RUNNING HEAD: IMPLICIT MEASURES IN IST

Implicit measures of "wanting" and "liking" in humans

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Abstract

Incentive Sensitization Theory (IST; e.g., Robinson & Berridge, 1993; 2003) suggests that a common dopamine system that deals with incentive salience attribution is affected by different types of drugs. Repeated drug use will sensitize this neural system, which means that drugs increasingly trigger the experience of incentive salience or "wanting". Importantly, Robinson and Berridge stress that there is a dissociation between drug "wanting" (the unconscious attribution of incentive salience) and drug "liking" (the unconscious hedonic experience when one consumes drugs). Whereas the former plays an essential role in the development and maintenance of drug addiction, the latter does not. Although this model was based mainly on research with non-human animals, more recently the dissociation between "wanting" and "liking" has been examined in humans as well. A widely used and promising means of studying these processes are behavioral implicit measures such as the Implicit Association Test (IAT), the Approach-Avoidance Task (AAT), different types of Stimulus-Response Compatibility (SRC) tasks, and Affective Simon Tasks (AST).

IST makes the clear prediction that (1) there should be a positive correlation between indices of "wanting" (e.g., drug consumption) and implicit "wanting" scores. Similarly, there should be a positive correlation between indices of "liking" (e.g., various expressions of subjective pleasure) and implicit "liking" scores; (2) there should be higher "wanting" scores in substance abusers or frequent substance users compared to non-users or infrequent users, and there should be no differences in "liking" between these groups (or even less "liking" in frequent substance users); (3) manipulations of "wanting" should affect implicit "wanting" scores whereas manipulations of "liking" should affect implicit "liking" scores. However, studies that tested these hypotheses did not produce equivocal results. To shed light on these discrepancies, we first discuss the different definitions of "wanting" and "liking" and the different tests that have been used to assess these processes. Then, we discuss whether it is

reasonable to assume that these tests are valid measures of “wanting” and “liking” and we review correlational, quasi-experimental, and experimental studies that inform us about this issue. Finally, we discuss the future potential of implicit measures in research on IST and make several recommendations to improve both theory and methodology.

1. Introduction

Many researchers have been baffled by the so-called addiction paradox. Why do addicts continue to pursue and use drugs even though they are fully aware of the harmful consequences of their behavior? One of the most influential theories that attempted to tackle this question is Robinson and Berridge's Incentive Sensitization Theory (IST; e.g., 1993; 2003; 2008). Robinson and Berridge (2000) note that earlier theories on addiction focussed mainly on negative reinforcement (i.e., addicts want to avoid unpleasant withdrawal symptoms and therefore continue to use drugs) and positive reinforcement (i.e., addicts continue to use drugs because they enjoy the pleasurable experience; e.g., Solomon & Corbit, 1973). Such theories could not explain several important questions, such as why addicts often relapse even though they no longer experience withdrawal symptoms, and why they continue to use drugs even when the pleasurable effects have become small or non-existent.

IST suggests that in vulnerable individuals, intermittent drug use sensitizes specific drug effects, whereas other effects habituate, and still other effects remain stable. According to the model, two processes become sensitized: first, there is the sensitization of psychomotor effects (i.e., habitual drug users become more active, aroused, and explorative, and they show stronger general approach tendencies). Second, and most importantly, brain systems that are involved in attributing a rewarding value (i.e., incentive salience) to stimuli are sensitized also. This hypersensitivity means that conditioned stimuli that are associated with drug administration become increasingly sought after and wanted, that these stimuli capture attention, and that they become more arousing. This creates a dissociation between drug "wanting" and drug "liking". Drugs are no longer pursued because of their euphoric effects ("liking") but because of the incentive-motivational properties of drugs and drug-related stimuli ("wanting"). IST suggests that incentive sensitization has lasting effects. It can thus explain why so many addicts relapse long after their withdrawal symptoms have disappeared:

drug cues remain desired and highly salient even when the physical need to use drugs is extinguished (e.g., Berridge & Robinson, 2003; Robinson & Berridge, 1993, 2001, 2003, 2008).

Even though usually "wanting" mirrors "liking" (i.e., we "want" and pursue things we "like" and we avoid things we do not "like"), these processes do not need to overlap. Winkielman and Berridge (2003) suggest that "wanting" may have evolved separately from and earlier than "liking". They distinguish two types of "wanting" that might have evolved at different stages. First, they state that "wanting" was originally (i.e., before conscious experience) an elementary and unconditioned means to make decisions about the pursuit of innate rewards such as food, water, and mates. This type of "wanting" was unrelated to "liking". Second, "wanting" evolved to become the conditioned motivational process to pursue incentives that were previously "liked". This means that different brain mechanisms are at play for "liking" and "wanting" and that consequently (and crucially) "wanting" can occur without "liking". Specific dopamine systems are assumed to play a role solely in the attribution of incentive salience ("wanting"), whereas they do not play a role in hedonic aspects of substance use ("liking") (e.g., Robinson & Berridge, 2008). Within the nucleus accumbens (NAcc), for instance, a "hedonic hotspot" has been identified that is assumed to be involved in "liking" but not "wanting", whereas other areas within the NAcc are assumed to be involved in "wanting" but not (necessarily) "liking". It should thus be possible to find dissociations between the two processes (e.g., to observe "wanting" in the absence of "liking").

Behavioral evidence for "wanting" in animal studies is typically assessed by measuring the extent to which an animal will choose, consume, or work for a specific substance (e.g., Berridge & Robinson, 1998). Animal studies show that sensitized rats work harder to obtain a drug reward, are quicker to learn conditioned place preference for locations

paired with drug cues, are more prone to relapse after receiving a priming dose of the substance, and attach more value to other rewards as well (e.g., Robinson & Berridge, 2003). Measures of "liking" include an assessment of affective facial expressions. For instance, tongue protrusions are considered to be indices of hedonic pleasure, whereas gaping is thought to indicate disliking.

