pictures. As predicted, the introduction of control over loss outcomes allowed for revealing the effects of loss anticipation on AB. However, the impact of probability information is less clear for chocolate reward anticipation.

One of the key differences between the current version of the task and the initial experiment (Study 2.2) was the introduction of two uncertainty conditions. On *certain* and *uncertain loss prevention* alcohol trials, AB for alcohol pictures was larger compared to the *unlikely loss prevention of loss* trials. No significant difference was observed between AB on *certain* and *uncertain loss prevention* alcohol pictures. This could indicate that participants were more engaged in both conditions where loss prevention was more achievable. However, these results are not consistent with the proposed interpretation of predictions made by Mackintosh (1975) – which would implicate a linear relationship between probability and AB; and Pearce and Hall (1980) – which would predict the maximal AB should under conditions of uncertainty.

The effects of chocolate loss anticipation were different from those presented for alcohol and more difficult to interpret. Although AB was higher during *uncertain loss prevention* in comparison to *certain loss prevention,* there was no difference in AB between conditions during which participants were likely to prevent the loss of chocolate (*i.e.*, *certain loss prevention* and *uncertain loss prevention*) and *unlikely loss prevention*. Since the presented evidence suggests that behavioural control may play a crucial role in the effects of loss anticipation on AB, the next step would be to include *certain loss* trials back into the task. This would give a reliable reference point for other probability conditions.

The adjustment of experimental method was sufficient to reveal the effects of loss anticipation on AB. Implicating that the effects of loss anticipation on AB for rewarding cues may depend on behavioural control over the outcomes.

Moreover, the results of Study 2.3 provide additional support for the outcome specific effects of anticipation of motivationally salient outcomes.

Study 2.4. The effects of reward anticipation on AB under behavioural control over the outcomes

2.4.1. Introduction

To obtain a complete picture of the effects of reward and loss anticipation the initial experiment (Study 2.1) was replicated, and behavioural control modifications already used in Study 2.3 were included. Taking into account the results of Studies 2.1 and 2.3, it was expected that the introduction of behavioural control (1) will result in outcome specific effects of reward anticipation. Predictions regarding the impact of probability information were corresponding to the results of Study 2.1; (2) Outcome-specific effects of reward anticipation and greater AB were expected for reward-related pictures for *certain reward* and *uncertain reward* in comparison to the *unlikely reward* trials.

2.4.2. Method

Participants

Thirty-one participants (16 female) were recruited from the staff and students at the University of Liverpool. Study 2.4 was approved by the University of Liverpool Research Ethics committee (Ref. IPHS-1415-012 (Generic approval IPHS-1213-LB-024)). Participant characteristics are shown in Table 2.4.2-1.

Table 2.4.2-1 *Participant characteristics Study 2.4*

Recruited participants	31 (F = 16, M = 15)
Participants included in the analysis	31 (F = 16, M = 15)
Age (years)	24.84 ± (4.90)
Alcohol consumption (in units per week)	14.60 ± (11.17)
AUDIT	8.42 ± (4.28)
Weekly chocolate consumption (in bars)	3.48 ± (2.69)
Chocolate bars usually kept at home	2.81 ± (2.99)
Chocolate use/craving - CUQ	20.52 ± (6.14)

AUDIT – Alcohol Use Disorders Identification Test, CUQ – Chocolate Use Questionnaire

Procedure

The experimental procedure, pictures and stimulus timings were identical to those used in previous experiments (Studies 2.1–3). To reinforce the fact they would be competing for actual rewards, participants were shown the beer and chocolate in the laboratory and were explicitly informed that the points that they accumulated during the task would be converted into actual rewards.

The task used in Study 2.3 was adjusted for the purpose of current experiment. Instead of being given chocolate and beer points at the beginning of the task and preventing their loss during the task, participants' goal was to collect as many chocolate and beer points as possible. The probability information used in Study 2.3 were re-written to match reward anticipation conditions. Like in Study 2.3, probability texts were presented on substance-congruent backgrounds *i.e.*, chocolate blocks with Cadbury's logo background for chocolate outcome trials and beer in a glass with Beck's logo background for beer outcome trials. For *certain reward* beer trials, the text '*100% chance of winning a beer point'* was superimposed on the top (or bottom; fully counterbalanced) beer picture, and the text '*0% chance of winning a beer point'* was superimposed on the bottom (or top) beer picture. On beer reward *uncertain reward* trials, identical text (*'50% chance of winning a beer point'*) was superimposed on both beer pictures. On *unlikely reward* beer trials, the text *'100% chance of winning a beer point'* was superimposed on one beer picture and the text *'0% chance of winning a point'* was superimposed on the other. In contrast to *certain reward* trials the location of the text rapidly switched between the top and bottom boxes at a rate of one flip per 100 *ms*. Chocolate anticipation trials used the same probability conditions but information about winning referred to chocolate points (*e.g.*, *'100% chance of winning a chocolate point'* vs. *'0% chance of winning a chocolate point'* etc.) and probability information was superimposed on the top of chocolate pictures. Probability pictures disappeared after participants pressed one of the trial specific buttons.

On each trial, participants responded on a Sony PlayStation 3 gamepad by pressing the left and right upper and lower shoulder (trigger) buttons. They were instructed to press the left sided buttons on chocolate outcome trials and

the right sided buttons on beer outcome trials, and to attempt to gain as many beer and chocolate points as they could over the course of the experiment. On *certain reward* trials, it was easy for participants to select the button that corresponded to the location of '100% chance of winning a chocolate/beer point' text. On *uncertain reward* trials '50% chance of winning a chocolate/beer point', participants were aware that they had to guess which reward specific button to press. For *unlikely reward* condition, participants were informed that gain on these trials depended on precise synchronisation of their response, but the rapidly oscillating display would make this very difficult. Participants were penalised for pressing an incorrect trigger (*e.g.*, one of the chocolate buttons during beer anticipation trials) and received the feedback 'you lose a beer and a chocolate point'.

On *certain reward* trials, if participants pressed the correct button the feedback stated *'you win a chocolate point'* or *'you win a beer point'* depending on the substance type on a given trial. The incorrect response resulted in '*you didn't win a chocolate point*' or '*you didn't win a beer point*' for chocolate and beer trials respectively. On *uncertain reward* chocolate trials, top and bottom buttons were fully counterbalanced – on half of chocolate trials pressing the top left button resulted in the *'you win a chocolate point'* feedback and pressing the left bottom button resulted in the '*you didn't win a chocolate point'* feedback and vice versa for remaining half. The *uncertain reward* beer trials were counterbalanced in the same manner but were followed by beer-specific feedback *i.e., 'you win a beer point'* or *you didn't win a beer point'*. On *unlikely reward* chocolate trials, 10% trials had the *'you win a chocolate point'* feedback and 90% had the *'you didn't win a chocolate point'*. The same feedback ratio was used for *unlikely reward* beer trials during which participants received beer specific feedback. As in Study 2.3, participants did not have an impact on outcome of *unlikely reward* trials and the feedback presented was selected randomly according to the contingencies described above.

The sounds effects previously used for successful loss prevention (Study 2.3) were now assigned to reward outcome. Whereas, the effects used for loss outcome were assigned to no reward feedback. The incorrect button response was accompanied by the buzzer sound.

Participants completed a practice block and the main block of trials which were counterbalanced and arranged in the same manner as in Study 2.3.

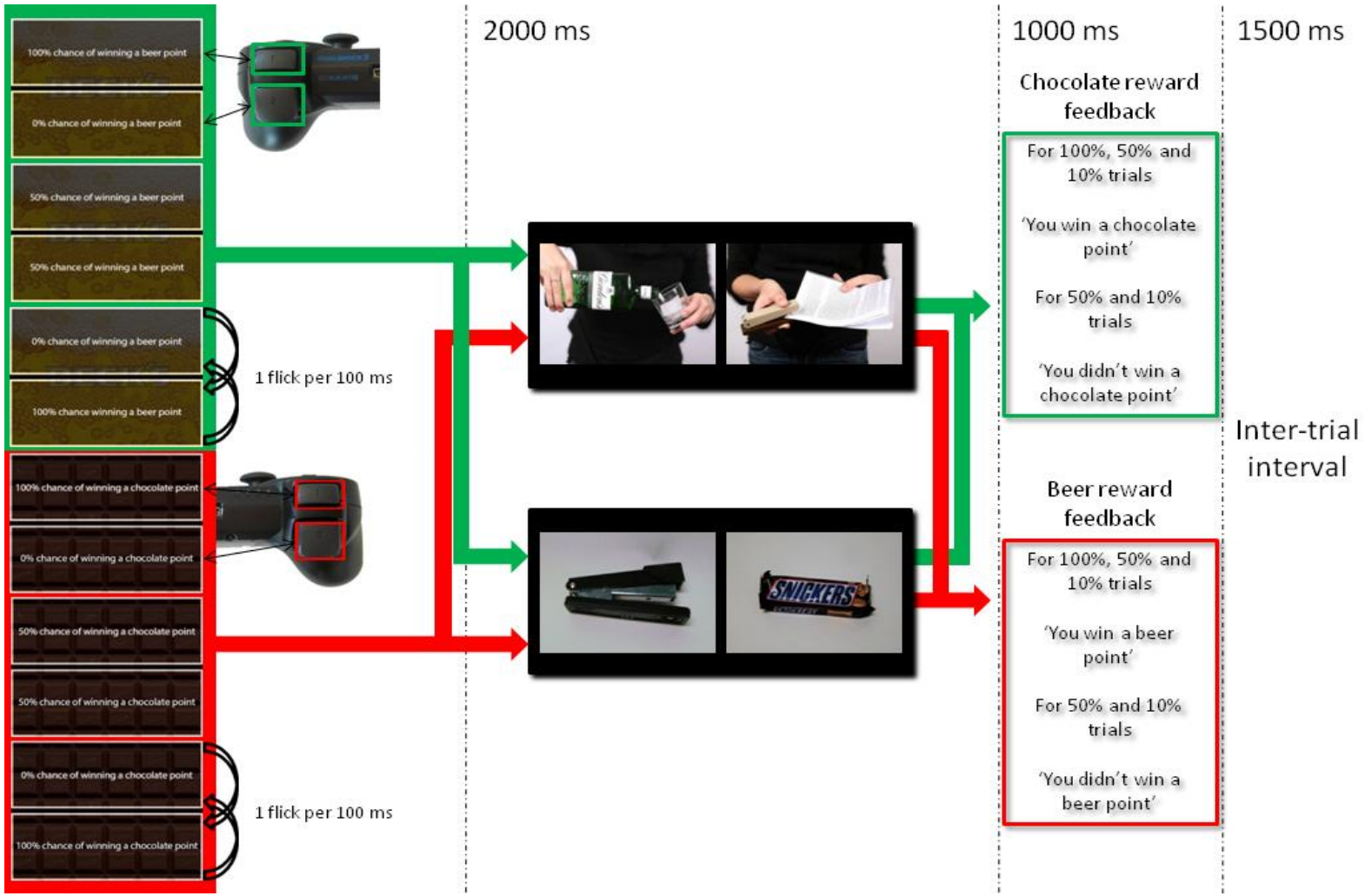

Figure 2.4.2.1. Flowchart of the experimental procedure Study 2.4.

Data reduction and analysis

Data was processed the same way as for the previous experiments. Skewness statistics for some dwell time variables were twice the standard error, so data were log transformed in order to normalise distribution before analysis. Data from all participants was included in the analysis (N = 31).

2.4.3. Results

Gaze dwell times were analysed using a four-way repeated-measures ANOVA (*see* Figures 2.4.3.1-2), with factors of *Outcome Type* (2: alcohol points vs. chocolate points), *Probability* (3: *certain reward* vs. *uncertain reward* vs. *unlikely reward*), *Picture Pair* (2: alcohol-neutral vs. chocolate-neutral) and *Picture Type* (2: alcohol/chocolate vs. neutral). The *Probability* x *Picture Type* interaction that would suggest general effects of reward anticipation on AB was non-significant ($F(2, 60) = 1.35$, $p = .268$, $\eta_p^2 = .04$). Also, the four-way *Outcome Type* x *Probability* x *Picture Pair* x *Picture Type* interaction which would indicate outcome specific effects was not significant ($F(2, 60) = 0.86$, $p = .428$, $\eta_p^2 = .03$). A significant main effect of *Picture Type* ($F(1, 30) = 20.67$, $p < .001$, $\eta_p^2 = .41$) was found, indicating that participants maintained their gaze on reward pictures for longer than on matched neutral pictures. As implicated by the *Outcome Type* x *Picture Pair* x *Picture Type* interaction ($F(1, 30) = 8.27$, $p = .007$, $\eta_p^2 = .22$) this overall AB was more pronounced for pictures which were congruent with the type of anticipated reward regardless of the *Probability*.

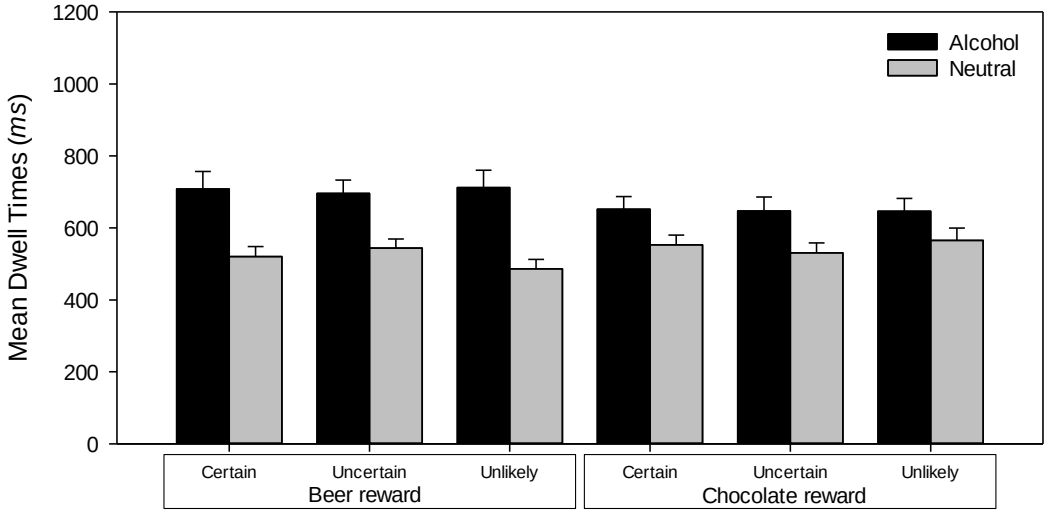

Figure 2.4.3.1. The effects of beer and chocolate reward anticipation on mean dwell times (*ms*) for alcohol-related and matched neutral pictures under behavioural control over the outcomes.

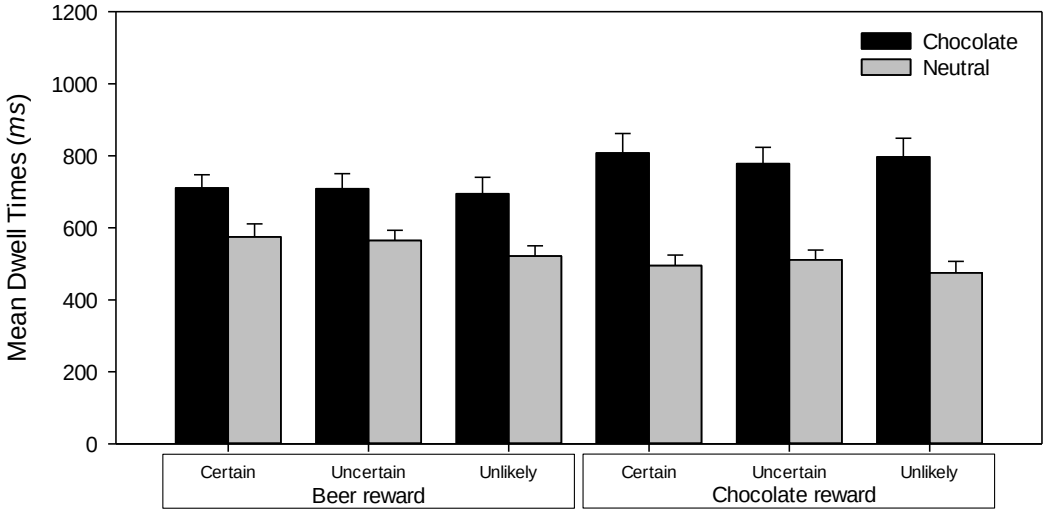

Figure 2.4.3.2. The effects of beer and chocolate reward anticipation on mean dwell times (*ms*) for chocolate-related and matched neutral pictures under behavioural control over the outcomes.

To further analyse this three-way interaction, the mean bias score values were calculated across three probability conditions for each of the *Outcome Type* - *Picture Type* combinations (*see* Figure 2.4.3.3). Then, a two-way ANOVA with factors of *Outcome Type* (2: alcohol and chocolate) x *Picture Type* (2: alcohol and chocolate) was run. Both main effects approached significance (*Picture Type* ($F(1, 30) = 3.99$, $p = .055$, $\eta_p^2 = .12$), *Outcome Type* ($F(1, 30) = 3.33$, $p = .078$, $\eta_p^2 = .10$)), but were subsumed under a significant *Outcome Type* x *Picture Type* interaction ($F(1, 30) = 8.27$, $p = .007$, $\eta_p^2 = .22$). Independent paired samples *t*-tests indicated that, for alcohol outcome, alcohol and chocolate AB did not differ ($t(30) = 0.68$, $p = .500$, $d = 0.14$). However, for chocolate outcome, chocolate AB was bigger than alcohol AB ($t(30) = 3.25$, $p = .003$, $d = 0.68$).

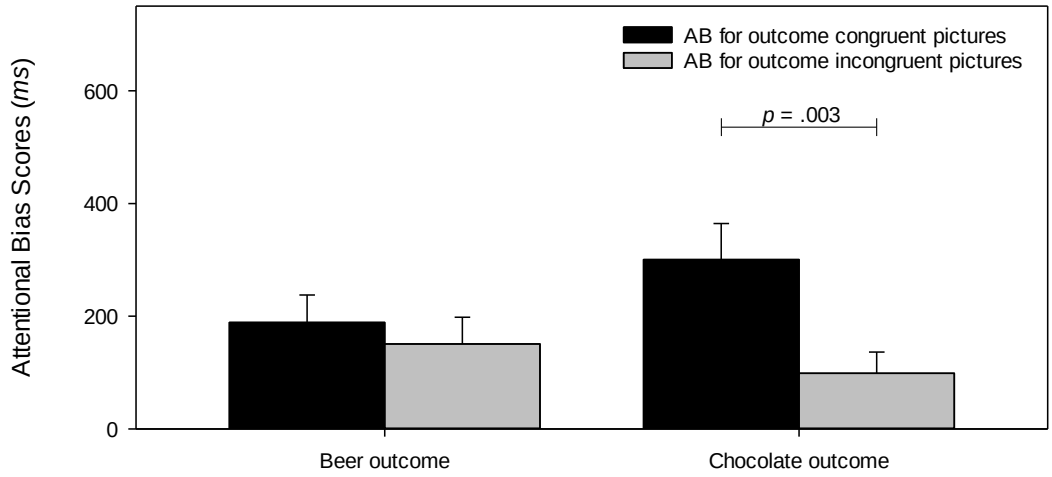

Figure 2.4.3.3. The effects of beer and chocolate outcome anticipation (averaged across probability conditions) on AB (*ms*) for outcome congruent and incongruent pictures.

2.4.4. Discussion

The goal of the final study was to examine whether behavioural control and anticipation of reward would have the same effects on AB as probability cues introduced in Study 2.1. Interestingly, while loss anticipation moderated AB when participants had an impact on the outcomes of the task, a different pattern of results was found for reward anticipation. The effects observed in Study 2.1 were abolished when participants had control over the outcomes. Probability manipulation did not have a distinctive effect on AB. However, it was found that when participants were expecting to win chocolate, their bias for chocolate-related pictures was higher in comparison to alcohol-related bias when averaged across probability conditions.

It could be hypothesised that the priming-like impact of chocolate anticipation on AB reflects and the overall effect of chocolate reward-anticipation. In Study 2.1 participants were exposed to fixed probability information indicating the likelihood of chocolate or beer reward. In the current task, participants had an impact on the outcomes during *certain reward* and *uncertain reward* trials. Participants were informed that they had an impact on the outcome of *unlikely reward* trials. However, the outcome of these trials depended on a fixed probability ratio (10% chance of reward). This experimental manipulation was conducted to maintain the perception of behavioural control across all probability conditions. As pointed out by some of the theoretical accounts, behavioural control may enhance involvement in the task (*see* Brandtstädter & Rothermund, 2002; Rothermund, 2011). Participants could have tried to adjust their response strategies in order to maximise chocolate reward and therefore it is possible that they expected to win chocolate across all three probability conditions. However, this hypothesis remains to be verified by further studies.

Studies 2.1-4 General Discussion

The goal of Chapter 1 was to explore the impact of different probabilities of reward and loss anticipation (*i.e.*, beer and chocolate) on AB for substance-related cues. All of the experiments have revealed a general AB for substance-related in comparison to neutral pictures. Cues signalling reward and loss were shown to have

outcome specific effects on AB (Studies 2.1–3). The effect of perceived control had a dissociable moderating role on effects of reward and loss anticipation: compared to passive viewing (Studies 2.1–2), it abolishes the effect of reward anticipation (Study 2.4) but it is necessary to detect the effect of loss anticipation (Study 2.3).

Outcome-specific effects of reward and loss anticipation

One of the hypotheses proposed that AB for chocolate and alcohol-related cues would be increased by reward anticipation regardless of the type of anticipated reward. This prediction was based on the general effects of reward anticipation on AB reported by Jones et al. (2012) and was consistent with general PIT effects - which demonstrate that a Pavlovian cue predicting one type of reward can energise instrumental responding for a range of rewards (*e.g.*, Cartoni et al., 2013; Corbit & Balleine, 2005, 2011; Holmes et al., 2010); as well as the 'broaden-and-build' theory of emotions - which suggests that positive affect triggered by reward anticipation could generate AB for a range of rewarding stimuli (Fredrickson, 2001; Fredrickson & Branigan, 2005; Tamir & Robinson, 2007).

Although the first experiment replicates and extends previous demonstrations of reward anticipation on AB for rewards (Wertz & Sayette, 2001; Field et al., 2011; *but see* Werthmann et al 2013; Hardman et al., 2014), the general effects of reward anticipation on AB showed by Jones et al. (2012) were not replicated. The anticipation of reward had outcome specific effects on AB whereby the anticipation of beer and chocolate affected only AB for stimuli congruent with the type of anticipated reward. This pattern of results could be considered as consistent with the outcome specific effects of PIT, where reward-specific Pavlovian cues increase instrumental responding only for the congruent rewards (Cartoni et al., 2013).

In the study conducted by Jones et al. (2012), participants responded in the same way for chocolate and alcohol anticipation trials by pressing the space bar. It was speculated that this could have encouraged participants to focus on the probability information that was presented on each trial rather than the type of reward that was on offer. This issue was addressed by incorporating two individual responses for chocolate and beer reward (Study 2.1), encouraging participants to

encode the type of anticipated reward in addition to the probability information. This methodological adjustment allowed for capturing outcome specific effects of reward anticipation. Therefore, suggesting that the generalised effects reported by Jones et al. (2012) were a study artefact.

The general effects were also suggested for loss anticipation studies by CRP (Rothermund et al., 2008), whereby a global increase in attentional preference for incongruent reward-related stimuli could reflect emotion regulation. This hypothesis was not supported by the current findings. Study 2.2 did not reveal the effects of loss anticipation whereas Study 2.3 revealed outcome-specific effects of loss avoidance. While a chance of keeping alcohol only influenced AB for alcohol-related pictures, an opportunity to preserve the loss of chocolate points only influenced AB for chocolate-related pictures. These findings improve the understanding of reward stimuli in the context of anticipated reward or loss; potentially indicating that anticipation of motivationally salient outcomes (reward and loss) could be sufficient to affect the attentional selection of reward-related stimuli (albeit only in the outcome specific manner).

Dissociative effects of control on the effects of reward and loss anticipation

The perceived control over the outcomes of tasks (loss or reward) had a dissociative impact on the effects of anticipation on AB. For the experiments which involved loss anticipation, AB was moderated by reward expectancy when participants had control over the outcome of behaviour. In Study 2.3, participants experienced greater AB for alcohol-related pictures when they could influence alcohol loss prevention during both *certain* and *uncertain loss prevention* conditions in comparison to *unlikely loss prevention*. However, the comparable effects were not reported for chocolate loss prevention. Therefore, the results of Study 2.3 are only partially consistent with availability account – *i.e.*, the ability to prevent loss could signal substance availability. In contrast, attention was only moderated by availability information during Study 2.1 when participants had no impact on the outcomes of the task. This suggests that the anticipation of loss could be guided by different mechanisms than the anticipation of reward.

