Dissociation Between Wanting and Liking: An Examination of the Incentive Sensitisation Theory in Human Substance Users

By

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BSc., GDipPsych

Thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

(Psychology)

Deakin University

July 2017
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This dissertation is dedicated to my beloved parents; I have no words to
acknowledge the sacrifices you made and the dreams you had to let go, just to
give me a shot at achieving mine.
Acknowledgements

While my name may be alone on the front cover of this dissertation, I am by no means its sole contributor. Rather, there are a number of people behind this piece of work who deserve to be both acknowledged and thanked.

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Publications


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I am grateful to the School of Psychology and Faculty of Health at Deakin University for supporting me and enabling me to present this research at the following conferences:


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<tbody>
<tr>
<td>UNODC</td>
<td>United Nations Office on Drugs</td>
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<tr>
<td>NIDA</td>
<td>National Institute on Drug Abuse</td>
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<tr>
<td>WDR</td>
<td>World Drug Report</td>
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<tr>
<td>WHO</td>
<td>World Health Organisation</td>
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<tr>
<td>IST</td>
<td>Incentive Sensitisation Theory</td>
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<tr>
<td>EMA</td>
<td>Ecological Momentary Assessment</td>
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<tr>
<td>I-EMA</td>
<td>Individualised Ecological Momentary Assessment</td>
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<tr>
<td>fMRI</td>
<td>Functional Magnetic Resonance Imaging</td>
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<tr>
<td>PET</td>
<td>Positron Emission Tomography</td>
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<tr>
<td>EEG</td>
<td>Electroencephalogram</td>
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<tr>
<td>PRISMA</td>
<td>Preferred Reporting Items for Systematic Reviews and Meta Analyses</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
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<tr>
<td>DAQ</td>
<td>Desires for Alcohol Questionnaire</td>
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<tr>
<td>DSQ</td>
<td>Desires for Speed Questionnaire</td>
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<tr>
<td>AUQ</td>
<td>Alcohol Urges Questionnaire</td>
</tr>
<tr>
<td>DEQ</td>
<td>The Drug Effects Questionnaire</td>
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<tr>
<td>STRAP-R</td>
<td>Sensitivity To Reinforcement of Addictive and other Primary Rewards</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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<tr>
<td>IAT</td>
<td>Implicit Association Task</td>
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<tr>
<td>MTurk</td>
<td>Mechanical Turk</td>
</tr>
<tr>
<td>HREC</td>
<td>Human Research Ethics Committee</td>
</tr>
<tr>
<td>PLS</td>
<td>Plain Language Statement</td>
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<tr>
<td>AUDIT-C</td>
<td>The Alcohol Use Disorders Identification Test (Consumption)</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal Digital Assessment</td>
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<td>MLM</td>
<td>Multi Level Regression</td>
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<td>MLLR</td>
<td>Multi Level Logistic Regression</td>
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<tr>
<td>DV</td>
<td>Dependent Variable</td>
</tr>
<tr>
<td>IV</td>
<td>Independent Variable</td>
</tr>
<tr>
<td>ICC</td>
<td>Interclass Correlation</td>
</tr>
<tr>
<td>DSM</td>
<td>The Diagnostic and Statistical Manual of Mental Disorders</td>
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<tr>
<td>ICD</td>
<td>International Statistical Classification of Diseases and Related Health Problems</td>
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Abstract

This thesis addressed the IST proposition that wanting and liking are two dissociable constructs of reward. Specifically, IST suggests that wanting and liking of addictive substances have the ability to dissociate over time and repeated substance misuse (i.e., substance addiction). This key tenet of IST is proposed to explain the transition from substance use to compulsive use, and the maintenance of substance misuse, in some individuals. However, limited studies have attempted to test the dissociation between wanting and liking in human substance users. Without this research it is difficult to establish the strength of the theory in human substance addiction behaviour. That is, whether the dissociation between wanting and liking is evident in humans across varying measures, levels of substance use and addictive substances. By systematically reviewing the human evidence for the dissociation between wanting and liking (Chapter 2), as well as conducting empirical studies of two different design types (cross-sectional [Chapter 3] and micro-longitudinal [Chapter 4]), this thesis sought to examine and test for the dissociation between wanting and liking.

Chapter 2 reviewed the existing literature testing the dissociation between wanting and liking in human substance users. The review illustrated that substance misuse or dependence is positively associated with wanting but not liking in 9/14 studies. These findings were demonstrated across different measures (self-report, implicit, behavioural and neurophysiological), different substances (alcohol, cocaine, amphetamines and a pharmaceutical drug- L-dopa) and various sample types (e.g., non-dependent/non-sensitised or dependent/sensitised). Although this evidence is partially supportive of IST, the direct test of one of the key tenets of IST is to test the increasing dissociation
between the two constructs over time and repeated substance use, yet only a limited number of studies in the review tested this, highlighting this as an area requiring further investigation.

Chapter 3 reports findings of empirical study one, a cross sectional study designed to test the increasing dissociation between wanting and liking in 285 alcohol drinkers and 134 coffee users, using the Sensitivity to Reinforcement of Addictive and other Primary Rewards (STRAP-R) questionnaire. This study indicated partial support for IST in alcohol users, though no support for IST in coffee users. Specifically, the strength of the relationship between wanting and alcohol consumption became stronger from low-risk to high-risk alcohol users. Conversely, the strength of the relationship between liking and alcohol consumption became weaker from low-risk to high-risk alcohol users, consistent with IST. These findings suggested that in high-risk alcohol users, wanting may play a greater role in alcohol consumption more so than liking compared to low-risk alcohol users. However, perhaps due to a lack of a clinically dependent sample, in this study, an increasing dissociation between wanting and liking was not illustrated across low-risk and high-risk alcohol users.

In Chapter 4, a unique momentary assessment protocol was used to test the dissociation between wanting and liking using a sample of 81 daily coffee users. The findings from this study illustrated some support for IST in coffee users, as coffee dependence was positively and significantly associated with wanting, but not liking. However, coffee dependence did not moderate the relationship between wanting and liking during coffee consumption. Nevertheless, this study established that subjective wanting and liking are both highly variable within subjects. Consequently, future research needs to take into
consideration the state-like properties and momentary confounds of these variables. As such, this study established that momentary designs are valuable when measuring wanting and liking.

Overall, the results from this thesis are partially consistent with IST. The results suggest that wanting and liking are separate processes and substance use/dependence may be associated with wanting but not liking. However, there is limited human evidence suggesting that the dissociation between wanting and liking increases following time and repeated substance use. This thesis may aid in the refinement of the theory and shed some light on how the dissociation should be tested in human populations in future.
Chapter One: General Introduction

1.1 Thesis Overview

Substance misuse is one of the most significant health, social and economic burdens in the world (United Nations Office on Drugs and Crime [UNODC], 2015). On an individual level, chronic substance abuse is associated with a series of negative consequences for one’s physical health, emotional wellbeing, personal and professional life (National Institute on Drug Abuse [NIDA], 2014). The social cost of illicit drug use is also significant in terms of crime, lost productivity and healthcare (World Drug Report [WDR], 2016). Given the substantial negative outcomes associated with substance misuse, a large amount of research has been directed towards understanding human substance addiction behaviour.

As such, many explanations of addiction have been proposed (Glass, 1991; Lowman et al., 2000; Robinson & Berridge, 1993; Stacey & Wiers, 2010; West, 2013). Addiction has been shown to be a multifaceted problem (Cami & Farre, 2003; Griffiths, 2005; Schaffer et al., 2004), caused by a complex interplay between biological, psychological and social factors (Berridge & Robinson, 2016; West, 2001; 2006). Although all factors are important, this thesis is focused on those that occur at the level of the individual, as they are informative for the refinement and development of clinical treatment and intervention. In particular, this thesis focuses on a biopsychological theory of addiction termed the Incentive Sensitisation Theory (IST; Robinson & Berridge, 1993).

IST provides a specific account of how substance misuse produces biological and psychological changes, which are responsible for the transition
from substance use to substance addiction (Robinson & Berridge, 1993). Specifically, this thesis examines a key component of IST. That is, wanting (the motivation to approach and obtain a reward [Robinson & Berridge, 2001; 2003]) and liking (the pleasure or hedonic enjoyment received after consuming a reward, [Robinson & Berridge, 2001; 2003]) are two independent constructs that operate according to separate underlying biological structures and processes (Berridge & Robinson, 2016). Robinson and Berridge (1993) argue that as substance addiction develops, the motivation to obtain and consume an addictive substance (i.e., wanting) can remain high even once the drug has become non-rewarding (i.e., less liked), which is consistent with reports of drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Berridge & Robinson, 1995; Grant et al., 2000; Hyman, 2007; Pickard & Ahmed, 2016). It is this symptom of addiction that many researchers have had difficulty trying to explain, and which IST intends to clarify.

Although this key claim of IST has been well tested using animal models (e.g., Berridge, Robinson & Aldridge, 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000), the evidence-base in human samples is less well developed (e.g., Evans et al., 2006; Goldstein et al., 2010; Hobbs, Remington, & Glaudier, 2005; Lambert et al., 2006; Ostafin, Marlatt & Troop-Gordan, 2010; Pieters et al., 2011). Moreover, there are some considerable concerns regarding the generalisability of animal studies to human substance addiction (Ahmed, 2010). Thus, the focus of this thesis is to first review the empirical human research and then build on the human evidence. Thus, this thesis adopts two broad aims:
To synthesize the already existing literature which investigates the dissociation between wanting and liking in human substance users.

To test the dissociation between wanting and liking directly in human substance users.

In this introductory chapter, a definition of addiction is briefly provided and past efforts to understand human addiction behaviour (i.e., theories and models) is summarised. Specific attention is then given to IST, with particular focus on a key tenet of IST, the dissociation between wanting and liking and its associated animal evidence. Chapter 2 consists of a systematic literature review on the human evidence base for the dissociation between wanting and liking. The specific aims of this review were to: (1) to examine the evidence for the dissociation between wanting and liking in human substance users. In light of the apparent diversity of methodological approaches used to address the dissociation in humans, another aim was to consider if and how measure choice, sample and addictive substance could impact on the overall findings of these studies. Thus, there were three subsidiary aims in the review: (1a) to report the types of measures used to assess wanting and liking (1b) to report the samples utilised in each of these studies and (1c) to report the various addictive substances utilised. Based on the review of the human evidence, it is argued that further studies are required to test the dissociation between wanting and liking in the literature.

Second, in order for IST to have clinical utility, a consistent self-report measure that examines wanting and liking is required in the literature. Finally, measuring wanting and liking in the moment (i.e., state) may offer evidence for the
dissociation between wanting and liking that is ecologically valid. These concepts were empirically tested across two studies, Chapters 3 and 4.

Specifically, Chapter 3 reports findings of study one, a cross sectional study designed to test the dissociation between wanting and liking in human alcohol and coffee users utilising the Sensitivity to Reinforcement of Addictive and other Primary Rewards (STRAP-R; Goldstein et al., 2010) questionnaire. In study two (Chapter 4) an Individualised momentary assessment protocol (I-EMA) was used to test the dissociation between wanting and liking across light and heavy coffee users. Data collection for the two studies was simultaneous such that data for study two were collected prior to data from study one being analysed.

Chapter 5 summarises the findings from the systematic literature review (Chapter 2 and the two empirical studies testing the dissociation between wanting and liking (Chapters 3 and 4). Additionally, it discusses what these findings mean, collectively, for IST and human addiction behaviour, and highlights clinical implications, thesis limitations and future research avenues.

1.2 Addiction Defined

Addiction has been referred to as the development and progression of compulsive drug-taking behaviour, which is often difficult to cease, takes precedence over alternate activities and can persist despite negative consequences (Redish, Jensen & Johnson, 2008; Robinson & Berridge, 2000). Furthermore, in an attempt to understand the behaviour Hyman (2007, p. 2) described it as a “diminished ability to control drug use, even in the face of factors that should motivate cessation… in a rational agent willing and able to exert control over behaviour”. Addiction encompasses substance dependence, which refers to a
normal adaptation to persistent exposure of an addictive substance, including tolerance and withdrawal characteristics (O’Brien, Volkow & Li, 2006).

This thesis relies heavily on the definitions of addiction described above as they both suggest that addicted individuals continue substance use even when the pleasurable effects of the substance no longer exist (Bechara, 2005; Grant et al., 2000; Hyman, 2007; Robinson & Berridge, 1993). In other words, the addictive substance is still craved or wanted, even when it is no longer rewarding (i.e., less liked). It is this symptom or characteristic (often referred to as a contradiction in addiction behaviour) of addiction that many researchers have found difficult to explain and will be the focus of this thesis. This contradiction along with other symptoms of addiction (such as craving and relapse) is important to understand especially for interventions and treatment as it suggests how once addicted, the maintenance of substance use is no longer a simple choice (Bechara, 2005; Grant et al., 2000; Hyman, 2007). That is, the continuation of substance misuse is partly controlled by something other than the pleasurable effects of the drug (Robinson & Berridge, 1993). However, not everybody who consumes an addictive substance develops an addiction (Robinson & Berridge, 2008). Therefore, an essential part of addiction research has been to explain how and why substance addiction develops and is maintained in some susceptible individuals.

1.3 Theories of Addiction

Many explanations of addiction have been proposed (See [Everitt & Robbins, 2016; Lowman et al., 2000; Robinson & Berridge, 1993; Stacey & Wiers, 2010; West, 2013], for an overview of theories and models). In 2013, West constructed a classification system with the intent to categorise the broad scope of
theories of addiction. Within this system, theories are classified according to one overarching theme: their level of explanation (see Figure 1.1). That is, they break theories into those that focus on individuals versus those that focus on populations. Individual based theories are centred on the individual and their circumstances (for example, the frequency of an individual’s substance use, an individual’s level of impulsivity, compulsivity, risk taking behaviour, abnormal drives, or their need to escape from an unpleasant state of mind). As such, the significant explanatory factors in these theories tend to be individual dispositions, surrounding environment and susceptibility. In contrast, theories focused on understanding addiction at the population level (e.g., overdose rates, prevalence, and drug-related crime) focus on social and economic variables such as policy, price and availability of drugs.
Figure 1.1. West's (2013) classification of models of addiction redrawn from the European Monitoring Centre for Drugs and Drug Addiction (EMCDDA; 2013)
To help conceptualise the key features of the multitude of theories, West (2001; 2006) argued that they could be thought of as pertaining to one or more explanatory domains: biological, social and psychological. The theories identified here all pre-suppose some biological substrate, but some theories make a stronger connection between behaviour and biology than others. Moreover, although some specific theories may focus exclusively on one domain, it is clear that at the level of the literature, addiction is a multifaceted behaviour influenced and maintained by a range of neurobiological and psychosocial factors (Cami & Farre, 2003; Griffiths, 2005; Schaffer et al., 2004).

Although population level theories make a valuable contribution to understanding addiction, this thesis is primarily concerned with understanding addiction at the individual level. Understanding addiction at this level is informative for the refinement and development of clinical intervention. In particular, this thesis will investigate the utility of IST; a theory of addiction well validated by animal models but less well tested using human samples.

IST is useful as it is a biopsychological theory, which integrates both neural adaptations (biological) and learned conditioned responses (psychological components) (Robinson & Berridge, 1993). These neural adaptations and learned conditioned responses have been illustrated in animal models. Consequently, the same processes are believed to also occur in human addiction behaviour (Robinson & Berridge 1993; 2000; 2003; 2008). Robinson and Berridge (2008) have reasoned that the mechanisms underlying IST do not solitarily lead to addiction. They believe that combinations of theories (i.e., biological, psychological, and environmental factors) play a role in the formation of substance use disorders. However, they do argue that IST is sufficient in
explaining some of the symptoms often presented in addiction behaviour (e.g., craving, relapse and the maintenance of substance use despite it being no longer rewarding).

1.4 The Incentive Sensitisation Theory

In order to explain the mechanisms underlying substance addiction behaviour, Robinson and Berridge (1993) devised a biopsychological theory of addiction, termed the Incentive Sensitisation Theory (IST). IST is an integrative theory of addiction that has been widely studied and applied within the field. The original review paper and subsequent updates of the review have been cited more than 5000 times (searched in Google Scholar) within the last 24 years. According to IST, addiction is a neurobiological process where permanent physical neurological changes in the brain (referred to as ‘neuroadaptations’ by Robinson and Berridge [1993]) are suggested to result from repeated substance use. It is these neuroadaptations that fundamentally underlie the transition from substance use to compulsive substance use (i.e., addiction) in susceptible individuals (Robinson & Berridge, 1993; 2000; 2001; 2003). Additionally, it is these neuroadaptations that explain some key features believed to be important in maintaining substance addiction behaviour.

Key features in substance addiction behaviour include craving (Drummond, 2001; Grusser, Morsen & Flor, 2006; Tiffany, Carter & Singleton, 2000) and relapse (Bottlender & Soyka, 2005; Flannery et al., 2001; Gordon et al., 2006). Craving refers to an intense urge to use an addictive substance (Grusser, Morsen & Flor, 2006). Drug craving has been a large focus of addiction research, particularly as it is believed to transform recreational drug-taking practices into compulsive drug-taking behaviour (Robinson & Berridge, 1993;
2000; 2001; 2003). Furthermore, resuming substance use after a period of abstinence (Flagel, Akil & Robinson, 2009) (i.e., relapse) is known to be a great challenge for the treatment of substance addiction (Flagel, Akil & Robinson, 2009; McLellan et al., 2000; Hser et al., 2001; Robinson & Berridge, 1993; 2000; 2001; 2003).

Another key feature of addiction behaviour that researchers have had difficulty explaining is the maintenance of drug use despite the adverse consequences it causes (Bechara, 2005; Grant et al., 2000; Hyman, 2007). During initial substance use (prior to addiction) addictive drugs produce positive feelings (i.e., pleasure), which ultimately encourage future use. However, when drug use transitions into compulsive drug use (i.e., addiction) the pleasurable effects of the drug often decreases (Fischman & Foltin, 1992; Katz & Goldberg, 1988; Lamb et al., 1991). This decrease in pleasure has often been related to a number of negative consequences that arise from maintaining substance use, such as: financial problems, work related issues and the loss of family and friends (Bechara, 2005; Grant et al., 2000; Hyman, 2007).

Craving, relapse, and the persistence (i.e., maintenance) of drug use despite adverse consequences are fundamental aspects of addiction that a good theory must explain. In other words, it is important for an individual level theory of addiction to address these questions: why do some substance users want or crave drugs so much? Why do drug cravings persist or can be easily returned long after the discontinuation of drug use for some individuals? And finally, why is it that some substance users continue to maintain drug use despite the apparent negative consequences often associated with the behaviour? The underlying mechanisms influencing these constituents of addiction are important to
understand. Some theories (e.g., learning theories) have only addressed these features individually, thus only addressing a part of the problem. However, Robinson and Berridge (1993) argue that these features must all be explained in order for any theory to adequately characterise human addiction behaviour. IST attempts to provide an explanation of these phenomena, and it is conceptualised within four distinct but related tenets. Together, these four tenets attempt to explain these three key features of addiction.

Robinson and Berridge (1993) argue that addictive substances can produce long lasting changes in certain neurological systems, called neuroadaptations (tenet one). The neurological systems affected by neuroadaptations include those that are usually involved in the process of incentive motivation and reward (tenet two). Through repeated drug use, these neurological systems become hypersensitive or sensitised to drugs and drug-associated stimuli (tenet three). Finally, liking for and wanting of drugs are dissociable constructs that are mediated by distinct neurological systems of the brain (tenet four). It is believed that when all four tenets are combined with impaired executive control over behaviour, which is suggested to result from drug induced prefrontal cortex dysfunction (Bechara, 2005; Schoenbaum & Shaham, 2008) incentive sensitisation turns into addiction behaviour (Robinson & Berridge 2000; 2003; 2008).

The focus of this thesis will be on tenet four. Tenet four offers an explanation of individuals’ continued drug use despite apparent negative consequences of the behaviour. However, in order to adequately explain tenet four, an overview of all four tenets is required. Thus, in the section below, an
overview of tenets one to three are presented. Following that is a detailed evaluation of tenet four specifically and its associated animal evidence.

1.4.1 Tenet one.

Robinson and Berridge (1993) argued that repeatedly taking addictive substances can produce long lasting molecular, cellular and neurochemical adaptations in certain neurobiological systems. It is these neuroadaptations that fundamentally underlie the transition from substance use to substance dependence (i.e., addiction) in certain individuals (Robinson & Berridge, 1993; 2000; 2001; 2003). They propose that these neuroadaptations are mediated in part by the mesotelencephalic dopamine projection systems. Specifically, dopamine projections to the nucleus accumbens and accumbens related circuitry, also known as the mesolimbic dopamine system. Due to the lasting effects of these neuroadaptations on the mesolimbic dopamine system (even long after discontinued drug use) individuals can be left susceptible to relapse (Robinson & Berridge, 1993; 2000; 2001; 2003; 2008). Thus, tenet one not only provides an explanation for substance dependence but also explains a major clinical problem in the treatment of addiction, relapse.

Consistent with this, animal studies have found strong evidence in support of this tenet (Bassareo et al., 2013; Di Chiara & Imperato, 1988, Mendez et al., 2009; Paulson, Camp & Robinson, 1991; Pierce & Kalivas, 1997; Stewart & Badiani, 1993; Vanderschuren & Kalivas, 2000). Studies have shown that addictive substances enhance mesotelencephalic neurotransmission (Di Chiara & Imperato, 1988; Wise & Bozarth, 1987) and acutely increase extracellular dopamine levels primarily in the nucleus accumbens (Di Chiara & Imperato, 1988). Similar findings were also found with the presentation of a morphine-
conditioned stimulus (Bassareo et al., 2013). The long lasting characteristic of these neuroadaptations has additionally been confirmed (Mendez et al., 2009; Paulson, Camp & Robinson, 1991; Pierce & Kalivas, 1997; Stewart & Badiani, 1993; Vanderschuren & Kalivas, 2000) where even months after drug exposure reward directed behaviour still persists (Mendez et al., 2009).

1.4.2 Tenet two and three.

Robinson and Berridge (1993) argue that the neurological systems changed from repeated substance use include those that are usually involved in the process of incentive motivation and reward. Incentive motivation refers to an external pull or drive, which acts by making a particular goal, objects or reward very attractive, and thus, wanted (Berridge, 1996).

Additionally, they argue that over time these neurological systems become hypersensitive or sensitised. That is, addictive substances stimulate neurobehavioral systems at a greater intensity than during initial use. Thus, the individual will acquire an increased level of level of wanting (i.e., craving) from drug use due to the dysregulation of dopamine neurotransmission, which in turn amplifies dopamine release. This amplification of wanting is much more intense than when the drug was used initially or prior to sensitisation.

Once this has occurred it can also increase the chances of previously neutral cues (e.g., beer bottle or a particular context) becoming conditioned to lead to an approach response (e.g., wanting / craving). This process is called incentive salience and it explains how through classical conditioning, an otherwise neutral cue changes into an incentive stimulus, which elicits a strong approach response (Berridge, 1996; Berridge & Robinson 1998; Robinson & Berridge, 1993) also known as motivational wanting.
It is predicted that this mechanism of incentive salience or motivational wanting directed towards reward predicting stimuli is related to drug taking behaviour in humans, where drugs and drug related stimuli have the ability to gain incentive value through time (Robinson & Berridge 1993; 2000; 2001; 2003). In other words, drug-associated stimuli become linked with the rewarding aspects of the drug, as such, the stimuli can also trigger craving just as much as the substance itself. The activation of sensitised neurobiological systems that attribute incentive salience to drugs and drug related stimuli could manifest through behaviour implicitly, as unconscious wanting (Berridge & Winkielman, 2003; Robinson & Berridge, 2001) and produced behaviourally or explicitly through conscious craving (e.g., motivation to purchase a wanted substance can be considered a behavioural manifestation of this).