Dissociations between "wanting" and "liking" in animals can be shown, for instance, in studies on Pavlovian-Instrumental transfer (PIT). Wyvell and Berridge (2000) trained rats to press one of two levers to obtain a reward (in this case, sucrose pellets). They also taught the rats that a specific Pavlovian cue (Conditioned Stimulus; CS+) co-occurred with the presentation of sucrose pallets (Unconditioned Stimulus; US). During a crucial test phase, rewards were no longer presented, and lever-pressing was measured during the presence and absence of the CS+. Results showed that rats pressed the lever more often (i.e., they worked harder to obtain the substance, implying they "wanted" the substance more) when the CS+ was present, showing that this cue increased incentive motivation. This effect increased when rats had received micro-injections of amphetamine, a dopamine agonist that is known to increase instrumental performance. Importantly, Wyvell and Berridge showed that amphetamine injections did not increase hedonic facial reactions, which implies that "liking" was not affected by this manipulation, therefore providing evidence that "wanting" and "liking" can indeed become dissociated. [1]

[1] Note that from a strict functional perspective (see Catania, 2013, for a review), there is no contradiction in saying that a disliked stimulus can be a reinforcer. A stimulus qualifies as a reinforcer of a behavior whenever the probability of the behavior increases as the result of the behavior-stimulus relation. Hence, the concept "reinforcer" is defined merely in terms of a stimulus' function (i.e., it increases the likelihood of behaviors to which it is related). The concept "reward", on the other hand, differs from the concept "reinforcer" in that it points at a stimulus property that is supposed to explain *why* a stimulus functions as a reinforcer. Whereas it is typically assumed that rewards have a reinforcing value because of their hedonic properties, Robinson and

It is important to note that apart from the enormous impact that Incentive Sensitization Theory has had on addiction research, it has affected the study of other types of (health) behaviors and psychopathology as well. For instance, dissociations between "wanting" and "liking" have been assumed to play a role in food consumption, (e.g., Finlayson, King, & Blundell, 2007; but see also Havermans, 2011), impulsive economic choice (e.g., Lades, 2014), depression (e.g., Bushmann, Moeller, Konrath, & Crocker, 2012), schizophrenia (Heerey & Gold, 2007), compulsive sexual behavior (Voon et al., 2014), and autism (Kohls, Chevallier, Troiani, & Schultz, 2012). Even though IST has provided valuable new insights in drug addiction and a striking influence on the study of a broad range of behaviors, there is uncertainty regarding the operation of incentive sensitization in humans. There is some evidence for the role of sensitized activations in the mesolimbic dopamine system in addiction (Leyton, 2007), but the question remains how to measure incentive processes behaviorally in humans (e.g., Robinson & Berridge, 2000). An increasingly popular line of research focuses on using so-called *implicit measures* to examine "wanting" and "liking" in humans (e.g., Wiers & Stacy, 2006). The aim of this paper is to examine the validity of behavioral implicit measures of "wanting" and "liking". Because a measure can be valid only to the extent that there is clarity about the to-be-measured concept (Borsboom, Mellenbergh, & van Heerden, 2004; De Houwer, Teige-Mocigemba, Spruyt, & Moors, 2009), we first analyse the definitions of "wanting" and "liking" as they are described in the IST literature. Next, we discuss different behavioral measures that are assumed to assess "wanting" and "liking" in the context of addiction. Subsequently, we examine the validity of implicit measures of "wanting" and "liking". Finally, we formulate suggestions for future research and theory development.

Berridge (2000) argue that, at least in some contexts, the reinforcing function of a stimulus is mediated by a non-hedonic property which they refer to as "incentive salience".

Our evaluation of the validity of implicit measures of "wanting" and "liking" was inspired by the criteria proposed by Borsboom et al. (2004) and De Houwer et al. (2009), who stress the importance of causality. From this perspective, measures of "wanting" and "liking" can be considered as valid if measurement scores are causally determined by the degree of "wanting" and "liking". This type of validity can be assessed on the basis of studies using correlational, quasi-experimental, and experimental designs. Although experimental designs can provide the strongest evidence for causality, correlational and quasi-experimental designs are not without merit for establishing whether the preconditions for causality are met (see De Houwer et al., 2009; Van Bockstaele et al., 2014). Hence, we discuss only studies that examine (one or more of) the hypotheses of IST: (1) there should be a positive correlation between indices of "wanting" (e.g., drug consumption, drug craving; e.g., Wiers et al., 2002) and "wanting" scores on a particular implicit measure (i.e., correlational designs). Similarly, there should be a positive correlation between indices of "liking" (e.g., various expressions of subjective pleasure) and "liking" scores on a particular implicit measure; (2) higher "wanting" (but not necessarily "liking")[2] scores in substance abusers or frequent substance users compared to non-users or infrequent users (i.e., quasi-experimental designs), and no differences in "liking" or even less "liking" in frequent substance users; (3) manipulations of "wanting" should affect "wanting" scores (and not "liking" scores) whereas manipulations of "liking" should affect "liking" scores (and not "wanting" scores; i.e., experimental designs). This means that we will not discuss papers in which modified implicit behavioral tasks are used to manipulate "wanting" or "liking" effects (e.g., Eberl et al., 2013), unless they include (pre- and post-) assessments using the implicit measures of "wanting" and "liking" that are

[2] It is important to note that according to IST, "wanting" and "liking" are commonly related (e.g., Berridge & Robinson, 2003; Winkielman & Berridge, 2003). Only in extreme circumstances (i.e., when casual drug use has evolved into an addiction) are "wanting" and "liking" dissociated. Thus, we would only expect dissociations between "wanting" and "liking" measures in samples of drug-abusers (i.e., not in casual drug users).

central in this paper (e.g., Wiers, Eberl, Rinck, Becker, & Lindenmeyer, 2011). This also means that we will not discuss papers in which other factors than "wanting" or "liking" are manipulated (e.g., mindfulness, negative affect, cognitive load,; e.g., Ostafin, Bauer, & Myxter, 2012; Ostafin & Brooks, 2011; Sharbanee, Stritzke, Jamalludin, & Wiers, 2014) and their effect on "wanting" and "liking" measures is examined. The reason for this exclusion criterion is that IST makes no clear predictions about how these manipulations should affect "wanting" and "liking". Thus, such studies do not inform us about the validity of implicit measures of "wanting" and "liking".

2. Definitions of "wanting" and "liking"

Berridge (1996) notes that it is not easy and maybe even uncalled for to demand a complete and strict definition of reward. He therefore argues for a minimal definition of reward that will grow as the amount of research on this topic increases. There is a vast literature on the concepts of "wanting" and "liking" which reveals that the definition of these concepts has changed considerably over the years. Based on an analysis of the literature, we were able to distinguish between four possible definitions of the terms "wanting" and "liking". In the following section, we discuss each of these definitions. A summary can be found in Table 1.