It was initially argued (Study 2.2) that the withdrawal behaviour associated with anticipation of loss would be reflected by attentional avoidance of otherwise rewarding stimuli (chocolate or alcohol). It is possible that during Study 2.2 withdrawal behaviour was initiated by the task itself. Brandtstädter et al. (2004) demonstrated that participants paid more attention to cues signalling a danger of losing a point if they could prevent its' lose by identifying the location of the cue. In the uncontrollable condition, the presentation of cues signalling loss was associated with lower perceptual sensitivity. This could explain observed effects of loss anticipation reported in Study 2.3. It is possible that participants were not sensitive to probability cues when they had no control over the outcomes, and cues signalling unavoidable loss could have led to an adaptive response in the form of disengagement from the task. Consistent with predictions based on Brandtstädter et al. (2004), the effects of loss anticipation were revealed when behavioural control was introduced in Study 2.3, and participants could prevent the loss of rewards. These results are consistent with theories which posit that the level of involvement in behaviour may depend on perceived control over its outcomes (*see* Brandtstädter & Rothermund, 2002; Rothermund, 2011).

A different pattern of results was found in the reward anticipation experiments. Despite the fact that participants had no impact on the outcomes, Study 2.1 showed that anticipation of reward had an impact on AB. This could be explained by the conceptual differences between the loss (Study 2.2) and reward (Study 2.1) anticipation tasks. Participation in Study 2.2 was associated with a progressing decrease in the number of reward points which arguably triggered behavioural withdrawal. Contrastingly, the reward anticipation experiment (Study 2.1) was associated with an increasing amount of chocolate and alcohol rewards (points). Hence, goal achievement did not require demanding behavioural adaptations or efforts which could potentially affect task engagement (s*ee* Rothermund, 2011).

The final study on the reward anticipation was based on the findings of three previous experiments. The same type of outcome-specific effects of reward anticipation on AB to those reported in Study 2.1 was expected. Contradictory to this prediction, an overall boost in AB was observed for chocolate-related pictures during

chocolate anticipation trials when obtaining a reward depended on participants' performance. During the trials where a chocolate reward could be won, attention was directed in the outcome specific manner towards chocolate-related pictures. However, AB was not moderated by outcome probability. It is possible that while participants were actively involved in goal pursuit they were trying to come up with 'trial specific strategies' which would allow them to win points (*i.e.*, during the previous *uncertain reward* trial I pressed the top button and I won nothing hence if I press it again during the current trial I should win a point). Therefore, active involvement in the task could have abolished the predictive value of *uncertain reward* and *unlikely reward* cues, explaining an overall boost in preference for chocolate-related pictures during chocolate trials. However, this does not explain why the effects were only visible for chocolate anticipation trials.

The presented results suggest that some of the effects of loss anticipation on AB may depend on the level of perceived control over the negative outcomes (Study 2.3), where low levels of control may potentially prevent engagement in the task (Study 2.2). In contrast to loss anticipation, the low level of perceived control does not appear to hinder the effects of fixed probability information on AB as reflected by the results of Study 2.1. It can be speculated that AB is affected by fixed reward probability information when goal achievement does not require behavioural adjustments and use of internal resources. However, when participants have control over the outcomes they expect their efforts to be rewarded, regardless of the likelihood of reward (Study 2.4).

The impact of probability information on AB for rewarding cues

The current experiments did not provide an unequivocal answer to the role of uncertainty in the effects of anticipation of motivationally salient outcomes on AB. Studies 2.1-3 showed that cues signalling reward and loss can direct attention towards reward-related stimuli, and these effects may depend on the level of control. However, these experiments did not provide unequivocal support for either linear relationship between probability and AB indicated by the Mackintosh theory (1975), or maximal AB under uncertainty conditions suggested by Pearce and Hall's (1980) model of associative learning. For chocolate reward anticipation, the *uncertainty*

(*i.e.*, 50% chance of gain) and *certainty* (*i.e.*, 100% chance of gain) conditions did not differ from each other, and both increased AB in comparison to *no gain* condition (Study 2.1). For alcohol reward anticipation, the *certainty* condition increased AB for alcohol-related pictures in comparison to the *no gain* condition. However, there was no difference in AB for alcohol-related pictures between the *uncertainty* and *no gain* alcohol anticipation conditions (Study 2.1).

The anticipation of alcohol loss investigated in Study 2.3 led to a similar pattern of results. AB for alcohol pictures was increased when participants were likely to preserve their alcohol reward during *certain loss prevention* (*i.e.*, 100% chance of keeping a point) and *uncertain loss prevention* (*i.e.*, *50%* chance of keeping a point) in comparison to *unlikely loss prevention* (*i.e.*, 10% chance of keeping a point) condition. However, there was no difference between *certain loss prevention* compared to *uncertain loss prevention* conditions. Therefore, these results are only partially consistent with Mackintosh's theory of associative learning (1975) which suggests that more reliable predictors of the outcome should receive more attention. The results of chocolate trials were more complicated to interpret. AB for chocolate-related pictures was lower during *certain loss prevention* trials in comparison to *uncertain loss prevention* trials. This could be considered as consistent with the Pearce and Hall model (1980) which states that in order to facilitate learning CSs which accurately predict US receive less attention than those which are inaccurate predictors of US. However, contradictory to Pearce and Hall's model, AB during *unlikely loss prevention* trials did not differ from *certain loss prevention* and *uncertain loss prevention* trials.

The variability in the impact of *certainty* and *uncertainty* information could indicate that different mechanisms could be involved in the moderation of AB. Therefore, the effects of certainty could be qualitatively different from the effects of uncertainty. It is possible that the effects of certain outcome predictors are driven by a Mackintosh-type mechanism, and the effects of uncertain outcome predictors are be driven by a Pearce-Hall-type mechanism. This could explain why sometimes uncertainty and certainty condition have comparable and the other time dissociable effects on AB. This hypothesis should be addressed by further studies on the role of reward anticipation in moderation of AB.

Conclusion

Four studies were conducted to examine the effects of reward and loss anticipation under different control conditions on AB for reward-related cues. Evidence for outcome specific effects of reward and loss anticipation was found. The anticipation of chocolate and alcohol loss/reward influenced AB only for reward congruent stimuli. The effects of loss and reward anticipation depended on the level of control over the outcomes of tasks. The effects of loss anticipation on AB were only significant when participants had control over the outcome of behaviour, whereas, availability information only influenced AB when participants had no impact on the outcomes of the task. When outcome control was introduced, AB was increased across probability conditions for pictures congruent with the anticipated outcome – although this was only reported for chocolate gain. The current studies did not provide an unequivocal answer for the role of uncertainty in the effects of anticipation of motivationally salient outcomes on AB. It was proposed that that uncertainty may have an independent effect on AB from uncertainty. These findings expand the current knowledge of the effects of reward and loss anticipation on AB and help to clarify some of the issues associated with previous research (Jones et al., 2012).

CHAPTER 3 - THE EFFECTS OF REWARD ANTICIPATION ON EVENT-RELATED POTENTIALS

This chapter provides an overview of event-related potential (ERP) studies with the focus on neurophysiological indices of enhanced attentional processing of motivationally relevant stimuli (P300). A previous experiment (Study 2.1) revealed outcome specific effects of the reward of anticipation on AB. The current experiment was conducted to further explore the effects of reward anticipation on the attentional processing of motivationally relevant information. It was expected that anticipation of reward (chocolate and beer) should enhance processing of the congruent alcohol and chocolate related stimuli, and this should have been reflected by the facilitated electrical activity of the brain. Contrary to what was expected, the presentation of reward-related stimuli did not evoke the P300 component. In comparison to substance-related cues, neutral pictures evoked more pronounced N2 amplitudes (280 ms).

Study 3.1. An exploratory study on the effects of reward anticipation on event-related potentials associated with processing of substance-related cues.

3.1.1. Introduction

Electroencephalography (EEG) enables the direct measurement of physiological changes associated with AB, hence, making it a perfect tool for studying the effects of reward anticipation (Field & Franken, 2014). Synaptic activity, including both excitatory and inhibitory postsynaptic potentials is the main source of electric potentials recorded with EEG (Olejniczak, 2006). The electrical changes are generated in the intracellular fluid by neurotransmitter-induced ion flux across the neuronal membrane (Woodman, 2010). EEG allows for the recording of electrical changes related to unison group activation of cortical neurons. The magnitude of the change depends on the size of a group of neurons activated in synchrony (Nunez & Srinivasan, 2006).

Recording of ERP waveforms allows for capturing electrophysiological brain activity in response (or in preparation for) to stimulus exposure. ERP waveforms consist of series of positive and negative voltage deflections (peaks) which are referred to as components (Luck, 2005). ERPs are named using polarity (*P* for positive and *N* for negative peaks) combined with either time (*e.g.*, 200, 300 after the latency in *ms* after stimulus onset) or ordinal (*e.g.*, 1 for first, 2 for the second peak in the waveform, etc.) nomenclature. It is assumed that the variation in component's amplitude reflects the intensity of processes operating in response to stimuli (Kok, 1990).

P300 is one of the most widely studied components and is generally agreed that it may indicate selective attention and information processing (*e.g.*, Littel et al., 2012; Schupp et al., 2004; Schupp, Flaisch, Stockburger, & Junghofer, 2006; Schupp et al., 2007). P300 is a large positive peak (ranging from 5 μV to 20 μV) conventionally assessed at the midline electrodes (Fz, Cz, Pz) which typically occurs between ≈ 300 *ms* to ≈ 800 *ms* – P300 is a term used in reference to classical P300 or

more inclusive late positive component (Littel et al., 2012; Patel & Azzam, 2005; Polich, 2007).

The classical P300 component was defined as a time locked positive peak typically appearing approximately 300 to 400 *ms* from the onset of stimulus presentation (Patel & Azzam, 2005). This component is typically obtained using an *oddball* paradigm. This paradigm requires either a covert (*i.e.*, silent counting) or an overt (pressing a button in response to) detection of an infrequent 'target' stimulus presented within a train of repetitive standard visual cues. Presentation of 'oddball' stimuli results in more pronounced P300 amplitudes in comparison to frequent cues (*e.g.*, Donchin, 1981). This may reflect memory processes involved in the classification of goal relevance of target stimuli and associated allocation of attention (*see* Bledowski, Prvulovic, Goebel, Zanella, & Linden, 2004; Kok, 2001; Polich, 2007).

It is generally agreed that evolutionary relevant stimuli signalling reward and threat receive selective attention (*e.g.*, Jackson & Calvillo, 2013; Ohman, Flykt, & Esteves, 2001; Rupp & Wallen, 2008; Werthmann et al., 2015). Attentional preference for highly arousing motivationally relevant information has been termed *motivated attention* (Lang, Bradley, & Cuthbert, 1997). There is strong empirical evidence demonstrating the relationship between P300 as well as SP which can be thought as a long-lasting continuation of P300, and motivated attention. These components are known to be more pronounced in response to highly arousing unpleasant and pleasant stimuli when compared to neutral stimuli, and the magnitude of the enhancement may depend on the motivational significance, relevance or the level of arousal triggered by the stimuli (Briggs & Martin, 2009; Hajcak, MacNamara, & Olvet, 2010; Olofsson, Nordin, Sequeira, & Polich, 2008; Schupp et al., 2004). Therefore, P300 and SP are considered indices of motivated attention (Schupp et al., 2004).

Motivationally relevant cues like drugs and food are capable of evoking P300 and SP, indicating their capability to attract selective attention (Littel et al., 2012; Nijs, Franken, & Muris, 2008). The intensified processing of substance related cues in comparison to neutral stimuli found in substance users but not in non-users is

reflected by increased P300 and SP components. These findings represent a robust phenomenon found across cannabis, heroin, cocaine, alcohol and cigarettes users, and were obtained using passive viewing paradigms and active paradigms like the aforementioned 'oddball' task (*see* Littel et al., 2012). Similarily to drug-related cues, attention and motivation toward food-related stimuli are associated with P300 and SP. Appetite research suggests that greater magnitude of P300 and SP may reflect a general attentional bias for food stimuli related to its motivational value (Nijs & Franken, 2012; Nijs et al., 2008; Sarlo, Ubel, Leutgeb, & Schienle, 2013). Furthermore, P300 and SP might be attenuated in individuals concerned about their eating behaviour as a consequence of cognitive strategies applied in order to avoid food-related cues (Nijs & Franken, 2012).

Some studies suggest that anticipation of reward may enhance P300 while participants wait for feedback (*e.g.*, Pfabigan et al., 2014). Since P300 is considered an index of motivated attention (Schupp et al., 2004), it can be expected that reward-related pictures (*i.e.*, alcohol and chocolate) will increase the magnitude of reward-related component – possibly P300 – relative to the exposure to matched neutral pictures. These effects should be moderated by the likelihood of reward. For instance, anticipation of substance reward could enhance motivational value of substance-related cues and therefore increase P300 amplitudes (*see* Nijs & Franken, 2012; Nijs et al., 2008; Sarlo et al., 2013). Such predictions are also based on the results of eye-tracking studies which demonstrated that anticipation of substance reward can increase AB for substance-related cues (*see* Study 2.1; Field et al., 2011; Jones et al., 2012), as well as studies which demonstrated that P300 can be sensitive to the effects of reward anticipation (*e.g.*, Pfabigan et al., 2014).

Alternatively, cues signalling reward availability could influence brain activity in a similar manner to feedback information. The experience and evaluation of outcomes of events, both positive and negative, is crucial for human survival and represents the late stage of decision making (Ernst & Paulus, 2005). The evaluative processes may be automatic, therefore allowing for instant decision making in response to feedback value (Bargh & Ferguson, 2000). For instance, the strategic monitoring of outcomes could enable correct action selection via response inhibition required for readjustment (Botvinick, Cohen, & Carter, 2004;

Folstein & Van Petten, 2008). Thus, evaluative processes are crucial for successful goal-directed behaviour.

ERP evidence supports the existence of a neural system for error detection. The examination of feedback-related ERPs revealed a negative deflection at around 230-270 *ms* following the onset of feedback information. These components are often labelled as N200, feedback error-related negativity (fERN) or feedback-related negativity (FRN), and are arguably generated in the anterior cingulate cortex (Holroyd & Coles, 2002; Nieuwenhuis et al., 2004). It was proposed that this deflection could be a consequence of a mismatch between expectations and the actual outcomes (*i.e.*, error detection). Reinforcement learning error related negativity theory (Holroyd & Coles, 2002; Nieuwenhuis et al., 2004) posits that N200 could be the reflection of learning processes mediated through the impact of phasic dopamine activity in the midbrain dopamine system on the dorsal anterior cingulate cortex (dACC). The dopamine system monitors whether outcomes are better (increased dopamine response) or worse (decreased dopamine response) than predicted, and the dACC uses this signals to adapt the behaviour. This account argues that N2 reflects unexpected negative feedback. However, it appears that the magnitude of N2 could be mediated by both positive and negative feedback information, where positive feedback could attenuate fERN (Baker & Holroyd, 2011; Holroyd, Pakzad-Vaezi, & Krigolson, 2008).

The binary categorization account posits that feedback-related negativity could encode categorical characteristics of feedback distinguishing between good and contrasting bad outcomes *i.e.*, goal failure vs. goal achievement. Bad outcomes (*i.e.*, lack of reward or loss – depending on the context) evoke greater negativity amplitude in comparison to positive feedback (*i.e.*, reward), but this difference is independent of outcome magnitude (Hajcak, Moser, Holroyd, & Simons, 2006; Yeung & Sanfey, 2004).

Motivational context could define the occurrence of fERN. Holroyd, Larsen, and Cohen (2004) showed that feedback signalling unexpected lack of reward evoked fERN when reward was the alternative outcome. However, the unexpected lack of reward feedback did not evoke fERN when loss was the alternative outcome.

The results of this study demonstrate that 'negativity' of the outcome could be defined relative to alternative outcomes rather than being pre-assigned to the valence of the event.

It is possible that outcome probability cues (*i.e.*, 100%, 50% and 0% chance of reward) could influence brain activity in a similar manner to feedback information. For example, probabilistic information about pending motivationally salient outcomes can influence FRN via interaction between outcome valence and outcome expectancy. Liao, Gramann, Feng, Deak, and Li (2011) demonstrated that cues signalling motivationally salient outcomes evoked FRN, with unexpected outcomes generating larger difference waves than expected outcomes. Additionally, cues signalling loss have a greater impact on FRN than cues signalling positive outcomes.

This study was conducted in order to examine if there would be an effect of reward anticipation on either P300 or N200 ERP components. Taking into account the results of previous research, this experiment investigates congruent effects of reward anticipation. Therefore, the effects of chocolate anticipation on the processing of alcohol-related stimuli and vice versa, is not the goal of the current study. On the one hand it is expected that (1) the presentation of substance-related stimuli should evoke greater P300 relative to neutral. Furthermore, (2) in comparisons to *no reward* condition, gain probability information could enhance the motivational value of substance-related cues leading to more pronounced P300 peaks. On the other hand, it can be expected that relative to *no reward* condition, cues signalling reward outcome could trigger outcome evaluation processes reflected by N200. Taking into account the results of previous research (*e.g.*, Holroyd & Coles, 2002; Liao et al., 2011; Nieuwenhuis et al., 2004) which revealed enhancement of N200 during unexpected feedback (3) it can be expected that N200 should be most pronounced for the *uncertainty* condition. The outcome evaluation processes reflected by N200 (4) should be further enhanced across both gain conditions when *reward* gain information is followed up by neutral stimuli (*i.e.*, unexpected outcome), in comparison substance-related stimuli.

3.1.2. Method

Participants

Twenty-nine participants (20 female) were recruited from the staff and students at the University of Liverpool. Inclusion criteria included: regular consumption of chocolate and beer (both at least once per week), aged above 18 and fluency in English. Participants who had received treatment for alcohol problems could not take part. Study 3.1 was approved by the University of Liverpool Research Ethics committee (Ref. IPHS-1314-LB-256), and all participants provided informed consent before taking part. Participant characteristics are shown in Table 3.1.2-1.

Table 3.1.2-1 *Participant characteristics Study 3.1*

Participants recruited	29 (F = 20, M = 9)
Participants included in the analysis	22 (F = 14, M = 8)
Age (years)	24.32 ± (6.47)
Alcohol consumption (in units per week)	14.61 ± (5.70)
AUDIT	7.91 ± (3.89)
Weekly chocolate consumption (in bars)	3.00 ± (1.35)
Chocolate bars usually kept at home	2.68 ± (2.03)
Chocolate use/craving - CUQ	22.41 ± (5.34)

AUDIT – Alcohol Use Disorders Identification Test, CUQ – Chocolate Use Questionnaire

Pictorial stimuli

The majority of the pictures presented in the previous experiments (Studies 2.1-4) were used in the current study, but due to the increased number of trials within probability conditions, 5 pairs of new reward-related and matched neutral pictures were added for each of the reward categories. The pictures used in the current study were considerably larger (176.4 *mm* wide by 117.6 *mm* high) than for Studies 2.1-4 (130 *mm* by 90 *mm*). Therefore, some of the stimuli were replaced with new matched pictures – if enlargement of initial pictures affected their quality and the raw image files were not available for size reduction. Pictures were also matched on complexity and brightness. The experiment involved 15 alcohol-related images (*e.g.*, a close-up of a model opening a bottle of beer, a can and a glass of beer) and 15 matched neutral stationery-related pictures (*e.g.*, a close-up of a model sharpening a pencil, pens in desktop organizers). Chocolate stimuli involved a set of 15 chocolate-related images (*e.g.*, a chocolate bar, chocolate buttons) and 15 matched neutral stationery-related pictures (*e.g.*, a voice recorder, clothing buttons).

Expectancy task

At the beginning of each trial, a blue fixation cross was displayed in the centre of the screen for 1500 *ms*. Subsequently a picture of a *Becks* beer bottle or a bar of *Cadbury's Diary Milk* chocolate (75 *mm* by 75 *mm*) defining the type of point that could be won, was displayed in the centre of the screen, directly above text that indicated the probability (100%, 50%, or 0% - representing *certain reward*, *uncertain reward* and *no reward* respectively) of winning on that trial. These stimuli were presented for 1000 *ms* and were immediately replaced by either a reward-related or a neutral picture presented for 2000 *ms*. Chocolate anticipation trials included only chocolate-related and chocolate-matched neutral pictures, whereas alcohol anticipation trials included only alcohol-related and alcohol-matched neutral pictures. Immediately after the offset of the picture, the following text was displayed in the centre of the screen: '*press the left key to try to win chocolate*' on chocolate outcome trials, or '*press the right key to try to win beer*' on beer outcome trials. Text feedback was presented for 1000 *ms* as soon as participants pressed the appropriate key: '*you win a beer point!*' on all *certain reward* and half of *uncertain*

reward beer outcome trials; 'you win a chocolate point' on all *certain reward* and half of *uncertain reward* chocolate outcome trials; '*you win nothing*' on all *no reward* trials and the remaining *uncertain reward* trials; '*incorrect*' if participants pressed a button incongruent with the type of trial. Furthermore, participants received feedback '*too fast*' if they pressed any of the buttons before being prompted to make a response, which resulted in skipping the 'failed' trial. The inter-trial interval ranged from 450 *ms* to 750 *ms* in 50 *ms* increments to control for trial preparation and temporal expectations which may affect EEG recording.

Participants completed a practice block of 6 trials comprising equal numbers of trials in which *certain reward*, *uncertain reward* and *no reward* beer and chocolate probability information were presented before neutral pictures (*e.g.*, porcelain cups); data from these trials were not analysed. The main block comprised of 360 critical trials, 180 with beer rewards and alcohol and matched neutral pictures, and 180 with chocolate rewards and matched neutral pictures. For alcohol and matched-alcohol neutral pictures there were an equal number of alcohol reward trials (90 trials each) and within this an equal number of *certain reward*, *uncertain reward* or *no reward* probability trials (30 trials each). Chocolate anticipation trials were intended to be counterbalanced in exactly the same way. Unfortunately, due to a programming error, participants were presented with 15 x *certain reward* probability trials and 45 x *uncertain reward* probability trials (15 win, 30 loss) before neutral pictures, when they should have received 30 repetitions of both of these trial types. Participants had the opportunity to take a short break after every 90 trials.

Procedure

All testing took place between 1 pm and 6 pm in the in electroencephalogram (EEG) laboratory in the Department of Psychological Sciences. Participants were tested during a single experimental session lasting approximately 1 hour 30 minutes. Bottles of Becks beer and bars of Dairy Milk chocolate were placed around the laboratory so that they were visible to participants as they entered, but these were out of view when participants completed the task. After providing informed consent, participants completed three questionnaires: a two week Time-Line Followback

alcohol consumption diary (Sobell & Sobell, 1992), AUDIT (Babor et al., 2001) and a chocolate use questionnaire (Tibboel et al., 2011).

Participants then completed the expectancy task. The electrode cap was fitted before participants were asked to take a seat in a sound attenuated, shielded recording room. Participants sat approximately 150 *cm* away from a 40 *cm* x 30 *cm*, 60 *Hz* CRT stimulus presentation monitor (Mitsubishi, Tokyo, Japan). They were shown the beer and chocolate in the laboratory and were explicitly informed that the points that they accumulated during the task would be converted into actual rewards that they would receive at the end of the experiment. The beer and chocolate were then hidden from view before the task was explained. Participants were asked to pay close attention to the information about the type of outcome and the probability of winning that would be presented at the beginning of each trial, to rest their index fingers on two labelled keys ('c' for chocolate outcome trials and 'b' for beer outcome trials), and to respond on the appropriate key when prompted to do so. They were informed that responding before being prompted would result in skipping the trial and therefore forfeiting the potential reward. As they completed the task, the EEG activity was continuously recorded. At the end of the experiment, the EEG cap and electrodes were removed and participants were fully debriefed. Participants received course credit or a shopping voucher instead of the beer and chocolate, and the requirement for the deception was explained during debriefing.