It is important to note that this process of sensitisation differs from other processes found to exist in addiction behaviour such as tolerance. Sensitisation results in pathological levels of incentive salience being attributed to drugs and drug-associated cues (Robinson & Berridge 1993; 2000; 2001; 2003). Tolerance refers to taking a higher dose of an addictive substance to achieve the same level of response (Griffiths, 2005; Robinson & Berridge, 1993). In other words, sensitisation means that one might crave the drug more, whereas tolerance means they need more of the drug to get the same physiological effect.

Sensitisation of reward systems (associated with incentive salience) via repeated drug use has been illustrated in animals through a number of behavioural paradigms such as: the search and self-administration of psychostimulant drugs (Deroche, Le Moal & Piazza, 1999; Horger, Giles, & Schenk, 1992; Horger, Shelton, Schenk, 1990; Lorraine, Arnold, & Vezina, 2000; Mendrek, Blaha, &

Conditioned place preference occurs when an animal comes to prefer one place to another because the preferred location has been previously paired with rewarding stimuli (i.e., an addictive substance). Thus, sensitisation to an addictive substance (such as cocaine, amphetamine, and morphine) is manifested as time spent in the location increases (Gaiardi et al., 1991; Lett, 1998; Shippenberg et al., 1996). The point at which animals responding to a drug or (other rewards) on a progressive ratio schedule of reinforcement cease to respond (Clark & Bernstein, 2006) is known as breakpoint and a progressive increase in this is believed to be associated with sensitisation (Lorraine, Arnold, & Vezina, 2000; Mendrek, Blaha, & Phillips, 1998). Together, the studies presented above demonstrate that repeated substance use sensitises specific neural systems responsible for the attribution of incentive salience (or motivational wanting) to reward-related stimuli.

In sum, tenets one, two and three fundamentally explain certain aspects of addiction behaviour. For example, tenet one suggests that repeatedly taking addictive substances leads to neuroadaptations that foster substance dependence. Furthermore, due to the lasting effects of these neuroadaptations even long after discontinued drug use individuals can be left susceptible to relapse. Tenet two and
three suggests that drug associated stimuli become linked with the rewarding aspects of drugs can also trigger craving just as much as the substance itself, again fostering relapse in susceptible individuals. Finally, we turn to tenet four, which explains how substance users often still crave or want addictive substances, even when they are no longer rewarding.

1.4.3 Tenet four.

Robinson and Berridge (1993) make a distinction between ‘liking’ and ‘wanting’. Liking has been defined as the pleasure or hedonic enjoyment received after consuming a reward (Robinson & Berridge, 1993; 2000; 2001; 2003). Wanting refers to the incentive salience that motivates obtaining a reward (Robinson & Berridge, 1993; 2000; 2001; 2003). The two constructs are predicted to be structurally and functionally distinctive from one another (Berridge & Robinson, 2016). It is posited that the mesolimbic dopamine system is involved in the process of attributing incentive salience or motivational wanting to reward predicting stimuli, whereas, other brain systems are responsible for liking processes (Robinson & Berridge, 1993; 2000; 2001; 2003).

The dissociation between liking and wanting is believed to have direct implications to substance addiction behaviour. Specifically, although during initial drug use, an individual may simultaneously want the drug and find its use rewarding, over time and repeated use the motivation to obtain and consume drugs can remain high even once the drug has become non-rewarding (less liked) (i.e., the two constructs become increasingly dissociated (Berridge & Robinson, 2016), see Figure 1.2, a schematic illustration of the relationship between wanting and liking over time).
In other words, initially wanting and liking tend to co-occur. Over time, neural sensitisation occurs (consistent with processes outlined in tenet two) and only targets the neural systems that mediate incentive salience or wanting, thus wanting increases excessively which behaviourally manifests into conscious pathological craving and the drug itself becomes less liked (Miller & Goldsmith, 2001). Tenet four explains why substance users often continue to maintain drug use despite the negative consequences, such as the loss of family members, poor health, and financial difficulties and even when no pleasure from the drug can be obtained (Bechara, 2005; Berridge & Robinson, 1995; Grant et al., 2000; Hyman, 2007). Thus, it is the psychological process of incentive salience that is responsible for an individual’s drug seeking and drug taking behaviour (i.e., drug wanting) (Robinson & Berridge 2000).
Although each tenet contributes to the overall understanding of human addiction behaviour, tenet four is the particular focus of this thesis. Not only does tenet four provide an explanation for the transition from recreational drug use to compulsive drug use (i.e., when substance use no longer becomes liked but still wanted), the tenet aims to provide an explanation for the maintenance of substance use in some individuals despite the negative consequences the behaviour brings, a contradictory symptom of addiction, many researchers find difficult to explain.

1.5 Evidence for the Dissociation in Animal Models

Over the last 100 years, animal studies have been crucial to the addiction research field (See Koob & Simon, 2009; Lynch et al., 2010 for a review of animal models). These studies allow for the control of numerous variables in a contained environment in a way that would not be possible with human participants. They also allow for the manipulation of certain brain systems and thus assist in identifying specific changes in behaviour. Given this, the primary form of evidence for tenet four comes from animal studies. The evidence has been developed from studies predominantly using natural rewards (i.e., food). This next section will examine animal models that have examined tenet four.

1.5.1 The assessment of liking in animal models.

The behavioural operationalisation of liking has been exclusively based on the taste reactivity test devised by Grill and Norgren (1978). Based on this work, liking has been conceptualised as the number of times an animals tongue protrudes outwards or the number of times lip licking occurs in response to a palatable food (Berridge & Robinson, 1989; Clark & Bernstein, 2006, Berridge, Robinson & Aldridge, 2009; Wyvell & Berridge 2000). These specific facial
reactions have been found to be controlled by a number of areas in the brain related to hedonic impact (i.e., liking) (Berridge, Robinson & Aldridge, 2009). Such brain systems include the opioid neuronal network in the rostro-dorsal medial shell region of the nucleus accumbens and the ventral pallidum (Berridge, Robinson & Aldridge, 2009; Berridge & Kringelbach, 2008; Ikimoto, 2007; Kringelbach, 2010; Mahler, Smith & Berridge, 2005; Smith, Mahler, Pecina & Berridge, 2010; Steiner, Glaser, Hawilo & Berridge, 2001). Thus, taste reactivity tests are believed to ultimately assess hedonic impact (i.e., liking) of a food reward by measuring affective facial reactions elicited by a particular stimulus (e.g., sucrose) (Robinson & Berridge, 2000). Despite this widespread belief, the way in which liking is captured in animal models is limited. That is, taste reactivity tests are highly subjective as researchers need to distinguish whether facial reactions are either appetitive or aversive. Practically the technique is labour intensive as it requires test subjects to be individually recorded and the video images hand-scored while being played back in slow motion. Moreover, taste reactivity is typically restricted to a very small timing of consumption and thus tend to provide only a glimpse of any hedonic reaction rather than one that naturally tracks across time.

1.5.2 The assessment of wanting in animal models.

A number of measures have been developed to assess wanting in animals. They all generally involve the motivation to approach or consume rewards (i.e., food) or reward related stimuli. The most popular methods to assess wanting in animal models has been to measure the frequency of some behavioural response that leads to the presentation of the wanted stimulus; for example, the number of lever presses in return for a food reward (Wyvell & Berridge, 2000). Another
means of assessing wanting is the ‘runway’ task (Pecina et al., 2003). In this task, animal behaviours are observed as the animal moves from a start box to a goal box where a specific reward existed. Motivation is measured via the length of time it takes animals to reach the goal box or a count of hesitations or reversals that occur whilst getting to the goal box. A highly motivated animal will quickly make its way towards the goal box without hesitations or reversals. A study by Wilson and colleagues (2006) has demonstrated that wanting can also be assessed via the use of anticipatory errors (the number of trials per session rats withdrew their nose from a nose-poke hole before the presentation of a conditioned stimulus), reaction time (the time taken for rats to remove their nose from a nose-poke hole following conditioned stimulus presentation) and reward collection latency (the time taken for rats to lick the lever to trigger reward delivery after removing their nose from the nose-poke hole).

1.5.3 The dissociation in animal models.

Multiple lines of animal evidence have supported the proposition that liking and wanting are separate constructs that arise from separate neurological process. Some studies have established this dissociation via neurological scans (See Berridge, Robinson & Aldridge, 2009), some through the manipulation of the mesocorticolimbic dopamine system (Berridge, Venier & Robinson, 1989; Berridge & Robinson, 1998; Berridge 1996; Galverna et al., 1993; Berridge & Valenstain, 1991; Berridge & Zajonc, 1991; Pecina et al., 2003; Wyvell & Berridge, 2000), and others through manipulating the extent to which rats crave salt (Clark & Bernstein, 2006).

First, neurological imaging studies have investigated the dissociation by examining differences in brain activity characterising wanting (Abler, Erk &
Walter, 2007; Aragona & Carelli, 2006; Salamone, 2005; Smith, Berridge, Tindell et al., 2005; Volkow et al., 2006) versus liking (Berridge, Robinson & Aldridge, 2009; Berridge & Kringelbach, 2008; Ikimoto, 2007; Kringelbach, 2010; Mahler, Smith & Berridge, 2007; Smith & Berridge, 2005; Smith, Mahler, Pecina & Berridge, 2010; Steiner, Glaser, Hawilo & Berridge, 2001). These studies have indicated that liking maps onto a distinct neuroanatomical and neurochemical brain reward system (Berridge, Robinson & Aldridge, 2009; Pecina, 2008) from those brain systems related to wanting. Specifically, the opioid neuronal network in the rostro-dorsal medial shell region of the nucleus accumbens and the ventral pallidum are said to be associated with liking (Berridge, Robinson & Aldridge, 2009; Berridge & Kringelbach, 2008; Ikimoto, 2007; Kringelbach, 2010; Mahler, Smith & Berridge, 2007; Smith & Berridge, 2005; Smith, Mahler, Pecina & Berridge, 2005; Steiner, Glaser, Hawilo & Berridge, 2001) and the dopamine and dopamine interactions with corticolimbic glutamate and other neurochemical systems are said to be associated with wanting (Abler, Erk & Walter, 2007; Aragona & Carelli, 2006; Berridge, Robinson & Aldridge, 2009; Salamone, 2005; Tindell et al., 2005; Volkow et al., 2006). These different patterns of activity associated with each construct are consistent with the notion that they are separable processes.

Second, this dissociation between wanting and liking has also been illustrated via studies that have been able to manipulate the mesocorticolimbic dopamine system (those systems involved in attributing incentive salience or motivational wanting to reward predicting stimuli) in order to examine whether levels of wanting and liking can change after such manipulation. For example, Pecina and colleagues (2003) were able to find dissociation with the use of mice
with elevated levels of synaptic dopamine (mutant mice). This study utilised a ‘runway task’ to assess wanting and a taste reactivity test to assess liking. The results of this study showed that these mutant mice in comparison to wild-type mice attributed greater incentive salience (wanting) to a sweet reward in the runway test, however did not show an increase in the palatability of sweet reward (liking). Again, they argued this lack of correlation between change in wanting and liking was explained by the dissociability of the two psychological constructs, liking and wanting. Furthermore, Wyvell and Berridge (2000) have shown that after promoting sensitisation through mesolimbic activation, increased cue triggered wanting for sucrose reward occurred with no increases in positive hedonic liking of sucrose (illustrated via taste reactivity patterns). Similar dissociations between wanting and liking have also been found after lesions (e.g., Berridge 1996; Berridge, Venier & Robinson, 1989; Berridge & Robinson, 1998; Galverna et al., 1993), electrical stimulation (Berridge & Valenstain, 1991) and cooling (Berridge & Zajonc, 1991) to the dopamine system and its related structures in various animals.

Finally, salt depleted rats have also been used to assess this dissociation (Clark & Bernstein, 2006). Salt depleted rats are sensitised to salt and thus have a strong craving for it. This was displayed behaviourally through a strong motivation to seek, obtain and ingest salt. Wanting was assessed via breakpoint: the point at which animals stop responding for rewards (in this case, provision of salt) via lever pressing on a progressive ratio schedule of reinforcement. A higher breakpoint was indicative of greater wanting. This study concluded that although wanting of salt increased there was no increase in the palatability of salt (liking).
assessed via facial reactivity, suggesting dissociation between wanting and liking (Clark & Bernstein, 2006).

Robinson and Berridge make the assumption that these animal studies may generalise to human addiction behaviour (the focus of this thesis). However, given the concerns some researchers have put forward regarding the generalisability of animal studies of addiction (detailed in the section below), it is important to evaluate the theory’s utility in human populations directly rather than exclusively through animal models.

This leads us to question—why did the brain evolve separate wanting and liking mechanisms for the same reward? One explanation put forward by Berridge (2001) is that, originally, wanting might have evolved first as a basic form of goal directedness to pursue particular incentives even before the experience of their hedonic effects (i.e., liking). Later, as liking evolved, wanting spread to learned stimuli associated with liked rewards (Berridge, 2001). The important point is that wanting and liking normally go hand in hand, but they can be split apart under certain circumstances, especially by certain brain manipulations.

1.6 Limitations of Animal Models

Although animal evidence utilising food as rewards tends to support the key claims of tenet four (i.e., the dissociation between wanting and liking), it is not clear that the same processes necessarily operate in humans and that the same processes are the main factors explaining human addiction behaviour. In particular, there are two main areas of concern outlined by Ahmed (2010) when generalising animal findings to human drug addiction behaviour. First, humans possess higher cognitive processes than animals. Second, in contrast to many animal studies, humans make a choice to self-administer drugs, usually with no
limits to drug amount or time of next use. All of these factors may play an
important role in processes relating to substance use and maintenance; however,
they are not necessarily adequately addressed in animal models tested in a
laboratory setting.

Despite the similarities animals have to humans on a physiological and
anatomical level, animal models utilised in addiction research do not capture the
social, higher cognitive and personal factors that may operate in humans, which
may influence substance use and maintenance (Ahmed et al., 2010; Lynch et al.,
2010). Social factors such as family (Galea et al., 2004; Whitesell et al., 2013),
friends (Sheridan et al., 2009; Sherman et al., 2008; Whitesell et al., 2013,
education (Haider et al., 2009), culture, laws, group norms (Dew et al., 2007;
Watts & Rabow, 1983), religion (Jones & Rossiter, 2008) and finances (Levy &
Sheflin, 1985) have all been shown to influence an individual’s drug seeking and
drug taking behaviour. Even though IST does not claim to address these social
factors, whether these factors influence an individual’s level of wanting for and
liking of an addictive substance remains unknown. Thus, findings from animal
models may not be generalised so easily to humans.

Moreover, in a laboratory animals are often administered drugs, however
this is not similar to human drug taking practices where drugs are often self-
administered and a choice to use exists (Lynch et al., 2010). Although
experimenter administered drugs are often used in animal models and have
provided much information on how repeated substance use effects neuronal
function, a fundamental aspect of addictive behaviour is an individual’s choice,
drug seeking and drug taking behaviour (i.e., amount used and time of the next
use) (Steketee & Kalivas, 2011). Natural human drug taking practices are
administered on an individual level where often substance users spend most of their time searching for their drug of choice and having the independence to use freely (or not use) (Ahmed et al., 2010; Lynch et al., 2010). Given this, it is possible that self-administering drugs can influence levels of neural sensitisation and consequently affecting the incentive properties of drugs and drug associated stimuli.

1.7 Chapter Summary

As detailed above there are some considerable concerns when generalising animal models to human substance addiction behaviour. In sum, given that animal models are similar to humans on a physiological level, these processes found in animal models may generalise to humans; however, the extent to this generalisation may be limited. Further to this, it is unknown whether the same underlying processes will occur when examining the dissociation between wanting and liking with the use of addictive substances given that animal studies have primarily used food as rewards. Thus, it is important to test this tenet directly with human participants and addictive substances, to ultimately compliment the already existing animal evidence base with direct human research.

To date the supporting literature for the dissociation between wanting and liking is primarily based on animal studies mostly using food as reward cues (Berridge, 1996; Berridge and Robinson, 2003). The assumption being that these findings may generalise to human substance addiction behaviour. Moreover, the dissociation between wanting and liking in humans is restricted in two ways. First, only a limited amount of studies have examined the dissociation between the two constructs in human substance users (e.g., Evans et al., 2006; Goldstein et
Second, the evidence includes varying methodology, samples and addictive substances when examining both constructs. Given this, it is difficult to comment on the validity of the dissociation between wanting and liking in human populations. The next step is to evaluate the theory’s utility in human populations directly rather than exclusively through animal models. Thus, the following chapter (Chapter 2) addresses this by systematically reviewing the human evidence base for the IST claim that wanting and liking are two distinct psychological components of reward that become dissociated over time and repeated substance use.
Chapter Two: Systematic Literature Review Examining the Human Evidence for the Dissociation between Wanting and Liking

2.1 Introduction

2.1.1 Rationale.

In order to explain the mechanisms underlying substance addiction behaviour, Robinson and Berridge (1993) devised a biopsychological theory of addiction, termed the Incentive Sensitisation Theory (IST). Robinson and Berridge (1993) argue that addictive substances can produce long lasting changes in certain neurological systems, called neuroadaptations (tenet one). The neurological systems affected by neuroadaptations include those that are usually involved in the process of incentive motivation and reward (tenet two). Through repeated drug use, these neurological systems become hypersensitive or sensitised to drugs and drug-associated stimuli (tenet three). Finally, liking for and wanting of drugs are dissociable constructs that are mediated by distinct neurological systems of the brain (tenet four). It is believed that when all four tenets are combined with impaired executive control over behaviour, incentive sensitisation turns into addiction behaviour (Robinson & Berridge 2000; 2003; 2008). Although each tenet of IST contributes to the overall understanding of human addiction behaviour, tenet four provides an explanation for the transition from recreational drug use to compulsive drug use (i.e., when substance use no longer becomes liked but still wanted). Moreover, tenet four aims to provide an explanation for the maintenance of substance use in some individuals despite the negative consequences the behaviour brings, a contradictory symptom of addiction, many researchers find difficult to explain.
Specifically, tenet four suggests that as substance dependence develops, wanting for a substance increases as liking for it decreases (i.e., they dissociate over time and with repeated substance use). The evidence in support of the independent nature of wanting and liking has come from a range of animal studies (Berridge, Robinson & Aldridge, 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000) (see Chapter 1). However, there are some considerable concerns when generalising animal models to human substance addiction behaviour. In sum, given that animal models are similar to humans on a physiological level, these processes found in animal models may generalise to humans; however, the extent to this generalisation may be limited. Further to this, it is unknown whether the same underlying processes will occur when examining the dissociation between wanting and liking with the use of addictive substances given that animal studies have primarily used food as rewards. Given this, the next step is to evaluate the theory’s utility in human populations directly rather than exclusively through animal models. Thus, a synthesis of the current human evidence regarding the dissociation between wanting and liking is required. The overall aim of this chapter is to review the human evidence-base for the IST claim that wanting and liking are two distinct psychological components of reward that become dissociated over time and repeated substance use.

The dissociation between wanting and liking in humans has received some support, however the methodology used varies considerably. Given that some measures (e.g., self-report, implicit measures, behavioural measures and neurophysiological measures) may be more or less valid, some samples (e.g., risky substance users, recreational users, dependent users) and addictive substances (e.g., alcohol, cocaine and nicotine) may show greater dissociation
between wanting and liking, it is important to evaluate the consistency of the overall level of support for tenet four. Thus, it is worthwhile to conduct a review that synthesises the findings across different studies to make a clear conclusion about the dissociation between wanting and liking in human populations.

Currently there is no review synthesising the human evidence regarding the dissociation between wanting and liking. Recently Pool and colleagues (2016) systematically reviewed studies of wanting and liking for a range of rewarding behaviours (e.g., food, addictive substances, sex, attractiveness and money) in human populations. The aim of this review was to describe systematically the methodology used across studies investigating human reward (this review differed from the current review as it did not examine the dissociation between wanting and liking in human substance addiction behaviour specifically). Pool and colleagues (2016) included 84 publications using a stringent criteria in their review, including studies that: (i) explicitly aimed to measure wanting and/or liking and (ii) gave specific reference to IST. The review reported on the type of sample, study and reward used to examine wanting and/or liking.

Specifically, the review found that the majority of the studies (55.55%) investigated wanting and/or liking in healthy humans. A large proportion (25.55%) investigated wanting and/or liking in individuals reporting substance misuse; a proportion (11.11%) targeted a population reporting problematic eating behaviour, mostly related to excessive food consumption (e.g., overeating, bulimia, binge eating); and a smaller proportion of studies (3.33%) extended this investigation to behavioural addiction such as excessive videogame playing or gambling. Finally, a small proportion of studies (4.44%) measured wanting and/or
liking in populations reporting psychopathologies such as schizophrenia and depression.

Moreover, physiological studies (e.g., mobilized effort, electromyography, food or drug administration) represented the largest proportion (53.57%) of studies investigating wanting and/or liking in human populations. Neurobiological studies (e.g., Functional Magnetic Resonance Imaging (fMRI), Positron Emission Tomography (PET), Electroencephalogram (EEG), brain lesions) also represented a large proportion of the selected studies (30.95%). Behavioural (10.71%) and survey/questionnaire (4.76%) studies were less frequent.

Most of the methodological procedures in the studies measured wanting and/or liking for food reward (52.79%). Studies measuring wanting and/or liking for addictive substances (e.g., cocaine, alcohol, nicotine), was relatively frequent (17.25%). Less frequent were studies measuring wanting and/or liking for money (7.61%), erotic/attractive stimuli (8.12%), pleasant touches (1.01%) or pleasant activities (e.g., video gaming, physical activity; 2.53%).

The number of studies included in the review by Pool et al, (2016) suggests that there is a great deal of interest in testing IST in humans among researchers. The review also illustrated that most human studies have integrated key elements of IST in their methodological procedures. In other words, most studies operationalised wanting and liking in congruency with the animal literature. This is of importance as IST was formulated on the basis of an animal model (Robinson & Berridge, 1998, 2003). However, there were some studies included in the review that did not reflect wanting and liking as defined by Robinson and Berridge (1993) in the animal literature. These studies are suggested to generate confusion about wanting and liking constructs and
consequently may represent the source of the contradictory findings in relation to the dissociation between wanting and liking in the human experimental literature. However, the focus of the review by Pool et al. (2016) was not on the dissociation between wanting and liking. Moreover it did not examine wanting and liking processes precisely in human addiction behaviour. Given the substantial negative outcomes associated with substance misuse in humans, the overall aim of this systematic review was to:

(1) Examine the evidence for the dissociation between wanting and liking in human substance users.

In light of the apparent diversity of methodological approaches used to address the dissociation in humans, another aim was to consider if and how measure choice, sample and addictive substance may influence the findings of these studies. Thus, there were three subsidiary aims:

(1a) To report on the types of measures used to assess wanting and liking.

(1b) To report on the samples utilised in each of these studies.

(1c) To report on the various addictive substances utilised.

2.2 Method

2.2.1 Inclusion criteria.

In order to examine the dissociation between wanting and liking in human substance users, this review adopted a similar inclusion criteria presented by Pool (2016):

1. The article had to be published in a peer-reviewed journal and written in English
2. The article had to report original data collected from a human population between January, 1990 (Robinson and Berridge introduced IST in their first publication in 1993) and May, 2017.