2.1. Mental process definition: "wanting" and "liking" as (preconscious) affective and cognitive processes

Most commonly, "wanting" and "liking" are defined as mental processes. Hence, we will refer to this definition as a "mental process" definition. Initially, Robinson and Berridge (1993) used the terms "wanting" and "liking" in accordance with the common definitions of these processes. "Liking" was simply defined as pleasure, whereas "wanting" was a strong feeling of craving that resulted in drug administration (p. 249). "Wanting" was considered to be the result of incentive salience attribution (i.e., associating a rewarding value to drug-

related cues; p. 261). Importantly, the authors raised the possibility that these processes were more implicit rather than explicit (p. 267) and later stress that these implicit processes do not necessarily need to be consciously experienced (Berridge & Robinson, 2003).

However, "wanting" was sometimes also described as drug administration itself (Robinson & Berridge, 2000, p. 94). Whereas this might be a useful operational definition in animal research, drug consumption in humans is dependent on more factors besides "wanting", such as social desirability and the availability of cognitive resources to inhibit drug use (e.g., Wiers, Bartholow, et al., 2007). In later papers, both "wanting" and "liking" were defined solely in terms of pre-conscious processes (e.g., Berridge, 1996; Berridge & Robinson, 1995). Incentive salience attribution was assumed to be a pre-conscious process, whereas the result of this process was thought to be conscious. Similarly, "liking" was not described as a conscious process either, but it could lead to a conscious feeling of pleasure (e.g., Berridge & Robinson, 1995, p. 72; Berridge & Robinson, 2003, p. 508). Wanting and liking without quotation marks were suggested to refer to wanting and liking in their common sense, whereas "wanting" and "liking" with quotation marks refer to their meaning in the IST context (e.g., Berridge, 2010).

Subsequently, to clarify this distinction between wanting and liking in their common sense and "wanting" and "liking" in the IST framework, Berridge and Robinson (2003, p. 508) explained that both affect and motivation consist of two subcomponents. Affect consists of conscious pleasure (liking) and core hedonic impact ("liking"). Within motivation, they distinguished cognitive incentives (wanting) from incentive salience ("wanting"). Cognitive incentives refer to cognitive goals and explicit desires, whereas incentive salience refers to a motivational process that translates affect ("liking") into action (pursuit of the reward). It is important to note that whereas "liking" is an affective process, "wanting" is not. Interestingly, earlier papers thus considered "wanting" to be the result of incentive salience (e.g., Robinson

& Berridge, 1993), but this view shifted: the two were considered to be synonymous in later papers (Berridge & Robinson, 2003).

Berridge (2004) stressed that both "wanting" and "liking" play an essential role in reward, and that reward is not complete if only one of these two components is present. Importantly, he states that "liking" in itself is nothing more than an affective state, a brain reaction that is triggered by the experience of something pleasant. This means that in "liking", there is no object of desire, no incentive target (p. 195). "Wanting" is the process that links a specific stimulus, experience, or action to this hedonic experience, thus transforming this stimulus, experience, or action into an object of desire.

2.2. Effect definition: "wanting" as characteristics of drug-related CSs, and "liking" as hedonic impact

Berridge, Robinson, and Aldridge (2009) elaborately defined "wanting" in terms of the effects that specific drug-related CSs have on animal behavior. We therefore will refer to this definition as an "effect" definition.[3] They suggest that when an individual attributes incentive salience to a CS, this CS gains three different "wanting" properties (p. 68).

First, the rewarding CS becomes a "motivational magnet" that triggers strong approach tendencies that can become compulsive. An example of this "wanting" feature is so-called "auto-shaping" or sign-tracking. When a CS is consistently paired with the delivery of a reward, an individual might begin to approach or even try to consume the CS (Uslaner, Acerbo, Jones, & Robinson, 2006).

Second, a rewarding CS automatically triggers "wanting" for the US with which it was associated. An example is the PIT phenomenon as discussed above in which the presentation

[3] It must be noted that, surprisingly, there is no "effect definition" of "liking". In this context, "liking" is regarded as a mental process. Thus, some of the relevant literature is focused mainly on "wanting" rather than "liking". This means that there are fewer definitions of "liking" than of "wanting". However, the aim of this paper is to focus on both processes, and more importantly, on dissociations between these two processes.

of a CS increases behavioral indicators of "wanting" (i.e., rats more often pressed a lever that previously delivered a reward) even when rewards were no longer delivered. Another aspect of this "wanting" feature is that cue-triggered US "wanting" can also spill over to other USs (i.e., drug abusers can also exhibit compulsive approach toward other types of rewards, such as gambling or sex).

Finally, the CS can become a conditioned reinforcer. This means that an individual will work to gain the CS, even when a US is not presented. The CS thus becomes rewarding in itself. An example is instrumental conditioned reinforcement, which is the process by which a CS supports instrumental behavior. This was examined by, for instance, Parkinson, Roberts, Everitt, and Di Ciano (2005). Their study started with a Pavlovian acquisition phase in which rats were presented with two levers. Above each lever, a light was located. When one light (the CS+) was illuminated, the lever below it would deliver a sucrose solution (US). When the other light (the CS-) was illuminated, nothing happened. Subsequently, the US was devalued. In a test phase rats were again placed in an operant chamber with two levers, with lights located above each lever. Lever presses never resulted in sucrose delivery, but only in the illumination of the CS+ or the CS-. Results showed that rats were inclined to approach the lever that caused the illumination of the CS+ more than the other lever. This study thus showed that the CS+ in itself became rewarding because rats worked to obtain the CS+ in the absence of the US. Importantly, this effect persisted even when the US was devalued (i.e., in the absence of "liking").

Note that in this definition, a clear distinction is made between the different behavioral "wanting" measures in animals. The "motivational magnet" feature refers more to approach behavior, whereas the latter two refer to the extent to which an animal will work to obtain the US (the cue-triggered US "wanting" feature) or the CS (the conditioned reinforcer feature).

2.3. Utility definition: "wanting" as decision utility, "liking" as experienced utility

"Wanting" and "liking" have also been defined in terms of utility. We will refer to this definition as a "utility" definition because dissociations between "wanting" and "liking" are considered to depend on a difference in the level of different types of utility. Berridge and Aldridge (2008) examined how the utility of specific hedonic goals is represented in the brain and how it can drive behavior. They distinguished four different types of utility. *Predicted utility* refers to the expectation of the hedonic impact of a future reward; *decision utility* is the essence of the decision at the moment it is made; *experienced utility* is the hedonic experience produced by the reward after it is obtained; *remembered utility* is the memory of how pleasant the reward was. Berridge and Aldridge suggested that "wanting" can be understood as "decision utility" (e.g., p. 627), or the means to make decisions concerning which types of rewards should be pursued, and that "liking" can be understood as "experienced utility" (see also Berridge, 2010; Berridge & O'Doherty, 2014).