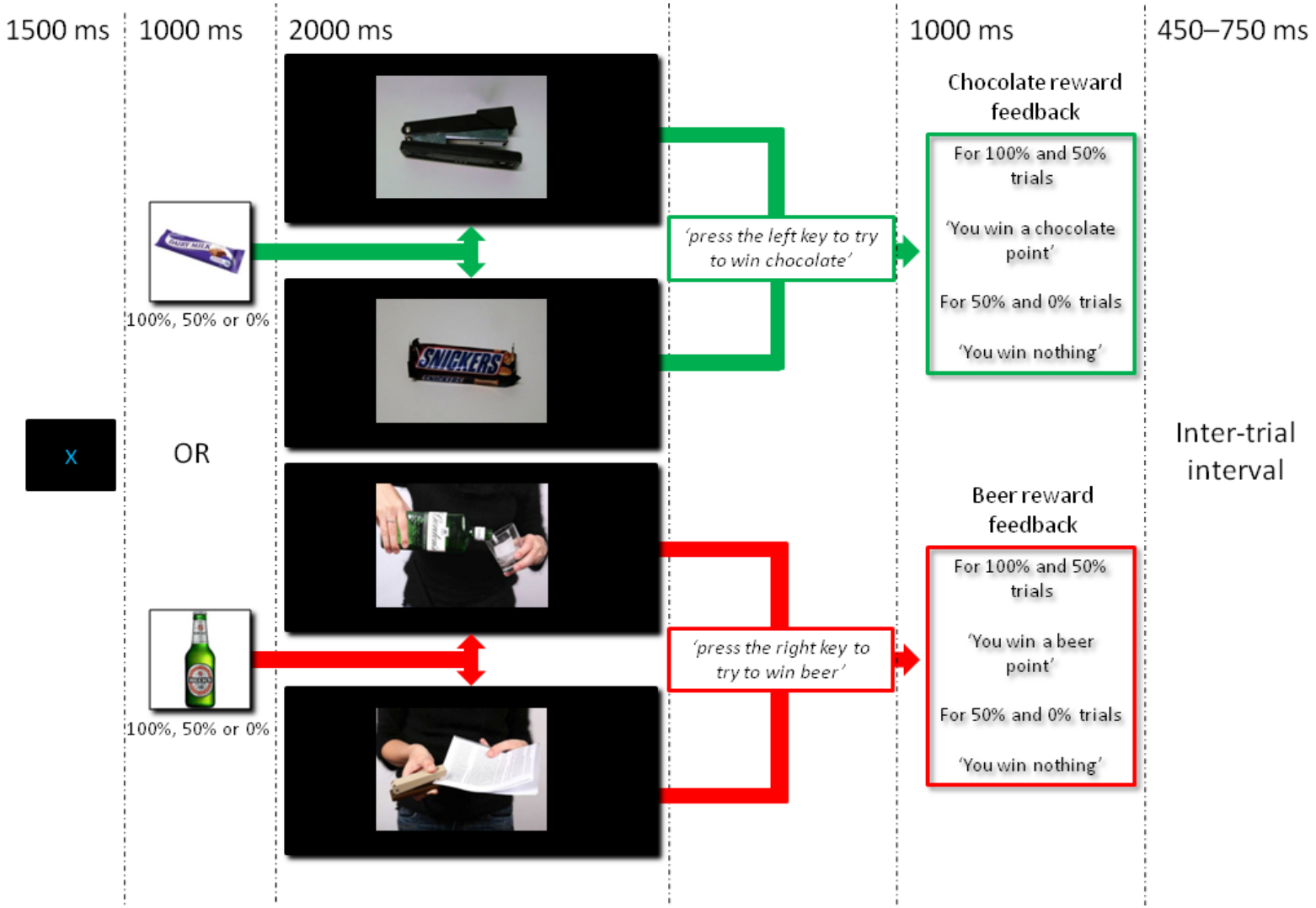

Figure 3.1.2.1. Flowchart of the experimental procedure Study 3.1.

EEG Recording

EEG activity was continuously recorded using a BioSemi Active-Two amplifier sampling at 512 *Hz* (BioSemi, Amsterdam, Netherlands). Sixty-four electrodes were arranged in an elastic cap with plastic electrode holders according to the 10–20 system. Additionally, Common Mode Sense (CMS) reference and Driven Right Leg (DRL) ground electrodes were used. Horizontal and vertical electrooculograms (EOG) were recorded with four external electrodes.

Data reduction and analysis

EEG data was analysed using Brain Electrical Source Analysis version 6.0 (MEGIS GmbH., Germany). EOG artefacts were corrected using principal component analysis procedure (Berg & Scherg, 1994). Each EEG recording was visually inspected to eliminate muscular artefacts and remaining eye blinks before averaging. Common average reference method was applied in order to spatially transform data to reference-free data. Data were then segmented into epochs from 200 *ms* to 3000 *ms* and ERPs were time-locked relative to the onset of pictorial stimuli. The raw EEG data were initially filtered using a band pass filter at 0.5 – 70 *Hz* to remove artefacts and a notch filter at 50 *Hz*. Epochs containing artefacts were removed from the analysis. The remaining epochs were averaged across all twelve reward type (chocolate and alcohol), probability (*certain reward*, *uncertain reward* and *no reward*) and picture (reward and matched neutral) conditions. The average data were filtered at 0.5 – 30 *Hz* and grand averages for individual electrode analysis were exported to Matlab 2014 (Mathworks: Natick, Massachusetts, USA). During the visual inspection of data files, seven participants were excluded from the analysis due to low quality data.

3.1.3. Results

ERP Component at midline electrodes

In contrast to the initial predictions, P300 was not observed during the task. However, visual inspection identified a negativity peak at around 280 *ms* (N2) for both chocolate and beer anticipation trials. To investigate effects of reward

anticipation on ERP components, the midline electrodes FCz, Cz, CPz and Pz were analysed in detail. The grand average ERPs for these electrodes are shown in Figure 3.1.3.1.

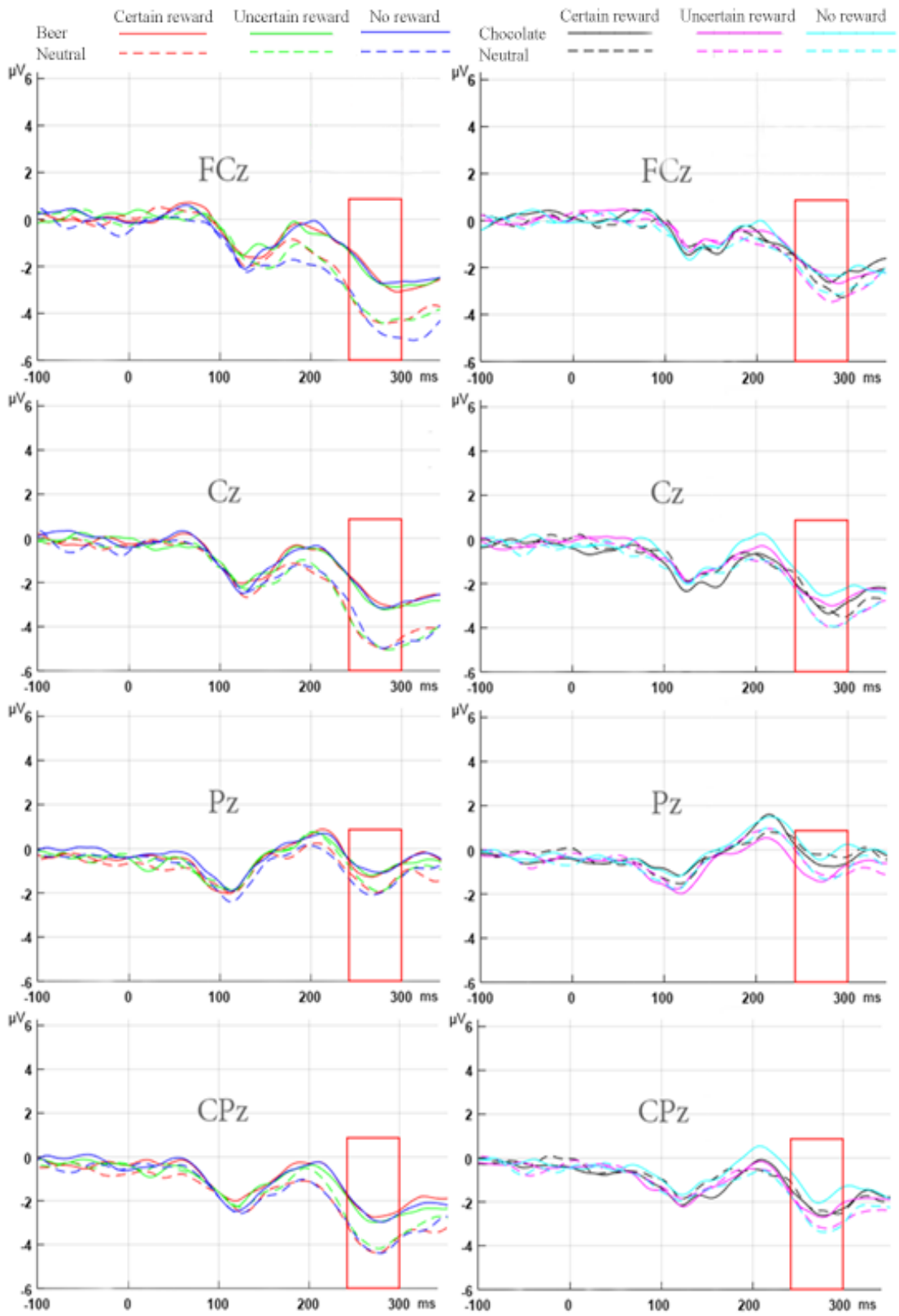

Figure 3.1.3.1. The effects of beer and chocolate reward anticipation (*certain*, *uncertain* and *no reward*) on ERPs (μV) for congruent reward-related and matched neutral pictures recorded at FCz, Cz, Pz and CPz electrodes.

N2 ERP

In order to explore the effects of reward anticipation on the N2 (taken from the epoch between 260 – 300 *ms*), data were analysed using a four-way repeated-measures ANOVA, with factors of *Electrode* (4: FCz vs. Cz vs. CPz vs. Pz), *Outcome Type* (2: beer points vs. chocolate points), *Probability* (3: *certain reward* vs. *uncertain reward* vs. *no reward*) and *Picture Type* (2: alcohol/chocolate vs. neutral). This revealed significant main effects of *Electrode* ($F(3, 63) = 35.14$, $p < .001$, $\eta_p^2 = .63$; indicating the largest N2 amplitude at the central electrode compared to fronto-central, centro-parietal and parietal electrodes); *Outcome Type* ($F(1, 21) = 20.01$, $p < .001$, $\eta_p^2 = .49$; indicating larger N2 amplitudes for beer outcome)); and *Picture Type* ($F(1, 21) = 60.01$, $p < .001$, $\eta_p^2 = .74$; indicating larger N2 amplitudes for neutral pictures). The four-way *Electrode* x *Outcome Type* x *Probability* x *Picture Type* interaction was not significant ($F(6, 126) = .51$, $p = .208$, $\eta_p^2 = .07$). This suggests that the effects of reward anticipation on ERP did not vary across the electrodes. The three-way *Outcome Type* x *Probability* x *Picture Type* interaction was not significant ($F(2, 42) = 1.11$, $p = .339$, $\eta_p^2 = .05$). However, a two-way *Probability* x *Picture Type* interaction approached significance ($F(1, 21) = 3.18$, $p = .052$, $\eta_p^2 = .13$) and a two-way *Outcome Type* x *Picture Type* interaction was significant ($F(1, 21) = 11.73$, $p = .003$, $\eta_p^2 = .36$).

To further analyse the *Outcome Type* x *Picture Type* interaction, mean N2 values were calculated across three probability conditions for each of the *Outcome Type* - *Picture Type* combinations. For beer *Outcome Type* trials, a paired-sample *t*-test revealed larger N2 amplitudes for neutral in comparison to alcohol-related cues ($t(21) = 9.17$, $p < .001$, $d = 0.91$). Similarly for chocolate *Outcome Type* trials, larger N2 amplitudes were evoked by the presentation of neutral cues in comparison to chocolate-related cues ($t(21) = 2.98$, $p = .007$, $d = 0.38$). To further investigate the two-way *Probability* x *Picture Type* trend interaction ERP values were averaged across electrodes, and mean N2 amplitudes were calculated for accumulated *Outcome Type* (beer + chocolate) and accumulated *Picture Types i.e.*, beer +

chocolate for *reward pictures*, and alcohol-neutral + chocolate-neutral for *neutral pictures*) at each level of probability. Figure 3.1.3.2 demonstrates that at each level of reward probability, *neutral pictures* evoked greater N2 amplitudes in comparison to *reward pictures*. This difference appears to be smaller for the *certain reward* relative to *no reward* condition. However, two independent one-way ANOVAs conducted for *reward pictures* and *neutral pictures* revealed no difference in the amplitudes of N2 components between probability conditions (*reward pictures* ($F(2, 42) = 1.55$, $p = .224$, $\eta_p^2 = .07$); *neutral pictures* ($F(2, 42) = 2.05$, $p = .142$, $\eta_p^2 = .09$)).

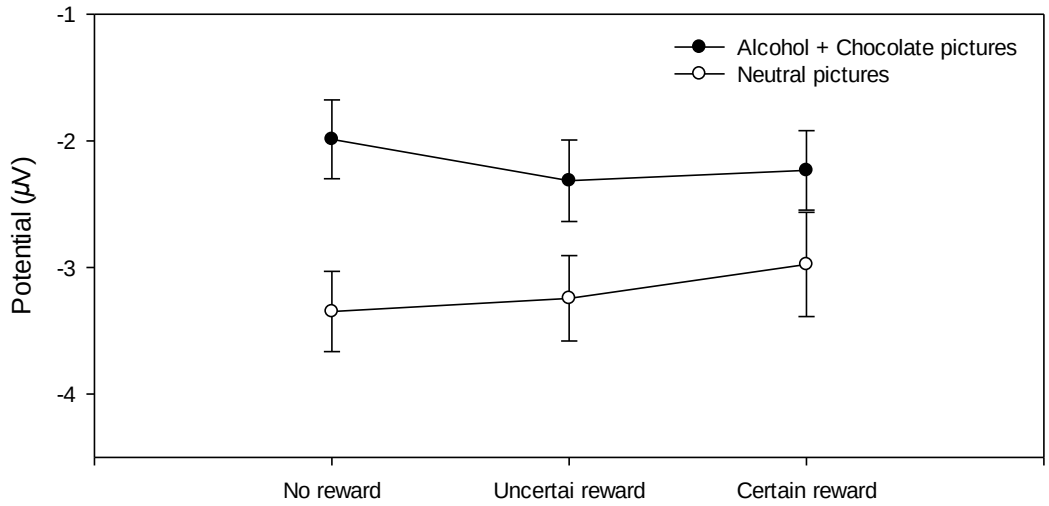

Figure 3.1.3.2. The effects of reward anticipation (beer and chocolate) beer on ERPs (μV) averaged across FCz, Cz, Pz and CPz electrodes for reward-related (alcohol and chocolate) and neutral pictures.

3.1.4. Discussion

One of the hypotheses proposed that the attentional processing of reward-related pictures should be more pronounced in comparison to neutral stimuli. It was predicted that these difference would be associated with shifts in the magnitude of P300 component. Moreover, it was expected that this difference would be moderated by the effects of reward anticipation. The presented results did not provide support for the presence and enhancement of P300 during viewing of reward-related stimuli under different probabilities of reward. However, current findings revealed N2 component for both chocolate and beer anticipation trials. Therefore, the hypothesis based on research findings which revealed an enhanced P300 during the presentation of motivationally salient stimuli (*see* Littel et al., 2012; Nijs et al., 2008) has to be rejected.

Alternatively, it was proposed that probabilistic cues which indicate pending motivationally salient outcomes could influence N2 (Liao et al., 2011). Such a neurophysiological response could suggest the activation of learning processes (Holroyd & Coles, 2002; Nieuwenhuis et al., 2004). For example, some research suggests that positive feedback could attenuate N2 whereas negative feedback information could enhance it (Baker & Holroyd, 2011; Holroyd et al., 2008). This could explain why N2 amplitudes were smaller for substance-related cues in comparison to neutral ones. The negative component observed approximately 280 *ms* after the onset of pictorial stimuli could reflect the activation of automatic evaluative processes and decision-making response to feedback value (*see* Bargh & Ferguson, 2000). For instance, pictures associated with reward could be perceived as a form of positive feedback and thus attenuate N2 amplitudes. Neutral pictures that were not associated with reward could be evaluated as negative feedback as they may indicate a decreased likelihood of receiving a reward. Alternatively, the neutral stimuli could be considered as unexpected outcome or feedback error, thus explaining greater N2 amplitudes. Such an interpretation is consistent with the accounts which suggest that N2 deflection is a consequence of a mismatch between expectations and the actual outcomes (*i.e.*, error detection) (Holroyd & Coles, 2002; Nieuwenhuis et al., 2004). These results provide a partial

support for the hypothesis which suggested the activation of evaluative processes during reward anticipation.

It was expected that a greater negativity would be elicited during both *reward* anticipation trials relative to *no reward* condition, with the highest N2 amplitude for *uncertainty* condition. This prediction was made taking into account research which reported most pronounced N2 amplitudes for unexpected outcomes (Holroyd & Coles, 2002; Liao et al., 2011; Nieuwenhuis et al., 2004). This hypothesis was not supported by current results as probability of reward did not influence N2 amplitudes.

The second part of the hypothesis proposed that effects of anticipation should be further enhanced by the presentation of 'unexpected' neutral stimuli. The hypothesised interaction was not observed. Instead for chocolate and beer trials, the presentation of neutral pictures evoked greater N2 amplitude relative to substance-related pictures, and these differences were consistent across probability conditions.

This pattern of results could be interpreted in the following way – overall the anticipation of chocolate reward activated evaluative processes as demonstrated by the difference between substance-related and neutral cues. For instance, during substance anticipation, outcome congruent cues could be perceived as expected and rewarding and diminish N2. On the other hand, it could by hypothesised that neutral cues increase N2 amplitudes as they could indicate diminished likelihood of reward or could be perceived as unexpected feedback (*see* Baker & Holroyd, 2011; Holroyd & Coles, 2002; Holroyd et al., 2008; Nieuwenhuis et al., 2004). This difference in N2 may implicate changes related to strategic monitoring preceding response adjustment which might be necessary for unexpected events (*see* Folstein & Van Petten, 2008). These effects were not moderated by the perceived likelihood of reward and were consistent across all of the probability conditions.

It is also possible that the pictorial cue signalling the outcome type (*i.e.*, a bar of *Cadbury's Diary Milk* chocolate) contributed to the differences in N2 observed between chocolate-related and neutral picture. The enhanced N2 recorded during the presentation of neutral stimuli relative to the chocolate stimuli could have been

a consequence of the mismatch between the outcome-type cue and the subsequently presented neutral stimuli. Accordingly, it is possible that the observed differences in N2 were not triggered by the effects of outcome anticipation but by the stimulus novelty (*see* Daffner et al., 2000; Ferrari, Bradley, Codispoti, & Lang, 2010; Folstein & Van Petten, 2008).

It can be hypothesised that the impact of probability information on N2 would be revealed when anticipated outcome is confronted with actual feedback at the end of a trial. Alternatively, the methodological differences between the current EEG research method and the previous eye-tracking studies (*see* Study 2.1, Field et al., 2011; Jones et al., 2012) which demonstrated the effects of reward anticipation, should be considered. It can be hypothesised that reward-related cues need to be presented in competition with neutral cues to reveal the effects of reward anticipation on attentional processing. Future research could investigate if the simultaneous presentation of reward and neutral stimuli could influence the evaluative processes and interact with perceived likelihood of reward.

It should be emphasised that the interpretation of current results is limited due to the possible effect of the counterbalancing error, which could have influenced the subjective experience of probability information during chocolate anticipation trials. Due to a programming error, *uncertain reward* neutral pictures trials suffered from decreased likelihood of winning chocolate *i.e.*, 33% instead of intended 50%. As a consequence, this condition could have appeared more similar to *no reward* neutral pictures trails.

In general, the neurophysiological response to substance-related and neutral stimuli preceded by the outcome probability cues (*i.e.*, N2) was different from the one implicated by the results of AB studies (*i.e.*, P300, *see* Littel et al., 2012). The current study did not provide support for the role of probabilistic reward information on the responsiveness to substance-related stimuli. The presented component is different from the one implicated by attention studies (*i.e.*, P300). This could suggest that the presentation of substance-related cues in the context of reward anticipation is sufficient for the activation of evaluative processes which are influenced by a type of external cue.

CHAPTER 4 - THE EFFECTS OF ANTICIPATION OF SUBSTANCE REWARD AND LOSS ON ATTENTIONAL BIAS FOR MOTIVATIONALLY SALIENT STIMULI

It has been demonstrated that the anticipation of reward or loss may have a moderating effect on AB for substance-related stimuli (Chapter 2). The current chapter explores whether the effects of anticipation of motivationally salient outcomes (reward or loss) on AB could generalise to a different type/category of motivationally relevant stimuli. Two studies based on emotion regulation literature were conducted to investigate the effects of reward anticipation on AB for motivationally salient stimuli (facial expressions of emotions). Study 4.1 revealed significant linear effects of reward and loss anticipation on AB when sad and happy facial expressions were presented in competition and five levels of probability were used (definitely win, maybe win, cannot win or lose, maybe lose, definitely lose). These effects were not present in Study 4.2 when uncertainty conditions were excluded from the task.

Introduction

AB may be a crucial mechanism in successful goal-directed behaviour whereby it highlights reward opportunities or potential threat, allowing for adequate response selection. Therefore, both positivity and negativity biases are important from the perspective of goal-directed behaviour. However, neither general positivity or negativity bias accounts provide a complete explanation of affective processing (Rothermund, 2011). In fact, a rigid AB could be problematic insofar as distorting the perception of reality and jeopardising everyday behaviour. The hindering effects of rigid AB are present in mental health disorders some of which could be characterised by the enhanced processing of either negative (*e.g.*, anxiety - AB for threat) or positive information (*e.g.*, addiction/obesity - AB for drug/food reward, respectively). Additionally, aside from AB being one of the symptoms, it could also be involved in the aetiology (Everaert et al., 2012; Field & Cox, 2008; Hendrikse et al., 2015; Van Bockstaele et al., 2014). Therefore, rigidity in attentional processing can be considered as threatening for successful goal-directed behaviour (Rothermund et al., 2008).

Emotion regulation processes allow for handling the extent of positively and negatively valenced information. Preventing individuals from becoming locked up in extreme emotional states and hence allowing for flexible switching between motivational orientations and goal achievement (*see* Koole & Rothermund, 2011; Rothermund, 2011; Rothermund et al., 2008). For instance, the counter-regulation principle (CRP) argues that during goal-directed behaviour, emotional equilibrium is achieved via attention being automatically directed towards stimuli incongruent with the experienced affective-motivational state (Rothermund, 2011; Rothermund et al., 2008). Therefore, the experience of goal success can direct attention towards negatively valenced cues whereas goal failure can direct attention towards positively valenced information. Research indicates these counter regulation processes can be activated even when motivationally salient outcomes are anticipated and have not yet been experienced (Rothermund et al., 2008).

On the contrary, some theoretical accounts suggest that AB could depend on the match with the content of working memory (*see* Olivers, 2008; Soto et al., 2008).

These accounts indicate that the anticipation of motivationally salient outcomes should direct attention towards stimuli congruent with the content of working memory. Assuming that information about the likelihood of motivationally salient outcomes is maintained in working memory, it can be expected that attention should be directed towards stimuli relevant to the current affective context.

The present chapter reports findings from two studies which attempted to clarify the psychological mechanisms that underlie the effects of substance loss and reward anticipation on AB for motivationally salient cues (*i.e.*, facial expressions of emotion). The predictions implicated by incongruency accounts (*e.g.*, Rothermund, 2011; Rothermund et al., 2008) and those suggested by congruency accounts (*see* Olivers, 2008; Soto et al., 2008) were investigated using a modified version of eye-tracking tasks previously used in Studies 2.1-2. The current research was conducted to clarify whether the anticipation of substance-related loss and reward would have a congruent or incongruent effect on AB for motivationally salient cues. The role of uncertainty in comparison to the expectation of certain reward gains and losses was also considered, as different theories of associative learning make competing predictions in this regard (Mackintosh, 1975; Pearce & Hall, 1980).

Study 4.1. The effects of certain and uncertain predictors of motivationally salient outcomes on AB for facial expressions of emotions.

4.1.1. Introduction

The current examination of the role of anticipation in emotional regulation is different from the previously reviewed studies, which showed that the anticipation of motivationally salient outcomes (*i.e.*, substance reward) can have a powerful energizing effect leading to increased cue reactivity (*e.g.*, AB and craving). For example, it was demonstrated that the anticipation of substance reward/availability can increase AB for substance-related stimuli (e.g., Study 2.1, Field et al., 2011; Jones et al., 2012). Studies 2.1 and 2.3 clarified that the effects of anticipation of reward and loss anticipation are outcome specific within the substance-specific domain. The results of these studies implicate that AB is greater when substances are perceived as available *i.e.*, when reward is anticipated or loss prevention is possible. However, these experiments do not provide an answer to the effects of anticipation of motivationally salient outcomes on AB for different categories of valenced stimuli. These effects are implicated by CRP. Studies which found incongruency effects during goal-directed behaviour (*e.g.*, Rothermund et al., 2008; Rothermund, Wentura, & Bak, 2001; Wentura et al., 2009) suggest that the anticipation of reward should increase AB for negatively valenced stimuli whereas the anticipation of loss should increase AB for positively valenced stimuli.