3. The study had to have measured both of the constructs of interest (i.e., “wanting”, “incentive salience”, “incentive motivation”, “craving”, “motivational wanting” AND “liking”, “pleasure”) with an explicit reference to IST (e.g., Berridge & Robinson, 1998; 2003; Robinson & Berridge, 1993; 2003).

2.2.2 Literature search strategy.

This systematic literature review was carried out in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement guidelines (Liberati et al., 2009). Papers were identified by searching electronic databases, PsycINFO and MEDLINE. All available records were searched starting from January 1990 until May 2017, using the following combination of keywords in the title or abstract of the article: (“incentive salience” OR “wanting” OR “motivational wanting” OR craving OR urge OR desire OR “drug craving” OR “substance craving” OR “salience attribution” OR “stimulus salience” OR “appetitive” OR “appetitive drive”) AND (liking OR pleasure OR “enjoy*” OR reward*) AND (“addict*” OR “dependen*” OR “substance dependen*” OR “substance addict*” OR “substance related disorder*” OR “substance use disorder*” OR “drug addict*” OR “drug depend*” OR “drug abus*” OR “addictive behavi*” OR “addictive disorder*” OR “behavi* addict*” OR “compulsive behavi*” OR alcohol OR smoking OR cocaine OR “amphetamine*” OR “opiate*” OR nicotine OR heroin OR cannabis OR marijuana.

After the removal of duplicates, 578 unique articles were obtained.
Abstracts were read to assess whether each article met the inclusion criteria. During this process, 540 papers did not meet the inclusion criteria and were removed. These papers included 479 papers that did not relate to wanting and/or liking, 4 papers that only examined liking (without wanting), 44 papers that only examined wanting (without liking), 13 papers that examined rewards other than addictive substances (e.g., food). This left 38 possibly relevant papers, which were read in full whilst applying the inclusion criteria to each paper. During this review process a further 25 papers were excluded as there was no explicit reference to examining IST in the paper. The remaining 13 papers included were identified as being relevant to the review. A manual search for additional papers was conducted by examining the reference lists of identified papers. From this, an additional paper was acknowledged as being relevant. In total, 14 papers were included in this systematic literature review.
Figure 2.1. Flow diagram illustrating the selection process for the systematic review of the literature.

1. Literature search:
   Databases: MEDLINE and PsycINFO

2. Search results combined after duplicates removed (n = 578)

3. Papers screened on basis of title and abstract:
   Excluded (n = 540)
   - Papers not relating to wanting and/or liking (n = 479)
   - Papers only examining liking (n = 4)
   - Papers only examining wanting (n = 44)
   - Papers that examined rewards other than addictive substances (n = 13)

4. Included (n = 38)

5. Papers screened on basis of full manuscripts:
   Excluded (n = 25)
   - Papers not giving an explicit reference to IST (n = 25)

6. Included (n = 13)

7. Papers identified from reference lists of included papers (n = 9)

8. Papers screened on basis of full manuscripts:
   Excluded (n = 8)
   - Papers not giving an explicit reference to IST (n = 8)

9. Included (n = 1)

10. Included (n = 14)
2.2.3 Data extraction.

For each of the selected articles, different aspects of the study are summarised (see Table 2.1 for an overview). First, the way in which wanting and liking are measured (e.g., self-report, behavioural, implicit or neurophysiological measuring tools) has been characterised. Second, the type of sample that the study investigated (i.e., the study authors may have been interested in a sample of light substance users, heavy/risky substance users, or dependent substance users) has been specified. Third, the target addictive substance used in each study (e.g., alcohol, cocaine, nicotine) has been stated. Fifth, when the measure was taken during the experimental procedure (i.e., before during or after substance use) has been described (if relevant). And finally, the findings in relation to the dissociation between wanting and liking are detailed.

In addition, whether studies included in this review are consistent (or inconsistent) with IST has been summarised (see Table 2.2 for an overview).

2.3 Results

Nine out of fourteen of the included studies were somewhat supportive of the key claim of tenet four. That is, these studies individually provided some support for the dissociation between wanting and liking. However, as expected, this literature was characterised by considerable heterogeneity in terms of the measures used as well as the samples and substances studied. In this respect, it was not tenable to conduct a meta-analytic review. A detailed presentation of the evidence relevant to tenet four: the dissociation between wanting and liking is first presented below. Subsequent to this, the measurement of wanting and liking, the samples and addictive substances used in each study are also reported.
2.3.1 The Dissociation in human substance users.

The way in which the dissociation between wanting and liking was tested across the 14 studies included in this review varied considerably. The majority of studies ($N=9$) utilised analysis of variance (ANOVA), few used regression analyses ($N=3$), correlations ($N=3$) and t-tests ($N=1$). Specifically, ANOVA’s were used to determine whether there were any statistically significant differences between the means of wanting and liking across groups of substance users (e.g., light to heavy or not dependent to dependent) (Goldstein et al., 2010; Hobbs, Remington & Glautier, 2005; King et al., 2011; Lambert et al., 2006; Rose et al., 2010; Tibboel et al., 2011; Tibboel et al., 2015; Wiers et al., 2002; Willner et al., 2004). Regression analyses were used to examine the relationship between wanting, liking and substance dependence/substance use (Kalapatapu et al., 2012; Ostafin, Marlatt & Troop-Gordan, 2010; Pieters et al., 2011). Correlation analyses were utilised in various ways across studies. Specifically, Goldstein et al., (2010) examined the relationship between wanting and liking across varying levels of substance-users (i.e., non-users and dependent users). Evans et al., (2006) examined the relationship between neural localisation and wanting and liking responses. Ostafin, Marlatt and Troop-Gordan (2010) used partial correlations to examine whether liking and wanting predicted unique variance of substance consumption. Finally, Small et al., (2009) utilised a repeated measures t test to establish the changes in wanting and liking between early and present substance use.

Of the 14 studies included in this review, nine reported findings that were consistent with IST (See Table 2.2 for an overview). Most studies have illustrated that substance use or dependence is associated with wanting but not liking (e.g.,
Evans et al., 2006; Hobbs, Remington & Glaubier, 2005; Lambert et al., 2006; Ostafin, Marlatt & Troop-Gordan, 2010; Pieters et al., 2011; Rose et al., 2010; Small et al., 2009; Wiers et al., 2002). For instance, Pieters and colleagues (2011) have examined the dissociation between wanting and liking with a sample of alcohol drinkers ranging in their alcohol use experience. Wanting was illustrated in participants by a genetic marker dopamine D4 receptor gene-DRD4, which has been linked to subjective craving after having a few alcoholic drinks. And, liking was illustrated by mu-opioid receptor gene-OPRM1, which has been linked to increases in affective reactions following alcohol consumption (Ray & Hutchinson, 2004). Results of this study indicated that there was a relationship between attentional bias and alcohol consumption in the adolescent OPRM1 group and a relationship between attentional bias and alcohol consumption in the young adult DRD4 group. It was proposed that an attentional bias for alcohol is related most strongly to liking and wanting in early adolescents, while in young adults, an attentional bias may reflect wanting. That is, prolonged substance use was associated with wanting but not liking. Although this (and findings of other studies) provides some support for IST, it does not directly test the dissociation between wanting and liking.

That is, the strongest test of the theory is to test the proposition that wanting and liking will become increasingly dissociated as a result of repeated drug use (i.e., the relationship between wanting and liking should increasingly separate over time and repeated substance use). A few studies have examined this proposition in this manner (e.g., King et al., 2011; Lambert et al., 2006; Small et al., 2009), however, findings are varied (i.e., some are supportive [Lambert et al., 2006; Small et al., 2009] and others are not [King et al., 2011]).
Overall, 9 studies included in this review illustrate that the maintenance of substance use is predominantly driven by wanting (and not liking) in some susceptible substance users, consistent with IST.

Moreover, five studies (out of 14) have failed to support the contention that wanting and liking are dissociable constructs (e.g., Kalapatapu et al., 2012; King et al., 2011; Willner et al., 2005; Tibboel et al., 2011; Tibboel et al., 2015). Specifically, studies have illustrated that substance use/dependence is associated with both wanting and liking (King et al., 2011; Willner et al., 2005; Tibboel et al., 2011), both wanting and liking decreased as a function of dependence/use (Tibboel et al., 2015) and both wanting and liking remained the same regardless of substance use/dependence (Kalapatapu et al., 2012). Despite 9/14 studies supporting tenet four of IST, overall, studies from this review suggest that the findings are not unanimous.

2.3.2 Measures Used to Assess Wanting and Liking.

There is a high level of variability in the measurement of wanting and liking in humans. The most common type of measure used to assess wanting and/or liking was self-report (11/14 papers reviewed). A few studies employed non-self-report measures (e.g., implicit, neurophysiological and behavioural). Specifically, wanting and liking have also been assessed using implicit measures (3/14 papers) and neurophysiological methods (1/14 papers). Moreover, wanting has been assessed using behavioural measures (1/14) (see Table 2.2 for an overview).
Table 2.1 *Frequency (in percentage) of the measure, sample and target addictive substance of studies investigating the dissociation between wanting and liking in human substance users*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Descriptor</th>
<th>N</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure</td>
<td>Self-report</td>
<td>11</td>
<td>78.57</td>
</tr>
<tr>
<td></td>
<td>Implicit</td>
<td>3</td>
<td>21.43</td>
</tr>
<tr>
<td></td>
<td>Behavioural</td>
<td>1</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>Neurophysiological</td>
<td>1</td>
<td>7.14</td>
</tr>
<tr>
<td>Sample</td>
<td>Low-risk/ light users</td>
<td>6</td>
<td>57.14</td>
</tr>
<tr>
<td></td>
<td>High-risk/ heavy users</td>
<td>6</td>
<td>57.14</td>
</tr>
<tr>
<td></td>
<td>Dependent users</td>
<td>8</td>
<td>42.86</td>
</tr>
<tr>
<td>Target substance</td>
<td>Alcohol</td>
<td>8</td>
<td>57.14</td>
</tr>
<tr>
<td></td>
<td>Cocaine</td>
<td>4</td>
<td>28.57</td>
</tr>
<tr>
<td></td>
<td>Nicotine</td>
<td>1</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>Amphetamine</td>
<td>1</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>Pharmaceutical drug</td>
<td>1</td>
<td>7.14</td>
</tr>
</tbody>
</table>

2.3.3 **Measures used to assess wanting in human participants.**

2.3.3.1 *Self-report.* Items taken from previously developed and established questionnaires to assess wanting include: The Desires for Alcohol Questionnaire (DAQ; Love et al., 1998), The Desires for Speed Questionnaire (DSQ; James et al., 2004), Alcohol Urge questionnaire (AUQ; Bohn et al., 1995), The Questionnaire on Smoking Urges (Tifanny & Drobes, 1991), The Schafer & Brown (1991) Subjective Responses Questionnaire and The Drug Effects Questionnaire (DEQ; Johanson, 1980).
Each of the above mentioned questionnaires comprise an item or a number of items (a factor) that aim to assess a participant’s level of desire or urge to use or re-use an addictive substance (i.e., wanting behaviourally manifested as subjective craving). To assess wanting, ‘do you want more of what you consumed right now?’ (DEQ; Johanson, 1980) and ‘always wanted more’ (The Schafer & Brown (1991) Subjective Responses Questionnaire) are some example items that have been used to assess wanting.

A second group of studies developed their own items to measure wanting. Items in this group were similar to those above (i.e., aimed to assess wanting behaviourally manifested as subjective craving). To assess wanting, ‘I want cocaine’ (Kalapatapu et al., 2012) and ‘how much do you want to use/drink it right now’ (Goldstein et al., 2010) are example items that have been used to assess wanting.

2.3.3.2. Neurophysiological. One paper utilised a neurophysiological assessment method to examine wanting (Pieters et al. 2011). In this study, the authors identified craving responses following alcohol consumption in young adult drinkers (in comparison to early adolescent drinkers) with the DRD4 allele. The DRD4 allele has been associated with subjective craving, but not liking (Hutchinson et al., 2002).

2.3.3.3. Implicit. Three papers adopted implicit measures to assess wanting. This was done via sensitised arousal associations through an implicit association task (IAT; Greenwald et al., 1998). In one study (Wiers et al., 2002), target categories within the IAT were “alcohol” and “soda” and the attribute categories were “passive” and “active”, where effects in the arousal IAT were believed to reflect wanting. Similarly, Tibboel et al. (2011) used a valence IAT
with the attribute categories “I want” and “I don't want” to assess implicit wanting. Target categories were “nicotine” and “household” in both IATs. Subsequently, Tibboel et al. (2015) used an IAT, where two personalised single target IATs with labels “I want” and “I do not want” were used to assess wanting.

2.3.3.4. Behavioural. One study utilised three behavioural measures of wanting. Specifically, choice (the number of times an alcoholic beverage was chosen in comparison to a non-alcoholic beverage), number of alcoholic choices and overall alcohol consumption (Hobbs, Remington & Glautier, 2005) was used to measure wanting.

2.3.4 Measures Used to Assess Liking.

2.3.4.1. Self-report. Items taken from previously developed and established questionnaires to assess liking include: The Desires for Alcohol Questionnaire (DAQ) (Love et al., 1998), The Desires for Speed Questionnaire (DSQ) (James et al., 2004), The Drug Effects Questionnaire (DEQ; Johanson, 1980), The Schafer & Brown (1991) Subjective Responses Questionnaire and The Questionnaire on Smoking Urges (Tiffany & Drobes, 1991).

Each of the above mentioned questionnaires comprise an item or a number of items (a factor) that aim to assess participant’s level of subjective enjoyment or positive affect that arises from using an addictive substance (i.e., liking). To assess liking, ‘do you like the effects you are feeling right now’ (DEQ; Johanson, 1980) and ‘euphoric’ (The Schafer & Brown (1991) subjective response questionnaire) are some example items that have been used to assess liking.

A second group of studies developed their own items to measure liking. Items in this group were similar to those above (i.e., aimed to assess liking, behaviourally manifested as subjective enjoyment or positive affect). To assess
liking, ‘drug liking’ (Kalapatapu et al., 2012) and ‘how pleasant would it be to use/drink it?’ (Goldstein et al., 2010) are some example items that have been used to assess liking.

2.3.4.2. Neurophysiological. One paper utilised a neurophysiological assessment method to examine liking (Pieters et al. 2011). In this study, the authors identified increases in affective reactions (i.e., liking) following alcohol consumption in early adolescent drinkers (in comparison to young adult drinkers) with the OPRM1 gene. The OPRM1 gene has been associated with subjective liking, but not wanting (Ray & Hutchinson, 2004).

2.3.4.3. Implicit. Three papers adopted implicit measures to assess liking. First, this was done via sensitised arousal associations through an implicit association task (IAT; Greenwald et al., 1998). In one study (Wiers et al., 2002), the target categories within the IAT were “alcohol” and “soda” and the attribute categories were “pleasant” (interpreted as liking) and “unpleasant”, where effects in the arousal IAT were believed to reflect liking. Similarly, Tibboel et al. (2011) used a valence IAT with the attribute categories “I like” and “I don't like” to assess implicit liking. Target categories were “nicotine” and “household” in both IATs. Subsequently, Tibboel et al. (2015) used an IAT, where two personalised single target IATs with labels “I like” and “I do not like” were used to assess liking.

2.3.5 Samples used to assess wanting and liking.

Wanting and liking have been investigated in relation to a variety of samples including dependent substance users, high-risk/heavy substance users and low-risk/light substance users. These groups can be assigned to one of two broad categories: sensitised and non-sensitised samples. Underlying this grouping is
whether addictive substances have impacted neural systems. Thus, sensitised
groups refer to dependent users and potentially high-risk/heavy substance users,
for whom following time and repeated substance use brain systems commonly
associated with wanting motivation is believed to be hypersensitive or sensitised
(Robinson & Berridge, 1993). In contrast, non-sensitised groups refer to low-risk/
light substance users, for whom sensitisation may not have occurred.

2.3.6 Addictive substance used to assess wanting and liking.

Wanting and liking have been investigated in relation to a variety of
substances including alcohol, cocaine, nicotine, amphetamine and a
pharmaceutical drug (L-dopa). The most commonly used substance has been
alcohol (see Figure 2.2 for an overview).

![Figure 2.2. Number of the target addictive substances of studies investigating the
dissociation between wanting and liking in human substance users. Note that the
total sample is N=14.](image-url)
<table>
<thead>
<tr>
<th>Study</th>
<th>Aim</th>
<th>Sample</th>
<th>Wanting Measure</th>
<th>Liking Measure</th>
<th>Target Substance</th>
<th>Timing of Measure</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evans et al. 2006</td>
<td>To examine whether the differences in L-dopa-induced endogenous dopamine release in DDS patients mediate the hedonic (pleasurable, euphoric) effects of L-dopa (drug liking, or a subcomponent of reward termed incentive salience (drug wanting).</td>
<td>8 non-demented Parkinson’s Disease patients with Dopamine Dysregualtion Syndrome (DDS), compulsively taking dopaminergic drugs Mean age= 51.2 years</td>
<td>Self report: Wanting was measured via a subjective rating of L-dopa effect from the Drug Effects Questionnaire (DEQ; Johanson, 1980). Item assessing wanting included: “Do you want more of what you consumed, right now?”</td>
<td>Self report: Liking was measured via subjective rating of L-dopa effect from the DEQ (Johanson, 1980). Item assessing liking included: “Do you like the effects you are feeling right now?”</td>
<td>Dopaminergic drug, L-Dopa (pharmaceutical)</td>
<td>Prior to and following an oral dose of L-dopa</td>
<td>The sensitized ventral striatal dopamine neurotransmission produced by L-dopa in Parkinson’s disease patients with DDS correlated with self-reported compulsive drug wanting but not liking. Drug wanting predicted levels of drug use in DDS patients.</td>
</tr>
<tr>
<td>Goldstein et al. 2010</td>
<td>To distinguish subjective appraisal of drug wanting from drug liking (hedonic ratings of pleasantness).</td>
<td>20 cocaine dependent participants, who met DSM-IV criteria for active cocaine dependence and had at least a 6-month history of cocaine abuse (at least 2 g of</td>
<td>Self report: Wanting was assessed via the Sensitivity to Reinforcement of Addictive and other Primary Rewards (STRAP-R) (Goldstein et al., 2010). For liking, subjects rated ‘How pleasant would it be to eat it</td>
<td>Self report: Liking was assessed via the STRAP-R (Goldstein et al., 2010). For liking, subjects rated ‘How pleasant would it be to eat it</td>
<td>Cocaine</td>
<td>Following methylphenidate or placebo (100mg dose of thiamine)</td>
<td>Drug wanting exceeded drug liking in the dependent participants when reporting about ‘under drug influence’ situations. Cocaine-dependent...</td>
</tr>
</tbody>
</table>
To test the IST prediction that wanting and liking for alcohol can be dissociated in humans, Hobbs, Remington, & Glautier, 2005 conducted three studies.

**Study 1:**
- **Participants:** 52 alcohol drinkers (Mean age = 23.3 years, SD = 6.0) and a 20 age-matched control group (Mean age = 31.1 years, SD = 6.4).
- **Treatment:** Cocaine per week (snorted or intravenously) for 4 weeks.
- **Measures:** Subjects rated ‘How much do you want to eat it (food), do it (sex) or use/drink it (drug)’ (right now, in general, and during a hypothetical situation).

**Study 2:**
- **Participants:** 40 alcohol drinkers (Mean age = 21.6 years, SD = 3.5).
- **Treatment:** Alcohol priming dose (high, moderate, and low).
- **Measures:** Wanting was assessed through number of alcoholic choices and amount of alcohol consumed. Liking was assessed by subjective ratings of liking after a taste test.

**Study 3:**
- **Participants:** 30 alcohol drinkers (Mean age = 26.2 years, SD = 10.0).
- **Treatment:** Flavours of alcohol (high, moderate, and low).
- **Measures:** Wanting was assessed via the amount of alcohol consumed. Liking was assessed by subjective ratings of liking after a taste test.

In study 1, heavy drinkers (high wanting) and light drinkers (low wanting) did not differ in liking for alcohol. In study 2, an alcohol-priming dose produced an immediate increase in wanting without a change in liking. In study 3, an alcohol-priming dose produced no change in wanting but did not impact liking.

**Alcohol Liking:**
In study 1, heavy drinking and light drinking did not differ in liking for alcohol. In study 2, an alcohol priming dose produced no change in liking but did not impact wanting. In study 3, manipulation of alcohol valence to high or low liking did not produce a change in wanting.
<table>
<thead>
<tr>
<th>Study</th>
<th>Approach</th>
<th>Participants</th>
<th>Measures</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kalapatu et al. 2012</td>
<td>To examine whether the acute subjective effects of a single administration of smoked cocaine varied as a function of years of cocaine use or current age and whether the subjective effects of a 25mg smoked cocaine dose varied as a function of years of cocaine use or current age.</td>
<td>36 non-treatment seeking healthy individuals who smoked cocaine (long term users). Mean age = 41.06 years (SD = 3.57)</td>
<td>Self report: Wanting was assessed via a computerised self-report Visual Analogue Scale (VAS), consisting of 25 items, two items assessed wanting: “I want…cocaine…alcohol and tobacco” and “how much would you pay for the dose you just received?” to assess craving.</td>
<td>The acute subjective effects of cocaine did not vary as a function of years of cocaine use or current age.</td>
</tr>
<tr>
<td>King et al., 2011</td>
<td>To prospectively assess the relationship of acute alcohol responses to future binge drinking.</td>
<td>104 participants, who were high-risk heavy social drinkers and habitually engaged in weekly binge drinking Mean age = 25.28 (SD = .30) 86 light drinkers (control group)</td>
<td>Self report: The Drug Effects Questionnaire (DEQ; Johanson, 1980) was used to assess wanting. Specifically one item was used, “would you like more of what you consumed right now?” Self report: The DEQ (Johanson, 1980) was used to assess liking. Specifically two items were used, “how much do you like the drug?” and “do you like the affects you are feeling now?”</td>
<td>Among heavy drinkers, both wanting and liking were associated with increased frequency of binge drinking over time.</td>
</tr>
</tbody>
</table>
To investigate the relationship between positive and negative subjective responses at the time of initial cocaine use with adult cocaine dependence and lifetime use rates. 202 adult participants who had tried cocaine on at least one occasion were studied prospectively from childhood into adulthood. 89 participants met Diagnostic and Statistical Manual version IV (DSM-IV) criteria for Attention Deficit Hyperactive Disorder (ADHD) and there were 113 age-matched controls.

Self-report: Wanting was assessed through subjective responses from The Schafer & Brown (1991) subjective response questionnaire. Specifically, the item ‘always wanted more’ was used to assess wanting.


Cocaine When cocaine was first tried, liking and wanting were significant predictors of cocaine dependence and lifetime use. Those who were pre-exposed by regular smoking or stimulant treatment had higher liking and wanting scores; but participants who were pre-exposed by both stimulant treatment and regular smoking reported the lowest liking and the highest wanting responses.
Ostafin, Marlatt & Troop-Gordan, 2010

To examine the dissociation between liking motivation and wanting motivation for alcohol. Additionally, to examine whether years of drinking experience is associated with an increased role for wanting motivation and a decreased role for liking motivation.

85 ‘at risk’ drinkers (as defined by the National Institute on Alcohol Abuse and Alcoholism) Mean age= 27.04 years (SD=5.71)

Self report: Wanting was assessed with an urge to drink Likert scale ranging from 1 (no urge at all to drink alcohol) to 11 (very strong urge to drink alcohol), immediately before drinking an alcoholic beverage.

Self report: Liking was assessed with the first two adjectives from a modified taste test (‘delicious’ and ‘satisfying’), immediately after drinking began.