Berridge and Aldridge (2008) proposed that decisions are not optimal when there is a mismatch between the different types of utility. "Miswanting" occurs when there is a dissociation between an individual's decision utility and predicted utility on the one hand, and experienced utility on the other hand, meaning that the individual decided to pursue a reward because they expected a large hedonic impact. However, when they obtained the reward, they were disappointed because the reward could not live up to their high expectations. The individual thus made an error in judgement, but they did make a rational decision because they pursued a reward that they assumed they would like. Note that this dissociation cannot be understood as a dissociation between "wanting" and "liking" as initially hypothesized by IST (e.g., Robinson & Berridge, 2003) if we assume that (a) decision utility is "wanting", experienced utility is "liking", and (b) predicted utility is a cognitive process regarding explicit expectations and desires. According to IST, "wanting" (decision utility) and predicted utility are independent: one decides to pursue drugs *regardless* of whether one expects

positive or negative outcomes. It is possible that decision utility and predictive utility are both positive (i.e., they both promote drug use), but this is not necessary (e.g., Winkielman & Berridge, 2003).

"Irrational miswanting" occurs when there is a dissociation between decision utility (i.e., "wanting") and predicted utility (i.e., expected "liking"). An individual does not expect that the reward is desirable, but decides to pursue this reward anyway. The outcome is wanted even though the individual correctly judges that the outcome will not be pleasurable (i.e., there is no experienced "liking"). The individual thus made a correct estimation of the likeability of the outcome (i.e., they know they will not like it), but the choice was irrational because he or she chose an unliked outcome. Again, if we use the definitions discussed above, this does not imply that "irrational miswanting" can be understood as a dissociation between "wanting" and "liking" in the way IST would predict. It does, however, reflect a dissociation between "wanting" as an unconscious desire (decision utility) and wanting as a conscious declarative process that involves explicit goals and expectations (predicted utility; e.g., Berridge & O'Doherty, 2014). Finally, it is interesting to note that the emphasis on the unconscious nature of "wanting" and "liking" disappeared in this literature, and it is suggested that "wanting" may be only a facet of decision utility (Berridge & Aldridge, 2008).

2.4. Neurological definition: "wanting" as activity in the mesocorticolimbic dopamine system and "liking" as activity in subcortical hedonic hotspots

A final definition regards "wanting" and "liking" as neurological processes. We will therefore refer to this definition as the "neurological" definition. According to this view, "wanting" is (the result) of activity in the mesolimbic dopamine system, which involves the midbrain, the NAcc, parts of the striatum, the amygdala, and the prefrontal neocortex. The most prominent neurotransmitter within this system is dopamine, but opioids, glutamate, and GABA also play a role (Berridge & Robinson, 2003; Berridge, 2009).

"Liking", in contrast, takes place in a more limited system consisting of small parts within the NAcc and the ventral pallidum, so-called "hedonic hotspots". Whereas "wanting" is triggered by activation in a single "wanting" hotspot, "liking" is triggered only when the multiple hedonic hotspots work in synchrony (Berridge & Robinson, 2003; Berridge & Kringelbach, 2008). Importantly, in contrast to the "wanting" system, the "liking" system does not involve dopamine but only opioid stimulation. Thus, boosting dopamine transmission in these networks will cause increases in "wanting", but not in "liking".

2.5. Summary

In short, there are four types of definitions of "wanting" and "liking". It is possible to view each type of definition as only a sub-component of these complex concepts: First, the mental process definition in which "wanting" was a combination of wanting in its common sense and the result of the preconscious process of incentive salience attribution. It was referred to as a need or desire, but also as drug use itself. "Liking" was referred to as an experience of pleasure. A later, but closely related view is that "wanting" refers solely to (preconscious) incentive salience attribution and "liking" refers only to (preconscious) hedonic impact. This view also holds that "wanting" and wanting are the two subcomponents of motivation, whereas "liking" and liking together form affect. Second, the effect definition suggests that "wanting" can be seen as an effect of a set of characteristics of the drug-related CS: the "motivational magnet" feature, the cue-triggered US "wanting" feature, and the conditioned reinforcer feature. Third, "wanting" and "liking" have been defined as different types of utilities: decision utility (i.e., the essence of the decision at the moment it is made) and experienced utility (the hedonic experience after obtaining an outcome), respectively. Fourth, "wanting" and "liking" have been defined in terms of neural activity in subcortical brain systems.

Thus, whereas the definition of "liking" is quite consistent, the definition of "wanting" varies across and even within papers (e.g., the description of "wanting" as both a preconscious process that motivates drug consumption and as drug consumption in itself; Robinson & Berridge, 2000, p. 94). We want to emphasize that regarding complex concepts from different perspectives is commendable because it enriches our understanding of these concepts. However, the occasional inconsistencies within the different definitions can hinder our understanding of the theory and our ability to articulate hypotheses regarding "wanting" and "liking" in addiction.

3. Dissociating "wanting" and "liking" in humans

Even though IST was based mainly on research with non-human animals, many researchers have tried to apply IST to humans. Some efforts have been made to examine "wanting" and "liking" in light of the effect definition and the neurological definition. For instance, several studies have examined PIT in humans (cf. the automatic cue-triggered US wanting feature) in combination with fMRI (e.g., Talmi, Seymour, Dayan, & Dolan, 2008), and even though neurological studies are still scarce, there is increasing evidence that the mesolimbic dopamine system plays an important role in drug addiction and relapse in humans (e.g., Leyton, 2007), as IST suggests (e.g., Robinson & Berridge, 2003).

However, the current focus is on research on the mental process definition of "wanting" and "liking". This research has become increasingly popular over the last few decades, even though it faces an important challenge: According to IST (e.g., Berridge & Robinson, 1995), "wanting" and "liking" are not directly subjectively experienced. As a result, one cannot simply resort to direct measurement procedures in which participants self-assess their level of "wanting" and "liking". For this reason, researchers have turned to the use of so-called implicit measurement procedures. Before we discuss different implicit

measures of "wanting" and "liking", we first discuss the rationale behind the use of implicit measures. Next, we review the use of such measures within the context of IST.

Implicit measures are assumed to have certain advantages over traditional explicit measures. Most importantly, it is commonly assumed that compared to explicit measures, implicit measures are (a) less susceptible to extraneous factors such as social desirability concerns, deception, and other conscious control strategies and (b) might capture processes that are not introspectively accessible or cannot be easily controlled. There is less agreement about what exactly distinguishes implicit measures from explicit measures.