The difference between studies which used fixed probability information to show the effects of anticipation on AB for substance-related stimuli and CRP studies should be emphasised. Some research which demonstrated incongruency effects during goal-directed behaviour involved an outcome focus manipulation (*e.g.*, Rothermund et al., 2008; Rothermund et al., 2001; Wentura et al., 2009). In these studies, depending on their performance, participants could win rewards (positive outcome focus trials) or prevent their loss (negative outcome focus trials). Therefore, in the case of all of these studies participants had an active role in winning or losing their rewards. Overall the manipulation of outcome focus results in

a greater interference of negatively valenced distractors during positive outcome focus and a greater interference of positively valenced distractors during negative outcome focus.

Contrastingly, in the aforementioned studies which demonstrated the impact of fixed outcome probability information on substance-related AB performance did influence the outcomes (*e.g.*, Study 2.1, Field et al., 2011; Jones et al., 2012), the lack of active control over the outcomes could have limited participants' emotional involvement in the task. For instance in the discussion of results of Studies 2.2-3, it was suggested that the lack of control over loss could have prevented participants from becoming involved in the task. For Studies 2.1 and 2.4, it was speculated that when participants had control over the reward outcomes they always expected their behaviour to be rewarded. This could explain the lack of impact of probability information and the overall boost in AB for chocolate stimuli during chocolate outcome trials. It is reasonable to argue that a limited involvement in the task may not be sufficient to affect emotional stability. Thus, fixed probability information may be not sufficient to activate the counter regulation processes. In such a case, assuming participants maintain information about chances of winning and losing in their working memory, the introduction of a different set of stimuli (*e.g.*, happy vs. sad faces instead of alcohol vs. neutral or chocolate vs. neutral pictures) is more likely to lead to the congruency effects. This prediction is consistent with theories which indicate that attention is allocated towards cues congruent with the contents of memory (Grecucci, Soto, Rumiati, Humphreys, & Rotshtein, 2010; Olivers, 2008; Smith et al., 2006; Soto et al., 2008; Van Dessel & Vogt, 2012).

The goal of the current study is to examine whether the anticipation of motivationally salient outcomes (loss or reward) triggered by fixed probability information would lead to congruency or incongruency effects in AB for facial expressions of emotion. Furthermore, a novel type of reward (*i.e.*, chocolate) could help to examine whether incongruency would occur for other types of rewards other than the previously reported incongruency effects for monetary reinforcement (*e.g.*, Rothermund et al., 2008; Rothermund et al., 2001; Wentura et al., 2009). Counter-regulation processes were previously shown using happy and sad faces

(Wentura et al., 2009) as well as happy and angry faces (Rothermund et al., 2008). Taking into account the passive nature of the task the choice of sad (rather than angry) and happy faces appears to be more adequate. Sadness is associated with behavioural withdrawal and giving up effort (Frijda, 1986). A loss could be considered as an unpleasant event, therefore, it could trigger avoidance or withdrawal behaviour (Carver, 2001; Gable & Harmon-Jones, 2010); especially when the loss is independent of participants' actions (*see* Studies 2.2-3). Additionally, anger is an affect associated with approach tendencies and activation of both approach and appetitive systems (Carver & Harmon-Jones, 2009). Therefore, sadness seems to be a more appropriate emotional response than anger when a goal cannot be reinstated (*see* Stein & Levine, 1990).

In order to test the competing hypotheses based on the congruency and incongruency accounts, the current study used a modified version of the expectancy AB task (Studies 2.1-2). The task involved loss and reward anticipation conditions and pictorial stimuli of happy, sad and neutral faces. (1) Congruency account implicates that reward anticipation should increase AB for happy faces for happy-sad and happy-neutral picture pairs. Congruency accounts make no predictions regarding AB pattern for sad-neutral faces during reward anticipation. Similarly, loss anticipation should increase AB for sad faces for happy-sad and sad-neutral picture pairs. Congruency accounts make no predictions regarding AB pattern for happy-neutral faces during loss anticipation. CRP based predictions were adjusted to match the nature of the AB task where pictures were presented in competition. (2) CRP account suggests that reward anticipation should increase AB for sad faces for happy-sad and sad-neutral picture pairs. Assuming that one of the functions of AB during goal-directed behaviour is the maintenance of emotional equilibrium, it can be expected that AB for neutral faces should be increased during reward anticipation for happy-neutral picture pairs. Similarly, loss anticipation should increase AB for happy faces for happy-sad and happy-neutral picture pairs. Whereas, loss anticipation should increase AB for neutral faces for sad-neutral picture pairs. The effects of probability were also investigated by testing if: (3) reliable predictors of motivationally salient outcomes (100% probability of reward/loss) have a greater impact on AB in comparison to uncertain ones (50% probability of reward/loss); or

if (4) the effects of uncertain motivationally salient outcomes predictors on AB are more pronounced than those of reliable ones.

4.1.2. Method

Participants

Thirty participants were recruited from the staff and students at the University of Liverpool. Study 4.1 was approved by the University of Liverpool Research Ethics committee (Ref. IPHS-1213-LB-024), and all participants provided informed consent before taking part. Participant characteristics are shown in Table 4.1.2-1.

Table 4.1.2-1 *Participant characteristics Study 4.1*

Recruited participants	30 (F = 25, M =5)
Participants included in the analysis	24 (F = 20, M= 4)
Age (years)	24.38 ± (4.20)
Weekly chocolate consumption (in bars)	5.38 ± (4.12)
Chocolate bars usually kept at home	4.13 ± (4.48)
Chocolate use/craving - CUQ	21.58 ± (5.94)
PANAS – positive attitude	29.13 ± (6.64)
PANAS – negative attitude	13.08 ± (3.54)

CUQ – Chocolate Use Questionnaire, PANAS – Positive and Negative Attitude Scale

Pictorial stimuli

The experiment involved pictures taken from the NimStim set (Tottenham et al., 2009). Pictures of four actors were used – two females (Asian and White) and two males (Black and White). For each of the actors, pictures of happy sad, and neutral facial expressions were selected. The combination of facial expressions established three types of picture pairs: happy vs. neutral, sad vs. neutral, and happy vs. sad. Each individual picture was 110 *mm* wide x 72 *mm* high (*as previously used by* Garner, Mogg, & Bradley, 2006).

The expectancy AB task

At the beginning of each trial, a picture of a *Cadbury's Diary Milk* chocolate bar (75 *mm* wide by 75 *mm* high) was displayed in the centre of the screen, directly above text which indicated the probability of winning or losing a reward point (definitely win, maybe win, cannot win or lose, maybe lose and definitely lose – referred to as *certain reward*, *uncertain reward*, *no reward/loss*, *uncertain loss* and *certain loss* respectively). Due to the involvement of reward and loss conditions in one task, the percentage information was replaced with text information in order to avoid confusion. These stimuli were presented for 1000 *ms* and were immediately replaced by one of the three picture pairs, with one picture to the left and one picture to the right of the central position, with their centres 186 *mm* apart, for 1500 *ms*. These time and picture settings have previously been used by Garner et al. (2006). Immediately after offset of the pictures, the following text was displayed in the centre of the screen: '*press the left key*' for *certain* and *uncertain reward trials*, '*press the right key*' for *certain* and *uncertain loss* trials and '*press the spacebar to continue*' for *no reward/loss* trials. Text feedback was presented for 1000 *ms* as soon as participants pressed the appropriate key: '*you win a chocolate point!*' on all *certain reward* and half of *uncertain reward* trials; '*you lose a chocolate point*' on all *certain loss* and half of *uncertain loss* trials; '*you win/lose nothing*' on all *no reward/loss*; '*you win nothing*' on the remaining *uncertain reward*; and '*you lose nothing'* on the remaining *uncertain loss* trials. The inter-trial interval was 1500 *ms*.

Participants completed a practice block of 10 practice trials during which each of the probability conditions was presented twice and 10 pairs of neutral picture

pairs (*e.g.*, household furniture) were presented. The main block of 120 critical trials comprised 40 happy-neutral, 40 sad-neutral and 40 happy-sad picture pairs. For each type of picture pair, there was an equal number of *certain reward*, *uncertain reward*, *no reward/loss*, *uncertain loss* and *certain loss maybe lose* and *definitely lose* probability trials (8 trials each). Participants had the opportunity to take a short break after 60 trials.

Picture Rating Task

Participants rated each of the pictures presented during the task. The task involved 36 trials (4 actors x 3 facial expressions x 3 ratings). Three blocks of pictures (happy, sad and neutral) were presented in random order and pictures were randomised within each of the blocks. Each of the pictures was presented three times so that participants could rate each picture on three scales: happy, sad and neutral. Participants rated each picture by pressing keys labelled from 1 (neutral) to 9 (extremely sad/happy) to indicate how sad or happy the facial expression was and by pressing keys labelled from 1 (extremely emotional) to 9 (neutral) for neutral pictures.

Procedure

All testing took place between 1 pm and 6 pm in the eye movement laboratory in the Department of Psychological Sciences. Bars of Dairy Milk chocolate were placed around the laboratory so that they were visible to participants as they entered, but these were out of view when participants completed the eye movement task. After providing informed consent participants completed two questionnaires, the Positive and Negative Affect Schedule (PANAS - Watson, Clark, & Tellegen, 1988) and a chocolate use questionnaire (Tibboel et al., 2011).

Participants then completed the expectancy AB task. Participants were informed the points they could win or lose during the task represented some small quantities of chocolate. At the beginning of the task participants received two chocolate bars and were informed that they could win more or lose chocolate depending on the number of accumulated points. The chocolate bars were then hidden from view before the eye-tracker (Eye-Trac D6; Applied Science

Laboratories, Bedford, MA) was calibrated and the task was explained. Participants were asked to pay close attention to outcome probability information presented at the beginning of each trial, to rest their index fingers and thumbs on three labelled keys ('c' for *certain* and *uncertain reward* trials, 'm' for *certain* and *uncertain lose* trials, and 'spacebar' for *no reward/loss* trials), and to respond on the appropriate key when prompted to do so. As they completed the task, their eye-movement data was continuously recorded at a sampling frequency of 120 *Hz*. After completing the expectancy AB task, participants completed the picture rating task. Participants were fully debriefed at the end of the experiment. Participants received course credit or a shopping voucher instead of the chocolate, and the requirement for the deception was explained during debriefing.

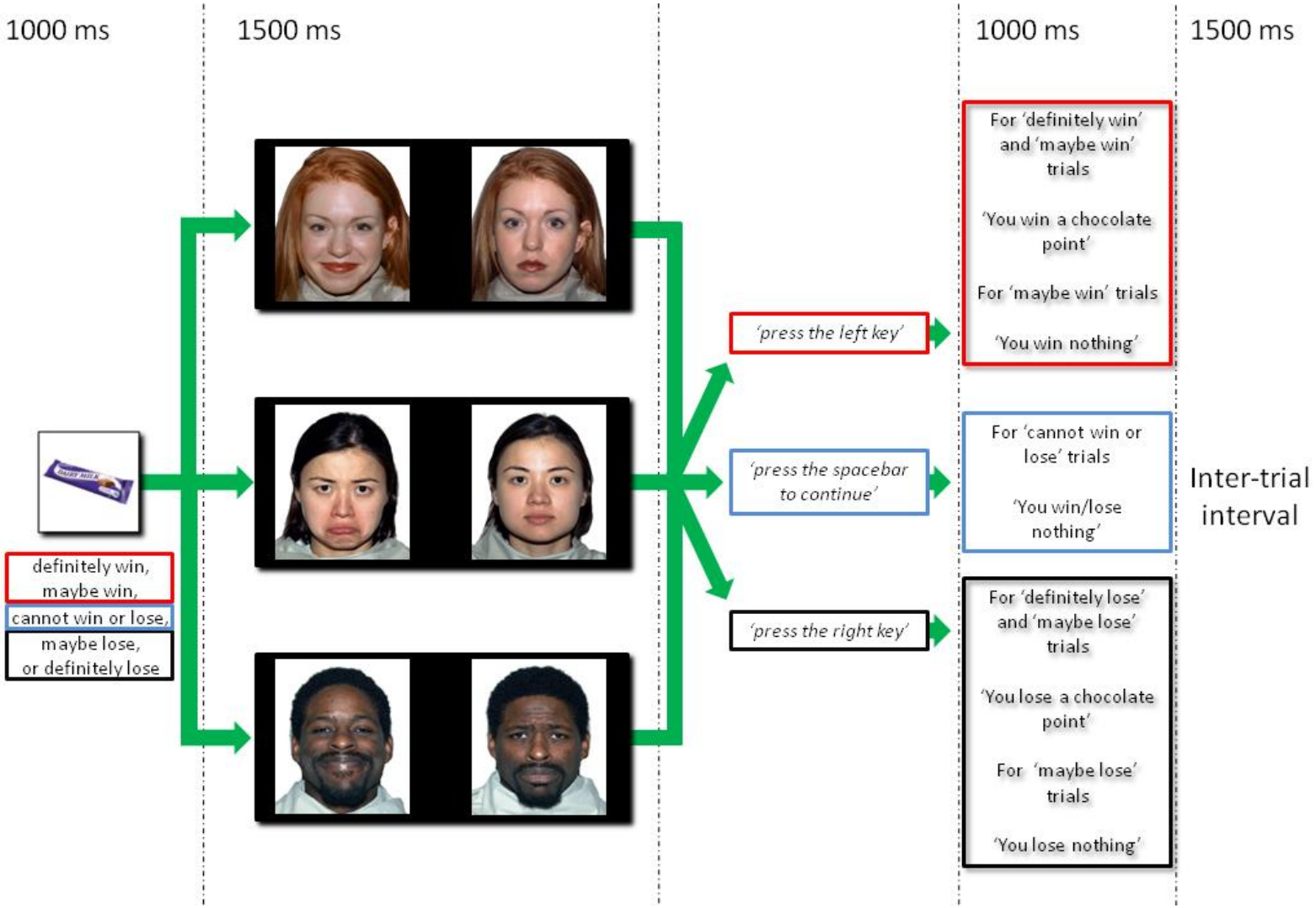

Figure 4.1.2.1. Flowchart of the experimental procedure Study 4.1.

Data reduction and analysis

Eye-movement data were recorded during the 1500 *ms* when happy-neutral, sad-neutral or happy-sad picture pairs were presented. The total duration of fixations was used to calculate gaze 'dwell time' on each picture. Fixations were defined as the maintenance of gaze within one degree of visual angle for 100 *ms*, as in previous AB research (Field et al., 2004; Jones et al., 2012; Mogg et al., 2003). Skewness statistics for some of the mean dwell times were twice the standard error, therefore, data was log transformed to normalise distribution. Data of two participants was excluded from the analysis due to no data recorded for certain types of trials. Due to missing data – less than 375 *ms* average total gaze fixation time per trial (less than 25% of 1500 *ms* stimulus presentation) – additional four participants were excluded from the analysis (N = 24). Due to incomplete data recordings one participant was excluded from the picture rating analysis (N = 23).

4.1.3. Results

Attentional bias

Gaze dwell times were analyzed using a three-way repeated-measures ANOVA (*see* Figures 4.1.3.1-3) with factors of *Probability* (5: *certain reward* vs. *uncertain reward* vs. *no reward/loss* vs. *uncertain loss* vs. *certain loss*) x *Face Pair* (3: happy vs. sad, happy vs. neutral, sad vs. neutral) x *Face Type* (2: expression 1 vs. expression 2). *Probability* x *Face Pair* x *Face Type* interaction was statistically significant ($F(8, 184) = 2.91$, $p = .022$, $\eta_p^2 = .11$), which indicates that AB for facial expressions was moderated by the effect of reward and loss anticipation. A significant main effect of *Face Type* was found ($F(1, 23) = 6.67$, $p = .017$, $\eta_p^2 = .22$). To deconstruct this effect, data from the different picture pairs was analysed in separate *Probability* x *Face Type* ANOVAs. There was a significant effect of *Face Type* for happy vs. sad picture pairs ($F(1, 23) = 6.70$, $p = .016$, $\eta_p^2 = .23$), indicating AB for happy faces. A *Face Type* effect approached significance for happy vs. neutral picture pairs, suggesting AB for happy faces

($F(1, 23) = 3.80$, $p = .064$, $\eta_p^2 = .14$). The effect of *Face Type* was not significant for sad vs. neutral picture pairs ($F(1, 23) = 0.77$, $p = .390$, $\eta_p^2 = .03$).

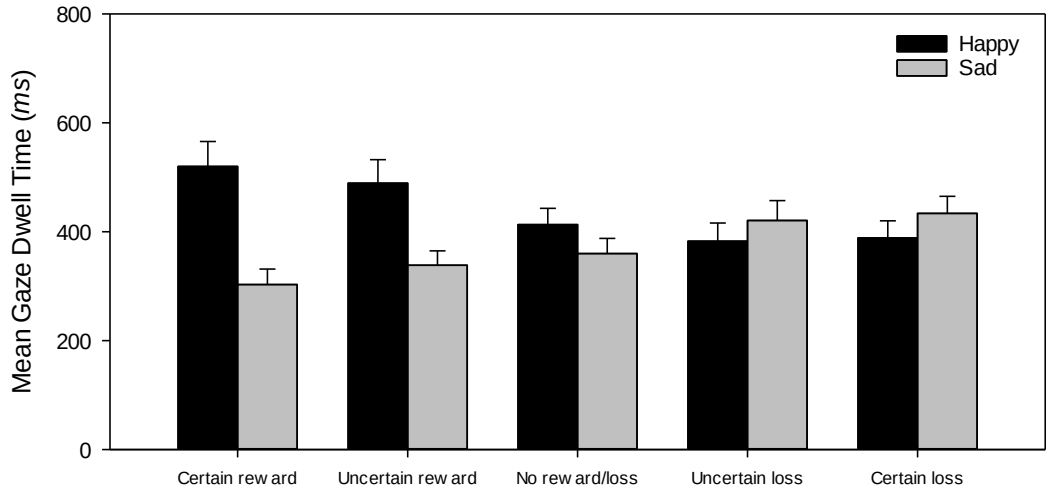

Figure 4.1.3.1. The effects of chocolate reward and loss anticipation on mean gaze dwell times (*ms*) for happy and sad facial expressions.

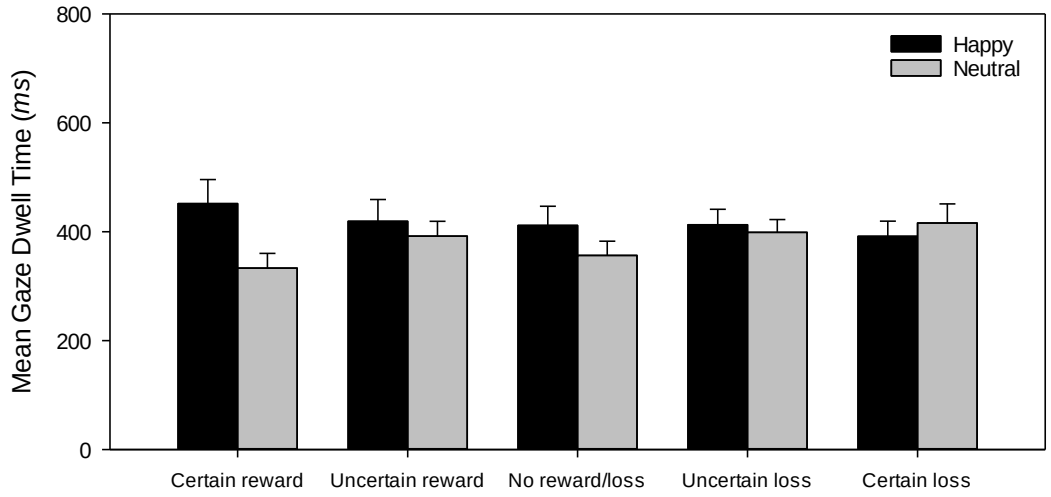

Figure 4.1.3.2. The effects of chocolate reward and loss anticipation on mean gaze dwell times (*ms*) for happy and neutral facial expressions.

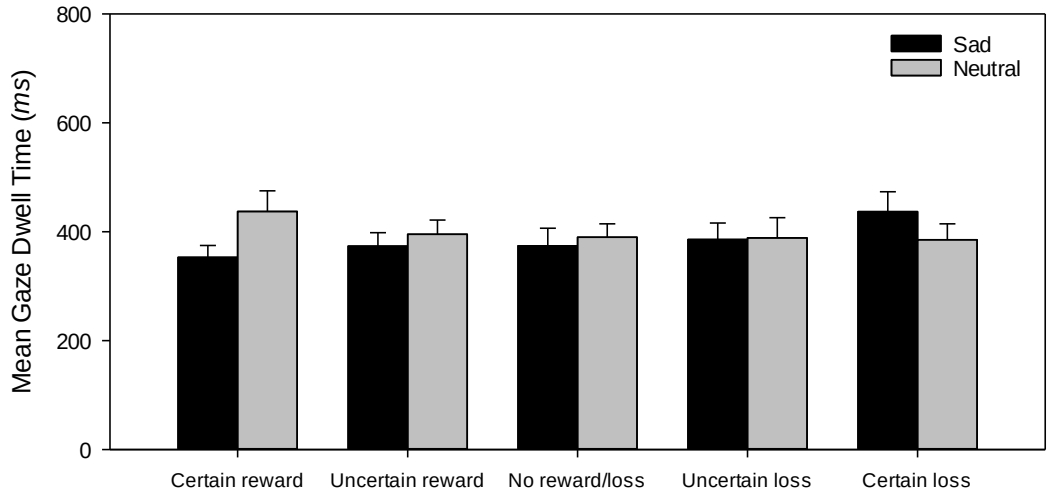

Figure 4.1.3.3. The effects of chocolate reward and loss anticipation on mean gaze dwell times (*ms*) for sad and neutral facial expressions**.**

To deconstruct the *Probability* x *Face Pair* x *Face Type* interaction, AB scores for each type of picture pairs (happy vs. sad; sad vs. neutral; happy vs. neutral) were calculated. The bias scores were obtained by subtracting gaze dwell time on matched neutral pictures from gaze dwell time on the corresponding happy and sad pictures. AB scores for happy vs. sad pairs of pictures were calculated by subtracting gaze dwell time on matched sad pictures from gaze dwell time on the corresponding happy pictures. Data was analysed using three independent one-way repeated measures ANOVAs with five levels of *Probability* (*certain reward* vs. *uncertain reward* vs. *no reward/loss* vs. *uncertain loss* vs. *certain loss*) run for each kind of AB scores. A significant effect of *Probability* on AB scores for happy vs. sad pairs was found ($F(4, 92) = 5.78$, $p = .003$, $\eta_p^2 = .20$) (*see* Figure 4.1.3.4) The effects of probability on AB scores for happy vs. neutral pairs ($F(4, 92) = 1.29$, $p = .281$, $\eta_p^2 = .05$) (*see* Figure 4.1.3.5) and sad vs. neutral pairs ($F(4, 92) = 1.07$, $p = .377$, $\eta_p^2 = .04$) (*see* Figure 4.1.3.6) were not significant.

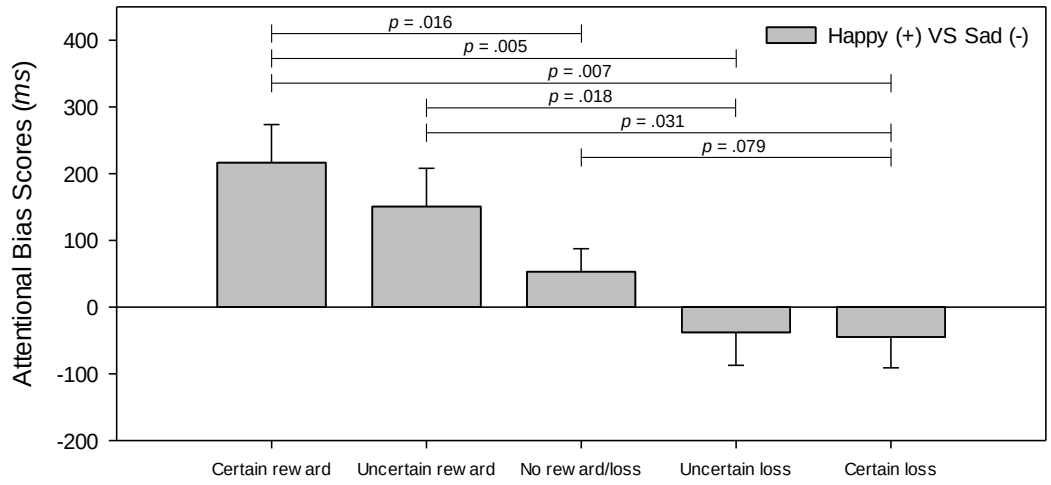

Figure 4.1.3.4. The effects of chocolate reward and loss anticipation on AB (*ms*) for happy and sad facial expressions.