Alcohol wanting was measured prior to alcohol consumption

Liking was measured following alcohol consumption

Pieters et al. 2011

To examine the moderating effect of OPRM1 and DRD4 on the association between attentional bias and alcohol use in two independent samples who differed in their alcohol involvement.

Study 1: 195 adolescents Mean age= 13.69 (SD = .89)

Study 2: 86 heavy drinking male undergraduate Mean age = 21.4 years (SD = 2.15)

Neurophysiological measure: Wanting illustrated by: Genetic marker: dopamine D4 receptor gene-DRD4 (which has been linked to subjective craving after having a few alcoholic drinks) (Ray & Hutchinson, 2004).

Neurophysiological measure: Liking illustrated by: Mu-opioid receptor gene-OPRM1, which has been linked to increases in affective reactions following alcohol consumption (Ray & Hutchinson, 2004).

Alcohol was measured prior to alcohol consumption

Liking was measured following alcohol consumption

There was a relationship between attentional bias and alcohol consumption in the adolescent OPRM1 (wanting and liking) group and a relationship between attentional bias and alcohol consumption in the young adult DRD4 (only wanting) group.
Rose et al. 2010
To compare alcohol urge, drinking behaviour and mood across two beverage conditions (alcohol/soft drink), over multiple drinks.

45 participants (22 men and 23 females) with a previous history of consuming alcohol on a weekly basis
Mean age =22.58 (SEM= .4 years)
Self-report:
Wanting was assessed via the Alcohol urge Questionnaire (AUQ; Bohn et al., 1995). A measure of current alcohol urge.
Self-report:
Liking was assessed via ratings of how much participants enjoyed drinking each beverage and how pleasant they found the drink.
Alcohol Following alcohol consumption
Alcohol urge positively correlated with enjoyment and liking a drink. However, as more alcohol was consumed, a dissociation of wanting and liking of alcohol occurred.

Small et al. 2009
To identify which model of addiction: the behavioural sensitisation, hedonic dysregulation or the incentive sensitisation best describes the neurobiological process of cocaine addiction.

100 cocaine dependent participants according to the DSM-IV and were treatment seeking.
Mean age= 43.6 years
Self-report:
Wanting was assessed via an item within a 94-item questionnaire. Item assessing wanting was: amount spent on the drug over time.
Self-report:
Liking was assessed via an item within a 94- item questionnaire. Item assessing liking was: ‘euphoria’.
Cocaine
- 
Over time, euphoria (liking) decreased and the amount of money spent on a drug (stated as a potential measure of wanting) increased.

Tibboel et al. 2011
To examine whether implicit and explicit measures of wanting and liking are differentially sensitive to manipulations of wanting and expected that

49 smokers
45 non-smokers
Implicit measure:
The Implicit Association Test (IAT; Greenwald, McGhee & Schwartz, 1998).
Self-report:
Questionnaire for smoking urges (QSU: Cox, Tiffany,
Implicit measure:
IAT (Greenwald, McGhee & Schwartz, 1998).
Self-report:
QSU (Cox, Tiffany, & Christen, 2001), which included two factors: the
Nicotine
- 
Explicit measures illustrated that smokers experienced more wanting and liking when smokers were deprived than when they were satiated, but this difference was larger for wanting.
these manipulations would affect primary measures of wanting. Christen, 2001), which included two factors: the desire to smoke and the extent to which smoking is considered to be rewarding (Factor 1-Wanting). anticipation of relief from negative affect (Factor 2-Liking). implicit measures illustrated that smokers experienced more implicit liking for nicotine when they were deprived than when they were satiated, whereas there was no difference in wanting.

Tibboel et al. 2015
To examine "wanting" and "liking" in three groups of participants: alcohol-dependent patients, heavy social drinkers, and light social drinkers.

52 alcohol dependent users
Mean age 44.88 years (SD=10.47)

25 heavy social drinkers
Mean age 38.36 years (SD=12.87)

30 light social drinkers
Mean age 49.77 years (SD=8.89)

Both explicit and implicit measures were used to assess wanting.

Implicit measure:
Participants performed a wanting and liking ST-IAT (Bluemke & Friese, 2007).

Self-report:
A 9-point Likert scale was used to ask participants to what extent they wanted the item in the picture. A score of 1 meant that they did not want it at all, and 9 indicated that they wanted it very much.

Both explicit and implicit measures were used to assess liking.

Implicit measure:
Participants performed a wanting and liking ST-IAT (Bluemke & Friese, 2007).

Self-report:
A nine-point Likert scale was used to ask participants how much they liked the item in the picture. A score of 1 meant that they did not like it at all, and 9 indicated that they liked it very much.

Alcohol

Heavy drinkers had higher scores than light drinkers and alcohol dependent participants and light drinkers on both the wanting ST-IAT and the liking ST-IAT.

There were no differences between alcohol dependent participants and light drinkers.
<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Participants</th>
<th>Measured Variables</th>
<th>Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wiers et al. 2002</td>
<td>To measure implicit and explicit alcohol related cognitions in two dimensions: valence (positive-negative) and arousal (arousal-sedation).</td>
<td>48 volunteer undergraduate students (24 heavy drinkers [12 men and 12 women] with high weekly alcohol use and high scores on alcohol-related problems, and 24 light drinkers [12 men and 12 women] with low scores on weekly alcohol use and on alcohol related problems).</td>
<td>Implicit measure: The Implicit Association Task (IAT; Greenwald et al., 1998) and related explicit measures was used. Arousal-sedation (wanting and not wanting).</td>
<td>Alcohol</td>
</tr>
<tr>
<td>Willner, James, &amp; Morgan, 2005</td>
<td>To test whether in non-clinical samples, dependence on amphetamines and excessive alcohol use are associated with increased wanting but decreased liking for the drug.</td>
<td>Study 1 - Alcohol: 238 recreational alcohol drinkers Mean age= 28.66 years (SD= 11.66)</td>
<td>Self-report: Wanting of alcohol or amphetamine were assessed by craving responses obtained from the: Desires for Alcohol Questionnaire (DAQ) (Love et al., 1998) Desires for Speed Questionnaire (DSQ) (James et al., 2004)</td>
<td>Alcohol</td>
</tr>
<tr>
<td></td>
<td>Study 2 - Amphetamine: 164 amphetamine users Mean age=23.26 years (SD= 6.05)</td>
<td>Self-report: Liking of alcohol or amphetamine were assessed by positive reinforcement responses and negative effects of consumption obtained from the: Desires for Alcohol Questionnaire (DAQ) Desires for Speed Questionnaire (DSQ)</td>
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</tr>
</tbody>
</table>
Table 2.3 *Overview of Studies Consistent and Inconsistent with IST*

<table>
<thead>
<tr>
<th>Studies consistent with IST (<em>N=9</em>)</th>
<th>Substance use/dependence is associated with wanting but not liking</th>
<th>Correlation between wanting and liking stronger in non-sensitised samples (i.e., control group or light users) compared to sensitised or heavy using groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evans et al. (2006)</td>
<td></td>
<td>Goldstein et al. (2010)</td>
</tr>
<tr>
<td>Lambert et al. (2006)</td>
<td></td>
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<tr>
<td>Ostafin, Marlatt &amp; Troop-Gordan (2010)</td>
<td></td>
<td></td>
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<tr>
<td>Pieters et al. (2011)</td>
<td></td>
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<tr>
<td>Rose et al. (2010)</td>
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<tr>
<td>Small et al. (2009)</td>
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<tr>
<td>Wiers et al. (2002)</td>
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<tr>
<td>Hobbs, Remington &amp; Glautier (2005)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Studies inconsistent with IST (<em>N=5</em>)</th>
<th>Substance use/dependence associated with both wanting and liking</th>
<th>Wanting and liking remained the same regardless of substance use/dependence</th>
<th>Wanting and liking decreased as a function of substance dependence/use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willner, James &amp; Morgan (2005)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibboel et al. (2011)</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
2.4 Discussion

The aim of this systematic literature review was to examine the evidence for the dissociation between wanting and liking in human substance users. In light of the apparent diversity of methodological approaches used to address the dissociation in humans, another aim was to consider if and how measure choice, sample and addictive substance may influence the findings of these studies. Thus, there were three subsidiary aims:

(1a) To report on the types of measures used to assess wanting and liking
(1b) To report on the samples utilised in each of these studies and to
(1c) To report on the various addictive substances utilised.

The next section will address the evidence for the dissociation between wanting and liking presented in this review, followed by an extensive explanation as to whether various measuring types, samples and addictive substances influenced the findings of these studies. Future research areas will be discussed, and limitations of the current review will also be presented. Finally, there will be a summary of the current review and how it informs the following empirical chapters presented in this thesis.

2.4.1 The dissociation in human substance users.

Findings from 9/14 studies were consistent with IST. Specifically, some of these studies suggest that wanting and liking are two separate constructs of reward. That is, substance use or dependence is associated with wanting but not liking (e.g., Goldstein et al., 2010; Evans et al., 2006; Hobbs, Remington & Glautier, 2005; Ostafin, Marlatt & Troop-Gordan, 2010; Pieters et al., 2011; Rose et al., 2010; Wiers et al., 2002). However, this support is not unanimous, as some
studies do not support the IST proposition (e.g., Kalapatapu et al., 2012; King et al., 2011; Willner et al., 2005; Tibboel et al., 2011; Tibboel et al., 2015).

Moreover, the strongest test of the theory (i.e., examining the underlying mechanisms involved in substance addiction behaviour over time) is to test the proposition that wanting and liking will become increasingly dissociated as a result of repeated drug use. The evidence supporting this increasing dissociation between wanting and liking over time and repeated substance use is important in human substance addiction behaviour, as it is believed to explain why in some dependent users there is a contradiction with the maintenance of substance use. That is, despite the negative consequences that often result from compulsive drug use (such as loss of finances, family and friends) (i.e., the drug itself becomes non-rewarding) some dependent individuals still continue to maintain drug use (Bechara, 2005; Grant et al., 2000; Hyman, 2007; Robinson & Berridge, 1993). The underlying mechanisms proposed to explain this is important to understand especially for interventions and treatment as it suggests how once dependent, the maintenance of substance use is no longer a simple choice (Bechara, 2005; Grant et al., 2000; Hyman, 2007) but is instead due to hypersensitisation of certain neuroadaptations. However, only a limited number of studies have examined the increasing dissociation between wanting and liking overtime (i.e., prospectively) (e.g., King et al., 2011, Lambert et al., 2006; Small et al., 2009). Two of which support IST (Lambert et al., 2006; Small et al., 2009) and one that does not (King et al., 2011).

This review suggests that, overall; there is some level of support for IST in human substance users. That is, substance use or dependence is associated with wanting but not liking. However, further studies are required specifically
examining the increasing dissociation between wanting and liking, as this is a more direct test of the theory.

2.4.2 Measures used to assess wanting and liking.

In the reviewed studies, there is no consistent measure of wanting and liking and instead a wide variety of measures have been employed (e.g., self-report, behavioural, implicit and neurophysiological). The most common type of measure used to assess wanting and/or liking was self-report (11/14). Some studies have adapted already existing questionnaires to examine wanting and liking, for example, the DAQ (Love et al., 1998). Others have created their own questionnaires for their study, for example, the STRAP-R (Goldstein et al., 2010). A few studies employed non-self-report measures such as implicit measures (3/14), for example, the IAT (Greenwald et al., 1998), neurophysiological methods (1/14), for example, genetic markers and behavioural measures (1/14), for example, overall substance consumption.

This variability in measures suggests that there is no gold standard measure of wanting and liking (i.e., how to best operationalise the constructs). Recently, there has been an increasing debate in the literature surrounding the validity of utilising explicit measuring tools such as self-report measures (Anselme & Robinson, 2016; Tibboel, De Houwer & Van Bockstaele, 2015). Some researchers have argued that implicit measuring tools are the most suitable as wanting and liking are believed to be unconscious processes (Anselme & Robinson, 2016; Tibboel, De Houwer & Van Bockstaele, 2015). However, out of the 3 studies included in this review that have utilised implicit measuring tools, only one (Wiers et al., 2002) reported findings that were partially consistent with IST. That is, Wiers et al. (2002) found that heavy and light drinkers showed
different effects on an arousal IAT (that is assumed to measure wanting) but not on a valence IAT. However, research has since raised concerns about the findings (see Tibboel, De Hower & Van Bostaele, 2015). The question thus remains whether implicit measures of wanting and liking are valid measures of the constructs (Tibboel, De Hower & Van Bostaele, 2015).

Additionally, some researchers (Arulkadacham et al., 2017) argue that in order for the theory to have clinical utility, the constructs should be able to be measured explicitly. That is, IST attempts to give an explanation for drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Berridge and Robinson, 1995; Grant et al., 2000; Hyman, 2007). If this is true, then the behavioural manifestations of wanting and liking (craving and pleasure) should be able to be directly measured. Interestingly, most studies in the review have employed explicit measuring tools to examine wanting and liking (e.g., self-report, behavioural, neurophysiological), the most popular being self-report measures. Some argue that self-report measures are cost effective and less time-consuming than other measures of assessment that have been utilised (e.g., neurophysiological and implicit measures) (Goldstein et al., 2011; Tibboel et al., 2011). However, despite this recognition not one self-report measure has been consistently used in the literature.

Wanting and liking have been assessed by several self-report measures. The majority of self-report measures utilised to assess wanting and liking have adapted items either from previously developed questionnaires (e.g., the Desires for Alcohol Questionnaire (DAQ; Love et al., 1998) and the Alcohol Urge Questionnaire (AUQ; Bohn et al., 1995)) or have developed unique items.
independently and exclusively for their study. The one exception is the Sensitivity to Reinforcement of Addictive and other Primary Rewards questionnaire (STRAP-R, Goldstein et al., 2010), designed to simultaneously measure wanting and liking as defined by Robinson and Berridge (1993).

The STRAP-R was devised to specifically distinguish between wanting from liking. Goldstein and colleagues (2010) directed participants to think about a favourite food, sexual activity or drug or alcohol. To assess wanting participants were required to rate “how much do you want to eat it (food), do it (sex), or use it/drink it (drug). To assess liking participants were required to rate “How pleasant would it be to eat it (food), do it (sex) or use/drink it (drug)’’. These questions were repeated on three different situations: current, in general and hypothetically- while under drug influence of their favourite drug.

In total, 10 out of the 14 studies reviewed utilised self-report measures to assess wanting and liking. Of these 10 studies, seven studies provided some level of support for the dissociation between wanting and liking. Thus, it is plausible to suggest that self-report measures are effective in examining the behavioural manifestations of wanting and liking, however a consistent self-report measure in the literature is required. An agreed upon measure to assess wanting and liking (as defined by Robinson and Berridge, 1993) will allow for less measurement error. Further to this, a consistent measure will allow for researchers to come to more solid conclusions regarding the dissociation between the two constructs.

Pieters and colleagues (2011) was the only study to utilise a neurophysiological method to examine the dissociation between wanting and liking in this review. In this study, wanting was illustrated in participants by a genetic marker dopamine D4 receptor gene-DRD4, which has been linked to
subjective craving after having a few alcoholic drinks. And, liking was illustrated by mu-opioid receptor gene-OPRM1, which has been linked to increases in affective reactions following alcohol consumption (Ray & Hutchinson, 2004). Results of this study indicated that there was a relationship between attentional bias and alcohol consumption in the adolescent OPRM1 (wanting and liking) group and a relationship between attentional bias and alcohol consumption in the young adult DRD4 (only wanting) group. Neurophysiological methods have been useful to examine the dissociation between wanting and liking in animal models (e.g., Berridge & Kringelbach, 2008). Given that objective wanting and liking are defined in terms of brain activity, the most valid method to measure wanting and liking in humans would be to use neurophysiological and brain-imaging techniques. However, these techniques are not cost effective and more time consuming compared to other methods utilised (e.g., self-report) (Tibboel et al., 2011).

One study in the current review utilised behavioural measures to operationalise wanting (Hobbs, Remington & Glaatier, 2005) in humans. Specifically, choice (the number of times an alcoholic beverage was chosen in comparison to a non-alcoholic beverage), and the amount of alcohol consumed (Hobbs, Remington & Glaatier, 2005), was used to measure wanting. The behavioural operationalisation of wanting (i.e., consumption) is appropriate with animal models. However, in humans, substance consumption and the amount of energy spent to obtain a substance depends on more than just wanting. For instance, the impulse to pursue drugs can be inhibited when humans are motivated and when they have enough cognitive resources available to do so. Thus, wanting as defined by consumption may be a necessary condition for addictive behaviours
to occur, but it is not required (Wiers & Stacy, 2006). Moreover, researchers have also argued that craving may not be the source of all drug use in a dependent individual. An alternative view is that drug use could be characterised as a form of automated behaviour. The above explanations put forward may suggest why behavioural measures of wanting (such as consumption) may be limited, and perhaps why findings from Hobbs, Remington and Glautier (2005) were only partially supportive of IST.

2.4.3 The Addictive Substance and Sample Used to Assess Wanting and Liking.

Wanting and liking have been investigated in relation to a variety of substances including alcohol, cocaine, nicotine, amphetamine and a pharmaceutical drug (L-dopa). The most commonly used substance has been alcohol. Given that the dissociation between wanting and liking was consistent across substances, it can be assumed that the dissociation between the two constructs is not prominent in just one type of drug group, and may be consistent across varying drug types.

The dissociation between wanting and liking has been examined with a number of various sample types including dependent substance users and substance misusing groups. Despite the theory’s foundation in substance addiction behaviour, non-dependent/non-sensitised samples have predominantly been used as the target sample type in this review. The assumption being that an increasing independence between wanting and liking should become evident as substance misuse increases (Hobbs, Remington & Glautier, 2005; Ostafin, Marlatt & Troop-Gordan, 2010; Pieters et al., 2011; Rose et al., 2010; Wiers et al., 2002).
However, the strongest test of the theory would be to test the dissociation using substance dependent individuals.

### 2.4.4 Future research.

Some studies included in this review report findings that are consistent with IST. That is, substance use or dependence is associated with wanting but not liking. However, the strongest test of the theory (i.e., examining the underlying mechanisms involved in substance addiction behaviour over time) is to test the proposition that wanting and liking will become increasingly dissociated as a result of repeated drug use. However, only a limited number of studies have examined the increasing dissociation between wanting and liking overtime (i.e., prospectively) (e.g., King et al., 2011, Lambert et al., 2006; Small et al., 2009). Two of which support IST (Lambert et al., 2006; Small et al., 2009) and one that does not (King et al., 2011). Future research should implement similar study designs to specifically test the increasing dissociation between wanting and liking following time and repeated substance misuse.

The most popular measuring tool to examine wanting and liking has been self-report measures. However, there is currently no agreed upon self-report questionnaire utilised to examine wanting and liking. An agreed upon measure to assess the two constructs will allow for less measurement error (as the constructs would be operationalised in a uniform manner). Consequently, a consistent measure will allow for researchers to come to more solid conclusions regarding the dissociation between the two constructs. The STRAP-R (Goldstein et al., 2010) is a unique self-report questionnaire, as it was specifically designed to simultaneously measure wanting and liking as defined by Robinson and Berridge (1993). However, it has only been used once to examine the dissociation in
human substance addiction behaviour (Goldstein et al., 2010). It is possible that the STRAP-R could be used as a consistent measuring tool when examining the dissociation between the two constructs. However, (also noted by the authors) the STRAP-R requires further use across larger samples and various addictive substances. Future research should implement the use of the STRAP-R to test the dissociation between wanting and liking.

Although retrospective self-report measures provide a useful tool (i.e., quick and cost effective) to examine the dissociation between wanting and liking, they do not take into account the fluctuations of the constructs on a day-to-day basis. Momentary methods of assessing behaviours include the use of an Ecological Momentary Assessment (EMA) or daily diary, and involves the repeated collection of subjective responses in the daily life of an individual (i.e., assessments are taken in real time) (Shiffman et al., 2007; Stone & Shiffman, 1994; Schuz, Shiffman, Ferguson, 2015). No study has incorporated an EMA protocol to examine the dissociation between wanting and liking in the literature as of yet. This method of assessment may be useful to test the dissociation as it can capture the two constructs at various times during the day, which is a direct assessment, thus, providing evidence for IST that is ecologically valid.

The dissociation between wanting and liking is believed to be consistent across all addictive substances. According to this review, the dissociation has predominantly been tested using alcohol, cocaine and amphetamines. This review exemplifies that the dissociation between wanting and liking has not been tested with a number of other addictive substances, for example, caffeine, despite it being the most commonly used drug in the world (Griffiths, Juliano & Chausmer, 2003), and despite research suggesting that it can induce physical dependence.
(Budney et al., 2015; Juliano et al., 2012; Juliano and Griffiths, 2004). To examine whether the dissociation can be found in all types of addictive substances, future research should test the dissociation specifically across a range of addictive substances.

2.4.5 Limitations.

This systematic literature review was not without limitations. Due to the inclusion criteria, only the studies that explicitly mentioned IST in the study were included in this review, and therefore studies that indirectly have measured wanting and liking but do not refer to IST, were not identified. Furthermore, this review was limited to English studies and published data, which can limit the generalisability of the data (Cole & Kando, 1993).

2.5 Conclusion

In this review, the independent nature of wanting and liking was illustrated in 9/14 cross sectional studies (to some extent) across different measures (self-report, implicit, behavioural and neurophysiological), different substances (alcohol, cocaine, amphetamines and a pharmaceutical drug- L-dopa) and various sample types (e.g., non-dependent/non-sensitised or dependent/sensitised). Specifically, most studies suggest that substance use or dependence is associated with wanting but not liking. However, the direct test of the theory is to test the increasing dissociation between the two constructs as substance use increases, and this was addressed in one study included in this review (Goldstein et al., 2010). This type of evidence is particularly important as it directly explains why some individuals continue to maintain drug use, despite the negative consequences often involved. Given this, there is a need to establish
more direct evidence for the dissociation between wanting and liking in human substance users.

2.6 Chapter Summary

A systematic literature review was conducted to explore the dissociation between wanting and liking in human substance users. The overall findings of this review suggest that there is some evidence in support of IST in human substance users. However, there is limited evidence for the increasing dissociation between wanting and liking as substance misuse/dependence increases.

Nevertheless, the most popular measuring tool used to examine wanting and liking is self-report measures, however, there is some variation in the findings that have utilised self-report measures. Perhaps this variability is due to a lack of consistent measuring tool when examining wanting and liking. Moreover, it is argued that in order for the theory to have clinical utility a consistent self-report measure is required. Thus, it is proposed that the STRAP-R (Goldstein et al., 2010) questionnaire may be an appropriate candidate for this, but more studies utilising the STRAP-R with larger sample sizes and various addictive substances is required. In addition, it is proposed that measuring wanting and liking in the moment (i.e. state) may provide more valuable (direct) and precise data, which in turn may offer evidence for the dissociation between wanting and liking that is ecologically valid.

These concepts are empirically tested across the two empirical studies that follow this review chapter. It is important to note that data collection for the two studies was simultaneous such that data for study two were collected prior to data from study one being analysed. The following two empirical studies were designed to add to the limited human evidence for IST, thus, furthering our
understanding surrounding the dissociation between wanting and liking in human
substance addiction behaviour.
3.1 Introduction

3.1.1 Overview.

Over the last decade, advances in neuroscience have enabled a clearer understanding of the key motivational processes (Carter, 2009; Volkow & Li, 2005) involved in addictions. In particular, the Incentive Sensitisation Theory (IST; Robinson & Berridge, 1993) proposes that wanting (i.e., the motivation to approach and obtain a reward, Robinson & Berridge, 2001) and liking (i.e., the pleasure or hedonic enjoyment received after consuming a reward, Robinson & Berridge, 2001) are two independent constructs that are key to the development of addiction. Moreover, Robinson and Berridge (1993) suggest that they operate according to separate underlying biological structures and processes. They also argue that as substance dependence develops the motivation to obtain and consume drugs (i.e. wanting) becomes stronger even once the drug has become non-rewarding (i.e. less liked). The majority of the evidence in support of the dissociation between wanting and liking has come from a range of animal studies (Berridge et al., 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000). However, human evidence directly testing the increasing dissociation between wanting and liking is limited. This chapter reports the

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findings of the first of two empirical studies in this thesis that test the dissociation between wanting and liking in human substance users.