De Houwer et al. (2009) suggested that an implicit measure can be defined as the outcome of a measurement procedure that is caused by the to-be-measured-attribute automatically. The process that underlies a measure is automatic when it meets one or more of the following criteria: it is uncontrolled, unintentional, independent of goals, stimulus driven, unconscious, efficient, and fast (e.g., Moors & De Houwer, 2006). Most implicit measures are automatic according to some of these criteria, but not all. Some researchers have focussed only on the question whether implicit measures can capture processes or attitudes of which the participant is unaware. However, there is very little evidence that implicit measures are automatic in this sense (e.g., Gawronski, Hofmann, & Wilbut, 2006). Nevertheless, there is reason to argue that most implicit measures are automatic in the sense that they are based on processes that are less intentional and less easy to control than the processes that underlie most traditional, explicit measures. On the basis of this knowledge, researchers have suggested that implicit measures are possibly able to capture automatic processes such as "wanting" and "liking" (e.g., Wiers, Van Woerden, Smulders, & De Jong, 2002).

The Implicit Association Test (IAT; Greenwald, McGhee, & Schwarz, 1998) is beyond any doubt the most well-known implicit measure. The IAT was designed to capture associations between target and attribute concepts. In a first block, stimuli are classified as

belonging to one of two target concepts (e.g., as "flower" or "insect") by pressing one of two keys. In a second block, different stimuli are classified as referring to one of two attribute concepts (e.g., as "positive" or "negative") by using the same keys as in the first task. The critical blocks are those in which both target and attribute stimuli are presented. In some blocks, target and attribute categories are assigned to responses in an association-compatible manner (e.g., press a first key for "flowers" and "positive" and a second key for "insects" and "negative") whereas in other blocks, the category-response assignments are association-incompatible (e.g., press a first key for "insects" and "positive" and a second key for "flowers" and "negative"). In the association-compatible blocks, response latencies are usually shorter than in association-incompatible blocks. The difference in response latencies between both types of blocks is thought to reflect the relative strength of the associations. The IAT is assumed to be an implicit measure in the sense that it is difficult to control (e.g., Greenwald et al., 1998). By changing the labels and stimuli, the IAT can measure a wide variety of implicit attitudes.

In research on "wanting" and "liking" in addiction [4], researchers have explored not only the potential of the IAT but also other implicit measures, some of which are variants of the IAT. In the remainder of this section, we provide a brief overview of the various measures that have been used in this research (see Gawronski & De Houwer, 2014; and Nosek, Hawkins, & Frazier, 2011, for more complete reviews of implicit measures in general). A summary can be found in Table 2. The personalized IAT is a variant of the IAT that was developed to remove the influence of extra personal associations (e.g., societal stereotypes; Olson & Fazio, 2004). In this task, labels refer to the participants themselves (e.g., "I like"

[4] Even though researchers have performed many studies examining the role of "wanting" and "liking" in the context of over-eating as well, we will not discuss this literature. The main reason for this is that there is no theoretical basis for the assumption that incentive sensitization plays a role in eating behavior (e.g., Havermans, 2011).

instead of "positive" and "I dislike" instead of "negative"), to avoid confusion between societal norms and participants' own attitudes. Other IATs have been developed that reduce the relativity of the measure. Karpinski and Steineman (2006) introduced the Single Category IAT, a task that aims to measure attitudes towards a single target concept (e.g., flowers) without the need for a complementary category (e.g., insects). Another version of the IAT is the unipolar IAT (e.g., Jajodia & Earleywine, 2003), in which only one attribute category is needed (e.g., either "positive" or "negative" but not both). This allows researchers to take into account that participants might have an ambiguous attitude (i.e., both positive and negative) toward specific targets.

Importantly, researchers have assumed that by varying the labels of the IAT, different versions of the IAT can be used to capture different concepts. In line with this idea, "wanting" versions of the IAT have been created that are assumed to reflect "wanting", whereas effects on "liking" versions of the IAT are assumed to reflect "liking". First, Wiers et al. (2002) developed both a valence IAT, in which the target categories are "alcohol" and "soda", and the attribute categories are "positive" and "negative", and an arousal IAT, with the same target categories, but with "passive" and "active" as the attribute categories. Because "wanting" is assumed to cause drug cues to become more arousing, the arousal IAT was assumed to be a valid measure of "wanting". Second, Tibboel et al. (2011) designed a liking 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". They reasoned that these labels better reflected the processes proposed by Robinson and Berridge. Finally, in the approach-avoid IAT, the labels "approach" and "avoid" are used. It was designed as a measure of "wanting", as it is assumed it can capture automatic approach tendencies (e.g., Palfai & Ostafin, 2003).

Besides these variations of the IAT, several other implicit measurement tasks have been developed to assess the motivational component of "wanting". In these tasks, participants are required to make approach responses to one category of items, and avoidance responses to another category of items. In another block, the opposite responses must be given to the same categories of stimuli. These tasks are based on the assumption that it is easier to make an approach-movement towards stimuli that are rewarding than to avoid them.

In the (Affective) Simon Task (AST) and the Approach-Avoidance Task (AAT), stimuli need to be judged on a stimulus dimension that differs from the to-be-measured dimension (e.g., whether a picture has a portrait or landscape format; e.g., Field, Caren, Fernie, & De Houwer, 2011; Wiers, Rinck, Dictus, & Van den Wildenberg, 2009). In contrast, in the "relevant Stimulus Response Compatibility Task" (rSRC; Mogg, Bradley, Field, & De Houwer, 2003), participants approach or avoid stimuli on the basis of the stimulus dimension that is being assessed (e.g., whether a picture depicts an alcoholic drink or a soft drink). Importantly, this measure can still be considered implicit or indirect in the sense that participants are not asked to explicitly judge the attitude objects. Instead, their approach- or avoidance tendencies are inferred on the basis of the relative speed with which they make approach- or avoidance movements toward the objects. Responses can be given either by moving a manikin towards or away from the stimulus (in the rSRC, the AST) or by moving a joystick towards or away from the stimulus (in the AAT).