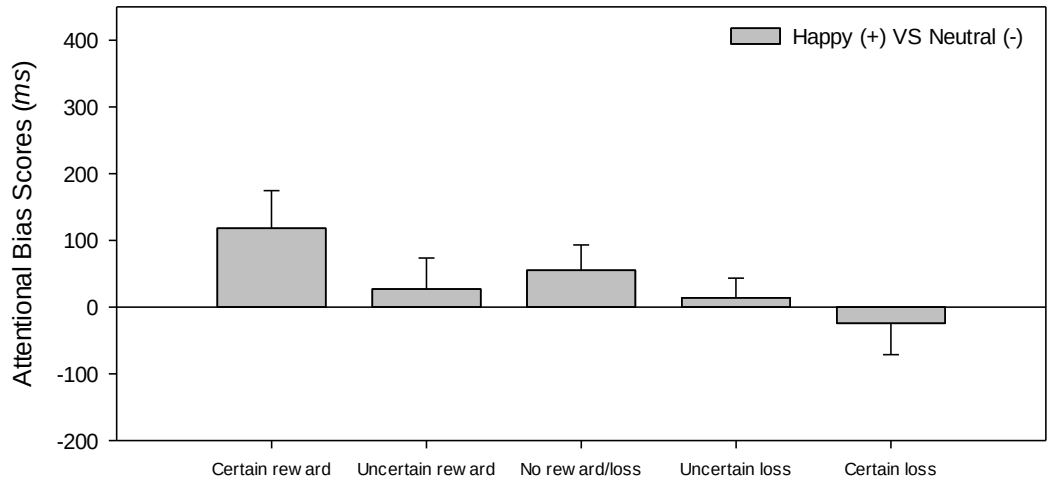

Figure 4.1.3.5. The effects of chocolate reward and loss anticipation on AB (*ms*) for happy and neutral facial expressions**.**

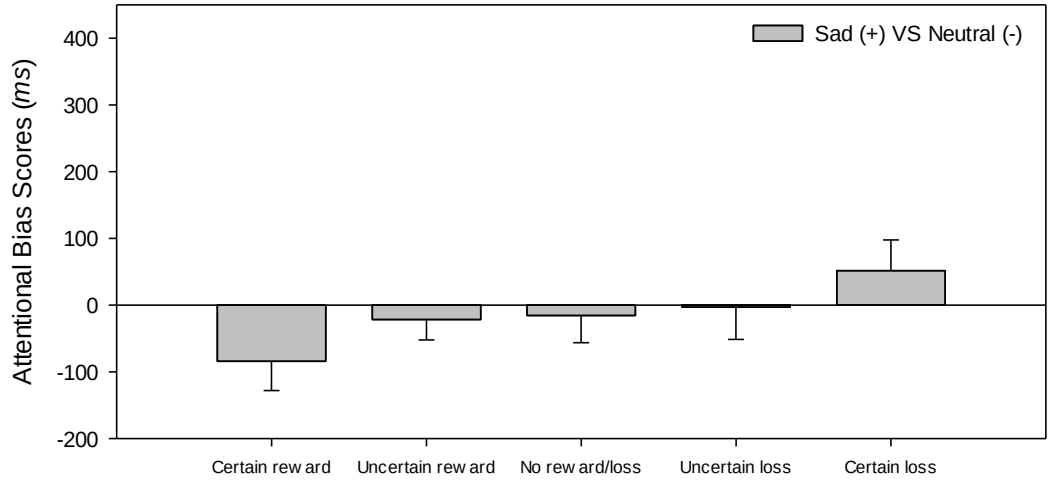

Figure 4.1.3.6. The effects of chocolate reward and loss anticipation on AB (*ms*) for sad and neutral facial expressions.

Paired-samples *t*-tests were conducted to investigate the effect of probability information on the magnitude of AB for happy vs. sad faces. Note that a positive value indicates a bias to attend to happy faces, while a negative value indicates a bias to attend to sad faces. The AB for happy faces was significantly larger on *certain reward* trials compared to: *no reward/loss* trials ($t(23) = 2.61$, $p = .016$, $d = .69$), *uncertain loss* trials ($t(23) = 3.09$, $p = .005$, $d = .96$) and *certain loss* trials ($t(23) = 2.93$, $p = .007$, $d = 1.02$). There was a difference between *uncertain reward* and *uncertain loss* ($t(23) = 2.55$, $p = .018$, $d = .71$) as well as *certain loss* trials ($t(23) = 2.30$, $p = .031$, $d = .76$). However, *uncertain reward* trials did not differ from *certain reward* ($t(23) = 1.34$, $p = .195$, $d = .24$), and from *no reward/loss* trials ($t(23) = 1.63$, $p = .117$, $d = .40$). Although this difference only approached statistical significance, in comparison to *no reward/loss* trials the AB scores for happy faces appeared to be smaller on *certain loss* trials ($t(23) = 1.84$, $p = .079$, $d = .50$). *Uncertain loss* trials did not differ *no reward/loss* ($t(23) = 1.74$, $p = .095$, $d = .44$) and from *certain loss* trials ($t(23) = .19$, $p = .848$, $d = .04$).

Comparison of AB scores with zero revealed significant AB for happy faces for both types of reward conditions *certain reward* ($t(23) = 3.77$, $p = .001$) and *uncertain reward* ($t(23) = 2.63$, $p = .015$). However, none of the other AB scores were significantly different from zero (*no reward/loss* ($t(23) = 1.59$, $p = .125$); *uncertain loss* ($t(23) = .75$, $p = .463$); *certain loss* ($t(23) = 1.00$, $p = .328$)).

Picture ratings

Ratings were analysed using a repeated measures ANOVA with factors of *Picture Type* (3: happy vs. sad vs. neutral) x *Question Type*: (3: happy vs. sad vs. neutral). A significant interaction of *Picture Type* and *Question Type* ($F(4, 88) = 222.87$, $p < .001$, $\eta_p^2 = .91$) was found. To deconstruct the interaction individual ANOVAs were run for each *Question Type*, with *Picture Type* as the within-subjects factor. The effect of *Picture Type* was statistically significant for happy *Question Type* ($F(2, 44) = 157.07$, $p < .001$, $\eta_p^2 = .88$), sad *Question Type* ($F(2, 44) = 165.72$, $p < .001$, $\eta_p^2 = .88$) and neutral *Question Type* ($F(2, 44) = 99.87$, $p < .001$, $\eta_p^2 = .82$).

Paired-sample *t*-tests confirmed that participants gave higher 'happy' ratings for happy pictures than sad ($t(22) = 27.99$, $p < .001$, $d = 8.18$) and neutral pictures ($t(22) = 11.28$, $p < .001$, $d = 3.50$). 'Sad' ratings were higher for sad pictures in comparison to happy ($t(22) = 12.72$, $p < .001$, $d = 4.35$) and neutral pictures ($t(22) = 14.62$, $p < .001$, $d = 4.16$). 'Neutral' ratings were higher for neutral pictures in comparison to happy ($t(22) = 13.32$, $p < .001$, $d = 4.20$) and sad pictures ($t(22) = 10.94$, $p < .001$, $d = 2.91$). These results confirm that participants were capable of correctly identifying the pictures of facial expressions used in the task.

4.1.4. Discussion

The results of Study 4.1 revealed that AB for facial expressions of emotion was moderated by the anticipation of motivationally salient outcomes. However, the moderating effects of reward and loss anticipation were only shown when happy and sad faces were presented in competition. While the anticipation of reward directed attention towards happy facial expressions, the anticipation of loss had the opposite effects, directing attention towards sad faces. Although for loss anticipation, these results only approached significance when *no reward/loss* condition was used as the reference point. It should be emphasised that only effects of reward anticipation resulted in AB for happy faces. The anticipation of loss caused a shift in preference towards sad faces and equal preference for happy and sad faces. Although the results of previous studies suggested the outcome specific effects of reward and loss anticipation within the substance-related domain (Studies 2.1 and 2.3), these findings suggest that the effects of substance reward and loss anticipation could also apply to a different type of motivationally salient stimuli like facial expressions of emotion.

These effects are in contrast to those predicted by the CRP. The anticipation of motivationally salient outcomes did not direct attention towards stimuli which had incongruent valence with the anticipated outcome. The anticipation of reward did not increase AB for sad faces in comparison to neutral or happy facial expressions, and the anticipation of loss did not increase AB for happy faces in comparison to neutral or sad facial expressions. These findings reveal an opposing congruent pattern of anticipation on AB for happy-sad picture pairs. Since these effects were

not present for happy-neutral pairs as well as sad-neutral pairs, these results provide partial support for the priming explanation of congruency effects (*e.g.*, Grecucci et al., 2010; Smith et al., 2006; Van Dessel & Vogt, 2012).

There seems to be a linear relationship between outcome probability and attentional preference for happy and sad faces. This could indicate that the impact of probability information may depend on its reliability. However, although AB scores for happy faces were smaller for *uncertain reward* in comparison to the *certain reward* condition and larger for *uncertain loss* when compared to the *certain loss* condition, these differences did not reach significance. AB scores for *uncertainty* conditions did not reliably differ from *no reward/loss* condition.

Study 4.2. The effects of certain and uncertain predictors of motivationally salient outcomes on AB for facial expressions of emotions.

4.2.1. Introduction

The first experiment demonstrated that the effects of anticipation were especially pronounced for the *certainty* condition (definitely win/lose) and were not as clear for *uncertainty* trials (maybe win/lose). To clarify the initial results, the study was replicated with *uncertainty* conditions excluded. To increase variability in stimuli and to prevent demand characteristics all of the three types of picture pairs were included. Results of the initial study suggest congruent effects of anticipation of motivationally salient outcomes on AB – with anticipation of reward increasing AB for happy faces and anticipation of loss directing attention towards sad faces.

4.2.2. Method

Participants

Thirty-two participants were recruited from the staff and students at the University of Liverpool. Study 4.2 was approved by the University of Liverpool Research Ethics committee (Ref. IPHS-1314-LB-145 (Generic approval IPHS-1213-LB-024), and all participants provided informed consent before taking part. Participant characteristics are shown in Table 4.2.2-1.

Table 4.2.2-1 *Participant characteristics Study 4.2*

Recruited participants	32 (F = 26, M = 6)
Participants included in the analysis	29 (F = 23, M = 6)
Age (years)	20.24 ± (5.12)
Weekly chocolate consumption (in bars)	2.59 ± (1.15)
Chocolate bars usually kept at home	3.41 ± (5.01)
Chocolate use/craving - CUQ	19.38 ± (4.75)
PANAS – positive attitude	31.90 ± 5.74
PANAS – negative attitude	18.41 ± 6.27

CUQ – Chocolate Use Questionnaire, PANAS – Positive and Negative Attitude Scale

Pictorial stimuli

This experiment involved the same picture pairs as the initial study.

The modifications to expectancy AB task

The second study involved a modified version of the task used in the first study. The procedure remained the same apart from the adjustments which were made to the probability conditions. The *uncertain reward* and *uncertain loss* conditions were removed, so that the number of probability conditions was reduced to: 'win', 'cannot win or lose' and 'lose' representing *certain reward*, *no reward/loss* and *certain loss*, respectively. Picture pairs were presented in the same way as in the initial experiment and participants responded in the same way to reward anticipation trials ('*press the left key*'); loss anticipation trials ('*press the right key'*); and neutral trials ('*press the spacebar to continue'*). Text feedback was presented for 1000 *ms* as soon as participants pressed the appropriate key: '*you win a chocolate point!*' on all *certain reward* trials; *'you lose a chocolate point'* on all *certain loss*; and '*you win/lose nothing*' on all *no reward/loss* trials. The inter-trial interval was 1500 *ms*.

Participants completed a practice block of 6 practice trials which contained 2 *certain reward*, 2 *no reward/loss* and 2 *certain loss* trials, in which 6 pairs of neutral picture pairs (*e.g.*, household furniture) were presented. The main block of 72 critical trials comprised 24 happy-neutral, 24 sad-neutral and 24 happy-sad picture pairs. For each type of picture pair, there were equal numbers of *certain reward*, *no reward/loss* and *certain loss* trials (8 trials each).

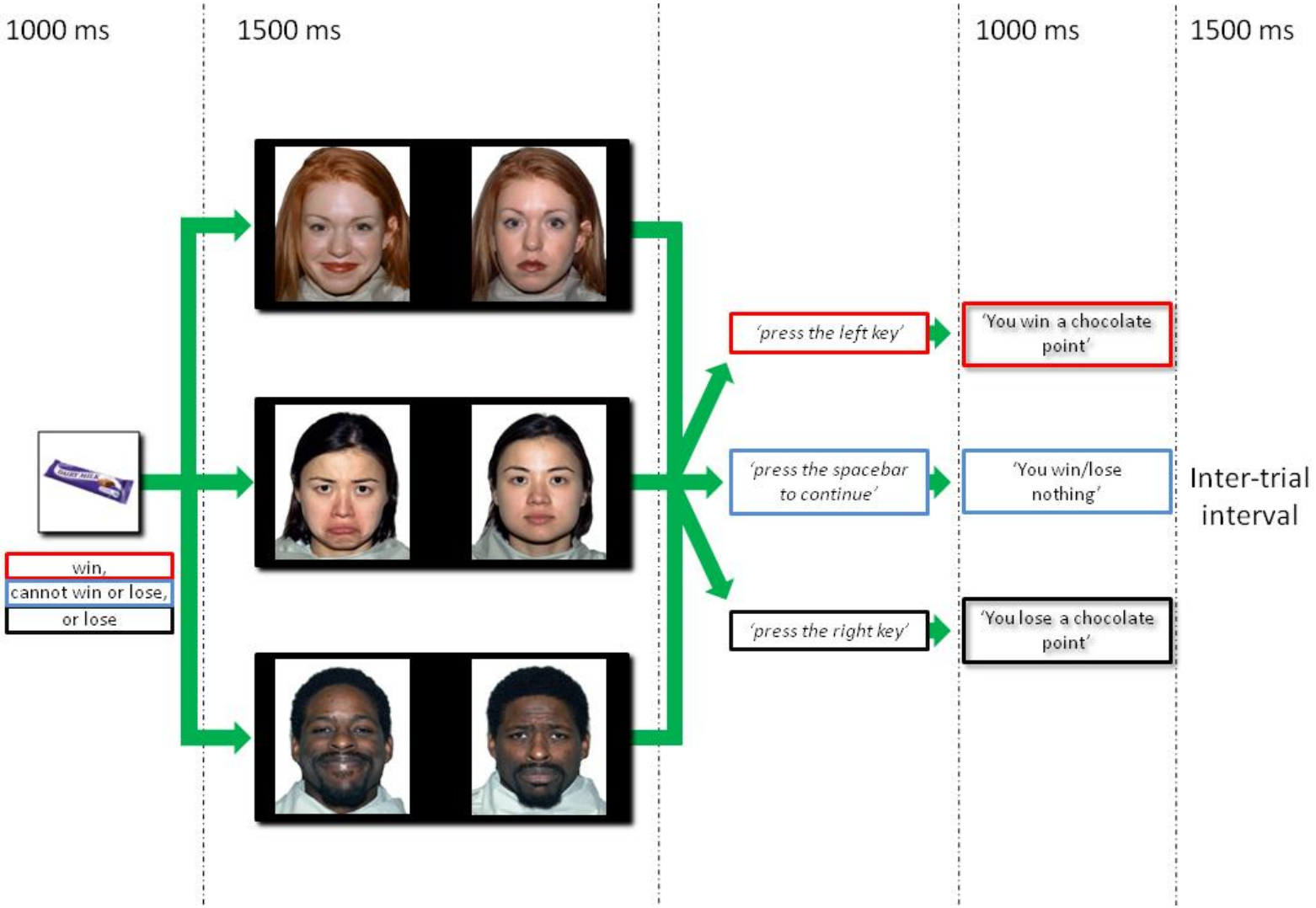

Figure 4.2.2.1. Flowchart of the experimental procedure Study 4.2.

Data reduction and analysis

Data was recorded and extracted in the same way as in the first experiment. Skewness statistics for some of the mean dwell times were twice the standard error hence data was log transformed to normalise distribution. Due to incomplete data recording, no data recorded for certain types of events, data from two participants were excluded from the analysis. Due to missing data – less than 375 *ms* average total gaze fixation time per trial (less than 25% of 1500 *ms* stimulus presentation) – an additional participant was excluded from the analysis (N = 29).

4.2.3. Results

Gaze dwell times were analysed using a three-way repeated-measures ANOVA (*see* Figures 4.2.3.1-3) with the factors of *Probability* (3: *certain reward* vs. *no reward/loss* vs. *certain loss*) x *Face Pair* (3: happy vs. sad, happy vs. neutral, sad vs. neutral) x *Face type* (2: expression 1 vs. expression 2). In contrast to the initial experiment the effect of *Face Type* was not significant ($F(1, 28) = .14$, $p = .709$, $\eta_p^2 = .01$). *Probability x Face Pair* x *Face Type* interaction ($F(4, 112) = 2.92$, $p = .042$, $\eta_p^2 = .09$) indicates that AB for facial expressions was moderated by anticipation.

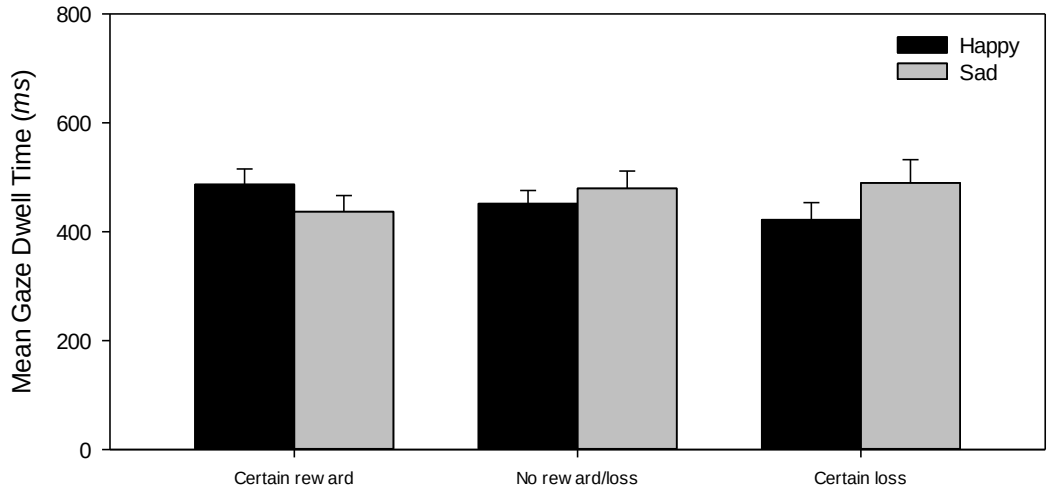

Figure 4.2.3.1. The effects of chocolate reward and loss anticipation on mean gaze dwell times (*ms*) for happy and sad facial expressions.

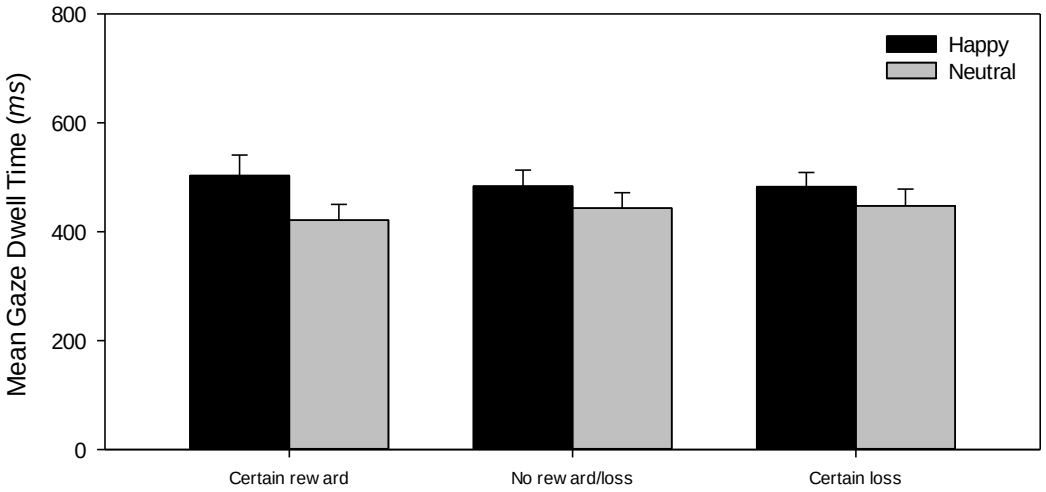

Figure 4.2.3.2. The effects of chocolate reward and loss anticipation on mean gaze dwell times (ms) for happy and neutral facial expressions.

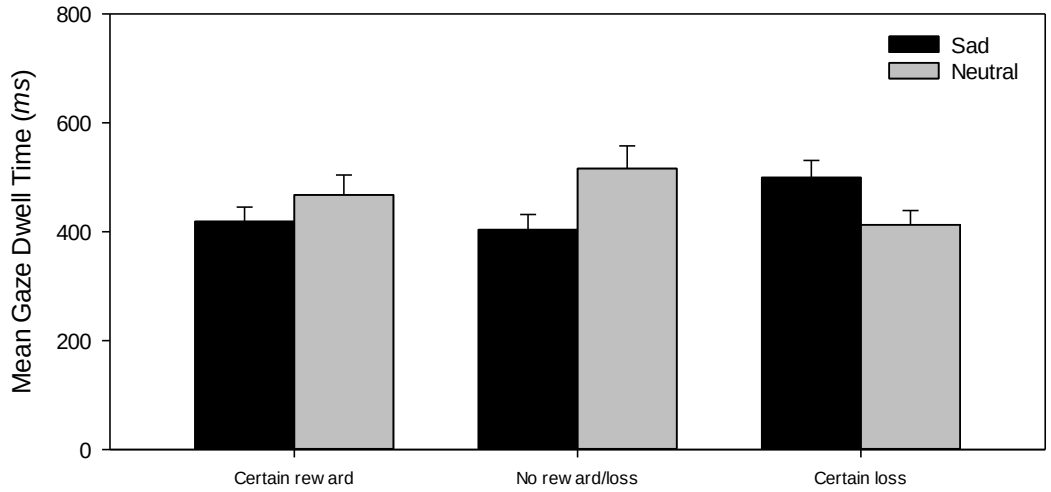

Figure 4.2.3.3. The effects of chocolate reward and loss anticipation on mean gaze dwell times (*ms*) for sad and neutral facial expressions.

To deconstruct the three-way interaction, AB scores were calculated the same way as in the first study. The AB scores were analysed using three separate one-way repeated measures ANOVAs with three levels of *Probability* (*certain reward* vs. *no reward/loss* vs. *certain loss*) for each type of bias score. The effect of probability for happy vs. sad ($F(2, 56) = 1.64$, $p = .204$, $\eta_p^2 = .06$) (*see* Figure 4.2.3.4) and happy vs. neutral bias scores ($F(2, 56) = .30$, $p = .745$, $\eta_p^2 = .01$) (*see* Figure 4.2.3.5) were not significant. The main three-way interaction was driven by the effect of Probability for sad vs. neutral AB scores ($F(2, 56) = 6.04$, $p = .004$, $\eta_p^2 = .18$) (*see* Figure 4.2.3.6).

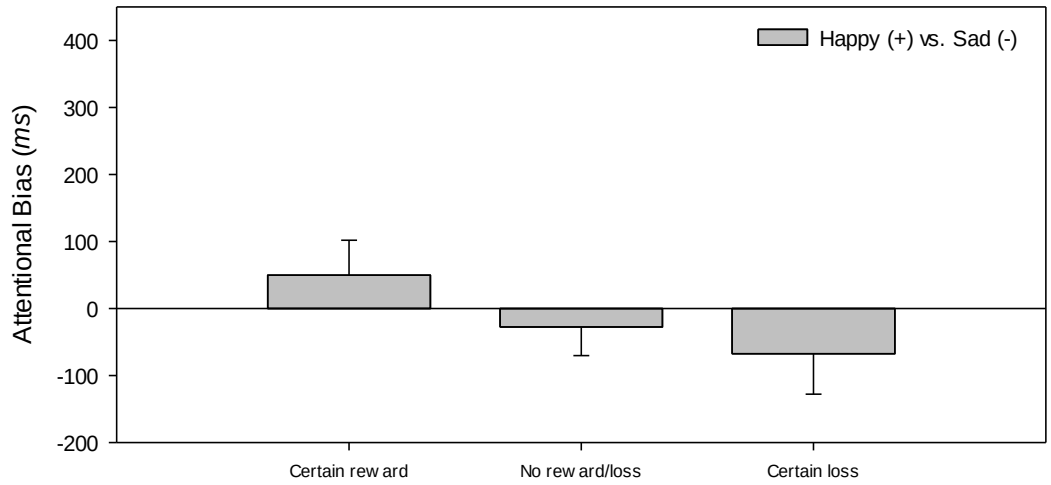

Figure 4.2.3.4. The effects of chocolate reward and loss anticipation on AB (*ms*) for happy and sad facial expressions.