**3.1.2 The Incentive Sensitisation Theory.**

Robinson and Berridge (1993) argue that wanting and liking are structurally and functionally distinct biopsychological constructs of reward underlying substance dependence. Furthermore, they argue that although wanting and liking associate during initial use, the constructs tend to become dissociated after repeated substance use (Robinson & Berridge, 1993; Robinson & Berridge, 2013). Specifically, over time addictive substances can produce long lasting changes in certain neurological systems, such as the mesocorticolimbic dopamine systems, involved in the process of wanting. Through repeated drug use, these neurological systems become *hypersensitive* or sensitised to drugs and drug-associated stimuli (Robinson & Berridge, 1993; 2000; 2001; 2008). As a result, wanting is permanently increased even in the case where liking of a substance decreases (i.e. they become increasingly dissociated). This is consistent with reports of drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Berridge & Robinson, 1995; Grant et al., 2000; Hyman, 2007).

**3.1.3 The animal evidence.**

As detailed in Chapter 2, a number of lines of animal evidence have supported the proposition that wanting and liking are separate constructs that arise from separate neurological processes (Berridge & Robinson, 2003). Neurological imaging studies have investigated the independent nature of wanting and liking by examining differences in brain activity characterising wanting versus liking
(Berridge et al., 2009). These studies have indicated that liking maps onto a distinct neuroanatomical and neurochemical brain reward systems from those brain systems related to wanting (Berridge, Robinson & Aldridge, 2009; Pecina, 2008). These different patterns of activity associated with each construct are consistent with the notion that they are separable processes.

Moreover, the dissociation between wanting and liking has been illustrated via studies that have been able to manipulate the systems involved in wanting in order to examine whether levels of wanting and liking can change after such manipulation (Berridge & Valenstain, 1991; Berridge & Zajonc, 1991; Clark & Bernstein, 2006; Galaverna et al., 1993; Pecina et al., 2003; Wyvell & Berridge, 2000). For example, Pecina and colleagues (2003) were able to examine the independent systems with the use of mice with elevated levels of synaptic dopamine (mutant mice). This study utilised a ‘runway task’ to assess wanting (the length of time it takes an animal to reach a goal box) and a taste reactivity test (the number of times an animals tongue protrudes outwards or the number of times lip licking occurs in response to a palatable food) to assess liking. The results of this study showed that mutant mice in comparison to wild-type mice attributed greater wanting to a sweet reward in the runway task, however did not show an increase in the palatability of sweet reward (i.e. liking). The study concluded that the lack of association between wanting and liking was explained by the ability of wanting and liking to dissociate. Overall, animal studies illustrate that wanting and liking are two biopsychological components of reward that are both structurally and functionally separate from one another, congruent with IST.
3.1.4 The human evidence.

The dissociation between wanting and liking has been tested to some extent in human substance users. Some studies have concluded that wanting and liking are two separate constructs of reward. That is, substance use or dependence is associated with wanting but not liking (e.g., Evans et al., 2006; Hobbs, Remington, & Glatier, 2005; Lambert et al., 2006; Ostafin, Marlatt & Troop-Gordan, 2010; Pieters et al., 2011; Rose et al., 2010; Small et al., 2009; Wiers et al., 2002). However, this support is not unanimous (e.g., Kalapatapu et al., 2012; King et al., 2011; Willner et al., 2005; Tibboel et al., 2011; Tibboel et al., 2015).

Moreover, the strongest test of the theory (i.e., examining the underlying mechanisms involved in substance addiction behaviour over time) is to test the proposition that wanting and liking will become increasingly dissociated as a result of repeated drug use (i.e., the relationship between wanting and liking should increasingly separate over time and repeated substance misuse). Only a limited number of studies have examined the increasing dissociation between wanting and liking overtime (i.e., prospectively) (e.g., King et al., 2011, Lambert et al., 2006; Small et al., 2009), with mixed findings. Overall, there appears to be some level of support for IST in human substance users. Though these findings are not unanimous, thus, further studies in this area are required.

Moreover, the measurement of wanting and liking in humans has not been uniform with studies utilising various methodologies (see Chapter 2 for a review of measures used to examine wanting and liking in humans). The most appropriate way to measure wanting and liking has been an ongoing debate in the IST literature. Some researchers have argued that implicit measuring tools are the most suitable as the constructs are believed to be unconscious processes.
However, there is an increasing number of studies that have adopted the view that the behavioural manifestations of wanting and liking are craving and pleasure, respectively (Hobbs, Remington, & Glaudier, 2005; Goldstein et al., 2010; Willner et al., 2005). This concept is also taken on board in this study (and the following empirical study) and additionally, this thesis argues that in order for the theory to have clinical utility, the constructs should be able to be measured explicitly. That is, IST attempts to give an explanation for drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Berridge & Robinson, 1995; Grant et al., 2000; Hyman, 2007). If this is true, then the behavioral manifestations of wanting and liking (craving and pleasure) should be able to be directly measured. One explicit self-report measure that was developed for the purposes of examining wanting and liking is the STRAP-R (Goldstein et al., 2010). However, the STRAP-R has only been used once with a small sample of cocaine addicts and the authors recommend using the STRAP-R across larger samples and various addictive substances.

### 3.1.5 The current study: aims and predictions

Thus, the overall aim of the current study is to test the dissociation between wanting and liking in humans across two commonly used licit substances, alcohol and caffeine. Specifically, the aim of this study was to test the dissociation using the STRAP-R by:

(i) Testing the predicted dissociation between wanting and liking among low-risk and high-risk alcohol users and light and heavy coffee users.
(ii) Testing the differential relationship of wanting, liking and consumption among individuals ranging in their level of alcohol and coffee use.

It is predicted that:

(i) The relationship between wanting and liking will be positive and significant in low-risk alcohol users and light coffee users.

(ii) The relationship between wanting and liking will be negative and non-significant in high-risk alcohol users and heavy coffee drinkers.

(iii) The strength of the relationship between wanting and alcohol and coffee consumption will significantly increase as levels of alcohol and coffee consumption increase from low-risk alcohol users/light coffee users to high-risk alcohol users and heavy coffee users.

(iv) The strength of the relationship between liking and alcohol and coffee consumption will significantly decrease as levels of alcohol and coffee consumption increases from low-risk alcohol users/light coffee users to high-risk alcohol users and heavy coffee users.

3.2 Method

3.2.1 Sample.

Two groups of participants took part in the study. Sample one comprised 285 alcohol users (male=177 and female=108) aged between 21 and 74 years (M=33.80, SD=8.83). Sample two comprised 134 daily coffee users (81 male, 53
female) aged between 20 and 61 years (M=33.05, SD=8.10). All participants were recruited through Amazon’s Mechanical Turk (MTurk). Mturk is a ‘crowdsourcing’ website that allows people to perform short tasks for small amounts of money. Anyone over 18 may use the site. MTurk has been shown to produce samples that are representative of the broader population (Berinsky, Huber, & Lenz, 2012; Buhrmester, Kwang, & Gosling, 2011). All participants were residents of the United States.

3.2.2 Procedure.

Ethics approval was obtained from the university’s Human Research Ethics Committee (HREC). The study was advertised on MTurk through a brief description of the study’s aim and procedure. Participants followed a link provided on MTurk, which directed them to the Plain Language Statement (PLS) and questionnaire consisting of demographics, measures of substance use and a measure of wanting and liking (see details below). Following completion of the questionnaire, participants were required to enter in a unique code they received on the last page. This acted as a quality check to ensure participants had filled out the questionnaire rather than simply clicking onto the study without responding. Once completed a payment of US$1 was manually confirmed and processed to each participant.

3.2.3 Materials.

Demographics. Age (“what is your age (in years)?”) and gender were obtained (“what is your gender?”).

Measures of substance use. Alcohol users were administered the Alcohol Use Disorders Identification Test- Consumption (AUDIT-C) to assess levels of consumption. The AUDIT-C is a modified version of the 10-question AUDIT.
The three-item AUDIT-C includes questions to assess alcohol intake, such as (i) how often do you have a drink containing alcohol? Responses include: a) Never, b) Monthly or less, c) 2-4 times a month, d) 2-3 times a week, e) 4 or more times a week, (ii) how many standard drinks containing alcohol do you have on a typical day? Responses include: a) 1 or 2, b) 3 or 4, c) 5 or 6, d) 7-9 and e) 10 or more, and (iii) how often do you have six or more drinks on one occasion? Responses include: a) never, b) less than monthly, monthly, c) weekly, d) daily or almost daily. Each 5 answer choice scores: a=0 points, b=1 point, c=2 points, d=3 points, e=4 points. The AUDIT-C scores sum for a possible score of zero to 12. Acceptable reliability and validity of the AUDIT-C has been demonstrated (Frank et al., 2008). The AUDIT-C has been validated as an independent screening tool for detecting heavy drinking and Alcohol Use Disorder in a variety of settings (Bush et al. 1998; Gual et al. 2002; Rumpf et al. 2002; Bradley et al. 2007; Kaarne et al. 2010).

Coffee users were asked about their daily coffee use (e.g. “how many cups of coffee do you consume daily?”) to assess levels of daily coffee consumption.

**Subjective wanting and liking of alcohol and coffee.** A minor modification of The Sensitivity To Reinforcement of Addictive and other Primary Rewards (STRAP-R; Goldstein et al., 2010) was used to examine subjective wanting and liking of coffee and alcohol. That is, only questions in relation to participants wanting and liking of *in general* was asked, all other questions were omitted and participants were specifically directed to *think* about either alcohol or coffee whilst completing the questionnaire. Specifically, to assess subjective wanting participants were required to rate on a five point Likert scale (1= Somewhat, 2= Slightly, 3= Moderately, 4= Very, 5= Extremely) “how much do
you want to drink [it]”. To assess subjective liking participants were required to rate on a 5-point Likert scale (1= Somewhat, 2= Slightly, 3= Moderately, 4= Very, 5= Extremely) “how pleasant would it be to drink [it]”.

3.3 Results

3.3.1 Data analytic strategy.

All analyses were conducted via R Studio (Version 3.1.3) with the ‘psych’ (Ravelle, 2017) and ‘segmented package’ (Vito & Muggeo, 2008). First, Pearson correlations were calculated to test the predicted dissociation between wanting and liking among low-risk and high-risk alcohol users and light and heavy coffee users. The AUDIT-C allowed for group divisions between low-risk and high-risk users. In this study, for the correlations, low-risk users represent those who scored less than eight on the AUDIT-C. High-risk users represent those who scored eight or more on the AUDIT-C. Individuals scoring eight or more on the AUDIT-C have been shown to be at increased risk for many complications of drinking, including alcohol dependence (Rubinsky et al., 2010). There is no currently accepted cut offs for categorising caffeine use levels (Addicott et al., 2009). In this study, using this particular analysis, the categorisation of light and heavy coffee users consistent with previous work by Schuh and Griffiths (1997) and Tinley et al., (2003) was adopted. That is, light use of <129 mg/day (equivalent to less than 2 cups of coffee per day) and heavy use of >300 mg/day (equivalent to 3 or more cups of coffee per day).

Second, piecewise (or segmented) linear regression models were used to test the differential relationship of wanting and liking among low-risk and high-risk alcohol users and light and heavy coffee users. A piecewise linear regression model is a method in regression analysis in which the independent variable is
divided into empirically derived intervals and a separate line segment is fit to each interval connected at ‘breakpoints’ where shifts in the slope may occur (Wagner et al., 2002). When examining alcohol in this study, a breakpoint was set at 8 for the independent variable consumption (i.e. AUDIT-C score) and dependent variables wanting and liking. That is, those that scored under 8 on the AUDIT-C had a separate line segment for wanting to those who scored eight or above on the AUDIT-C. Thus, in this specific model those scoring under 8 were considered to be ‘low-risk’ users and those scoring 8 and above were considered to be ‘high-risk’ users. When examining coffee in this study, a breakpoint was set at 5 for the independent variable consumption and dependent variables wanting and liking. Thus, in this specific model those scoring under 5 were considered to be light coffee users and those scoring 5 and above were considered to be heavy coffee users.

Data were screened for missing data, outliers, and normality. There was no missing data. All key assumptions of the General Linear Model were met (Tabachnick & Fidell, 2007).

3.3.2 Descriptive statistics

Descriptive statistics for the AUDIT-C and coffee consumption questionnaire are presented in Table 3.1. Descriptive statistics for alcohol and coffee users are presented in Table 3.2.

<table>
<thead>
<tr>
<th>AUDIT-C</th>
<th>Coffee Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>6.87</td>
<td>2.51</td>
</tr>
<tr>
<td>4.08</td>
<td>2.30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Possible score range</th>
<th>Possible Score range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-12</td>
<td>1-12</td>
</tr>
</tbody>
</table>
Table 3.2 *Descriptive Data for Key Variables across Low Risk and High Risk Alcohol Users and Light and Heavy Coffee Users*

<table>
<thead>
<tr>
<th></th>
<th>Low-Risk Alcohol Users (AUDIT-C score of &lt; 8) (n = 154)</th>
<th>High-Risk Alcohol Users (AUDIT-C score of 8 or above) (n = 131)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean  SD       Possible score range</td>
<td>Mean  SD       Possible score range</td>
</tr>
<tr>
<td>Wanting</td>
<td>2.82 .94 1-5</td>
<td>Wanting 3.63 .98 1-5</td>
</tr>
<tr>
<td>Liking</td>
<td>3.20 .95 1-5</td>
<td>Liking 3.91 .85 1-5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Light Coffee Users (&lt; 3 cups/day) (n = 41)</th>
<th>Heavy Coffee Users (≥ 3 cups/day) (n = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wanting</td>
<td>3.46 .84 1-5</td>
<td>Wanting 4.01 .83 1-5</td>
</tr>
<tr>
<td>Liking</td>
<td>3.66 .82 1-5</td>
<td>Liking 4.04 .87 1-5</td>
</tr>
</tbody>
</table>

### 3.3.3 Main analyses.

#### 3.3.3.1 Pearson correlations. Correlations were calculated to test the predicted dissociation between wanting and liking among low-risk and high-risk alcohol users and light and heavy coffee users. A moderate positive correlation between wanting and liking was present for low-risk alcohol users, $r = .64, p < .05, 95\% \text{ CI} [.53, .72]$ and high-risk alcohol users, $r = .57, p < .05, 95\% \text{ CI} [.44, .67]$. These correlations did not differ significantly (Fishers exact test: $p = .36$ [2 tailed]). There was a strong positive correlation between wanting and liking in light coffee users, $r = .88, p < .05, 95\% \text{ CI} [.79, .84]$ and heavy coffee users, $r =$
.74, $p < .05$, 95% CI [.63, .82]. These correlations did differ significantly (Fishers exact test: $p = .03$ [2 tailed]).

3.3.3.2. Piecewise regressions. Piecewise regression models were run to test the differential relationship of wanting, liking and consumption among individuals ranging in their level of alcohol and coffee use. Fitted segmented linear regression models for wanting, liking and consumption (alcohol and coffee) are presented in Figure 3.1 and 3.2, respectively. Table 3.3 and 3.4 summarises each of the models results, respectively.
Figure 3.1. Fitted segmented linear regression model for wanting and liking based on AUDIT-C score for low-risk and high-risk alcohol users.

Figure 3.2. Fitted segmented linear regression model for wanting and liking based on daily coffee consumption for light and heavy coffee users.
Table 3.3 Results of the Fitted Segmented Linear Regression model for Alcohol

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Segment/parameter</th>
<th>Slope Estimate</th>
<th>Std error</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wanting</td>
<td>Slope before breakpoint (8) i.e., low-risk users</td>
<td>.19</td>
<td>.03</td>
<td>5.87</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>Slope after breakpoint (8) i.e., high-risk users</td>
<td>.26</td>
<td>.11</td>
<td>2.34</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Liking</td>
<td>Slope before breakpoint (8) i.e., low-risk users</td>
<td>.24</td>
<td>.04</td>
<td>5.47</td>
<td>&lt; .05</td>
</tr>
<tr>
<td></td>
<td>Slope after breakpoint (8) i.e., high-risk user</td>
<td>.15</td>
<td>.07</td>
<td>2.27</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Table 3.4 Results of the Fitted Segmented Linear Regression Model for Coffee

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Segment/parameter</th>
<th>Slope Estimate</th>
<th>Std error</th>
<th>t value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wanting</td>
<td>Slope before breakpoint (5) i.e., light users</td>
<td>.34</td>
<td>.09</td>
<td>3.75</td>
<td>&lt; .001</td>
</tr>
<tr>
<td></td>
<td>Slope after breakpoint (5) i.e., heavy users</td>
<td>.19</td>
<td>.07</td>
<td>2.50</td>
<td>&lt; .01</td>
</tr>
<tr>
<td>Liking</td>
<td>Slope before breakpoint (5) i.e., light users</td>
<td>.25</td>
<td>.09</td>
<td>2.73</td>
<td>&lt; .01</td>
</tr>
<tr>
<td></td>
<td>Slope after breakpoint (5) i.e., heavy users</td>
<td>.24</td>
<td>.08</td>
<td>3.22</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

In the model with breakpoint, the slopes for wanting for alcohol estimated are .19 and .26. The slopes for liking for alcohol estimated are .24 and .15. In the
model with breakpoint, the slopes for wanting for coffee estimated are .34 and .19. The slopes for liking for coffee estimated are .25 and .24.

3.4 Discussion

While the evidence regarding the dissociation between wanting and liking appear to be well supported in animal studies (Berridge, Robinson & Aldridge, 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000), the evidence in human substance users is not as well established. Moreover, the STRAP-R appeared to be a useful measure that could be used in the literature consistently, however it needed to be utilised with larger samples and various other substances. Using the STRAP-R questionnaire, this study intended to test the dissociation between wanting and liking with alcohol and coffee users by (i) testing the predicted dissociation between wanting and liking among low-risk and high-risk alcohol users and light and heavy coffee users and (ii) by testing the differential relationship of wanting, liking and consumption among individuals ranging in their level of alcohol and coffee use. This study reports on several main findings. First, piecewise regression models illustrated that the strength of the relationship between wanting and alcohol consumption became stronger from low-risk to high-risk alcohol users. Conversely, the strength of the relationship between liking and alcohol consumption became weaker from low-risk to high-risk alcohol users, consistent with IST and the current studies predictions. However, correlational analysis failed to illustrate an increasing dissociation between wanting and liking across low-risk and high-risk alcohol users. Moreover, the dissociation between wanting and liking was not illustrated in
coffee users, both inconsistent with the current studies predictions. These findings will be addressed in detail below.

First, partial support of IST was found in a sample of alcohol users. Specifically, piecewise regression models illustrated that the strength of the relationship between wanting and alcohol consumption became stronger from low-risk to high-risk alcohol users. Conversely, the strength of the relationship between liking and alcohol consumption became weaker from low-risk to high-risk alcohol users. This suggests that in high-risk alcohol users, wanting may be driving alcohol consumption more so than liking compared to low-risk alcohol users.

Additionally, the theory suggests that as an individual’s level of use increases the relationship between wanting and liking should become increasingly independent of each other (i.e., wanting and liking should dissociate explaining why some individuals continue to maintain drug use despite the negative consequences involved). Although in this study, reported correlations between wanting and liking across low-risk and high-risk alcohol users did not demonstrate this.

This study is the first to test the dissociation between wanting and liking utilising the STRAP-R following its development in 2010 (Goldstein et al., 2010). However, compared to Goldstein and colleagues (2010), our study’s findings appear to be at variance. Goldstein et al. (2010) reported a strong significant correlation between wanting and liking in a non-dependent sample \( r = .63, p < .01 \) and a non-significant correlation between the two constructs in a sample of dependent cocaine users \( r = -.04, p > .9 \). These results were significant only when participants recalled drug-related situations and during methylphenidate
(but a similar trend was also found with a placebo). The type of sample utilised may explain the inconsistency between studies. For instance, Goldstein and colleagues (2010) compared two groups of participants, clinically dependent cocaine users and a healthy control group. Instead, the current study and previous studies (e.g., Kalapatapu et al., 2012; Ostafin, Marlatt & Troop-Gordan, 2010; Willner et al., 2005) have tested the dissociation amongst substance misusing groups, the assumption being that an increasing independence between wanting and liking should become evident as substance misuse increases. Thus, within this type of sample (sub clinical) wanting and liking were expected to be intercorrelated to some extent, but in a clinical sample (i.e., dependent users) it is assumed that dissociation between wanting and liking may become more apparent. Given this, the STRAP-R may have clinical utility; however further investigation is required.

Moreover, piecewise regression models showed that the strength of the relationship between wanting, liking and coffee consumption remained relatively the same across light and heavy coffee users. Additionally, strong positive correlations between wanting and liking were reported across light and heavy coffee users. As such, these findings are not in line with IST, despite research suggesting that caffeine can induce physical dependence (Budney et al., 2015; Juliano et al., 2012; Juliano and Griffiths, 2004). It is possible that caffeine functions differently at the neurological level compared to other addictive substances, such as alcohol, cocaine and amphetamines (Cauli & Morelli, 2005). For instance, repeatedly using alcohol, cocaine and amphetamines have been shown to produce adaptations in the mesocorticolimbic dopamine system (Bassareo et al., 2013; Di Chiara and Imperato, 1988, Mendez et al., 2009;
Vanderschuren & Kalivas, 2000), which is a system directly involved in the process of wanting (Mendez et al., 2009; Vanderschuren & Kalivas, 2000). Through repeated substance use, this system becomes sensitised and as a result, levels of wanting increases as liking decreases (i.e. the two constructs become dissociated) (Robinson & Berridge, 1993; 2008). However, research suggests that caffeine directly targets the prefrontal cortex rather than the mesocorticolimbic dopamine system (Cauli & Morelli, 2005; Ferre, 2016; Nehlig et al., 1986; Nehlig, 1999). Thus, it is possible that the mesocorticolimbic dopamine system in caffeine users may not become sensitised and consequently levels of wanting and liking can remain relatively similar (i.e. no dissociation) regardless of an individual’s level of caffeine use. Although this may explain why no apparent dissociation was evident in coffee users ranging in their levels of coffee use, further investigation is required.

3.4.1 Limitations.

A number of limitations warrant consideration. First, no specific measure was used to assess caffeine use levels, as no such validated measure exists. Additionally, there is no currently accepted cut offs for categorising caffeine use levels (Addicott et al., 2009) so the categorisation of low and heavy coffee users consistent with previous work by Schuh and Griffiths (1997) and Tinley et al., (2003) was adopted. That is, low use of <129 mg/day (equivalent to less than two cups of coffee per day), heavy use of >300 mg/day (equivalent to three or more cups of coffee per day). Despite this, it is possible that light and heavy coffee users were not separated accurately in this study.

Second, this study did not test the dissociation explicitly across non-dependent and dependent substance users. Rather, the AUDIT-C was used to
classify ‘low-risk’ and ‘high-risk’ (i.e. possible dependence) and the
categorisation of low and heavy coffee users was used to classify coffee users.
Perhaps, a stronger dissociation between wanting and liking may have been
illustrated had a non-dependent and dependent sample been examined.