5. Are implicit measures of "wanting" and "liking" valid?

Our assessment of the validity of implicit measures of "wanting" and "liking" is guided by the perspective on validity that was put forward by Borsboom et al. (2004). They suggested that a test is valid if a) the to-be-measured attribute exists and if b) there is a causal relationship between variations in the attribute and variations in the measurement outcomes. Although questions can be raised about whether "wanting" and "liking" do exist as

psychological attributes, it is difficult to arrive at definite answers to this type of ontological issues. Hence, we sidestep the ontological debate and focus on the causality aspect of validity. We first investigate whether, on an *a priori* theoretical basis, there are reasons to assume that "wanting" and "liking" as defined in the literature can causally influence performance on implicit measurement tasks that are assumed to capture "wanting" and "liking". Next, we review whether there is empirical support for the hypotheses that "wanting" and "liking" actually determine implicit measures that are assumed to capture these attributes. In doing so, we distinguish between three types of empirical studies. First, there are quasi-experimental studies, in which implicit measures of "wanting" and "liking" are examined in groups that are assumed to differ on these constructs (e.g., comparing heavy and light drinkers). Second, there is correlational research, in which correlations between scores on implicit "wanting" and/or "liking" measures and other indices of "wanting" and "liking" are examined. Third, there are experimental studies, in which researchers manipulate "wanting" and/or "liking" and examine how this affects outcomes of implicit "wanting" and "liking" measurement procedures. Borsboom et al. (2004) argue that experimental studies are preferred, because both measurement and validity are causal concepts. Thus, manipulations of "wanting" and "liking" should causally affect "wanting" and "liking" respectively.

5.1. Are there *a priori* theoretical reasons to assume that implicit "wanting" and "liking" measures are valid?

Ideally, valid measures of "wanting" and "liking" should be able to capture all facets of "wanting" and "liking" described in the mental process definition. Thus, a "wanting" test should assess an individual's desire or need to use drugs, instrumental drug-seeking, drug-taking behavior, and the (preconscious) process of incentive salience attribution. A valid measure of "liking", on the other hand, should capture the (preconscious) experience of pleasure.

Before we discuss the validity of each type of implicit measure separately, one first argument that makes us question the validity concerns the assumption that they can capture preconscious processes. According to several IST papers that refer to "wanting" and "liking" as psychological processes, "wanting" and "liking" are assumed to be preconscious (e.g., Berridge, 1996). Bargh (1994) notes that an unconscious attitude can be "unconscious" in three different ways. First, an individual may not be aware of the *source* of the attitude (i.e., the experiences that gave rise to the attitude), they may not be aware of the *content* (i.e., whether it is positive or negative), or they may not be aware of the *impact* of the attitude on behavior. Importantly, there is no evidence that implicit measures capture unconscious or preconscious processes (Gawronski, Hofmann, & Wilbur, 2006; Hahn & Gawronski, 2014). For instance, Hahn, Judd, Hirsch and Blair (2014) recently showed that participants were very good at predicting their own IAT scores, suggesting that the IAT does not measure unconscious processes. Interestingly, even though prediction accuracy was high, there was still low correspondence between the IAT and explicit attitude measures. This implies that implicit measures do tap into different, more automatic processes than explicit measures.

Thus, whereas it is doubtful that implicit measures can provide us with a valid estimation of "wanting" and "liking", implicit measures do seem to be more promising in capturing automatic processes than explicit measures. Furthermore, it is important to note, most researchers who examine IST using implicit measures interpret "wanting" and "liking" not as preconscious processes but as *implicit* or *automatic* processes (e.g., Wiers et al., 2002), a definition that has been used by Berridge and Robinson (2003; page 267). In this case, implicit measures might be considered as valid and valuable ways to examine "wanting" and "liking", because, as we mentioned above, one property of automaticity is indeed that it is unconscious (e.g., Moors & De Houwer, 2006), but a process can still be considered as automatic to some extent even when it does not (fully) meet this criterion.

Another consideration is that the different definitions of "liking" all stress that it concerns a temporary experience of pleasure. According to the mental process definition, it is a hedonic response that is experienced at the moment of drug consumption and that might not involve a specific "object of desire" (e.g., Berridge, 2004). It seems unlikely that IATs can access such responses. Because IATs are designed to assess memory representations, they are more likely to capture memory-based pre-consumption appetitive responses. Unlike the "liking" responses that are triggered *during* consumption, pre-consumption responses are assumed to reflect learned cue-affect associations in memory and might be more akin to "wanting".

5.1.1. Wanting, Liking, and Approach-Avoidance IATs

Even though the definition of "liking" seems more straightforward than the definition of "wanting", it is not clear whether the valence IAT (with labels "positive" and "negative") of Wiers et al. (2002) is a good "liking" test. First, the attribute labels "positive" and "negative" are not synonymous for "liking" and "disliking". Even though individuals usually experience "liking" for positive things, the definition of "liking" is limited to merely the hedonic experience of pleasure, whereas the label "positive" is a much broader concept. Second, stimulus items such as "sociable", "tedious" (Wiers et al., 2002), "sincere", and "vindictive" (De Houwer et al., 2004) which are typically used in the valence IAT are generically positive and negative words that are not even mentioned in any of the definitions by Robinson and Berridge (e.g., 1993, 2000, 2003). Because the nature of the (attribute) items can determine the conceptualization of the (attribute) labels (i.e., "positive" and "negative"; see Govan & Williams, 2004), it is unlikely that the attribute labels in the valence IAT are conceptualized by participants in line with the conceptualization of "liking" in IST. Similar arguments can be made to question the validity of the liking IAT of Tibboel et al. (2011). Even though they used target labels that were more closely related to IST (i.e., "I like" and "I

do not like"), they used generic positive and negative words (e.g., "holiday", "pain") as well, making it quite plausible that participants recoded these labels to mean nothing more that "positive" and "negative" instead of "I like" and "I do not like". In sum, it can be argued that none of the available valence or liking IAT effects reflect the hedonic impact as put forward in IST.

Wiers and colleagues (2002) assumed that their arousal IAT measures "wanting", which they interpreted as "sensitized arousal". One problem with this interpretation is that even though the attribution of incentive salience can coincide with feelings of arousal, research has shown that arousal and incentive salience cannot be equated (e.g., Berridge, Venier, & Robinson, 1989). Moreover, IST does not assign a major role for arousal to the development and maintenance of addiction (e.g., Robinson & Berridge, 1993). As such, an important theoretical problem with the arousal IAT is that it lacks content validity. Hence, at best it is causally determined only by a non-essential and trivial facet of "wanting".