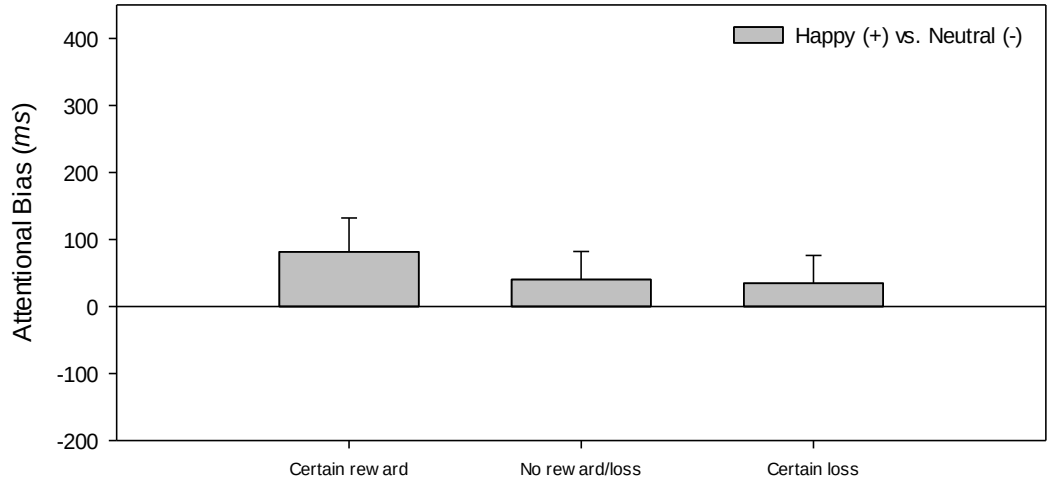

Figure 4.2.3.5. The effects of chocolate reward and loss anticipation on AB (*ms*) for happy and neutral facial expressions.

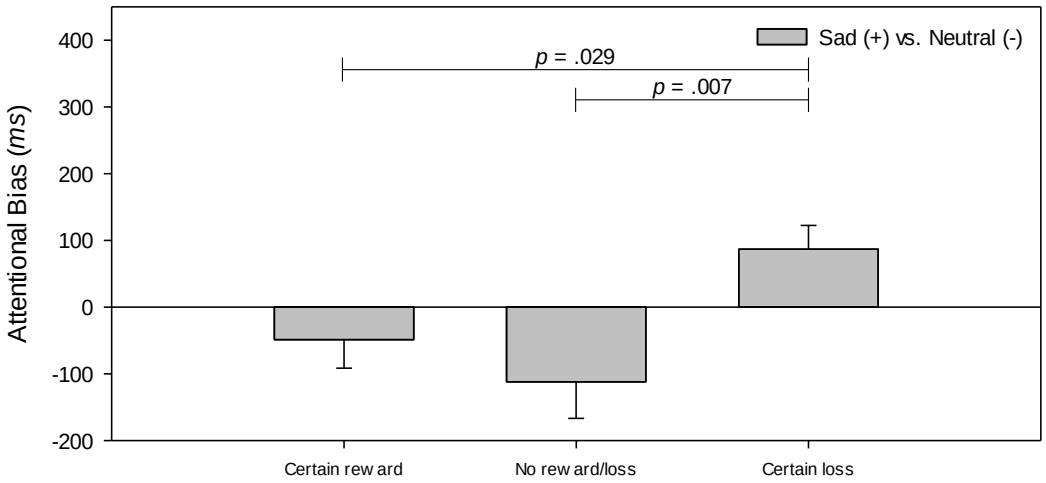

Figure 4.2.3.6. The effects of chocolate reward and loss anticipation on AB (*ms*) for sad and neutral facial expressions.

Paired-samples *t*-tests were conducted to investigate the effect of probability information on the magnitude of AB for sad vs. neutral faces. Note that a positive value indicates a bias to attend to sad faces, but a negative value indicates a bias to attend to neutral faces. Paired-samples *t*-tests revealed greater AB scores for sad emotional expressions for *certain loss* in comparison to *no reward/loss* trials ($t(28) = 2.93$, $p = .007$, $d = .76$) and *certain reward* ($t(28) = 2.31$, $p = .029$, $d = .63$). There was no difference in preference for sad and neutral facial expressions between *certain reward* and *no reward/loss* trials ($t(28) = 1.36$, $p = .186$, $d = .24$).

A comparison of the AB scores to zero revealed AB for sad faces during *certain loss* ($t(28) = 2.50$, $p = .019$) and AB for neutral faces for *no reward/loss* condition ($t(28) = 2.05$, $p = .050$). The same comparison showed no AB for neither neutral nor sad faces for *certain reward* condition ($t(28) = 1.06$, $p = .297$).

Picture ratings

Ratings were analysed using a *Picture Type* (3: happy vs. sad vs. neutral) x *Question Type* (3: happy vs. sad vs. neutral) repeated measures ANOVA. A significant interaction of picture type and question type ($F(4, 112) = 307.32$, $p < .001$, $\eta_p^2 = .92$) was found. To deconstruct the interaction individual ANOVAs were run for each *Question Type*, with *Picture Type* as the within-subjects factor. A significant effect of *Picture Type* for happy ($F(2, 56) = 426.42$, $p < .001$, $\eta_p^2 = .94$), sad ($F(2, 56) = 201.06$, $p < .001$, $\eta_p^2 = .88$) and neutral ($F(2, 56) = 194.80$, $p < .001$, $\eta_p^2 = .87$) *Question Type* was found.

Paired-sample *t*-tests were run to analyse the differences in picture evaluation for each of the questions. 'Happy' pictures were rated as more happy in comparison to 'sad' ($t(28) = 24.65$, $p < .001$, $d = 6.95$) and 'neutral' pictures ($t(28) = 28.13$, $p < .001$, $d = 5.63$). 'Sad' pictures were rated higher on a sadness scale than 'happy' ($t(28) = 18.63$, $p < .001$, $d = 5.33$) and 'neutral' pictures ($t(28) = 8.24$, $p < .001$, $d = 1.79$). 'Neutral' pictures received higher neutral ratings in comparison to 'happy' ($t(28) = 13.64$, $p < .001$, $d = 4.07$) and 'sad' pictures ($t(28) = 17.56$, $p < .001$, $d = 4.91$). These results confirm that participants were capable of correctly identifying the pictures of facial expressions used in the task.

4.2.4. Discussion

The second experiment sought to replicate the results of the initial study. In comparison to the first experiment, the *uncertainty* conditions were excluded. This was done because the first experiment revealed no difference between *certain* and *uncertain reward* conditions, *certain* and *uncertain loss* conditions as well as between *uncertain reward*/*loss* and *no reward*/*loss* conditions. The results of the second experiment are partially consistent with the findings of the initial one, as loss anticipation increased AB for sad faces for sad-neutral picture pairs – indicating congruency effects. However, the effects of anticipation were not replicated for happy-sad picture pairs. Taking into account the robust results of the first experiment it is possible that the manipulation of the original research method had a significant impact on the results of the second experiment.

Studies 4.1-2 General Discussion

The results of previous research, as well as experiments conducted as part of this thesis, indicate that the anticipation of motivationally salient outcomes may have an impact on AB for substance-related cues. Two experiments reported in the current chapter investigated whether the effects of anticipation would generalise to a different category of motivationally salient stimuli – *i.e.*, facial expressions of emotion. Emotion regulation research suggests that attention tends to be directed towards stimuli which are incongruent with the current motivational context (*e.g.*, Rothermund, 2003; Rothermund et al., 2008; Schwager & Rothermund, 2013; Wentura et al., 2009). These incongruency effects in affective processing, demonstrated during goal-directed behaviour, were argued to support emotion regulation (Rothermund et al., 2008). Furthermore, research suggests that the anticipation of motivationally salient outcomes could be a sufficient condition for triggering counter regulation processes (Rothermund et al., 2008). This concept appeared to be closely related to the aspects of motivated behaviour explored in this thesis. While the impact of anticipation of food and alcohol on AB for substance-related stimuli has received some research coverage, the effects of substance reward and loss anticipation on AB for other types of motivationally relevant information has received little attention.

The results of the first experiment demonstrated that anticipation of reward and loss of reward can have congruent effects on AB for facial expressions of emotion. These findings are consistent with accounts which suggest that attention is directed towards stimuli congruent with the content of working memory (*see* Olivers, 2008; Soto et al., 2008). Interestingly, the effects of anticipation were only revealed when happy and sad facial expressions were presented in competition. It can be speculated that the involvement of contrasting picture types catalysed the effects of anticipation. The observed effects for happy-sad picture pairs could be a consequence of two combined processes - one of them attracting attention towards the congruent stimuli and the other driving it away from the stimuli incongruent with the motivational context.

That is not to say that the presented congruency effects disprove the evidence provided for incongruency effects (*e.g.*, Rothermund et al., 2011; Rothermund et al., 2008; Rothermund et al., 2001; Schwager & Rothermund, 2013; Wentura et al., 2009). It is more likely that congruency effects might be a specific characteristic of attentional processing guided by fixed probability information. As previously emphasised, the lack of active control over the outcomes could have limited participants' emotional involvement in the task. Therefore, limited involvement in the task may not be sufficient to affect emotional stability and trigger the counterbalancing processes. Therefore, it is possible that congruency effects may depend on the level of behavioural control over the motivationally salient outcomes. While active involvement in goal pursuit or loss aversion may result in incongruent AB, passive response to probability information may result in congruency effects. However, this hypothesis needs to be evaluated.

The second study aimed to replicate the initial findings. The effects of anticipation were only revealed for sad-neutral picture pairs. This pattern of results is not mutually exclusive with the outcomes of the initial experiment and still could be considered as evidence for the congruent effects of anticipation on AB. However, these findings were clearly different from the expected ones.

It should be noted that participants demonstrated a general positivity bias for facial expressions of emotion during Study 4.1. This positivity bias was reflected by

AB for happy facial expressions for happy-sad picture pairs, a trend for preference for happy expressions for happy-neutral picture pairs and a lack of difference in AB between sad and neutral facial expressions. Comparable biases were not observed in Study 4.2. It could be speculated that the initial difference in affective bias could have reflected the differences in participants' mood (also notice the higher PANAS negative affect ratings for Study 4.2 (18.41 ± 6.27) vs. Study 4.1 (13.08 ± 3.54)). This difference in the baseline AB could have influenced responsiveness to the outcome probability cues demonstrated between two experiments. The congruent effects of reward anticipation were more pronounced in Study 4.1 (initial positivity bias) and the congruent effects of loss were more pronounced in Study 4.2 (lack of initial affective bias).

Alternatively, it is possible that removal of uncertainty conditions had an impact on the value of remaining probability trials. Despite the fact that the first experiment revealed no difference between *certainty* and *uncertainty* conditions for both reward and loss anticipation, and for the contrasts of neutral condition with the uncertainty ones, it is possible that the role of uncertainty was underestimated. For example, the initial study revealed a difference in AB score times between *uncertainty* and the predictors of opposite outcomes (*i.e.*, *uncertain loss* vs. *certain reward*, *uncertain reward* vs. *certain loss*, *uncertain loss* vs. *uncertain reward*). The lack of uncertainty could have had an impact on the subjective experience of the value of *win* and *lose* trials, which were always associated with reward or loss respectively. Therefore, the potential arousal associated with the *uncertainty* conditions was removed from the task. These issues should be addressed in further studies.

To conclude, current results suggest that the effects of anticipation could be generalised to other types of motivationally salient stimuli such as facial expressions of emotion. These findings are important because they imply that anticipation of reward and loss of drugs or food could also have a more global impact on attention apart from substance-related AB. The current understanding of these effects for food and drug-related rewards is limited and, as discussed, further research is required to distinguish factors determining the occurrence of congruency or incongruency of effects of reward or loss anticipation on AB for valenced information.

CHAPTER 5 - GENERAL DISCUSSION

The goal of the thesis was to explore the effects of anticipation of motivationally salient outcomes (*i.e.*, substance reward or loss) on AB for substance-related cues (*i.e.*, alcohol- and chocolate-related pictures). These effects were also investigated for another type of motivationally salient cues (*i.e.*, facial expressions of emotion). In this section, a general overview of findings will be provided to recall the results reported in each of the seven studies. Study 2.1 explored the effects of substance anticipation on AB for substance-related cues to clarify the general effects of anticipation previously demonstrated by (Jones et al., 2012). This study revealed that cues signalling substance reward increased AB for substance-related cues but in the outcome specific manner: the anticipation of beer increased AB for alcohol-related cues but not for chocolate-related ones, and the anticipation of chocolate increased AB for chocolate-related but not for alcohol-related cues. A follow-up Study 2.2 investigated the effects of loss anticipation. The anticipation of chocolate and beer loss had no impact on AB for substance-related cues. It was proposed that lack of control over loss outcome could have contributed to disengagement from the task which led to the lack of effects of loss anticipation. This hypothesis was subsequently tested and supported in Study 2.3. The effects of loss anticipation were revealed when behavioural control was introduced. Alcohol-related pictures received less attention when participants were unlikely to keep their rewards. Although the pattern of results obtained for chocolate loss anticipation was less clear and did not follow up the effects of alcohol, these results could be considered as outcome specific. Study 2.4 elaborated on the issue of behavioural control in the effects of reward anticipation on AB. This study revealed that probability cues did have differentiating effects on AB when participants had control over reward outcomes. It was hypothesised that during chocolate anticipation trials, participants always expect their behaviour to be rewarded. This explains the general boost in AB for chocolate-related cues. These findings demonstrate that anticipation of reward as well as loss prevention leads to outcome-specific increases in AB for substance-related cues. Nonetheless, some of these effects are dependent on participants' perceived control over outcomes.

Study 3.1 involved an exploratory design, examining the effects of reward anticipation on electrophysiological indices of enhanced attentional processing of

substance-related cues. N2 amplitudes were recorded during the presentation of substance-related as well as neutral cues. This particular component could suggest activation of outcome evaluation processes as well as decision-making response to feedback value (*see* Baker & Holroyd, 2011; Bargh & Ferguson, 2000; Holroyd et al., 2008). However, N2 amplitudes were not affected by the manipulation of outcome probability. Current results suggest that the general context of reward anticipation can trigger evaluative processes which are sensitive to the type of presented visual stimuli yet are not affected by outcome probability information.

The final chapter reported the results of two studies which investigated the effects of reward and loss anticipation on AB for facial expression of emotion. Studies 4.1-2 demonstrated that the effects of anticipation of motivationally salient outcomes can be generalised to a different category of motivationally salient stimuli. Study 4.1 revealed a linear relationship for the effects of chocolate reward and loss anticipation on AB for facial expressions of emotion when happy and sad were presented in competition. The anticipation of substance reward increased AB for happy faces, whereas the anticipation of loss directed attention towards sad facial expressions led to equal attentional preference for happy and sad faces. The result of the subsequent experiment also implied congruency effects of outcome anticipation for sad vs. neutral picture pairs. However, the effects demonstrated in the initial study for happy vs. sad picture pairs were not replicated when *uncertainty conditions* were removed from the task. Study 4.2 showed the effects of reward and loss anticipation when sad facial expressions were presented in competition with neutral ones. In comparison to *certain reward* and *no loss/reward* conditions, the anticipation of loss increased AB for sad faces. There was no difference in AB for sad and neutral faces between *certain loss* and *no loss/reward* conditions. These findings will be discussed in more detail in the follow-up sections.

Outcome specificity of effects of anticipation of motivationally salient outcomes on AB

Outcome specificity of effects of anticipation of motivationally salient outcomes on AB was one of the main themes investigated in this thesis.

The results of Study 2.1 revealed outcome specific effects of reward anticipation – cues indicating that reward only moderated AB for substance-related stimuli that were congruent with anticipated substance. Therefore, the predictions based on the theories which suggested the enhancing properties of positive affect associated with reward anticipation (*i.e.*, general effects *e.g.*, Fredrickson, 2001; Fredrickson & Branigan, 2005; Rowe, Hirsh, & Anderson, 2007; Tamir & Robinson, 2007), were not supported for the substance-related category of stimuli. The current results demonstrated that the effects of cues signalling the likelihood and outcome type on AB, conform strictly to '*if-then*' rule, which defines CS-US contingencies (*see* Field & Cox, 2008; Havermans, 2013; Hogarth et al., 2006). Hence, the outcome specific effects of reward anticipation on AB are similar to outcome-specific PIT effects. Outcome-specific PIT effects occur when the presentation of a Pavlovian cue which was previously paired with a reward, increases instrumental responding only for that specific reinforcer (*see* Cartoni et al., 2013).

The results of Study 2.1 indicate that the general effects demonstrated by Jones et al. (2012) were caused by the methodological confound. In the previous study (Jones et al., 2012) participants were not encouraged by the experimental design to pay attention to the outcome type information, *i.e.*, for both types of reward participants were required to press 'spacebar' to check if they had won a reward. This explains why their attention was exclusively guided by the probabilistic cues, and thus, why AB for both alcohol and chocolate-related cues was increased regardless of the type of anticipated substance. Study 2.1 introduced two independent responses for chocolate and beer reward (*i.e.*, independent buttons) to increase participants' awareness of the outcome type information. The modified version of the task allowed for revealing outcome-specific effects of reward anticipation. This indicates that the awareness of CS-US contingencies is crucial for the development of CRs (*see* Lovibond, 2004; Lovibond & Shanks, 2002; Shanks, 2010; Vadillo et al., 2016), and that the effects of reward anticipation could be determined by the content of working memory (*see also* Grecucci et al., 2010; Smith et al., 2006; Van Dessel & Vogt, 2012).

Predictions based on emotion-regulation theories (*e.g.*, Rothermund et al., 2008) implicated that the effects of loss anticipation could direct attention towards

rewarding stimuli, even when these stimuli are not directly associated with the anticipated loss. These predictions were not supported by the results of Study 2.2, which demonstrated that AB was not influenced by loss anticipation. Moreover, the follow-up study on the effects of loss anticipation revealed outcome specific effects of loss anticipation when participants had a control (or its' perception) over the outcomes (Study 2.3). The higher likelihood of loss prevention (*i.e., certain loss prevention* and *uncertain loss prevention*) increased AB for substance-related cues relative to *unlikely loss prevention* condition, albeit this pattern of results was only demonstrated for the prevention of alcohol loss. Similarly, the anticipation of chocolote loss prevention only influenced AB for chocolate-related pictures. This pattern of results was more difficult to interpret. *Uncertain loss prevention* increased AB for chocolate in comparison to *certain loss prevention* trials but ABes during both *uncertain* and *certain loss prevention* trials were not different from *unlikely loss prevention* condition.
A comparable modification of the reward anticipation task (Study 2.4) did not reveal the effects of probability information on AB. However, the outcome specific boost in AB for chocolate-related stimuli, observed in Study 2.4 during chocolate reward anticipation trials, could be considered to be partially consistent with the outcome-specific effects demonstrated in Studies 2.1 and 2.3. To summarise, the current results showed that when present, the effects of anticipation of motivationally salient outcomes on AB are outcome-specific, for the substance-related cues at least.

Probabilistic cues signalling motivationally salient outcomes and congruency effects in attentional processing of valenced stimuli.

Studies 4.1-2 investigated whether the anticipation of reward (*i.e.*, positive outcome) and loss (*i.e.*, negative outcome) would have a congruent or incongruent impact on AB for positively and negatively valenced cues. This research was conducted because some theories implicated incongruency effects of anticipation in affective processing (*e.g.*, Rothermund, 2011; Rothermund et al., 2011; Rothermund et al., 2008; Rothermund et al., 2001; Schwager & Rothermund, 2013; Wentura et al., 2009). The incongruency accounts suggested that attention should be directed towards stimuli that were incongruent with the anticipated outcome – *i.e.*, loss anticipation was expected to direct attention towards positively valenced stimuli and

reward anticipation was proposed to direct attention towards negatively valenced cues. This incongruency in affective processing was considered to contribute to emotion regulation during anticipation of motivationally salient outcomes. On the other hand, other congruency accounts indicated that attention would be directed towards stimuli that were congruent with a content of working memory and a current motivational state (*e.g.*, Grecucci et al., 2010; Smith et al., 2006; Van Dessel & Vogt, 2012).

The hypothesised incongruency effects were not revealed in Studies 4.1-2. Instead, the presented pattern of results was consistent with the congruency accounts. The results of the first experiment demonstrated that the anticipation of reward increased AB for happy faces whereas anticipation of loss shifted attention towards sad facial expressions, leading to equilibrium between happy and sad faces. However, these results were only partially replicated in the second experiment. When uncertainty conditions were excluded, the anticipation of loss increased AB for sad faces (vs. neutral faces) relative to *certain reward* and *no reward/loss* conditions, but there was no difference in AB between *certain reward* and *no reward/loss* conditions. Overall, these findings showed that counter-regulation processes were not triggered by the fixed probability cues. The fixed probability cues direct attention towards stimuli whose valence is congruent with the anticipated outcome.

It should be emphasised that during Study 4.1, participants experienced a general positivity bias for facial expressions which was reflected by AB for happy facial expressions (happy-sad picture pairs), a trend for preference for happy expressions (happy-neutral) and a lack of difference in AB between sad and neutral facial expressions. A comparable positivity bias was not observed in Study 4.2. It is possible that the initial difference in affective bias could have reflected the differences in participants' mood. The difference in the baseline AB could have influenced responsiveness to outcome probability information. For instance, the positivity bias could strengthen the impact of cues signalling reward, explaining the difference in results observed between Study 4.1 and 4.2. Although this hypothesis was not tested by the current research, it appears to be plausible and hence should be evaluated by future research.

In general, the results of Studies 4.1-2 demonstrated that the effects of anticipation could be generalised to another category of motivationally salient stimuli. This suggests, that in certain cases, probability cues signalling substance reward can enhance the processing of positively valenced stimuli leading to AB whereas the anticipation of loss can direct attention towards negatively valenced stimuli (Study 4.1), which in some situations can lead to a negativity bias (Study 4.2). Hence, it is possible that the effects of reward and loss anticipation are outcome specific within the substance-related category but also can be generalised to another category of motivationally relevant cues.

Dissociative effects of control on the effects of reward and loss anticipation

Studies 2.3 and 2.4 investigated the role of outcome control in the effects of anticipation of reward and loss on AB. The aspect of perceived control over outcomes of behaviour is important because it may moderate engagement in goal-directed behaviour (Brandtstädter & Rothermund, 2002; Brandtstädter et al., 2004; Rothermund, 2011). The following interpretation of results of Studies 2.1-4 can be proposed:

The results of Studies 2.2 and 2.3 suggest that the effects of loss anticipation on AB depend on the level of control over outcomes. When loss is unavoidable, probabilistic cues have a limited impact on AB because low levels of outcome control may prevent engagement in the task (Study 2.2). However, AB can be moderated by cues signalling loss when individuals are able to prevent the negative outcome (Study 2.3). This could suggest that individuals are more likely to direct attention to relevant cues when they can prevent loss, but their attention is not affected by cues signalling unavoidable negative outcomes (*see* Brandtstädter & Rothermund, 2002; Brandtstädter et al., 2004; Rothermund, 2011).

Although, fixed probability cues could seemingly not affect attentional processes (Study 2.2), the results of Studies 4.1-2 showed that comparable cues could influence the processing of negatively valenced information. These findings are important because they demonstrate that the same type of loss probability information may have an impact on attentional processing within one

domain of motivationally salient cues (facial expression of emotions), yet be not as pronounced or present in another one (substance-related cues).

The results of Study 2.4 revealed an overall boost in AB for chocolate-related pictures during chocolate anticipation trials when participants had control over reward outcomes. From the perspective of reward-driven behaviour, the results of Study 2.1 suggest that individuals might be sensitive to cues signalling reward and their attention is directed towards substances perceived as available. It might be proposed that when individuals are actively involved in substance-seeking behaviour and have an impact on reward outcomes, they may expect their attempts to be rewarded regardless of the outcome probability – as reflected by a general boost in AB (Study 2.4). This could mean that once the threshold is reached and the initial attentional response is translated into actions, individuals may become 'extremely' focused on the goal of behaviour. Therefore, it is unlikely that substance seeking behaviour is stopped until the goal is reached.