Third, despite mTurk being a valuable tool to recruit participants, the
service, so far, is only available in English and to make job requests you have to
have a U.S. address. This reduces the generalisability of the studies findings as
non-English speaking participants and those outside of the U.S were not included
in this study.

Fourth, Pool and colleagues (2016) suggest that the measures used in
human populations need to reflect wanting and liking as defined in the animal
literature. That is, wanting should be measured during or after the perception of a
reward or reward associated cue, as it is believed that wanting is produced by an
interaction between the current physiological state of an individual and the
encounter of a reward or reward related cue (Berridge & O’Doherty, 2014; Zhang
et al., 2009). Additionally, liking should be measured during or immediately after
consumption of a reward, as it is believed that liking is the hedonic experienced at
the time of or following the consumption of a reward (Berridge & O’Doherty,
2014). Thus, studies not measuring wanting and liking in this way are believed to
unlikely be measuring true wanting and liking and rather measuring predicted
wanting and liking (Pool et al., 2016). Although participants in this study were
instructed to think (a hypothetical scenario) about coffee and alcohol during the
completion of the STRAP-R questionnaire, it is possible that this does not govern
the same effects in wanting and liking, as would the direct consumption of coffee
or alcohol. The measurement of wanting and liking following consumption in an
experimental setting or momentarily in the daily life of an individual may be more direct assessments of the constructs.

### 3.4.2 Conclusion.

Despite the limitations of this study, the dissociation between wanting and liking across varying levels of alcohol and coffee users was able to be tested. This study was the first to test the dissociation between wanting and liking with caffeine. Although Robinson and Berridge (1993) suggest that the theory should be consistent across all addictive substances, the findings from this study illustrate that this may not be the case for caffeine. However, future research is required to establish this. Nevertheless, this study provides partial support for IST in alcohol users. Moreover, findings from this study provide support for the utility of the STRAP-R to test the dissociation between wanting and liking in human substance users. The STRAP-R is a cost effective and a less time-consuming method of assessment compared to other measures used (e.g. implicit, behavioural paradigms, physiological). Future studies should focus on utilising the STRAP-R with a clinically dependent sample to further test the dissociation between wanting and liking in human samples and to further validate the STRAP-R.

The next chapter (Chapter 4) reports the findings of the second empirical study testing the dissociation between wanting and liking in human substance users. Note that, data for study two were collected prior to data from study one being analysed.
Chapter Four: A Test of the Incentive Sensitisation Theory using an Individualised- Ecological Momentary Assessment Protocol

4.1 Introduction

4.1.1 Overview.

A key claim of IST is that as substance dependence develops, wanting for a substance increases while liking for it decreases. As a result, wanting and liking tend to dissociate over time and repeated use. The evidence in support of the independent nature of wanting and liking has come from a range of animal studies (Berridge, Robinson & Aldridge, 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000). The majority of studies that have tested this dissociation in humans have used self-report measures that ask participants how much they want or like a substance in an experimental setting (Goldstein et al., 2010; Willner et al., 2005) or retrospectively (Small et al., 2012). However, examining wanting and liking in the daily life of an individual offers a direct way to evaluate IST and may be able to better capture dynamic patterns between the two constructs. Ecological Momentary Assessment (EMA) methods allow for the measurement of various constructs and behaviours in the daily life of an individual. However, automated measurements of specific variables at the time of a particular behaviour have not been implemented in the literature as of yet. Thus, this study used a unique method of data collection, Individualised- Ecological Momentary Assessment (I-EMA), to precisely assess wanting and liking when an individual consumes coffee via automated and targeted survey prompts. This novel approach may provide human evidence for the dissociation between wanting and liking that is ecologically valid.
4.1.2 The Incentive Sensitisation Theory.

Robinson and Berridge (1993) make a distinction between wanting and liking predicting that they are structurally and functionally distinctive from one another. The proposed independent nature of wanting and liking is believed to have direct implications to substance addiction behavior. That is, although during the initial stages of drug use an individual may simultaneously want a drug and find its use rewarding, over time and repeated use the motivation to obtain and consume drugs can remain high even once the drug has become non-rewarding (i.e., less liked; the two constructs become increasingly dissociated) (Berridge & Robinson, 2016). This is consistent with reports of drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Grant et al., 2000; Hyman, 2007; Berridge & Robinson, 1995). Not only does IST provide an explanation for the transition from recreational drug use to compulsive drug use (i.e., when substance use no longer becomes liked but still wanted), the theory aims to also provide an explanation for the maintenance of substance use in some individuals despite the negative consequences the behaviour brings (Robinson & Berridge 2000).

4.1.3 Measures of Wanting and Liking in Human Substance Users.

The majority of studies that have examined the dissociation between wanting and liking have used self-report measures to examine the two constructs. For example, Willner and colleagues (2005) sought out to measure wanting and liking in a sample of recreational alcohol drinkers using craving and positive reinforcement responses obtained from the Desires for Alcohol Questionnaire (DAQ; Love et al., 1998). Furthermore, one self-report measure that was
specifically designed to simultaneously measure wanting and liking as defined by Robinson and Berridge (1993) is The Sensitivity To Reinforcement of Addictive and Other Primary Rewards (STRAP; Goldstein et al., 2011). Traditional self-report questionnaires are useful, however, they do not consider the fluctuations of momentary wanting and liking in everyday life. A momentary assessment method may be a more direct way to measure wanting and liking.

4.1.4 Ecological Momentary Assessment.

Momentary methods of assessing behaviours include the use of Ecological Momentary Assessment (EMA; Stone & Shiffman, 1994). EMA involves the repeated sampling of participants’ behaviours and experiences in real time, in participants’ natural everyday environments (Schuz, Shiffman, Ferguson, 2015; Shiffman et al., 2007; Stone & Shiffman, 1994). EMA is a rapidly expanding data collection strategy, specifically in the areas of clinical psychology, behavioural neurosciences and addiction research (aan het Rot et al., 2012; Lukasiewicz et al., 2007; van den Bos et al., 2013). Within EMA, there are three types of response recording for participants: signal-contingent (made in response to a signal), interval-contingent (made after a fixed period of time), and event-contingent (made when a specific event occurs) (Serre et al., 2015). EMA can also be referred to as micro-longitudinal, time frames, and sampling schedules vary depending on the research question or the various constructs being addressed (Ebner-Priemer & Sawitzki 2007, Palmier-Claus et al. 2011). EMA’s can be captured through a range of methods, including paper and pen diaries and Personal Digital Assistants (PDAs) (Csikszentmihalyi & Larson, 2014). Recently, advances in mobile technologies have permitted the collection of real-time data in natural environments using smartphones (Wonderlich, 2015). The feasibility and
validity of EMA has been demonstrated in individuals with many types of addictions (Freedman et al., 2006; Serre et al., 2012).

4.1.5 Using EMA to Examine Wanting and Liking.

There are a number of advantages of using EMA to examine subjective wanting and liking. Wanting and liking can be difficult to study in the laboratory, as they do not recreate the contexts associated with substance use, thereby reducing ecological validity. Given the importance of situational cues, mood and social context during substance use (Dvorak, et al. 2014; Kunstche, et al. 2015; Serre et al., 2015), subjective wanting and liking may be inaccurate within this type of setting which excludes these variables. EMA examines substance use in an individual’s natural environment. That is, the way in which a substance is consumed in an experimental setting significantly differs from the way in which a substance is obtained and consumed in real life (e.g., from a bar with friends) (Shiffman et al., 2007; Stone & Shiffman, 1994; Schuz, Shiffman, Ferguson, 2015). Thus, experimental studies do not necessarily reflect the way substances are obtained or consumed in everyday life and consequently may impact on subjective responses of wanting and liking. EMA, on the other hand, can allow participants to record wanting and liking during natural substance use occasions, consequently increasing ecological validity.

Measuring wanting and liking retrospectively can impact on the reported accuracy of these constructs. EMA can ask participants about their subjective wanting and liking in the moment of substance use (or very close to substance use) (e.g., “how much do you…right now”). This means that the period of time between substance consumption and the assessment of wanting and liking is much shorter than with a traditional, retrospective self-report questionnaire, which tends
to focus on participants’ experiences in general (e.g., “how much do you…in
general”). Thus, EMA may reduce the amount of error caused by differences in
the accuracy or completeness of recollections (i.e., recall bias) that would
otherwise be present in participant responses by using retrospective
questionnaires (Connor & Barrett, 2011; Wonderlich, 2015). For instance, prior
studies have indicated that participants poorly recalled their smoking quit dates
and they overestimated their actual experience of distress when quitting smoking
using a retrospective self-report measure, in comparison to what they reported in
real-time, using EMA (Shiffman et al., 2007). Additionally, women overestimated
their premenstrual symptoms using a retrospective self-report measure, compared
to when they reported symptoms in the moment (McConnell, 2011). Thus, these
studies highlight the advantages of measuring experiences in real-time to control
for such recall biases.

Finally, examining wanting and liking at one point in time does not take
into consideration the variance across scores over time. Repeated within-day
assessments across a pre-determined period (e.g., 7 days) can capture the rapid
fluctuations of various variables (Shiyko and Ram, 2011; Wonderlich, 2015) and
inform researchers about potential relationships between variables. Thus, EMA
can identify temporal changes and the relationship between momentary wanting
and liking- before, during and after substance use. Moreover, EMA allows the
collection of many data points; therefore they are likely to contain less random
error variance compared to other common methods (e.g., traditional self-report)
and, hence, may be more sensitive to change (Moskowitz & Zuroff, 2004). In
other words, with many data points, it is possible to look at the range of scores for
an individual on a variable. This could be done generally, or in response to a
specific event, for example, the range of moods in patients with bulimia and
temporal changes after binges (Moskowitz & Young, 2006). Thus, a wide variety
of complex predictions (in relation to IST and other research areas) can be
answered via the use of EMA (Serre et al., 2015).

4.1.6 Individualised EMA Design.

Standard EMA allows for the repeated measurement of behaviours and
constructs over time. Responses are generally collected in one of two ways: (1)
the participant is asked to provide event-contingent responses (e.g., every time
they use or consume a substance) or (2) moments are sampled for assessment
based on a regular or random time schedule (e.g., survey prompts given at 9am,
12pm, 3pm and 6pm every day). However, the first method assumes that
participants will reliably record their subjective wanting and liking every time
substance use/consumption occurs (this may or may not be accurate), and the
latter may not allow for the assessment of wanting and liking close to substance
use/consumption (i.e., before, during and after) (e.g., a single prompt at 12pm
may not be an effective examination of wanting and liking if substance
use/consumption occurred at 10am). Individualised-EMA (I-EMA) allows survey
prompts to be automated and targeted around the time at which typical substance
use/consumption occurs for each individual, thus attaining appropriate temporal
resolution and assessment of the patterns between variables.

4.1.7 Current Study.

The current study is a micro longitudinal study that uses I-EMA to ensure
survey prompts are automated and targeted around the time at which typical
coffee use occurs for each individual participant. I-EMA may facilitate a precise
and accurate measurement of subjective wanting and liking at the time of (or very
close to coffee consumption) and thus enable a test of the dissociation between wanting and liking that is ecologically valid. Therefore, the overall aim of the current study is to test the dissociation between wanting and liking in daily coffee users, using an I-EMA protocol. Specifically, this study addresses several predictions according to the theories relevance to substance dependence:

(1) Coffee dependence will be positively related with momentary wanting but not liking.

And substance consumption behaviour:

(2a) Coffee consumption will be positively related with both momentary wanting and liking.

(2b) Momentary wanting and liking will associate differently with coffee consumption for different individuals.

(2c) Coffee dependence will moderate the relationship between momentary wanting and liking during coffee consumption.

4.2 Method

4.2.1 Participants.

The sample in this study (N= 81) consisted of daily coffee drinkers (male=31 and female= 50) aged between 18 and 57 (M=25.08, SD=7.95). Daily coffee use ranged from 1-7 cups of coffee per day (M= 1.33, SD=.73). Participant demographic characteristics are displayed in Table 4.1. Nineteen participants in total were excluded from analysis because they completed considerably less than 50% of expected surveys (the number of total surveys differed across participants). This follows past EMA studies that have removed participants who contributed less than 50% of the possible data points (e.g., Colautti et al., 2011; Melnyk et al., 2004; Rudiger et al., 2007).
Table 4.1 *Participant demographics (N=81)*

<table>
<thead>
<tr>
<th>Demographics</th>
<th>N</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>31</td>
<td>(38%)</td>
</tr>
<tr>
<td>Female</td>
<td>50</td>
<td>(62%)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>25.08</td>
<td>(7.95)</td>
</tr>
<tr>
<td>Daily coffee use (cups of coffee p/d)</td>
<td>1.33</td>
<td>(.73)</td>
</tr>
<tr>
<td>Daily consumption of other caffeinated products</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tea</td>
<td>6</td>
<td>(7.41%)</td>
</tr>
<tr>
<td>Soft drink</td>
<td>13</td>
<td>(16.05%)</td>
</tr>
<tr>
<td>Energy drink</td>
<td>9</td>
<td>(11.11%)</td>
</tr>
<tr>
<td>No-Doz</td>
<td>2</td>
<td>(2.47%)</td>
</tr>
<tr>
<td>Smoker</td>
<td>6</td>
<td>(7.41%)</td>
</tr>
</tbody>
</table>

*p/d= per day

4.2.2 Procedure.

Following ethics approval, the study was advertised on social media platforms (such as Facebook), local advertisements were put up on online classified services and flyers were displayed around various metropolitan university campuses and local cafes. A brief overview of the study, along with participant inclusion criteria (i.e., daily coffee users who owned and used a smartphone) was provided when promoting the study. Interested individuals were asked to contact the principal researcher via email, at which time they received a web-link to the Plain Language Statement (PLS), a baseline questionnaire and
further instructions explaining how to install the application to their smartphone. After providing informed consent, participants were first required to download and install a free application, required for Phase 2 (EMA) of the study, called 'Instant Survey' (Richardson, 2015) to their smartphone, via the iTunes app store or Google Play. After enrolling in the study on their smartphone, participants entered their unique identification number from the app into the beginning of Phase 1 (Baseline questionnaire) to link their data across the two phases.

Participants then completed Phase 1, which took approximately 15 to 20 minutes to complete. Phase 1 consisted of questions in relation to participant demographics (participants’ age in years and gender), a coffee dependence questionnaire, and the days and times at which typical coffee use occurred on an average week for each participant. Following completion of Phase 1, participants were given the option to enter in their email address if they wished to receive a $20 Coles e-voucher (Australian supermarket). It was made clear that 80% of Phase 2 was required to be completed in order for participants to receive the voucher.

The following morning, Phase 2 of the study began and lasted 12-days [as suggested by Conner & Lehman (2011)] and was broken into a calibration phase and a testing phase. On days 1-4, participants were required to complete the survey (details presented below) whenever the application signalled (this occurred 7 times per day at semi-random intervals, between 8:00am and 9:00pm). Participants received a local notification on their smartphone, which directed them to the survey within the app. The survey took less than one minute and participants had a 30-minute window in which to complete each survey. The order of presentation of items was held constant across all testing intervals.
After 4 days, participants received automated surveys surrounding the times at which they usually consumed coffee. Participants received between 3 and 9 surveys daily, with consecutive surveys (i.e., a burst of surveys within a 60 minute period) (minimum of 3) targeted at typical coffee consumption times. The amount of surveys was dependent on how many cups of coffee they typically drank per day. This was implemented by the Principal researcher based on average times of coffee consumption per individual calculated from each participant’s baseline survey, and EMA responses from the calibration phase (days 1-4). The nature of the application allowed for an update of the survey alerts every time a participant would open the app. Thus, changes to individual survey alerts were possible at any time, which then resulted in notifications for each individual according to their individualised schedule (i.e., times at which each participant typically consumed coffee). Following completion of the 12-day period, participants who had completed at least 80% (the number of prompts throughout the 12 day period varied from individual to individual) of the app-based surveys were emailed an e-voucher.

4.2.3 Materials.

Phase 1 (Baseline questionnaire)

Demographics. This questionnaire obtained participants age ("what is your age? [in years]") and gender ("what is your gender?").

Coffee Dependence. Currently, there is no validated measure of coffee dependence. In this study, the Fagerstrom Test for Nicotine Dependence (Heatherton, et al., 1991) was adapted to assess levels of coffee dependence. Consistent with the Fagerstrom measure three broad constructs were examined within this questionnaire: (1) coffee use, (2) biological dependence and (3)
psychological factors. To measure coffee use, participants were asked: “On average, how many cups of coffee do you consume daily?” [Participants were required to state the number of average cups of coffee consumed daily]. Questions to measure physical dependence included: “If you do not consume coffee for a period of time, how severely do you experience these symptoms [headache, anxiety, decreased alertness, difficulty concentrating, and irritability]?” (Rated from 0- do not experience the symptom to 10- extremely severe), “Do you use coffee to avoid any of the symptoms listed above?” (Yes or No). Questions to measure psychological factors included: “In the last year, did you drink a lot more coffee than you used to in order to get the same desired feeling?” (Yes or No), “In the past year, did you notice that when you consumed the same amount of coffee it had less of an effect on you?” (Yes or No), “Have you had the desire to discontinue coffee use?” (Yes or No), “How soon after you wake up do you consume your first cup of coffee?” (Yes or No). Responses to questions resulted in an overall “coffee dependence” score.

Typical Coffee Use Time. Participants were required to report (tick the box) at which times they typically drink coffee on an average week (See Figure 4.1 below)
Measure of other caffeinated products: Participants were asked whether they consume other types of caffeinated products daily. If answering affirmatively, then they were required to state what other type of caffeinated products were consumed daily (e.g., Coca Cola, energy drinks [such as Red Bull], caffeine caplets [such as No-Doz awakeners]).

**Phase 2 (EMA)**

*Caffeine consumption.* Participants were asked whether they drank coffee since they last completed the survey, coded as 1 (Yes) and 2 (No). When participants selected “yes” they were asked further questions regarding the amount of coffee consumed “How many cups of coffee did you consume since you last completed the survey?”, and at what time they had consumed the last coffee “At what time did you consume your last coffee?” (See Figure 4.2 for an illustration of the EMA implemented through ‘Instant Survey’).

*Momentary wanting and liking.* If participants had reported that they had consumed coffee since the last assessment, they were also asked “How pleasant did you find drinking that coffee” [Measuring momentary liking] (Rated from 0-Not at all to 10- Extremely) and “How much were you craving the coffee just
before you consumed it?” [Measuring momentary wanting] (Rated from 0- Not at all to 10- Extremely). In addition, despite whether participants reported coffee consumption, all participants were asked “How much are you craving coffee right now?” (Rated from 0- Not at all to 10- Extremely) and “How pleasant would it be to drink coffee right now?” (Rated from 0- Not at all to 10- Extremely).
Figure 4.2. Schematic Representation of Phase 2 (EMA).
4.2.4 Data analytic strategy.

As participants reported wanting and liking across multiple time points, the data collected were considered hierarchical in nature. That is, responses to multiple surveys over the 12 days (Level 1) were nested within individuals (Level 2). Due to potential clustering effects, and intent to examine interactions between variables at different levels, multilevel modeling (MLM) was utilised (Bolger & Laurenceau, 2013; Hox & Maas, 2006; Jackson, 2010). Specifically, two MLM’s were constructed to examine whether the relationship between coffee dependence and momentary wanting and coffee dependence and momentary liking differ (Hypothesis 1). In addition to this, a Multi-Level Logistic Regression (MLLR) was used to examine whether the relationship between coffee consumption and momentary wanting and coffee consumption and momentary liking differ (Hypothesis 2a), whether momentary wanting and liking will associate differently for different individuals during coffee consumption (Hypothesis 2b) and whether coffee dependence moderates the relationship between momentary wanting and liking during coffee consumption (Hypothesis 2c).

The analyses for this study proceeded in several parts, consistent with the procedure described by Hox (2010). To build the MLM’s a null model was first run to assess degree of within- and between-participant variance in the DV (i.e., subjective responses of wanting and liking in the moment). Intra-class correlations (ICC) were calculated by dividing between-participant variance in the DV by total variance in the DV (i.e., between- plus within-person variance). Second, MLM’s were constructed following a bottom-up approach. That is, the daily predictor (Level 1; either wanting right now or liking right now) was individually included in the model as fixed effects. This step provided an estimate
of the relationship between the within-person factors and the outcome (i.e., either momentary liking or momentary wanting). Third, the individual-level variable (Level 2; “coffee dependence”) was entered into the model (Equations 1 and 2).

A bottom-up approach was also used to construct a MLLR. First, a null model was first run to assess degree of within- and between-participant variance in the DV (i.e., whether coffee was consumed- ‘yes’ or ‘no’) Second, the daily predictors (Level 1; wanting right before consumption and liking during consumption) were individually included in the model as fixed effects. This step provided an estimate of the relationship between the within-person factors and the outcome (i.e., whether coffee was consumed- ‘yes’ or ‘no’). Third, random effects were modeled in order to determine whether the strength of association between the Level 1 variables and the outcome variable differed across participants. Fourth, the individual-level variable (Level 2; “coffee dependence”) was entered into the model (Equations 1 and 2). Cross-level interactions between Level 1 variables and Level 2 variables were also tested (Equation 3).

The models are represented mathematically as follows:

Level 1: $Y_{ij} = \beta_{0j} + \beta_{1j}X_{ij} + T_{ij} + e_{ij}$  \[Equation 1\]

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01}W_j + u_{0j}$  \[Equation 2\]

$\beta_{1j} = \gamma_{10} + \gamma_{11}W_j + u_{1j}$  \[Equation 3\]

4.3. Results

4.3.1 Data preparation.

Prior to the main analysis, data were screened to ensure that they met the assumptions of multivariate analysis (Tabachnick & Fidell, 2006). There were no outliers or evidence of non-normality in any variables. The analyses were
performed using maximum likelihood estimation in R v3.1.3 (R Core Team, 2013) with the lme4 package (Bates et al., 2015). Momentary wanting and liking were group-mean centered and time (i.e., response number) was controlled for in both models.

4.3.2 Descriptive statistics.

Table 4.2 presents the means, standard deviations and possible range of scores for the key Level 1 and Level 2 variables in the current study.

Table 4.2 Descriptive Data for Key Variables

<table>
<thead>
<tr>
<th>Level</th>
<th>Variable</th>
<th>M</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wanting right now</td>
<td>5.08</td>
<td>3.21</td>
<td>1-10</td>
</tr>
<tr>
<td></td>
<td>Liking right now</td>
<td>5.51</td>
<td>3.06</td>
<td>1-10</td>
</tr>
<tr>
<td></td>
<td>Wanting experienced before consumption</td>
<td>7.20</td>
<td>1.59</td>
<td>1-10</td>
</tr>
<tr>
<td></td>
<td>Liking experienced during consumption</td>
<td>7.28</td>
<td>1.32</td>
<td>1-10</td>
</tr>
<tr>
<td>2</td>
<td>Coffee dependence</td>
<td>9.85</td>
<td>3.65</td>
<td>1-19</td>
</tr>
</tbody>
</table>

4.3.3 EMA Compliance Statistics.

In total, 81 daily coffee users (male= 31 and female= 50) aged between 18 and 57 (M= 25.08, SD= 7.95) provided 12 days of self-monitoring. The typical length of time participants responded to the EMA prompts was 10.26 days (SD= 2.19) out of a possible 12 days. During the calibration phase participants received 7 prompts daily (and were required to manually complete a survey every time coffee was consumed). Participants received between 3 and 9 surveys daily during the testing phase (this was dependent on how many cups of coffee they
typically drank per day). EMA recording descriptive data are displayed in Table 4.3. Overall, participants completed ~62% of expected surveys (i.e., 3446 surveys were completed out of ~5546 expected surveys to be completed- note that this does not take into account the manually completed prompts).