One can also doubt whether the "wanting" IAT used by Tibboel and colleagues (2011) actually captures "wanting". Because they used the labels "I want" and "I do not want", it could be that they captured the "layman's" definition of wanting. However, it is less clear whether this IAT can measure "wanting" in the IST sense. First, there is no reason to assume that participants coded these labels to mean something along the lines of the IST definitions mentioned above. Second, the design of this IAT faces the same problem as the design of Wiers et al. (2002) in the sense that the stimuli were quite general positive and negative words. Hence, there is no reason to assume that these words captured the theoretical meaning of "wanting". Because all "I want" items were positive and all "I do not want" items were negative, it is even possible that participants recoded both the "wanting" and the "liking" labels in this study as merely meaning "positive" and "negative".

The question whether the approach-avoid IAT can capture all facets of "wanting" can also not be answered in an unequivocally positive manner. The target labels in the task of Palfai and Ostafin (2003) were "alcohol" and "electricity" whereas the attribute labels were "approach" and "avoid". Even if it is safe to assume that an IAT with these labels indeed captures "alcohol-behavioral disposition associations", as the authors suggest (p. 1152), we cannot conclude that this version of the IAT is causally influenced by "wanting" in the sense of (the result of) the preconscious process of incentive salience attribution, a need or desire to use drugs, or drug use itself.

5.1.2. Measures of automatic motivational tendencies

The AAT is thought to be a measure of appetitive approach tendencies, which is assumed to be a property of "wanting". The AAT seems to assess the extent to which the presentation of a drug-related stimulus automatically triggers approach behavior. Eder and Rothermund (2008), however, argued that the activation of approach and avoid responses is driven merely by the valence of the presented stimuli. More specifically, they suggest that positive stimuli automatically activate positive responses, including the approach responses in an AAT. Thus, AAT effects could be driven by the mere valence of stimuli instead of their motivational salience. Furthermore, Krieglmeyer, De Houwer, and Deutsch (2013) suggested that such AAT-like effects occur mainly when participants have the conscious goal to evaluate stimuli. This implies that it would not be possible to interpret such effects as reflections of "wanting", as this process should not be affected by conscious goals (e.g., Berridge, 1996). In addition to these objections, it is also unclear how AAT effects relate to the other facets of "wanting". There is little reason to believe that they capture drug use, desire, or incentive salience attribution. The same holds for the modified versions of the Simon task and the rSRC task (Mogg et al., 2003).

5.2. Is there empirical evidence for the validity of "wanting" and "liking" measures?

5.2.1. Quasi-experimental research.

5.2.1.1. Wanting, Liking, and Approach-Avoid IATs

In a seminal study on implicit measures of "wanting" and "liking", Wiers et al. (2002) introduced the valence and the arousal alcohol IAT in a sample of heavy drinkers and a control group of light drinkers. Interestingly, their results suggested that both heavy and light drinkers had negative alcohol associations. This was assumed to imply that neither of the groups experienced "liking" for alcohol.[5] However, the heavy drinkers, but not the light drinkers, did reveal an arousal IAT effect that was indicative of associations between alcohol and arousal. This led the researchers to conclude that heavy but not light drinkers experienced "wanting" for alcohol. In line with these results, De Houwer, Crombez, Koster, and De Beul (2004) found that, just like heavy social drinkers, alcohol dependent patients showed negative alcohol associations and positive alcohol arousal associations. However, Dickson, Gately and Field (2013) used two unipolar IATs: one to measure positive alcohol associations, and one to measure negative alcohol associations. Their data showed that alcohol dependent patients' positive alcohol associations did not differ from controls, but their negative alcohol associations were less strong than those of controls. This suggests that valence might indeed play a role in addiction, although it is nuanced (i.e., a lack of negative associations instead of strong positive associations).

Other studies however, yielded contrasting results. First, Wiers, Houben, and De Kraker (2007) showed that cocaine users have stronger associations between cocaine and sedation than between cocaine and arousal. Furthermore, valence IATs showed that they had

[5] It is important to note that one cannot interpret positive and negative IAT scores to reflect positive and negative attitudes respectively. Blanton and Jaccard (2006), for instance, suggest that the zero-point of an IAT is meaningless and should be interpreted with caution. We want to emphasize that relative measures such as the implicit tasks that we describe in this manuscript should be interpreted only in a relative way (e.g., comparing scores between groups; examining pre- and post-measurements; or in correlations)..

stronger positive than negative associations with cocaine. Second, several other studies using standard, personalized, and unipolar versions of the valence IAT did yield higher liking scores for substance-related stimuli in substance (ab)users compared to controls (e.g., De Houwer, Custers, & De Clercq, 2006; De Houwer & De Bruycker, 2007; Jajodia & Earlywine, 2003; McCarthy & Thompsen, 2006; Robinson, Meier, Zetocha, & McCaul, 2005), even though IST would predict negative "liking". Third, several experiments by Swanson and colleagues (2001) revealed no differences in implicit "liking" between smokers and non-smokers. Fourth, Tibboel and colleagues (2011) used wanting and liking IATs in a group of smokers and a control group of non-smokers. Results showed that smokers had more positive scores on *both* IATs compared to non-smokers, suggesting that smokers both "like" and "want" smoking more than non-smokers. In contrast, IST would predict larger differences between the two groups on their wanting scores compared to their liking scores.

Finally, Tibboel et al. (2015) recently aimed to assess "wanting" and "liking" in a group of light social drinkers, a group of heavy social drinkers, and a group of alcohol-dependent patients. On the basis of IST, they expected that alcohol-dependent patients would experience more "wanting" and less "liking" compared to the light drinkers. They suggested that heavy social drinkers would have scores that would fall in between those of the light drinkers and the patients. To test this hypothesis they used two personalized single target IATs with labels "I want" and "I do not want" and labels "I like" and "I do not like". Surprisingly, results showed that there were no differences in "wanting" and "liking" scores. Furthermore, there were no differences between light drinkers and alcohol-dependent patients. Surprisingly, both groups had significantly more negative scores on both IATs compared to heavy social drinkers. These data suggest that IATs in fact do not tap into "wanting" and "liking". Instead, the IAT "liking" measure that Tibboel et al. used might reflect personal alcohol-associations that are affected by personal experiences. For light drinkers, a negative

"liking" score might reflect a lack of positive experiences or a disinterest towards alcohol, whereas for alcohol-dependent patients, the same score might reflect their lifelong struggle with the negative consequences of their addiction. In contrast, heavy social drinkers might have had negative experiences (e.g., hangovers) which might not yet outweigh the positive experiences. Furthermore, Tibboel et al. suggested that their "wanting" measure might not reflect incentive sensitization but instead might reflect more declarative goals. In this sense, alcohol is not "wanted" by alcohol-dependent patients, because it stands in the way of their goal to be healthy and productive.