Future research could be interested in the identification of factors which may facilitate the transition from a 'passive' attentional response to cues signalling substance reward to active goal pursuit. Some individuals may be more prone than others to the effects of substance availability and may experience problems with the regulation of once initiated eating or drinking behaviour (Guastello, Aruka, Doyle, & Smerz, 2008; Hetherington & MacDiarmid, 1993; Smerz & Guastello, 2008; Sugarman & Carey, 2007). It could be hypothesised that impulsive individuals should be more sensitive to cues signalling substance reward and hence more likely to initiate substance seeking behaviour (*e.g.*, Christiansen et al., 2012; Dawe & Loxton, 2004; Doran, McChargue, & Spring, 2008; Doran, Spring, & McChargue, 2007; Fernie et al., 2013; Jansen et al., 2015; Jentsch et al., 2014; Nederkoorn et al., 2015; Schag et al., 2013; van den Akker, Stewart, Antoniou, Palmberg, & Jansen, 2014). Impulsivity is a multifaceted construct, which, in a simplified way, can be described as a tendency to act on the 'spur of the moment' and a preference for the instance gratification over achievement of long-term goals. Hence, current findings could be expanded by the investigation of the impact of sensitivity to substances' rewarding value and spontaneous decision making on responsiveness to the probabilistic cues signalling substance availability.

Likewise, findings could be expanded by examining whether the initiation of active substance seeking behaviour would abolish the probability effects and result in a general boost in AB. This research would help to further clarify the role of probabilistic cues signalling substance reward in AB and substance seeking behaviour and could improve understanding of the relationship between drug and food-related AB and impulsivity (*see* Coskunpinar & Cyders, 2013; Hou et al., 2011).

The role of certainty and uncertainty in the effects of motivationally salient outcomes on AB and their neurophysiologic indices

All of the current studies tested competing predictions about the impact of outcome certainty and uncertainty information on AB (*see* Hogarth et al., 2010). According to the predictions based on Pearce and Hall (1980) model of associative learning, cues indicating reward uncertainty should evoke greater AB in comparison to the certain predictors of reward. Mackintosh's theory of associative learning (1975) suggests the opposite predictions, in that AB should closely track probability information and be maximal when reward is anticipated with certainty, lower under conditions of uncertainty, and lower still when the reward is not expected at all. It is reasonable to say that the current research did not provide an unequivocal answer to the role of certainty and uncertainty in the effects of anticipation of motivationally salient outcomes on AB. In general, Studies 2.1 and 2.3 demonstrated that cues signalling reward and loss prevention can increase AB for substance-related cues in the outcome specific manner. Study 4.1 revealed a linear relationship between probability and attentional processing of happy and sad facial expressions. However, in the case of all of these studies, the differences between *certainty* and *uncertainty* conditions as well as *uncertainty* and the neutral *no reward/loss* condition, were not clear. It was proposed that the effects of certain outcome predictors revealed when compared to the effects of 'no outcome' predictors could be driven by a mechanism described by Mackintosh (1975). Conversely, the effects of uncertain outcome predictors revealed when compared to the effects of 'no outcome' predictors could be driven by a mechanism defined by

Pearce and Hall (1980) model of associative learning. Therefore, the effects of certainty could be qualitatively different from the effects of uncertainty.

The results of Study 3.1 revealed that attentional processing of substance-related cues was not affected by reward anticipation. The effects of anticipation were expected to be associated with the differences in P300 amplitudes, which is the index of motivated attention (Briggs & Martin, 2009; Hajcak et al., 2010; Olofsson et al., 2008; Schupp et al., 2004). However, the general presence of the N2 component demonstrated in the context of reward anticipation could suggest that reward anticipation is accompanied by the activation of outcome evaluation processes. It was found that the presentation of neutral cues evoked greater N2 amplitudes relative to the presentation of substance-related cues. This observation is consistent with the results of previous research demonstrating that N2 amplitudes can be enhanced by unexpected or undesirable outcomes (*see* Baker & Holroyd, 2011; Holroyd & Coles, 2002; Holroyd et al., 2008; Nieuwenhuis et al., 2004). The difference in the N2 component between neutral and substance-related cues could reflect a decision-making response to feedback value required for correct action selection (*see* Bargh & Ferguson, 2000; Botvinick et al., 2004; Folstein & Van Petten, 2008) and learning processes (*see* Holroyd & Coles, 2002; Nieuwenhuis et al., 2004). These processes were not affected by the probability information. It should be emphasised that these particular results could have been affected by a programming error, and therefore, await replication. Alternatively, it could be hypothesised that these processes are responsible for the changes in attentional processing of substance-related cues when substance-related and neutral stimuli are presented in competition. In contrast, when attentional selection is 'blocked' by the independent presentation of neutral and substance-related stimuli, the N2 component is not affected by the probability information. This hypothesis remains to be tested by further research and could allow clarification of the differences in the impact of certainty and uncertainty reward information on AB.

Substance anticipation, craving and substance seeking behaviour - speculations

Franken (2003) argued that "enhanced attentional focusing on drug cues may trigger more explicit cognitive processes such as positive drug-related expectancies

and intrusive thoughts" (*p*. 572). This argument was one of the focal points of the model of craving proposed by Kavanagh and colleagues (Elaborated Intrusion (EI) Theory - Kavanagh et al., 2005). EI model proposes that external cues, anticipatory responses and substance associated thoughts can influence the experience of craving, which is an emotional and cognitive experience driven by a progressive activation of substance-related associations. EI suggests the experience of craving is a combination of both positive and negative affective states. The initial experience of craving could be positive. Probabilistic cue signalling substance reward may initiate the experience of positive memories, expectancies and emotional states associated with the previous instances of substance use. During the experience of craving, cues signalling substance availability could initiate elaborative processes. These processes could activate an attentional search for stimuli positively associated with substance use (*i.e.*, AB for positive happy facial expressions demonstrated in Study 4.1 and AB for substance-related cues in Study 2.1). For instance, anticipation of smoking availability may enhance AB for smoking-related cues (*e.g.*, ashtrays, lighters, cigarette packs) but also cues associated with positive smoking experience (*e.g.*, relief experienced during a cigarette break or positive social event associated with smoking). This could facilitate substance seeking and diminish the perceived impact of negative consequences of behaviour (*e.g.*, 'having a cigarette would make me feel good' or 'one cigarette does not make a difference'), promoting impulsive decision making. When the initial elaborative processes initiate active substance seeking, individuals may expect all of their behaviour to be followed up by substance use (Study 2.4). At this stage, the effects of probability could be abolished leading to a general boost in AB (*e.g.*, attention is even more sensitive to all available cigarette-related cues to increase the likelihood of goal achievement). Therefore, the enhancing properties of positive affect associated with reward anticipation, implicated by some theoretical accounts (*e.g.*, Fredrickson, 2001; Fredrickson & Branigan, 2005; Rowe et al., 2007; Tamir & Robinson, 2007) could be associated with the positive stage of craving.

The initial positive craving experiences could be followed by more negative associations related to the realisation of substance deficits (*e.g.*, thoughts of a desperate need to smoke to satisfy the urge or prevent the withdrawal).

Therefore, the awareness of physiological deficits and negative memories of the previous situations when the craving could not be satisfied can further initiate substance seeking (*see* Tiffany, 1990; Tiffany & Conklin, 2000). Active substance seeking can be guided by cues signalling loss prevention, which increase their AB for substance-related cues to avoid negative consequences of the deficit (*e.g.*, 'I cannot share my cigarettes because I only have limited amount' or 'I need to make sure I take my cigarettes with me'). If the negative outcomes cannot be prevented, participants may try to disengage themselves from the substance seeking behaviour to prevent their negative mood from escalating (*see* Brandtstädter & Rothermund, 2002). Therefore, cues signalling unavoidable substance loss may not have an impact on AB for substance-related cues (Study 2.2). In both of the scenarios, avoidable and unavoidable substance loss could hypothetically enhance the negative affect. The enhancement of negative affect could in turn increase sensitivity to cues signalling negative outcomes, leading to AB for negativity information (Study 4.2). This could further increase negative mood and enhance craving experience (*e.g.*, Bradley et al., 2007; Hepworth et al., 2010).

The interpretation of the current results is consistent with IE, which posits that craving is a combined experience of positive and negative substance-related associations (Kavanagh et al., 2005). The current findings demonstrate that anticipation of substance reward or loss could influence temporal changes in AB. This is important because Marhe et al. (2013) found that an increase in substance-related AB may precede relapse. Additionally, changes in AB for positively and negatively valenced stimuli associated with the anticipation of substance-related motivationally salient outcomes, can influence affective states, and therefore facilitate substance seeking behaviour.

Research methods and predictions for aversive disorders

The understanding of motivational processes involved in the effects of substance loss and reward on AB could be improved by the investigation of comparable effects in disorders characterised by pronounced aversive motivation (*e.g.*, depression). Negativity bias may be associated with the maintenance of depression (Beevers et al., 2015; Clasen et al., 2013). Consequently, the examination

of the cognitive mechanisms responsible for the decreased responsiveness to reward-related stimuli, or the preservation of negativity bias could allow for the improvement of treatment methods. The results of Studies 2.2-3 demonstrated that the ability to prevent loss was a sufficient condition for revealing the impact of probability information on AB. Learned helplessness theory of depression (Seligman, 1972), implies that the introduction of control over the outcomes would not have comparable effects on AB in individuals suffering from depression. Learned helplessness is a pattern of behaviour which may develop in individuals repeatedly exposed to unavoidable negative (aversive or painful) outcomes. Having learned that a situation could not be controlled, such an individual may become unable or unwilling to prevent those negative outcomes when prevention is possible. Accordingly, it could be expected that the effects of learned helplessness should be visible in both the clinical and non-clinical population when comparing performance on tasks involving behavioural control over negative outcomes. Depression can hinder the development of AB for reward-related stimuli (Brailean et al., 2014), and it could be argued that decreased sensitivity to cues signalling loss prevention could be a contributing factor. This aspect of depression could be investigated using the research methods developed as a part of this thesis (Studies 2.2-3).

Similarly, the tasks used for the purpose of Studies 4.1-2 could be used to investigate the negativity bias associated with depression (Gotlib, Krasnoperova, et al., 2004). As reflected in the results of Study 4.1, the effects of reward anticipation enhanced the positivity bias, whereas loss anticipation led to a balance in attentional preference for sad and happy faces. However, individuals suffering from depression can be expected to be more sensitive to cues signalling loss. Therefore, the opposite pattern of results could be expected. The research methods used in Studies 4.1-2 could clarify this if AB for one type of negative information (loss signalling cues) could further enhance the effects of another type of negative bias (facial expressions of sadness) on AB. Overall, the experimental designs developed for the purpose of this thesis could be adapted to examine issues beyond the current scope of research on addiction and appetite.

Limitations and further directions for future research

Although the current studies clearly demonstrate the moderating effects of substance reward and loss anticipation on AB, they do not explain why certain effects were observed for one substance but not the other. For instance, Study 2.3 demonstrated that anticipation of beer loss prevention increased AB for alcohol-related pictures in comparison to *unlikely loss prevention* trials. However, the pattern of results obtained for chocolate was different and more difficult to interpret (*i.e., certain loss prevention* evoked a lower AB for chocolate in comparison to the *uncertainty condition*, but none of these conditions differed from the *unlikely loss prevention* condition). Study 2.4 demonstrated an outcome specific general boost in AB during chocolate anticipation trials, but the results were not observed for alcohol anticipation. For instance, Study 2.3 could have included more participants motivated by obtaining an alcohol reward, whereas Study 2.4 could have included more participants focused on the chocolate reward. It can be speculated that this difference contributed to the lack of consistency in the effects of chocolate and beer anticipation. Thus, future research should consider this confound and control for participants' motivation for taking part in the study.

The current research focused on the investigation of general mechanisms which direct attention during anticipation of motivationally salient outcomes, and, consequently, the impact of individual differences was not considered. The inclusion of measurements of personality traits associated with the responsiveness to substance-related cues could help to clarify some of the results. For instance, it could be speculated that the individual level of sensation seeking and risk taking might be particularly relevant. Sensation seeking is a personality trait defined by the active pursuit of novel, complex and intense sensations, and the willingness to take the risks achieving these intense states (Zuckerman, 2001). It could be expected that high sensation-seekers could be more affected by the uncertainty conditions, whereas attention of low sensation seekers could prefer the predictors of certain outcomes. Therefore, follow-up research investigating the effects of certain and uncertain outcome predictors on AB should include the Sensation Seeking Scale (Zuckerman, 2007).

Similarly, responsiveness to alcohol and food rewards could be related to individual differences in impulsivity (Christiansen et al., 2012; Fernie et al., 2013; Jentsch et al., 2014; Nederkoorn et al., 2015; Schag et al., 2013). Meta-analysis revealed a small but robust relationship between substance-related AB and impulsivity (Coskunpinar & Cyders, 2013) and similar effects have been reported for obesity (Hou et al., 2011). This could indicate that high impulsivity may either enhance or overdrive the effects of reward anticipation. Thus, further research should consider measuring this trait as a potential moderator of effects of reward anticipation on AB.

Apart from the two aforementioned personality traits, the base-line levels of state characteristics, like craving or hunger, could be significant moderators of the effects of reward anticipation. This prediction is based on the results of studies which demonstrated a link between craving/hunger and AB (Field et al., 2009; Rose et al., 2013; Werthmann et al., 2015). Although the current studies recorded alcohol and chocolate use and habits as well as chocolate craving, this information was only obtained as a sample characteristic. Since this was not the purpose of current research, the impact of these variables on the effects of anticipation was not investigated. Taking into account the magnitude of positive correlation between craving and AB (r = .19) demonstrated in the meta-analysis conducted by Field et al. (2009), the authors reported that the sample size required to detect this correlation with 80% power at α = .05 would be at least N = 212. Therefore, the sample size required to investigate the impact of individual differences in craving on the effects of anticipation on AB is much larger than those used in the studies conducted as part of this thesis. Investigation of the impact of individual differences in the baseline craving and hunger on the effects of anticipation on AB could be considered as avenues for future research. Such studies could help further clarify the role of anticipatory processes in motivated behaviour.

Studies 4.1-2 demonstrated congruency effects of loss and reward anticipation on the attentional processing of facial expressions of emotion. However, these effects were demonstrated for different types of picture pairs (*i.e.*, happy-sad pairs for Study 4.1 and sad-neutral pairs for Study 4.2). It was speculated that the difference in results of Studies 4.1 and 4.2 was

the consequence of the baseline differences in affective bias (*i.e.*, positivity bias in Study 4.1 and the lack of comparable bias in Study 4.2). However, an alternative explanation cannot be ruled out. It is possible that the alterations that were done to the task did not allow for the replication of the initial findings. The *uncertainty* trials were not included in Study 4.2, because in Study 4.1 the differences in AB between *uncertainty* and *certainty* as well as *certainty* and *no reward/loss* conditions were not clear. This task adjustment could have influenced the results. Research suggests that uncertainty is positively associated with motivation (Ozcelika, Cagiltayb, & Ozcelikc, 2013) and can facilitate curiosity and emotional reactivity to motivationally valenced stimuli (Bar-Anan, Wilson, & Gilbert, 2009; Howard-Jones & Demetriou, 2009) which in turn may lead to enhanced task engagement. Therefore, even if there are no a clear differences between the effects of *uncertainty* and *certainty* on AB, the *uncertainty condition* could be crucial for participants engagement in the task. It is possible that the difference in task engagement could be responsible for the different patterns of results of Studies 4.1 and 4.2. Thus, the impact of uncertainty on task engagement and AB should be further investigated to clarify this issue.

The element of deception could be examined as a possible limitation of current studies. In Jones et al. (2012) study, participants expected that a number of points they accumulated during the task would be converted into actual rewards which they would obtain at the end of the study. However, due to ethical concerns, participants did not receive any substance-related rewards at any point in the task. Provision of small quantities of chocolate and beer during all of the *certain reward* and a half of *uncertain reward* trials conducted during the study could have made participants nauseous. Consumption of chocolate and beer during the study would also affect the level of satiety and intoxication, both of which could alter the value of rewards, thus making the interpretation of results problematic. This research method is different than one implemented in similar studies (Field et al., 2011; Wertz & Sayette, 2001a), during which participants received substances. However, it was proposed that the probability cues are sufficient to trigger the representations of substance-related reward and therefore direct attention (Hogarth, Dickinson, Wright, Kouvaraki, & Duka, 2007). The goal of Study 2.1 was

to replicate the results provided by Jones et al. (2012) while controlling for the potential study artefact (*i.e.*, single behavioural response for both substance types). Therefore, Study 2.1 scrupulously followed the design introduced by Jones et al. (2012) and included the element of deception. Since the studies, were by design, closely related to each other, the introduction of actual substance rewards would make interpretation of results difficult and would have raised the same ethical concerns as in the study. Although the effectiveness of deception was not formally tested, it should be emphasised that participants asked about the quantities of beer and chocolate they either 'won' or 'maintained' and some of them were visibly upset when they learned about the deception. This suggests that participants believed they would receive chocolate and beer at the end of studies.

Finally, it should be noted that the results of EEG study (Study 3.1) should be treated with caution as, due to the programming error probability, trials were not completely counterbalanced. The findings of this study await replication.

Conclusions

The results of the current studies provide further support for the effects of substance anticipation on cue reactivity by showing that reward anticipation is sufficient for altering AB for substance-related cues. However, the results extend beyond this by demonstrating that comparable effects can be observed for loss anticipation. The level of behavioural control over the reward or loss outcomes was identified as a moderator of the impact of probability cues on AB. The effects of anticipation of substance reward and loss were shown to be outcome specific for cues belonging to the substance-related domain. The anticipation of motivationally salient outcomes can also influence the processing of positively and negatively valenced information. The effects of anticipation may have an independent impact on AB for substance-related stimuli and AB for valenced information (*i.e.*, cues signalling unavoidable loss had a limited impact on AB for substance-related cues but influenced the attentional processing of facial expressions of emotion). Eye-tracking studies did not demonstrate a clear difference in the impact of certainty and uncertainty on AB. However, the results of the EEG study suggest that evaluative processes triggered by cues signalling uncertain outcomes might be

diminished when these cues are followed-up by neutral stimuli. Overall, these findings provide a further support for the dynamic nature of AB (*see* Field et al., 2016), and suggest that temporal changes in AB might be responsible for the variability in substance seeking behaviour. The current results and research methods may have important implications for addiction and appetite research, as well as psychological disorders characterised by altered processing of motivationally salient information.

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APPENDIX A - Questionnaires

Age:

Gender: M / F

Timeline Followback

To help me evaluate your drinking I need to get an idea of your alcohol consumption in the past fourteen days. Please fill out the table with the number of units of alcohol consumed on each day, being as accurate as possible. Please use the information given below to work out how many units you consumed on each day in the past week and fill in the number of units in the table. On days when you did not drink please write 0 (zero). I realise it isn't easy to recall things with 100% accuracy, but if you are not sure how many units you drank on a certain day please try to give it your best guess.

What is a unit of alcohol?

The list below shows the number of units of alcohol in common drinks:-

- A pint of ordinary strength lager (Carling Black Label, Fosters) - 2 units
- A pint of strong lager (Stella Artois, Kronenbourg 1664) - 3 units
- A pint of ordinary bitter (John Smith's, Boddingtons) - 2 units
- A pint of best bitter (Fuller's ESB, Young's Special) - 3 units
- A pint of ordinary strength cider (Woodpecker) - 2 units
- A pint of strong cider (Dry Blackthorn, Strongbow) - 3 units
- A 175ml glass of red or white wine - around 2 units
- A 750ml bottle of red or white wine – around 9 units
- A pub measure of spirits - 1 unit
- An alcopop (eg Smirnoff Ice, Bacardi Breezer, WKD, Reef) - around 1.5 units

Please now fill in the following table stating the total number of alcohol units you consumed for each day. Please start from whichever day it was yesterday and work backwards. For example if today is Monday start from Sunday and work backwards, with Monday being Monday a week ago. Please double check that you have filled in the number of units for all fourteen days.

Last week:

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

Previous week:

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday

AUDIT

1) How often do you have a drink containing alcohol?

Never Less than monthly 2-4 times a month 2-3 times per week 4+per week

2) How many drinks containing alcohol do you have on a typical day when you're drinking?

1-2 3-4 5-6 7-9
10+

3) How often do you have 6 or more drinks on one occasion?

Never Less than monthly Monthly Weekly Daily or almost daily

4) How often during the last year have you found that you were not able to stop drinking once you had started?

Never Less than monthly Monthly Weekly Daily or almost daily

5) How often during the last year have you failed to do what was normally expected from you because of drinking?

Never Less than monthly Monthly Weekly Daily or almost daily

6) How often during the last year have you needed a drink first thing in the morning to get yourself going after a heavy drinking session?

Never Less than monthly Monthly Weekly Daily or almost daily

7) How often during the last year have you had a feeling of guilt or remorse after drinking?

Never Less than monthly Monthly Weekly Daily or almost daily

8) How often during the last year have you been unable to remember what happened the night before because you had been drinking?

Never Less than monthly Monthly Weekly Daily or almost daily

9) Have you or someone else been injured because of your drinking?

No Yes, but not in the last year Yes, during the last year

10) Has a relative, friend, doctor or other health worker been concerned about your drinking or suggested you cut down?

No Yes, but not in the last year Yes, during the last year

Chocolate use questionnaire:

In an average week, can you please indicate how much chocolate (roughly, in standard sized bars, e.g. mars, snickers, twix, etc) you would consume?

_____

How many bars of chocolate do you usually keep at home?

_____

Please give an indication of how you feel about the following statements;

How much do you like to eat chocolate?

0 1 2 3 4 5 6 7
Not a lot Lots

How often do you feel the urge to eat chocolate?

0 1 2 3 4 5 6 7
Never Always

How strongly do you feel this urge?

0 1 2 3 4 5 6 7
Not very strongly Very strongly

To what extent do you feel you need to eat chocolate?

0 1 2 3 4 5 6 7
Not at all A large extent

How difficult do you find it to stop eating chocolate once you have started?

0 1 2 3 4 5 6 7
Not at all Extremely

PANAS

This scale consists of a number of words that describe different feelings and emotions.
Read each item and then circle the appropriate answer next to that word. Indicate to what extent you are feeling this way **right now**.

Use the following scale to record your answers.

(1) = Very slightly or not at all (2) = A little (3) = Moderately (4) = Quite a bit (5) = Extremely

	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
1. Interested	1	2	3	4	5
2. Distressed	1	2	3	4	5
3. Excited	1	2	3	4	5
4. Upset	1	2	3	4	5
5. Strong	1	2	3	4	5
6. Guilty	1	2	3	4	5
7. Scared	1	2	3	4	5
8. Hostile	1	2	3	4	5
9. Enthusiastic	1	2	3	4	5
10. Proud	1	2	3	4	5
11. Irritable	1	2	3	4	5
12. Alert	1	2	3	4	5
13. Ashamed	1	2	3	4	5
14. Inspired	1	2	3	4	5
15. Nervous	1	2	3	4	5
16. Determined	1	2	3	4	5
17. Attentive	1	2	3	4	5
18. Jittery	1	2	3	4	5
19. Active	1	2	3	4	5
20. Afraid	1	2	3	4	5

APPENDIX B - Jędras, P., Jones, A., & Field, M. (2013). The role of anticipation in drug addiction and reward. *Neuroscience and Neuroeconomics, 2014:3*, 1-10.

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Abstract: Addiction is a chronically relapsing disorder, and substance users frequently relapse when they encounter opportunities to use drugs. In this paper, we review evidence regarding the psychological response to anticipation of imminent drug availability, its neural substrates, and its relationship to other phenomena implicated in addiction. Naturalistic and laboratory studies indicate that drug anticipation increases cue-provoked craving and attentional biases for drug-related cues. As predicted by existing theoretical models, these effects reflect hyper-valuation of drugs that are perceived as available for consumption, which is linked to activation of the dorsolateral prefrontal cortex that, in turn, innervates subcortical regions associated with reward processing. Drug expectancy is necessary for the formation of conditioned responses to drug-related cues and it modulates the strength of conditioned responses. Furthermore, the role of impulsivity in addiction can be understood in terms of its interaction with the response to imminent drug availability. These results have a number of implications for the treatment of addiction, ranging from government policies that restrict the perceived availability of drugs to novel biological and psychological interventions that could blunt the response to signals of drug availability.

Keywords: attentional bias, availability, conditioning, cue-reactivity, expectancy, substance use disorders

Introduction

The majority of addicted individuals will relapse to drug use after a period of abstinence.[1] Relapses are frequently attributed to the presence of others who are using the drug, or to being in an environment in which the drug is readily available, such as a bar.[2–5] A large body of research demonstrates that the anticipation of an imminently available psychoactive drug has a potent emotional and motivational effect in addicts. In *Memoirs of an Addicted Brain*, the neuroscientist and recovered addict Marc Lewis describes the experience eloquently:

> I sit at the dinner table, gazing down at my plate, and imagine that liquid pearl of opium dripping from that Chinese woman's skewer. And my ventral striatum says "That's what I want. That's exactly what I want, and I want it now."[6]

In this paper, we will discuss theoretical models that incorporate a key role for drug anticipation in the development of substance use disorders (more colloquially known as addiction).[7] We will then review evidence regarding the role of drug anticipation in learning, subjective craving, cognitive processing, and the underlying neural substrates of these effects. Finally, we will discuss the clinical implications of this work and how it can be applied in the search for more effective treatments for substance use disorders.