**4.3.4 Burst Compliance Statistics.**

In this study, a “burst” was defined as more than 2 responses to surveys within 60 minutes of one another. It was found that on 86 occasions, 3 or more consecutive surveys were completed. On 13 occasions, 4 or more consecutive surveys were completed. And on 1 occasion, 6 consecutive surveys were completed.

Table 4.3. *EMA recording descriptive data*

<table>
<thead>
<tr>
<th>EMA descriptive data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of EMA recordings</td>
<td></td>
</tr>
<tr>
<td>Calibration phase</td>
<td>1403</td>
</tr>
<tr>
<td>Test phase</td>
<td>1932</td>
</tr>
<tr>
<td>Average number of EMA recordings p/d/p</td>
<td></td>
</tr>
<tr>
<td>Calibration phase</td>
<td>4.23</td>
</tr>
<tr>
<td>Test phase</td>
<td>2.88</td>
</tr>
</tbody>
</table>

*p/d/p= per day, per participant

**4.3.5 Main Analyses.**

To test hypothesis 1, two MLM’s were constructed. Calculation of the ICC (ICC = .33 and .37) revealed that 33% and 37% of variance in momentary wanting and momentary liking, respectively, was attributable to between-group differences, whereas the remainder (67% and 64% respectively) was attributable
to intra-individual variability from moment to moment. These ICC values indicate that much of the variance in wanting and liking has both between and within individual variance, illustrating that both constructs have trait and state like components.

The MLM’s illustrated that, at the within-subject level, liking right now was a significant predictor of wanting right now and wanting right now was a significant predictor of liking right now. At the between-subject level, coffee dependence was a significant predictor of wanting right now, but not liking (see Table 4.4).
Table 4.4. *Two Multilevel Models Predicting Wanting Coffee Right Now and Liking Coffee Right Now*

<table>
<thead>
<tr>
<th>Wanting Right Now</th>
<th>Liking Right Now</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within-person effects</strong></td>
<td></td>
</tr>
<tr>
<td>Liking right now</td>
<td>.78</td>
</tr>
<tr>
<td>Wanting right now</td>
<td>-</td>
</tr>
<tr>
<td><strong>Between-person effects</strong></td>
<td></td>
</tr>
<tr>
<td>Coffee dependence</td>
<td>.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model Fit</th>
<th>Intercept Final Model</th>
<th>Intercept Final Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIC</td>
<td>13847.72 3802.70</td>
<td>13599.15 3105.60</td>
</tr>
<tr>
<td>BIC</td>
<td>13859.51 3110.82</td>
<td>13610.94 3133.72</td>
</tr>
<tr>
<td>LogLik</td>
<td>-6921.86 -1535.35</td>
<td>-6797.58 -1546.80</td>
</tr>
<tr>
<td>R^2</td>
<td>.77</td>
<td>.81</td>
</tr>
</tbody>
</table>

To test hypothesis 2a, b and c, a MLLR was constructed. The model illustrated that, at the within-subjects level, wanting experienced before consumption and liking during consumption were positively associated with coffee consumption (see Table 4.5). Moreover, coffee dependence was not a significant predictor of coffee consumption. Random effects illustrated that momentary wanting and liking associated differently with coffee consumption for different individuals (see Table 4.6), however, cross-level interactions between momentary wanting and coffee dependence and momentary liking and coffee dependence were not significant.
### Table 4.5. Multilevel Logistic Regression Predicting Coffee Consumption

<table>
<thead>
<tr>
<th>Within-Person Association</th>
<th><strong>β</strong></th>
<th><strong>SE</strong></th>
<th><strong>Z</strong></th>
<th><strong>p</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Wanting experienced before consumption</td>
<td>0.74</td>
<td>.11</td>
<td>6.93</td>
<td>0.001*</td>
</tr>
<tr>
<td>Liking experienced during consumption</td>
<td>1.01</td>
<td>.11</td>
<td>8.10</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

**Between-person effects**

| Dependence                                             | 0.10  | 0.10   | 0.99  | 0.33  |

**Interaction effects**

| Wanting experienced before consumption*Dependence       | 0.03  | 0.03   | 1.29  | 0.20  |
| Liking experienced during consumption*Dependence        | -0.04 | 0.03   | -1.52 | 0.13  |

*Wanting experienced before consumption and liking experienced during consumption were significant predictors in the final model

---

### Table 4.6. Analysis of Variance (ANOVA) to Test Model Fit between the Null and Random Effects Model

<table>
<thead>
<tr>
<th></th>
<th><strong>df</strong></th>
<th><strong>AIC</strong></th>
<th><strong>BIC</strong></th>
<th><strong>loglik</strong></th>
<th><strong>p</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Null model</td>
<td>2</td>
<td>4930.90</td>
<td>4942.90</td>
<td>-2463.19</td>
<td></td>
</tr>
<tr>
<td>Random effects model</td>
<td>4</td>
<td>302.90</td>
<td>328.10</td>
<td>-147.47</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

4.4 Discussion

4.4.1 Overview.

Chapter 3 reported on the first test of dissociation between wanting and liking, and found that while the effect was partially evident in alcohol users, it was not present in daily coffee drinkers. To consider the fluctuations of these constructs momentarily and to improve ecological validity, this study employed a novel, I-EMA protocol to test the dissociation between wanting and liking in daily coffee users. The results of this study partially support IST. First, coffee dependence was significantly and positively related to momentary wanting but not liking, consistent with hypothesis 1. Second, coffee consumption was significantly and positively related to momentary wanting and liking, consistent with hypothesis 2a. Momentary wanting and liking associated differently with coffee consumption for different individuals, consistent with hypothesis 2b, however, coffee dependence did not moderate the relationship between momentary wanting and liking during coffee consumption, inconsistent with hypothesis 2c. Although, there was mixed success using, I-EMA, this study provided a novel method of assessing wanting and liking momentarily. These theoretical and methodological implications will now be addressed in detail below.

4.4.2 Theoretical implications.

This study demonstrated differences in the relationships between coffee dependence and momentary wanting, and coffee dependence and momentary liking. Particularly, coffee dependence was significantly associated with momentary wanting but not momentary liking. This is consistent with the prediction that wanting and liking are separate processes (Berridge, 1996;
Robinson & Berridge, 1993). These findings are in line with previous studies also suggesting that substance use or dependence is associated with wanting but not liking (e.g., Evans et al., 2006; Hobbs et al., 2005; Lambert et al., 2006; Ostafin et al., 2010; Pieters et al., 2011; Rose et al., 2010; Small et al., 2009; Wiers et al., 2002), consistent with IST, however this was not a directly test of the increasing dissociation between wanting and liking.

IST suggests that the dissociation between wanting and liking is a function of liking decreasing, and wanting increasing (Berridge & Robinson, 2016). Particularly, as dependence increases, wanting should become a stronger predictor of consumption and liking should become less influential, explaining why some individuals continue to maintain drug use, despite the negative consequences involved. In this study, momentary wanting and liking appeared to predict coffee consumption and both constructs associated differently with coffee consumption for different individuals, however, an individual’s level of coffee dependence did not moderate the relationship between the two constructs during coffee consumption, suggesting that as levels of dependence increase wanting and liking did not dissociate from each other. As such, these findings are not in line with IST.

There are potentially a number of explanations for these non-significant findings. First, it is possible that caffeine functions differently at the neurological level compared to other addictive substances (Cauli & Morelli, 2005). As such, the increasing dissociation between wanting and liking, observed in individuals dependent on alcohol (Pieters et al., 2011) and cocaine (Goldstein et al., 2010), may not generalise to caffeine. Repeatedly using addictive substances such as alcohol and cocaine has been shown to produce adaptations in the mesocorticolimbic dopamine system (Bassareo et al., 2013; Di Chiara &
Imperato, 1988; Mendez et al., 2009; Vanderschuren & Kalivas, 2000), which is a system proposed to be directly involved in the process of wanting (Mendez et al., 2009; Vanderschuren & Kalivas, 2000). Through repeated substance use, this system becomes sensitised and as a result, levels of wanting increases as liking decreases (i.e. the two constructs become dissociated; Robinson & Berridge, 1993; 2008). However, research suggests that caffeine directly targets the prefrontal cortex rather than the mesocorticolimbic dopamine system (Cauli & Morelli, 2005; Ferre, 2016; Nehlig et al., 1986; Nehlig, 1999). Thus, it is possible that the mesocorticolimbic dopamine system may not become sensitised in caffeine users and consequently levels of wanting and liking can remain relatively similar (i.e. no dissociation) regardless of an individual’s level of caffeine use, despite being separable processes.

Second, the finding that coffee dependence did not moderate the relationship between wanting and liking during coffee consumption may also be the result of a restricted range of coffee drinkers used in this study. Given that sensitisation is a function of repeated heavy use (i.e., dependence; Robinson & Berridge, 2003), these effects would likely be more clearly demonstrated in a sample that included very highly dependent users. In the current sample, only 10% of the sample scored very highly (15 and above out of 19) on the coffee dependence measure. Given this, if dissociation between wanting and liking occurs in caffeine use comparably to other substances, it may not have begun to manifest in the heavier coffee drinkers within this sample.

Moreover, this study was the first to measure wanting and liking together (framed in IST) momentarily in the daily life of an individual. In this respect, this study was the first to empirically demonstrate the state-like properties of wanting
and liking in a human sample. Specifically, in this study wanting and liking were reported to vary significantly within individuals as ICC’s indicated that within participant variance was 67% (wanting) and 64% (liking). That is, wanting and liking are not stable individual differences but demonstrate appreciable change across time. Thus, this study highlights the significance in using momentary assessment protocol such as EMA/I-EMA to examine such constructs.

4.4.3 Methodological implications.

A novel I-EMA design was implemented in this study. That is, survey prompts were automated and targeted around the time at which typical coffee use occurred for each individual participant. This was useful, as it allowed for the appropriate temporal resolution and assessment of the patterns between wanting and liking for each individual. Moreover, participants received a ‘burst’ of surveys (i.e., consecutive surveys [minimum of 3] targeted at typical coffee consumption times). Consecutive surveys at the time of coffee use was important in this study, as they allowed for the measurement of wanting and liking proximate to coffee use (i.e., before, during and after coffee use—as the direct effects of coffee was essential to examine). Overall EMA compliance statistics suggest that individuals were adequate at responding to surveys over the 12-day testing period. However, responding to consecutive surveys (i.e., bursts) at the time of coffee consumption was considerably low. There are several reasons for why this may have occurred in the following study. For example, it is possible that participants were possibly burdened by the prompts and did not respond to prompts. Moreover, participants in the following study were given a brief procedure prior to participation. That is, they were asked to simply download the application to their smartphone and following the testing phase to complete the
surveys when prompted. It could have been the case that participants misunderstood multiple prompts as a glitch in the application, and thus, did not respond to more than one survey within a 60-minute period.

Although an I-EMA design with bursts of surveys appears to be a suitable data collection strategy in theory, in practice it requires substantial participation from participants. Future research should consider possible refinements to the protocol. For example, researchers should establish to participants that responding to consecutive surveys within a 60-minute period is an important aspect of the study as it measures the fluctuations of both constructs surrounding substance consumption. If this can be implemented, given the acute measurement of variables proximate to a specific behaviour, this method should not include measurements taken outside of the behaviours window, thus capturing the direct effect of the behaviour rather than capturing effects that are likely to be dominated by trait level effects and random variance. Moreover, an I-EMA can enable the assessment of behaviours with infrequent, and individually variant time courses (e.g., smoking), thus, providing substantial advantages over consistent, high-intensity measures and erratic average behaviour sampling.

Consequently, it is recommended that and I-EMA protocol be used in future research within IST, enabling a test of the dissociation between wanting and liking that is direct and ecologically valid in human populations. Further studies utilising this protocol with various other addictive substances and samples is also recommended.

**4.4.4 Limitations.**

In addition to the above, there were several other limitations. First, a validated caffeine dependence measure does not currently exist in the literature.
Additionally, there is no currently accepted cut offs for categorising caffeine use levels (Addicott et al., 2009). For this study, the Fragerstrom Nicotine Dependence Questionnaire (Heatherton, et al., 1991) was adapted to construct a measure of coffee dependence. However, given the assumption that individual consumption would be correlated with dependence, the moderate correlation between the coffee dependence scale and the average coffees consumed per day per individual ($r = .67$) supports the validity of this measure. However, validation of this measure against the Diagnostic and Statistical Manual of Mental Disorders (DSM) or the International Classification of Diseases (WHO; ICD-10) would improve confidence in the measurement of coffee dependence.

Second, prior to the testing phase the Principal researcher allocated survey prompts for each individual calculated from his or her baseline survey, and EMA responses from the calibration phase (days 1-4). This was done manually, thus there was a potential for human error during this procedure. Implementing algorithms imbedded in the program may resolve this issue in the future.

Third, this study was only focused on collecting wanting and liking responses close to coffee consumption. To avoid burdening participants, this study employed an individualised data collection strategy- prompting participants to complete the survey at times they would typically drink coffee. However, it is possible that some individuals did not drink coffee during the survey times (and perhaps drank coffee on other occasions), as such the measurement of wanting and liking may not have been as close to coffee consumption as was anticipated.

4.5 Conclusion

Despite these limitations, this study provides new insights into the dissociation between wanting and liking in daily coffee users using a unique I-
EMA protocol. Importantly, this study established that subjective wanting and liking are both highly variable within subjects, and due consideration of these variables should be sensitive to their state-like properties and momentary confounds (e.g., context and mood). As such, EMA designs may be valuable when examining the dissociation between wanting and liking, and particularly I-EMA protocols may be useful in examination of these variables proximately to consumption behaviours; however, future refinements and use with other addictive substances and samples is required.

The following chapter (Chapter 5) will summarise the findings from the systematic literature review (Chapter 2) and the two empirical studies testing the dissociation between wanting and liking (Chapters 3 and 4). Additionally, it will discuss what these findings mean, collectively, for IST and human addiction behaviour, and highlight future research avenues and clinical implications.
Chapter Five: General Discussion

5.1 Overview

This thesis addressed the IST proposition that wanting and liking are two dissociable constructs of reward. Specifically, IST suggests that wanting and liking of addictive substances have the ability to dissociate over time and repeated substance misuse (i.e., substance addiction; Berridge & Robinson, 2016). This key tenet of IST is proposed to explain the transition from substance use to compulsive use, and the maintenance of substance misuse, in some individuals (Robinson & Berridge, 1993). However, limited studies have attempted to test the dissociation between wanting and liking in human substance users. Without this research it is difficult to establish the strength of the theory in human substance addiction behaviour. That is, whether the dissociation between wanting and liking is evident in humans across varying measures, levels of substance users and addictive substances. By systematically reviewing the human evidence for the dissociation between wanting and liking, as well as conducting empirical studies of two different design types (cross-sectional and micro-longitudinal), this thesis sought to examine and test for the dissociation between wanting and liking.

Across the two empirical studies and systemic literature review, it was established that there is some level of support for IST in human substance users across varying measurement types, however, the type of sample and the addictive substance used appeared to influence the strength of the findings. In this final chapter, a brief summary of each study (Chapter 2, 3 and 4) will be provided. Following this will be a detailed discussion regarding the key implications of this thesis to IST. This chapter will end with an overview on the clinical implications...
of the findings from this thesis and IST in general, thesis limitations and recommendations for future research in this area.

5.2 Summary of Main Findings

5.2.1 Systematic literature review.

Chapter 2 reviewed the existing literature testing the dissociation between wanting and liking in human substance users. The review illustrated that substance misuse or dependence is positively associated with wanting but not liking in 9/14 studies. These findings were demonstrated across different measures (self-report, implicit, behavioural and neurophysiological), different substances (alcohol, cocaine, amphetamines and a pharmaceutical drug- L-dopa) and various sample types (e.g., non-dependent/non-sensitised or dependent/sensitised). Although this evidence is supportive of IST, the direct test of tenet four is to test the increasing dissociation between the two constructs over time and repeated substance use (i.e., prospectively), yet limited studies in this review tested this (King et al., 2011, Lambert et al., 2006; Small et al., 2009). The three studies that did use prospective designs illustrated varied findings, highlighting this as an area requiring further investigation.

The review indicated that the most common measuring tool used to examine wanting and liking was self-report measures, however, no consistent self-report measure exists in the literature with each study operationalising wanting and liking differently. Thus, it was argued in this thesis that the STRAP-R questionnaire (Goldstein et al., 2010) may be an appropriate candidate for consistent use given the items are most in line with the conceptualisation of wanting and liking put forward by Robinson and Berridge (1993). However, the authors recommend additional studies to assess the reliability of the STRAP-R in
larger samples and various addictive substances. Moreover, some commonly used addictive substances have not been tested on (e.g., caffeine), thus the generalisability of the theory to these commonly used addictive substances is limited.

5.2.2 Empirical study one.

The systematic review indicated the need to test the dissociation between wanting and liking in human substance users. The focus of the first empirical study was to test the dissociation between the two constructs in a cross-sectional study using the STRAP-R questionnaire in alcohol and caffeine drinkers. This study indicated partial support for IST in alcohol users only. Specifically, the strength of the relationship between wanting and alcohol consumption became stronger from low-risk to high-risk alcohol users. Conversely, the strength of the relationship between liking and alcohol consumption became weaker from low-risk to high-risk alcohol users, consistent with IST. These findings suggested that in high-risk alcohol users, wanting may play a greater role in alcohol consumption more so than liking compared to low-risk alcohol users. However, perhaps due to a lack of a clinically dependent sample, in this study, an increasing dissociation between wanting and liking was not illustrated across low-risk and high-risk alcohol users.

This study was the first to test the dissociation between wanting and liking using caffeine. However, dissociation between wanting and liking for caffeine was not found. As discussed in Chapter 3, it is possible that caffeine functions differently at the neurological level compared to other substances (Cauli & Morelli, 2005). As such, the dissociation between wanting and liking, observed in individuals dependent on alcohol (Pieters et al., 2011) and cocaine (Goldstein et
al., 2010), may not generalise to caffeine. Alternatively, it could be that the sample did not include heavy enough caffeine drinkers for the dissociation to be revealed. Nevertheless, findings from this study provided some support for the theory in alcohol users, which support the utility of the STRAP-R to test the dissociation between wanting and liking in human substance users.

### 5.2.3 Empirical study two.

While Study one showed that the dissociation between wanting and liking was partially evident in alcohol users and not in coffee users using the STRAP-R questionnaire, the I-EMA study presented in Chapter 4 aimed to test the dissociation between wanting and liking in coffee within everyday life. It was argued that a design that examines the fluctuations of wanting and liking momentarily might be more sensitive to the influence of wanting and liking in coffee users. The findings from this study illustrated some support for IST in coffee users, as coffee dependence was positively and significantly associated with wanting, but not liking. However, coffee dependence did not moderate the relationship between wanting and liking during coffee consumption. These findings are consistent with the explanation put forward in study one, that caffeine may not sensitise the mesocorticollimbic dopamine system as it does with other addictive substances (e.g., alcohol), thus preventing dissociation between the two constructs from emerging. Or it may have also been the result of a restricted range of coffee drinkers used in the study (i.e., only 10% of the sample scored very highly on the coffee dependence questionnaire). Further studies are required before any firm conclusions can be reached.

Nevertheless, this study established that subjective wanting and liking are both highly variable within subjects. Consequently, future research needs to take
into consideration the state-like properties and momentary confounds of these variables. As such, this study established that EMA designs are valuable when measuring wanting and liking, and particularly I-EMA protocols are most useful in examination of these variables proximate to consumption behaviours.

5.3 Key Implications

By systematically examining accumulated evidence, as well as conducting several empirical studies of varying design types (cross-sectional and micro-longitudinal), this thesis provides a unique summary of the evidence for tenet four of IST with commonly consumed substances. Across the studies provided in this thesis, several key themes have emerged; a) measures used to assess wanting and liking, b) the nature of the two constructs, and c) addictive substances used to test the dissociation. Further investigation and discussion of these themes may aid in the refinement of the theory and address issues regarding the test of the dissociation in human populations. These themes will be discussed in detail below.

5.3.1 Measuring wanting and liking.

The systematic literature review contained in this thesis illustrated some support for IST across varying measurements (e.g., neurophysiological, behavioural, implicit and self-report). The most common measure of wanting and liking are explicit self-report measures. However, using explicit self-report measures to examine wanting and liking is not without controversy. The controversy has been briefly discussed in Chapter 3, but a more detailed discussion will be provided below.

The neurophysiological measurement of wanting and liking is considered the most direct measurement of wanting and liking in humans (Berridge &
Robinson, 2016; Tibboel et al., 2015). This is due to the neurological foundation of IST and the strong evidence in support of the theory in animal models using neurological methods (Berridge, Robinson & Aldridge, 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000). There is some human evidence suggesting that the mesocorticolimbic dopamine system is associated with wanting and not liking, consistent with IST (e.g., Leyton, 2007; Pieters et al., 2011), however this evidence is scarce, and thus, further evidence in this area is required in the literature.

More pragmatic methods to test the dissociation between wanting and liking are to examine its manifestations (i.e., the psychological and experiential aspects of wanting and liking in humans, which was the focus of this thesis). This is commonly done explicitly via self-report measures (e.g., empirical study one and two) or few studies have done this indirectly via implicit tasks. For example, Tibboel et al. (2011) designed a liking Implicit Association Task (IAT), in which the attribute labels were “I like” and “I do not like” and a wanting IAT, in which the attribute labels were “I want” and “I do not want”. However, there has been an increasing debate in the literature surrounding the validity of utilising explicit measuring tools such as, self-report measures to examine wanting and liking (Anselme & Robinson, 2016; Tibboel et al., 2015).

Research suggests that unconscious components of reward effect our behaviour, and are not always accompanied by conscious awareness (Aarts et al., 2008; Berridge & Winkielman, 2003; Pessiglione et al., 2007, 2008). Given this, some researchers have argued that implicit measuring tools are more suitable, and debate whether self-report measures are sufficiently sensitive when measuring wanting and liking (Anselme & Robinson, 2016; Tibboel, De Houwer & Van
Bockstaele, 2015). However, it is argued in this thesis (and by other researchers e.g., Hobbs, Remington, & Glaution, 2005; Goldstein et al., 2010; Willner et al., 2005) that the constructs should also be able to be measured explicitly. That is, IST provides an explanation for drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Berridge and Robinson, 1995; Grant et al., 2000; Hyman, 2007). If this explanation holds, then the behavioural manifestations of wanting and liking (craving and pleasure) should be able to be explicitly measured.

Perhaps there is utility for using both implicit and explicit self-report measurements for examining the manifestations of wanting and liking in humans, as there is some support for IST across both measurement types. Measuring complex concepts from different perspectives enriches our overall understanding. For example, research in impulsivity suggests that objective measures (e.g., Stop Signal Reaction Time [SSRT]) and subjective measures (e.g., self-report measures such as the Barratt Impulsivity Scale [BIS-11]) often fail to correlate, possibly suggesting that both measures are assessing different aspects of impulsivity (Moeller et al., 2001). Although, research also suggests that impulsivity (in general) consists of different components, which can all be measured in one individual (Daley, Everitt, Robins, 2011). Furthermore, many have argued that our understanding of impulsivity has been enriched by the different measurement types and its state and trait like qualities. Thus, it is likely that the measurement of wanting and liking requires a composite approach resulting in varied measurement modalities, similar to impulsivity. Thus, it is possible that we need to view each type of measurement approach as assessing a
component of wanting and liking. Also, it may be the case that the most effective measurement of the manifestations of wanting and liking in humans (either implicit or explicit measurement) may still be evolving, and perhaps a combination of measurement types can add to our overall understanding of the multifaceted concepts.

5.3.2 The nature of wanting and liking.

Empirical study two demonstrated that wanting and liking have both trait- and state-like properties. That is, wanting and liking constructs differ in somewhat predictable ways from one individual to the next (in a trait-like way) and also within each individual from one context to the next (in a state-like way). While both of these trait- and state-like aspects appear to hold importance in understanding wanting and liking, the vast majority of past research using self-report measures have generally investigated the trait-like aspect of these constructs (e.g., Small et al., 2009) or have measured wanting and liking on one occasion (e.g., Hobbs, Remington, & Glautier, 2005; Goldstein et al., 2010; Willner et al., 2005). These studies do not directly examine wanting and liking in an individual’s everyday life, and do not take into account the fluctuations of the constructs overtime, which may influence the dissociation in human substance users.

Within this thesis, empirical study one measured wanting and liking with caffeine using the STRAP-R questionnaire, and empirical study two-measured wanting and liking with caffeine using an EMA design. Findings from the two studies differed. Specifically, the dissociation between wanting and liking was more evident with coffee users in study two than in study one, which may suggest that measuring wanting and liking directly in the everyday life of an individual
and micro-longitudinally, is more sensitive than measuring the two constructs on a single occasion within a laboratory setting. Thus, implementing more direct measurement approaches (e.g., momentary assessment methods) that take into consideration the fluctuations of these constructs overtime may be a useful type of assessment of the two constructs.

5.3.3 Type of reward.

Findings from the two empirical studies presented in this thesis questions the generalisability of IST to all addictive substances. Specifically, study one and two examined the dissociation between wanting and liking in daily coffee users. Interestingly, the dissociation was not clearly evident in either study, despite research suggesting that caffeine can induce physical dependence with tolerance and withdrawal properties (Budney et al., 2015; Juliano et al., 2012; Juliano and Griffiths, 2004). Caffeine Use Disorder is not a specified diagnosis in the Diagnostic and Statistical Manual (WHO; DSM-5), but has been placed in the category of Conditions for Further Study (American Psychiatric Association, 2013), thus it has potential to effect an individual’s psychological well-being, however more research is required.

Given the inconsistent findings, it is suggested that perhaps caffeine functions somewhat differently at the neurological level compared to other addictive substances (Cauli & Morelli, 2005). That is, the mesocorticolimbic dopamine system may not become sensitised (or may not sensitise to the same extent as it does with other addictive substances) in caffeine users and consequently levels of wanting and liking can remain relatively similar (i.e. no dissociation) regardless of an individual’s level of caffeine use. As such, the dissociation between wanting and liking in humans, observed in individuals
dependent on alcohol (Pieters et al., 2011) and cocaine (Goldstein et al., 2010), may not generalise to caffeine. Repeatedly using alcohol, cocaine and amphetamines have been shown to produce adaptations in the mesocorticolimbic dopamine system (Bassareo et al., 2013; Di Chiara and Imperato, 1988, Mendez et al., 2009; Vanderschuren & Kalivas, 2000), thus these types of rewards are more likely to demonstrate dissociation between wanting and liking in humans (e.g., Goldstein et al., 2010).

Findings from this thesis suggest several points. First, in order for the dissociation between wanting and liking to emerge in human substance users, the reward type (i.e., substance) should not only be reinforcing or ascribed positive value by an individual, it needs to also target the mesocorticolimbic dopamine system. Thus, findings from this thesis confirm the IST proposition that the mesocorticolimbic dopamine system plays an essential role in the development of the dissociation between wanting and liking in human substance users. Second, caffeine may not directly target the mesocorticolimbic dopamine system. Thus, it is possible that the dissociation between wanting and liking may not develop across all addictive substances; consequently the generalisation of the theory to all addictive substances may be limited.

5.4 Clinical Implications

In this thesis it is argued that explicit self-report measures (although they may not be as sensitive as implicit tools) have important clinical utility. It is possible that IST is able to provide an explanation for drug users who say they no longer find taking the drug pleasurable, with many negative consequences and yet they still have a strong craving and need for the drug (Bechara, 2005; Berridge and Robinson, 1995; Grant et al., 2000; Hyman, 2007). Thus, an individual
scoring very highly on an item measuring wanting and very low on an item measuring liking, may help with the diagnoses of substance dependence and perhaps in deciding whether treatment is required. Similarly, explicit self-report measures have been traditionally used for research in eating disorders (e.g., The Eating Disorder Inventory; EDI-3; Garner, 2004), however, clinicians are increasingly finding such measurements useful in evaluating and treating patients in practice (Mitchel & Peterson, 2007).

Moreover, IST provides an explanation for how and why substance dependence develops and is maintained in some susceptible individuals, which may be used to implement treatment strategies for substance addiction. According to IST, addiction is a neurobiological process where permanent physical neurological changes in the brain (i.e., neuroadaptations) are suggested to result from repeated substance use. In theory, reversing the neuroadaptations underlying sensitised mesolimbic sensitivity to drugs and drug-related cues might help treat addiction. This kind of treatment has not been established in humans yet and may be challenging to practically develop, given the difficulty in inhibiting problematic motivations (i.e., compulsive wanting) while not inhibiting normal motivations (e.g., eating healthy) (Berridge & Robinsons, 2016). Though, recent animal studies suggest that it may be possible (Pascoli, Turiault, Luscher, 2011; Pascoli et al., 2014). Optogenetic protocols (i.e., a novel neuroscientific technique that involves the use of light to probe neural circuits) have been used to restore cocaine-induced neuroadaptations in mice and consequently reverse neural sensitisation (Creed et al., 2015). It may take some considerable time for this type of treatment to become available to humans, however this novel treatment is promising.
5.5 Thesis Limitations

Although the current thesis adds to the IST literature, it was not without limitations. Given that caffeine can induce physical dependence (Budney et al., 2015; Juliano et al., 2012; Juliano and Griffiths, 2004), the dissociation between wanting and liking was primarily tested with coffee users in this thesis. However, the dissociation between the two constructs was not clearly evident in this sample. There are number of potential explanations for this. First, as previously discussed, it is possible that caffeine functions differently at the neurological level compared to other addictive substances (Cauli & Morelli, 2005). The mesocorticolimbic dopamine system may not become sensitised (or may not sensitise to the same extent as it does with other addictive substances) in caffeine users and consequently levels of wanting and liking can remain relatively similar (i.e. no dissociation) regardless of an individual’s level of caffeine use. As such, the dissociation between wanting and liking in humans, observed in individuals dependent on alcohol (Pieters et al., 2011) and cocaine (Goldstein et al., 2010), may not generalise to caffeine. Second, it could be that self-report measures are less sensitive to the dissociation of caffeine particularly given so few self-report studies have tested the dissociation in caffeine users. Third, it could be that the samples used in this thesis were not dependent enough. Every effort was made to find heavy coffee users but nonetheless the samples used in this thesis did not comprise a large proportion of dependent alcohol or coffee users to test the dissociation between wanting and liking. Given that sensitisation is a function of repeated heavy use (i.e., dependence; Robinson & Berridge, 2003), dissociation would likely be more clearly demonstrated in a sample that included very highly
dependent users. Given the non-clinical population used in both empirical studies, dissociation between wanting and liking may not have begun to manifest within these samples. Although it should be noted that many of the studies in the review were not highly dependent samples and yet showed some evidence in support for IST.

This thesis focussed on examining the behavioural manifestations of wanting and liking. This was done by explicitly measuring craving and pleasure of coffee and alcohol, via self-report. Thus it is possible that this thesis only examined a sub-component of these constructs as it did not address wanting and liking as unconscious processes, rather only conscious process. That is, some researchers define wanting and liking as “preconscious cognitive and affective processes”, (Tibboel et al., 2015, pg. 9), respectively. However, this thesis examined wanting and liking as a “characteristic of reward” (Tibboel et al., 2015, pg. 11). That is, when an individual attributes incentive salience to a reward, the reward becomes heavily desired and triggers strong approach tendencies that can become compulsive (i.e., craving) (Berridge, Robinson & Aldridge, 2009), and liking is the hedonic experience produced by the reward (i.e., pleasure). It is possible that wanting and liking are multifaceted constructs and thus require various measurement types. Thus, this thesis may have only addressed one component of wanting and liking.

Finally, this thesis limited its focus for pragmatic reasons to the key tenet of IST, tenet four. This thesis could have also investigated tenets one, two and three in human substance users to provide a complete examination of IST, but chose to give attention to just one element of the theory.
5.6 Future Research Areas

This thesis provides several recommendations to be implemented in order to improve future research, IST and its role in understanding addiction. First, even though there is support for IST from both the animal and human literature, further research in this area is required, in particular with regard to the human evidence illustrating the increasing dissociation between wanting and liking over time and repeated substance use. Future research should target sensitised samples (i.e., clinically dependent populations) to more clearly identify non-significant relationships (i.e., dissociation) between wanting and liking. Human studies have predominantly tested the dissociation between wanting and liking using alcohol and cocaine, however, there are multiple addictive substances yet to be examined, for example, marijuana, opiates and methamphetamines.

Second, the lack of dissociation found in caffeine users in this thesis may be due to the fact that caffeine does not directly target the mesocorticolimbic dopamine system. Conversely, it could be that caffeine users were just not dependent enough (as suggested above). Future research is required to establish whether these justifications are accurate. This will not only hold implications for research in IST, but for our understanding of caffeine dependence in general.

Third, although the IST literature is not perfectly clear as to how to validly measure the manifestations of wanting and liking in humans, the neural manifestations of these constructs are more strongly agreed upon (Tibboel et al., 2015). That is, wanting is believed to be the result of neural sensitisation in the mesocorticolimbic dopamine system, which involves the dopamine and dopamine interactions with corticolimbic glutamate and other neurochemical systems.
Liking, in contrast, takes place in the opioid neuronal network in the rostro-dorsal medial shell region of the nucleus accumbens and the ventral pallidum (Berridge, Robinson & Aldridge, 2009; Berridge & Kringelbach, 2008; Mahler, Smith & Berridge, 2007; Smith, Mahler, Pecina & Berridge, 2010). Given this, the most valid test of the theory would be to examine an individual’s brain activity before and after substance consumption. Limited studies have tested this dissociation using neurophysiological methods (e.g., Leyton, 2007; Pieters et al., 2011), thus, future research in this area is required. Moreover, researchers can use cognitive neuroscience to validate implicit and self-reported wanting and liking, thereby potentially resolving the issues of how best to measure the manifestations of wanting and liking in human populations and confirming whether more novel approaches are required.

Fourth, empirical study one was the first study to examine wanting and liking using the STRAP-R following its conception in 2010 by Goldstein and colleagues. Although findings from study one provided some support for the utility of the STRAP-R to test the dissociation between wanting and liking in human substance users, the psychometric properties of this questionnaire needs to be tested. For instance, whether STRAP-R ratings of wanting and liking are predictors of craving and pleasure and whether the STRAP-R can be reliably used across a range of other drugs (e.g., marijuana, opiates and methamphetamines), are questions yet to be answered. This will consequently aid with the STRAP-R potentially being a traditional self-report measure used consistently in the IST literature and consequently generate clinical utility.
Finally, given this study focused on examining the behavioural manifestations of wanting and liking (i.e., craving and pleasure), it is possible that this thesis only examined a sub-component of these constructs as it did not address wanting and liking as unconscious processes, rather only conscious process. Future studies may want to look at both of these components in the one study to increase our understanding of how they are/or not related.

5.7 Summary and Conclusion

Given the substantial negative outcomes associated with substance misuse (National Institute on Drug Abuse [NIDA] 2014), a large amount of research has been directed towards understanding human substance addiction behaviour. IST proposes that as substance dependence develops the motivation to obtain and consume drugs (i.e. wanting) becomes stronger even once the drug has become non-rewarding (i.e. less liked). The IST literature has illustrated pioneering research with animal models (e.g., Berridge, Robinson & Aldridge, 2009; Clark & Bernstein, 2006; Pecina et al., 2003; Wyvell & Berridge, 2000) and human studies (e.g., Goldstein et al., 2010; Hobbs, Remington & Glautier, 2005; Lambert et al., 2006; Rose et al., 2010; Wiers et al., 2002; Willner et al., 2004), using a range of assessment methods. The empirical studies within this thesis used the STRAP-R questionnaire and an I-EMA protocol to measure wanting and liking, both methods demonstrating utility in IST research. It is believed that the findings from this thesis have made a unique contribution to our understanding of the nature and measurement of wanting and liking in humans. However, it is important to note that even though there is support for IST from both the animal and human literature, further research in this area is required, in particular with regard to the human evidence illustrating the increasing dissociation between
wanting and liking over time and repeated substance use. The recommendations put forward in this thesis may further improve future research, IST and its role in understanding addiction.
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and Cancer Research UK.


Appendix A

Link to: Arulkadacham et al. (2017). Dissociation between wanting and liking for alcohol and caffeine: A test of the Incentive Sensitisation Theory

Original Paper

Dissociation between wanting and liking for alcohol and caffeine: A test of the Incentive Sensitisation Theory

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Abstract

Limited human studies have directly tested the dissociation between wanting and liking with human substance users, a core test of the Incentive Sensitisation Theory (IST). The aim of this study is to test the dissociation between wanting and liking in humans across two commonly used illicit substances, alcohol and caffeine. The STRAP-R (Sensitivity to Reinforcement of Addictive and other Primary Rewards) questionnaire was administered to 280 alcohol users (mean age=33.30, SD=8.83) and 134 coffee users (mean age=33.05, SD=8.40) ranging in their levels of substance use to assess wanting and liking. Findings showed that in high risk alcohol users wanting may drive alcohol consumption more so than liking, compared with low risk alcohol users. However, wanting and liking did not significantly dissociate as alcohol consumption increased. These findings partially support IST. Additionally, IST was not supported in coffee users. It is possible that caffeine functions differently at the neurological level compared with alcohol, perhaps explaining the lack of dissociation emerging in coffee users as caffeine use increased. Nevertheless, the current study makes several contributions to IST research. Future studies should focus on utilising the STRAP-R with a clinically dependent sample to test the dissociation between wanting and liking.

Keywords

Incentive Sensitisation Theory, wanting, liking, humans, addiction, alcohol, caffeine, dissociation
PLAIN LANGUAGE STATEMENT

Full Project Title: Testing the Dissociation between wanting and liking using the STRAP-R questionnaire

Principal Researchers: Miss Lilani Arulkadacham (PhD Candidate) & Dr Ben Richardson

Thank you for following up on our invitations to seek more information regarding our study, we truly appreciate your interest. Please read on for a description of our study, after which you are invited to participate.

Purpose
This study intends to investigate a measure of ‘wanting’ (i.e., craving) and ‘liking’ (i.e., pleasure) of addictive substances.

Demands
This study will utilise a 15-minute online questionnaire, hosted on Qualtrics. This questionnaire will contain items pertaining to your consumption of coffee and alcohol use, perceived wanting and liking of coffee and alcohol.

Risks and Benefits
No risks are anticipated for any participants, and benefits are likely to be indirect.

Privacy and Confidentiality Protection
Your responses will be collected in a wholly anonymous format, so your privacy and confidentiality is assured.
Data from this study will be stored for a minimum of 5 years, according to Deakin University’s protocols, before being permanently destroyed. Until then, digital data will be stored on Deakin University’s secure server.

**Dissemination of Results**

It is the intent of the research team to publish the findings of this research in peer-reviewed articles, utilise them in the completion of Lilani Arulkadacham’s PhD thesis. If you would like to receive a summary of results, please contact Lilani at larulkad@deakin.edu.au

**Incentives**

As a reimbursement for your time and efforts you will receive $1.00 as dispensed through the Amazon MTurk service.

**Conflicts of interest**

The researchers have no conflicts of interest to declare. The research is fully funded internally by the School of Psychology.

**Your Rights**

This is a voluntary study, so you should feel under no pressure to participate. Further you may withdraw at any time up to the completion of your online questionnaire; after this time, due to our privacy protocols, removal of your responses from the sample may be impossible.

**More information?**

If you want to know more before participating, or just want to find out more about this research please contact:

Lilani Arulkadacham

ladulkad@deakin.edu.au

Dr Ben Richardson

ben.richardson@deakin.edu.au

Although we believe that the project is low risk, there is a very small chance you may become distressed while participating. If this occurs, please feel free to discontinue at any stage. There are no consequences for withdrawing or choosing not to participate.

If you do become distressed, support and/or information about substance dependence can be found by contacting:

DirectLine on 1800 888 236.

DirectLine is a 24-hour, 7-day a week, telephone counselling, information and referral service that is free, anonymous and confidential.

Quitline on 13 QUIT
Quitline provides a free, confidential and individually tailored service to assist you in the process of quitting smoking.

Turning Point at [http://www.turningpoint.org.au](http://www.turningpoint.org.au)

Turning Point is an online resource aimed at providing treatment and research in the drug and alcohol field

Complaints

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about your rights as a research participant, then you may contact:

The Manager, Research Integrity, Deakin University, 221 Burwood Highway, Burwood Victoria 3125, Telephone: +61 3 9251 7129, [research-ethics@deakin.edu.au](mailto:research-ethics@deakin.edu.au)

Please quote project number **175_2015**

By clicking the red arrow button below, you are agreeing that you have read and understood the Plain Language Statement and that you are consenting to participate in this research.
Appendix C

Advertisement for study II

DO YOU DRINK COFFEE?

And use a smartphone?

If so, you are eligible to participate in a research study examining craving and pleasure of caffeine.

You will be rewarded with a $20 Coles/Myer voucher!

If you would like to participate or have any questions, contact Lilani

Email: larulkad@deakin.edu.au
Mobile: 0400 157 638
PLAIN LANGUAGE STATEMENT

TO: The participant

Date:

Full Project Title: To examine the association between wanting and liking amongst light and heavy coffee drinkers

Principal Researcher: Dr Ben Richardson

Student Researcher: Miss Lilani Arulkadacham

Associate Researcher(s): Dr Nicolas Kambouropoulos, Associate Professor Petra Staiger

1. Your Consent

You are invited to take part in this research project.

This Plain Language Statement contains detailed information regarding this research project. Its purpose is to explain to you as clearly as possible all the procedures involved in this project so that you can make an informed decision on whether to participate or not.

Please read this Plain Language Statement carefully. Feel free to ask any questions about the information in the document.

2. Purpose and Background
Research has suggested that the association between craving and pleasure of an addictive substance may be relevant in the development and maintenance of compulsive substance use. The aim of the current study is to investigate this association in a sample of human coffee drinkers.

To address this question, we aim to have approximately 100 participants take part in this project. You are invited to participate in this research project if:

1. You are over the age of 18 years
   **AND**
2. You own and use an iPhone with iOS8 or above.
   **AND**
3. You are a daily coffee drinker

3. **Funding**

This research is totally funded by Deakin University.

4. **Procedures**

First, you will be invited to complete a baseline questionnaire (presented online via Qualtrics) that measures: demographic information (age and gender), trait affect, sensitivity to reward, perceived stress, impulsivity, history of coffee use and other caffeinated substances, your smoking status and subjective wanting and liking of various rewards (e.g., food, sex and coffee).

After you complete the web-based questionnaire, you will be asked to download a free 5MB application to your iPhone. Once installed you will be prompted the following morning (Day 1) to start some short surveys. Please note that consent to participate in this research project is implied once you download the app and complete the survey.

There will be two stages in this study.

**First stage (Day 1-4):**

On day 1, simply open the application and complete the survey every time you are about to have a coffee or when prompted. The survey will include questions about your current mood, whether you have used coffee or other caffeinated products, and further questions in relation to your wanting/craving and liking/pleasure of the substance/s (e.g., “How much did you like the coffee?”). Repeat this on day 2 and 3. The survey will take less than 1 min to complete.

**Second stage (Day 5-12):**

On day 4 you will receive automated prompts to complete the survey for 8 days. Once prompted, simply complete the survey. The same questions will be asked as per the first stage.
Once participation is complete (after 12-days), you are eligible to receive a $20 Coles voucher in recognition of your time. To receive the voucher, you need to provide your email address in the optional field when you complete the baseline questionnaire (your email address will be stored separately to your questionnaire responses and is used only for the purpose of sending your iTunes voucher once you complete the study). If you choose to provide this information, the voucher will be electronically sent to this address upon the completion of the study.

5. Possible Benefits

We do not expect that you will necessarily receive any direct benefit from participation. However, it is possible that you may become more aware of your caffeine intake on a daily basis.

The larger benefits of this study are directed towards the research area. Specifically, we predict that this project will further our understanding of both wanting/craving and liking/pleasure of addictive substances.

6. Possible Risks

Although we believe that the project is low risk, there is a very small chance you may become distressed while participating. If this occurs, please feel free to discontinue at any stage. There are no consequences for withdrawing or choosing not to participate.

If you do become distressed, support and/or information about substance dependence can be found by contacting:

- DirectLine on 1800 888 236. DirectLine is a 24-hour, 7-day a week, telephone counselling, information and referral service that is free, anonymous and confidential.
- Turning Point at [http://www.turningpoint.org.au](http://www.turningpoint.org.au) Turning Point is an online resource aimed at providing treatment and research in the drug and alcohol field

7. Privacy, Confidentiality and Disclosure of Information

Data collected as part of the project will not be associated with identifying information. Your responses are linked using an anonymous ID generated randomly when you first install the app.

Publications resulting from this study will only report aggregated group level data that will not identify you. Data obtained as part of the study will be securely stored for a minimum of six years, consistent with Deakin University guidelines.

The primary researcher will monitor the conduct and progress of the research during regular supervision meetings. These meetings will involve discussion of the issues surrounding the implementation of the study, design and management of the collected data.

8. Results of Project
If you are interested in the outcome of the research please contact the primary researcher on the project Lilani Arulkadacham (lilani.arulkadacham@deakin.edu.au) who will be able to provide you with a summary of results. In addition, we plan to report the results in a peer-reviewed publication, at peer-reviewed conferences, and as a part of the thesis requirement for Lilani Arulkadacham’s Doctor of Philosophy (Psychology) course.

9. **Participation is Voluntary**

Participation in any research project is voluntary. **If you do not wish to take part you are not obliged to.** If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. Simply provide your unique (anonymous) ID to the researchers via email, phone and the researchers will withdraw your data from the study. Your decision whether to take part or not to take part, or to take part and then withdraw, will not affect your relationship with Deakin University.

Before you make your decision, the primary researcher will be available to answer any questions you have about the research project. You can ask for any information you want.

Please remember to complete the questionnaire only after you have had a chance to ask your questions and have received satisfactory answers.

10. **Ethical Guidelines**

This project will be carried out according to the *National Statement on Ethical Conduct in Human Research* (2007) produced by the National Health and Medical Research Council of Australia. This statement has been developed to protect the interests of people who agree to participate in human research studies.

The ethics aspects of this research project have been approved by the Human Research Ethics Committee of Deakin University.

11. **Complaints**

If you have any complaints about any aspect of the project, the way it is being conducted or any questions about your rights as a research participant, then you may contact:

The Manager, Ethics and Biosafety, Deakin University, 221 Burwood Highway, Burwood Victoria 3125, Telephone: 9251 7129, [research-ethics@deakin.edu.au](mailto:research-ethics@deakin.edu.au)

Please quote project number 175_2015

12. **Further Information, Queries or Any Problems**

If you require further information please contact any of the researchers involved in the project.

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