Theoretical background

Smith et al[8] propose that reward (including drug reward) comprises three distinct components: liking, wanting, and learning. Drugs are initially used primarily for their hedonic rewarding properties (liking). With repeated drug use, a Pavlovian conditioning process (learning) causes the rewarding properties of drugs to be paired with environmental cues that are present at the time of drug consumption, such as the sight and smell of alcoholic drinks or cigarettes. As addiction progresses, excessive wanting for the drug develops, which leads to compulsive drug use and loss of control. This wanting process is thought to reflect adaptations in dopamine function in the brain reward system (including the nucleus accumbens [NAcc] and ventral tegmental area [VTA]) as well as impaired function in subregions of the prefrontal cortex. In the addicted brain, excessive wanting can be evoked by drug-related cues, which trigger increases in dopamine activity in the reward system. This increase in dopamine activity is experienced as the expectation of imminent consumption of the drug, which is powerfully motivating.[9]

There is now a broad consensus regarding the core psychological changes that occur in addiction. That is, dependent individuals continue to use drugs despite negative consequences because they overestimate the hedonic rewarding value of the substance, but become relatively insensitive to other forms of reinforcement (eg, from social interactions and/or occupational achievement).[10] It has been proposed that addiction is maintained because the expectation of hedonic effects obtained from drug reward becomes more motivating over time. However, at the same time, both cognitive control and the actual hedonic effects of drugs begin to decline.[9,11] Anticipation of the hedonic effects of drugs can be triggered by information that the drug is available (eg, "Would you like a beer?") or by the detection of drug-related cues that signal the availability of the drug.[12] Therefore, the theories discussed in this section propose that anticipation of drug effects evokes powerful motivational and emotional responses that may maintain drug use, despite negative consequences of drug use and the fact that the hedonic experience of drug use never quite lives up to that which was anticipated.

Does drug expectancy play a role in drug conditioning?

The theoretical models discussed in the previous section suggest that reactivity to drug-related cues occurs because those cues have been repeatedly paired with the rewarding effects of drugs, which leads to the formation of conditioned associations. Exposure to drug-related cues reliably leads to increased craving and physiological arousal in drug users. These responses have been documented in patients with alcohol, nicotine, opiate, and cocaine dependence as well as in pathological gamblers.[13–17] According to conditioning accounts of cue reactivity, the drug acts as an unconditioned stimulus (US) that elicits unconditioned responses. With repeated drug use, the user learns the contingency between drug effects and cues associated with drug administration (eg, the sight and smell of a lit cigarette) such that those cues function as conditioned stimuli (CS) that are able to evoke conditioned responses (CRs). Once the CS-US contingency has been learned, the CS functions as a signal for the imminent availability of the drug, and, arguably, it is this anticipation that is responsible for the initial development of CRs such as changes in subjective state (particularly craving), physiological changes (eg, increases in heart rate), and behavioral responses (such as drug-taking behavior).[18,19]

Awareness of CS-US contingencies may be a crucial condition for the initial development of CRs. A considerable number of human conditioning studies

demonstrate that, during the formation of conditioned associations, participants show CRs only after they can verbalize the CS-US contingency, ie, when presentation of the CS leads to the expectation that the US is imminent.[20]This is also true when participants are learning associations between the opportunity to consume drugs and arbitrary stimuli. An arbitrary cue that is paired with smoking is able to evoke an increase in cigarette craving (and other conditioned responses), but only after participants have learned the predictive significance of the cue, such that its presence elicits an expectation of the opportunity to smoke.[21] For example, one study[22] showed that a CS that had been paired with the opportunity to smoke (CS+) led to increased cigarette craving compared to a CS that had been explicitly unpaired with the opportunity to smoke (CS−). This CR (craving) was particularly pronounced in individuals who were aware of the contingency between the CS and the US. Furthermore, the craving CR to the CS+ (versus the CS−) was completely abolished if participants were informed that smoking was unavailable. This study, and several others reviewed by Hogarth and Duka,[21] reveal that drug expectancy in response to a CS that is paired with a drug use opportunity is an important determinant of other CRs in response to that cue.[18] To summarize, drug-related cues are able to evoke craving and physiological arousal only when individuals are aware of the predictive significance of those cues, such that their presence leads to an expectation that the drug is available.

Naturalistic studies of the effects of drug anticipation

Theoretical models suggest that drug expectancy should increase craving, and results from studies discussed in the previous section demonstrate that this is an important determinant of the development of craving reactivity to drug-related cues. Two elegant studies demonstrate that drug expectancy influences the strength of craving in naturalistic settings, outside of the laboratory. Dar et al[23] assessed the strength of cigarette craving in flight attendants during a two-way short flight (each leg was between 3 and 5.5 hours in duration) and a one-way long flight (between 8 and 13 hours duration). In both short and long flights, the strength of craving increased gradually and peaked as landing approached. The strength of craving appeared to be proportional to the proximity to the opportunity to smoke, rather than to the duration of nicotine deprivation; craving strength at the end of the first leg of the short flight was comparable to that at the end of the long flight (when a smoking opportunity was imminent). However, craving was much stronger at the end of the first leg of the

short flight compared to the equivalent time point in the long flight, when the duration of nicotine deprivation was the same. This study demonstrates that cigarette craving increases when individuals anticipate an imminent opportunity to smoke and decreases when cigarettes are not available for a period of time. Although nicotine deprivation also influences the strength of cigarette craving, the powerful effects of smoking opportunity can be clearly seen when nicotine deprivation is controlled.

In another study, Dar et al[24] investigated the effects of habitual abstinence on cigarette craving in a population of Orthodox Jewish smokers. Craving strength was generally lower during the Sabbath (when Orthodox Jews must not smoke) in comparison to both a regular workday, when they could smoke as usual, and on a different workday, when smoking was not permitted. However, craving levels did not differ between the regular workdays in which smoking was allowed versus those in which smoking was not permitted. One interpretation of these findings is that, when individuals habitually abstain from drug use for religious reasons, they may perceive the drug as "unavailable" on those days, and this results in lower craving. On the other hand, the absence of a difference in the strength of craving on working days when smoking was permitted versus days on which it was not allowed suggests that the effects of smoking opportunity on cigarette craving in naturalistic settings are moderated by other factors, such as the reason for the opportunity, or lack thereof, to smoke.

Laboratory research exploring the role of drug expectancy on cue reactivity and subjective craving

In addition to the aforementioned naturalistic studies,[23,24] laboratory research reveals that the anticipation of drug availability can have a robust impact on the strength of subjective craving, particularly craving that is evoked by drug-related cues. Numerous studies demonstrated that the strength of subjective craving during drug cue exposure was significantly higher among participants who were able to use the drug soon after cue exposure versus those who were not. Some of these studies also suggested that craving was elevated when drug use was anticipated, even among participants who were not exposed to drug cues[12,25–31] (see Wertz and Sayette[32] for review). The majority of these studies were conducted with cigarette smokers, although one study demonstrated comparable findings in individuals with cocaine dependence. In this study, all participants received a dose of cocaine, but one group was expecting to receive cocaine whereas another group believed that there was only

a 33% chance that they would receive the drug. The most important finding was that the participants who were expecting to receive cocaine reported significantly higher levels of cocaine craving immediately before the cocaine was actually administered, compared to the participants who were uncertain if they would receive cocaine.[33] Overall, these studies are consistent with the suggestion that subjective craving may involve anticipation of further drug-related reward.[10]

Despite this consistency, some studies have failed to replicate the finding of increased craving in response to drug cues when the drug is perceived as available. Field and Duka[34] observed no effects of smoking opportunity on craving and physiological measures of smoking cue reactivity. However, those authors noted that participants who expected to be able to smoke soon still had to wait around 20 minutes before they were able to smoke, and this delay may have reduced the impact of the expectancy information. With regard to alcohol cue reactivity, Davidson et al[35] and Kruse et al[36] found no effect of alcohol availability on subjective craving in response to alcohol cues, although the anticipation of alcohol did lead to a reduction in negative mood in the Davidson et al[35] study. One study demonstrated that craving induced by alcohol cues was stronger in participants who thought that they could not consume alcoholic drinks after cue exposure compared to those who expected to be able to consume alcohol[37] (see also MacKillop and Lisman[38]). The latter findings are consistent with Tiffany's[39] theoretical model. This model posits that drug self-administration becomes habitual in experienced users, such that it is elicited automatically in the absence of strong cravings. However, addicts experience cravings when automatic drug self-administration behaviors are blocked because the drug is not available. Therefore, the findings from this study lend support to Tiffany's model, although it is notable that the other studies discussed in this section fail to support the predictions made by this model.

Overall, it is possible that anticipation of imminent drug availability may lead to increased craving, but exposure to drug cues alongside information that the drug cannot be consumed may lead to frustration and negative mood, which leads to increased craving via a different mechanism. A further possibility is that drug expectancy has differential effects on craving for tobacco and alcohol. We emphasize that there are so few studies on this topic that this issue, and these alternative explanations, await further study.

Effects of drug expectancy on attentional bias for drug cues

In addition to its effects on subjective craving, drug expectancy influences other aspects of cue reactivity including attentional biases for drug cues. It is known that drug users have an attentional bias for drug-related cues; drug cues are able to capture and hold their attention at the expense of other stimuli.[18] It has been demonstrated that attentional biases for drug cues develop as a consequence of the same classical conditioning process that results in other aspects of cue reactivity, including changes in physiological activity and subjective craving,[40] as discussed in the previous section on conditioning. Whilst the clinical relevance of attentional bias in substance use disorders is debated,[41] it is generally agreed that attentional bias is modulated by dopamine activity[42] and it reflects the current motivational value of the drug.[43,44]

Field and Cox[18] proposed that, during conditioning, drug cues elicit an expectation of imminent drug availability and, as a consequence of this, the drug user preferentially shifts their attention to the cue. This theory makes the prediction that attentional bias for drug cues should be moderated by the perceived availability of the drug. Wertz and Sayette[45] showed that attentional bias for smoking-related words was highest in nicotine-deprived smokers who expected to be able to smoke imminently compared to those who believed that they would not be able to smoke, or who were uncertain if they could smoke or not. These effects were replicated by McCarthy et al[46] who showed that anticipation of smoking increased attentional bias for smoking-related words and other emotionally valenced words in smokers who were deprived from nicotine, but there were no effects of smoking expectancy in smokers who were nicotine sated at the time of testing. Using a within-subjects design, Field et al[47] informed social drinking (nondependent) participants about the probability that they would receive beer (100%, 50%, or 0%) before each trial of an eye-tracking task. During this task, alcohol-related and neutral pictures were presented on a computer screen while participants' eye movements were recorded. Results revealed that attentional bias for alcohol cues was elevated when participants expected to be able to consume alcohol imminently, compared to when they knew that alcohol was not available. However, this sensitivity to availability information was only seen in relatively light drinkers. In heavier drinkers, attentional bias for alcohol cues was seen regardless of availability information. This finding may suggest that attentional bias can become decoupled from anticipation of reward in

those who drink more heavily or more frequently (see also Hogarth et al[48] for broader discussion of this issue).

In a follow-up study, Jones et al[49] used a similar methodology and replicated the basic demonstration of increased attentional bias for alcohol cues when alcohol was anticipated imminently. However, unlike in the Field et al[47] study, these effects were apparent in all participants regardless of whether they were a relatively heavy or light drinker. In the same study, Jones et al[49] also demonstrated that anticipation of chocolate reward led to increased attentional bias for chocolate-related cues, which suggests that the effects of reward anticipation on attentional bias are not limited to drugs of abuse, but are seen with all rewarding stimuli (however, see Werthmann et al,[50] discussed below). Importantly, in the Jones et al[49] study there was some crossover of these effects, because anticipation of alcohol led to increased attentional bias for chocolate cues and vice versa. This demonstration that the effects of reward anticipation on attentional bias are general rather than specific to the reward that is anticipated is problematic for conditioning-based accounts of this effect.[18] However, methodological issues in this study may account for these findings and suggest an alternative explanation for the results, as discussed in Jones et al.[49]

Finally, a recent study from Werthmann et al[50] found no effect of perceived availability of chocolate on attentional biases for chocolate-related cues. However, in this study there was a fairly long interval (we estimate it at 15–20 minutes) between giving participants the availability information and the actual opportunity to consume chocolate. Therefore, the null effects may be attributed to the availability information losing its motivational impact because the reward was not available soon enough, as discussed in relation to the Field and Duka[34] study in a previous section. The available studies suggest that the effects of anticipation of drugs (and other rewards) on attentional bias are readily detected when anticipation (expectancy) is manipulated on a within-subjects, trial-by-trial basis, which ensures that participants expect to receive the reward (or not receive it) at the exact moment that attentional bias is measured.

The underlying neural circuitry of reward anticipation

Research on patterns of brain activation during drug cue reactivity has identified an important role for drug anticipation. Wilson et al[51] identified two regions of the prefrontal cortex – the orbitofrontal cortex (OFC) and the dorsolateral prefrontal cortex (DLPFC) – that were reliably activated by drug-related stimuli in current or

continuing drug users, ie, those who were not receiving treatment at the time of testing. In drug users who were receiving treatment at the time of testing, the OFC and DLPFC were not activated during drug cue exposure. Wilson et al's[51] explanation was that these differential patterns of brain activity during drug cue exposure can be attributed to the greater expectancy of drug use in the current drug users compared to those seeking treatment, because, presumably, the former group were able to use drugs as soon as they finished taking part in the study whereas the latter group were not. Subsequent studies have manipulated the availability of smoking on a trial-by-trial basis while smokers (who are not attempting to quit) are exposed to smoking cues, and results have supported this account; activity in the OFC and DLPFC in response to smoking cues was increased when smokers perceived an opportunity to smoke, compared to when smoking was not available.[52–54] Furthermore, deactivation of the DLPFC with transcranial magnetic stimulation (TMS) eliminated the effect of smoking expectancy on subjective craving. In addition, this deactivation of the DLPFC reduced the degree of activation in the OFC that was evoked by the anticipation of smoking.[54] Hayashi et al[54] concluded that the function of the DLPFC in this context is to increase the subjective value of the drug in response to availability information. This value information is then transmitted to other cortical (OFC, anterior cingulate cortex) and subcortical (eg, NAcc) regions of the brain.

Other studies have confirmed the role of the DLPFC in anticipation of other types of reward. Anticipation of monetary reward directly increases activation of the DLPFC, and thereby indirectly increases activity in the NAcc and VTA,[55] a similar pattern of activity to that reported in the Hayashi et al[54] study on smoking availability. Other studies conducted with humans and primates have confirmed that the DLPFC is involved in intertemporal valuations, ie, the sensitivity to immediate versus delayed reinforcement.[56–58] In summary, the DLPFC can be considered as one of the primary brain substrates involved in the response to drug expectancy.

How does drug expectancy relate to loss of control in addiction?

We have shown that drug expectancy has clear effects on subjective craving and attentional bias for drug cues, and we have identified the DLPFC as an important neural substrate of these effects. In this section, we show that the effects of drug expectancy are related to aspects of loss of control in addiction. Substance use disorders are characterized by elevated impulsivity. Arguably, impulsivity comprises

two distinct components: temporal discounting (or cognitive impulsivity) and disinhibition (or motor impulsivity).[59] Temporal discounting and disinhibition are well-established features of substance use disorders.[60,61] Importantly, both components of impulsivity are related to the effects of drug expectancy on drug users.

Temporal discounting (or delay discounting) refers to the tendency to devalue rewards as a function of the delay to their receipt; most people would prefer to receive $10 now than $11 next month, for example. This preference for immediate gratification is greatly exaggerated in those with substance use disorders.[60] Bickel and Marsch[62] argued that a high level of delay discounting could result in preference shifts that ultimately increase the risk of relapse to drug use after a period of abstinence. In a treatment setting, when an abstinent drug user is asked about their intentions to remain abstinent in the long-term, they may indicate that they prefer a life of abstinence (that carries long-term benefits to their health and general well-being) instead of a life of drug use (that involves immediate gratification but is harmful in the long-term). However, this preference is (sincerely) expressed in a treatment setting in which there is no opportunity to use the drug in the near future. When the drug user leaves the treatment setting, it is only a matter of time before they encounter an opportunity to use the drug again. This time the choice is between immediate gratification versus maintaining the commitment to the longer-term goal of abstinence (which carries long-term but not immediate benefits). Elevated rates of delay discounting in drug users can explain why they are particularly vulnerable to such preference shifts and, therefore, likely to relapse after a period of abstinence.[60,63,64] Most relevant to the current review paper, we have shown that the strong emotional and motivational response to drug availability information can explain why these preference shifts occur.

Disinhibition is defined as the inability to suppress, delay, or change a response that is no longer required or is inappropriate. This inability to control behavior can be measured in the laboratory using computer tasks, such as the stop signal[65] and go/no-go[66] tasks, both of which require participants to inhibit a dominant motor response. Participants with substance use disorders tend to perform poorly on these tasks, and when participants are in a disinhibited state they are more likely to drink alcohol to excess.[61] One recent study suggests that individual differences in disinhibition may moderate the strength of cue reactivity when the drug is perceived as available.

Papachristou et al[67] reported that, amongst social drinkers, craving for alcohol was stronger in participants who expected to receive alcohol imminently compared to those who did not. Most importantly, individual differences in disinhibition moderated these effects. Participants who were highly disinhibited and expected to receive alcohol showed a much larger increase in cue-induced alcohol craving compared to disinhibited participants who did not expect to receive alcohol. Among participants who were not highly disinhibited, expectancy of receiving alcohol had no effect on cue-induced craving. Although this result awaits replication, it suggests that disinhibition may be an important individual difference that may moderate the strength of subjective cue reactivity when drugs are perceived as available. These findings are complemented by other studies that revealed an association between impulsivity and other aspects of cue reactivity, such as attentional bias.[68,69] A recent meta-analysis demonstrated a small but robust association between impulsivity and attentional bias for drug cues.[70]

Synthesis and theoretical implications

We propose a theoretical framework that can incorporate much of the evidence described in this review. In common with the models discussed in the first section of this paper, we suggest that, in the addicted brain, there is an imbalance between the overestimation of the rewarding value of drugs, which is combined with decreased sensitivity to alternative forms of reinforcement. The first element of this imbalance (overvaluation of drug effects) is particularly sensitive to the anticipation of imminent drug availability, which results in the development of conditioned responses to drug cues and subsequently triggers a powerful emotional and motivational response. This response can be described as an increase in the value of the drug that is experienced as elevated subjective craving in response to drug-related cues, and increased allocation of attention to those cues (attentional bias). The corresponding brain substrates are an increase in activity in the DLPFC in response to drug availability information, which innervates subcortical reward system structures such as the NAcc and VTA.[9]

Other features of addiction, such as increased impulsivity and poor self-control, are closely linked to this response to imminent drug availability. The increased temporal discounting that is seen in drug users can be readily explained as a result of the psychological response to imminent drug availability. Furthermore, elevated disinhibition in substance users may have a direct effect on drug-seeking

behavior,[61] but it may also have a more indirect effect by causing an exaggerated response to information about imminent drug availability.[67] However, we must be clear that the evidence described in this review cannot provide a complete account of addiction. Other processes such as opponent processes[71,72] that may ultimately lead to hedonic homeostatic dysregulation are also likely to play an important role.[73]

Practical and clinical implications

People with substance use disorders who wish to reduce their drug use or abstain altogether may be helped by broad policy interventions that reduce the availability of drugs or at least reduce the likelihood that they will be reminded that drugs are available for purchase or consumption. One example of the latter is recent legislation introduced in the UK that ensures that cigarettes must be hidden from view in shops. This ensures that cigarettes are still available for purchase, but people are not constantly reminded that cigarettes are available every time they walk into a shop. We suggest that bans on smoking in public places introduced in many countries around the world in recent years are likely to have the same effect. Another development is the introduction of dry bars (eg, The Brink; http://thebrinkliverpool.com/about) where people can go to socialize in the evenings but alcohol is not available for purchase. A further example is restrictions on advertising; tobacco advertising has been banned in the UK for several years, and restrictions on alcohol advertising are likely to increase in the future. We suggest that one indirect effect of such restrictions may be to reduce awareness of the availability of those drugs and thereby bring about a subtle but important reduction in consumption of alcohol and tobacco in the population as a whole.

Restrictions on where alcohol and tobacco can be purchased are an example of how governments can reduce the psychological impact of perceived availability of those drugs, but of course this will never be a complete solution. Illicit drugs such as heroin, cocaine, methamphetamine, and cannabis are completely illegal in most countries but they are still used by a substantial minority of the world population, despite the (il) legality of those drugs meaning that most people are rarely confronted with cues for the availability of those drugs (unless they are currently making an attempt to find somewhere to purchase them).

This leads us to a more fundamental point about drug availability, which is that psychological representations of drug availability may be more important than the physical availability of that drug. For example, alcohol consumers could probably

purchase alcohol whenever they want to. However, we tentatively suggest that they probably do not perceive alcohol as available all the time for a variety of reasons (eg, they are at work and they do not drink alcohol at work). It should be emphasized that further research is required in order to investigate this suggestion. We also suggest that psychological interventions for substance use disorders should attempt to target and boost representations of (un)availability of drugs. Arguably, some forms of psychological treatment, such as cognitive behavioral therapy, already do this, for example, by encouraging drug users to form a more realistic expectation of the immediate outcomes of drug use (eg, "it will not feel as good as you expect it to"). Alternatively, drug users may be encouraged to restrict their use by thinking of drugs as unavailable at certain times or in certain contexts, and gradually increase the number of situations at which drug use is considered unavailable.[2] We speculate that recovered addicts who are able to achieve long-term (or permanent) abstinence are able to do so because they reach a point at which they consider drugs to be permanently unavailable (despite their obvious physical availability). The key to understanding recovery from addiction may be to understand how this occurs, and this awaits empirical testing in future research.

The evidence discussed in this paper suggests some additional approaches to the treatment of substance use disorders that could be explored. Firstly, cue exposure therapy (CET) has arguably proved to be an ineffective treatment for addiction because it does not incorporate a role for perceived availability.[74] In this therapy, substance users are exposed to drug-related cues in treatment settings until their responses to those cues (eg, craving and physiological arousal) are extinguished. The hope is that this will lead to a blunting of cue reactivity outside of the treatment context and relapse will be less likely to occur. However, meta-analysis indicates that CET does not reduce relapse rates.[74] This may be because CET sessions always take place in treatment settings where drugs are not available, so the drug expectancy response is never evoked and therefore cannot be extinguished. One solution may be to try to selectively extinguish the drug expectancy response, perhaps by asking substance users to imagine that they will soon be consuming the drug, and allowing this particular response to extinguish. Secondly, if activity in the DLPFC in response to signals of drug availability could somehow be blunted, this may prevent the emotional and motivational response to drug expectancy from gathering strength and (in some cases) leading to relapse after a period of abstinence. Some methods for achieving this may include repeated sessions of transcranial magnetic stimulation

applied to the area[75,76] or some form of cognitive training that could lead to a blunting of activity in the DLPFC in response to availability information.[77] Finally, existing psychological therapies, such as cognitive behavioral therapy, might be improved by incorporating additional elements that explicitly target the emotional response to imminent drug availability and focus on ways of preparing for and coping with the response when it occurs.

Limitations and directions for future research

Much of the experimental work on perceived substance availability and subjective craving has been conducted with tobacco smokers. However, when similar studies have been attempted with alcohol consumers, results have not always been consistent. There is, therefore, a risk that we may use this evidence to develop theoretical models of substance use disorders when those models may be more relevant for some substance use disorders than others. Further research is required to establish whether the findings reported here can be generalized to substance use disorders other than addiction to tobacco.

Laboratory research has provided us with a good understanding of the psychological response to instructed drug availability and the brain mechanisms that underlie this response. However, it is unclear how this research translates to our understanding of the effects of perceived drug use opportunity in naturalistic settings outside of the laboratory. An important gap in our knowledge here is how substance users represent drug availability and what they can do to boost representations of drugs as unavailable. This is likely to lead to important insights into novel treatments for substance use disorders.

Conclusion

The psychological response to perceived drug availability is a very important piece of the addiction puzzle. Subjective craving and attentional biases for drug-related cues are elevated when substance users perceive drugs as available, and these effects are likely to reflect an increase in the subjective value of drugs that are anticipated imminently. The response to drug availability plays an important role in the development and maintenance of reactivity to drug-related cues, and individual differences in impulsivity may influence drug-seeking behavior precisely because they interact with, or even directly determine, the response to perceived drug availability. Innovations in treatment for substance use disorders are likely to follow

from an improved understanding of why drug expectancy has such powerful and wide-ranging effects, and an understanding of what can be done to mitigate these effects.

Disclosure

The authors report no conflicts of interest in this work.

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