Quasi-experimental research with the approach-avoid IAT is quite rare. De Houwer et al. (2006) found that both smokers and non-smokers had negative valence IAT scores but that smokers had positive approach associations with smoking, whereas this score was negative for non-smokers. This is in line with the findings of Wiers et al. (2002) and, more importantly, it is in line with the predicted dissociation between "wanting" and "liking" in the IST.

To summarize, quasi-experimental studies do not yield consistent evidence for the hypothesis that substance (ab)users have higher scores on arousal, wanting, or approach-avoid IATs and equal (or lower) scores on valence IATs compared to non-users or less frequent users.

5.2.1.2. Measures of automatic motivational tendencies.

Research with the rSRC task showed that smokers have a stronger approach bias toward smoking-related pictures compared to non-smokers (Mogg et al., 2003). Similarly, using an rSRC task, Field, Kiernan, Eastwood, and Child (2008) showed that heavy social drinkers had an approach bias toward alcohol whereas light drinkers did not. Field, Caren, et al. (2011) asked social drinkers to perform both an rSRC task and an alcohol Simon task. Their rSRC task revealed that heavy drinkers had a stronger approach bias toward alcohol,

whereas the Simon task did not. Thus, it seems that the rSRC is better able to capture motivational processes in addiction than modified versions of the Simon Task. However, some studies yielded contrasting results. Spruyt and colleagues (2012) used an rSRC task to examine alcohol-approach tendencies in alcohol-dependent patients. In contrast to their hypothesis, they found that patients had an avoidance bias, whereas a control group of non-problematic social drinkers had an approach bias toward alcohol. Another discrepant result was found by Barkby, Dickson, Roper, and Field, (2012), who showed no difference between alcohol-dependent patients and controls on their rSRC task.

In several quasi-experimental studies the AAT has been used to examine group differences in automatic approach tendencies. Wiers et al. (2009) found that heavy drinkers with at least one g-allele in a mu-opioid receptor gene (i.e., a gene that is associated with rewarding effects of alcohol) showed a stronger approach bias towards alcohol and other appetitive stimuli than heavy drinkers who did not carry this allele, suggesting that AAT scores are higher in at least a subgroup of heavy drinkers. Similarly, Cousijn, Goudriaan, and Wiers (2011) used a cannabis-AAT to show that heavy cannabis users had a stronger approach bias towards cannabis than controls.

Some results are more difficult to interpret: Sharbanee, Stritzke, Wiers, et al. (2013) did an AAT study with heavy and light drinkers. They found that heavy drinkers with low working memory capacity had more difficulties to avoid alcohol than light drinkers. However, heavy drinkers with high working memory capacity were quicker to avoid alcohol than light drinkers. It is not clear whether we can assume that these AAT findings support IST, because IST does not make specific predictions regarding the influence of one's working memory capacity on "wanting".

Other findings are clearly not in line with IST's predictions. First, Cousijn, Snoek, and Wiers (2013) asked two groups of heavy cannabis users to perform a similar AAT. One group

was tested while they still had the intention to smoke but before they actually smoked cannabis; the other group was tested after they had smoked cannabis. Even though cannabis users who had the intention to smoke had higher levels of subjective craving and lower levels of satiation than the group who had already smoked cannabis, the pattern of AAT scores was surprising: the "intention" group showed no implicit approach bias, whereas the group who had just smoked cannabis did have positive AAT scores. Clearly, this goes against the idea that satiation reduces "wanting" and should thus reduce approach scores on the AAT. Second, Wiers and colleagues (2013) asked a group of smokers and a group of ex-smokers to perform a smoking AAT. They found that only current smokers and not ex-smokers had positive approach scores. Whereas IST would predict positive AAT scores in current smokers, it would predict also that ex-smokers would have positive AAT scores, as incentive sensitization has very long lasting effects (e.g., Robinson & Berridge, 2003). In sum, quasi-experimental research is either scarce (for the modified Simon task) or produced mixed results (for the rSRC task and the AAT).

5.2.2. Correlational research.

Because IST does not specify how incentive processes in humans manifest themselves in behavior (e.g., Robinson & Berridge, 2000), it is difficult to decide what kind of variables different "wanting" and "liking" test scores should correlate with in order to be valid. Nevertheless, as mentioned above, several criteria that seem in line with IST have been suggested and used by several researchers. For instance, it has been argued that "wanting" should correlate with drug use and questionnaires regarding drug craving or drug problems and that measures of "liking" should correlate with explicit liking ratings and questionnaires

as well (e.g., Wiers et al., 2002).[6] In this section, we review studies in which implicit measures of "wanting" and "liking" were related to this type of criterion variables.

Besides the fact that it is difficult to judge what kind of variables "wanting" and "liking" test scores should correlate with, it is also difficult to decide what kind of variables they should *not* correlate with. At first sight, IST clearly predicts that "wanting" and "liking" are dissociated, and should thus not correlate with each other. This implies that we would expect weak or non-existing correlations between "wanting" and "liking" test scores, between "liking" test scores and "wanting" indices, and between "wanting" test scores and "liking" indices. However, it is important to note that, as we mentioned above, "wanting" and "liking" are commonly closely related (e.g., Winkielman & Berridge, 2003) and only become dissociated after casual drug use has developed into addiction. The samples in most of the studies we report here consist of casual drug-users rather than drug abusers, which means that hypotheses concerning correlations are not clear-cut. In casual drug-users "wanting" and "liking" test scores and other behavioral manifestations of "wanting" and "liking" can all be expected to be intercorrelated to some extent, because "wanting" and "liking" are not (yet) dissociated. This sheds doubt on the assumption that correlational designs with casual drug-users can be used to draw any conclusions about the respective validity of different "wanting" and "liking" measures and suggests that results should be interpreted with caution. Instead, as suggested by an anonymous reviewer, researchers could focus on quasi-experimental designs that compare the predictive validity of wanting and liking measures in addicts and non-

[6] It is important to note, however, that IST assumes that "wanting" and "liking" are independent of their conscious counterparts (e.g., Berridge, 2010), implying that calculating correlations between implicit and explicit measures are not meaningful in this context. However, we will discuss these correlations because it is common practice to calculate and report such correlations and to draw conclusions on the basis of these correlations (e.g., Houben & Wiers, 2007a; 2007b; 2008).

addicts. For instance, wanting measures might have unique value in predicting drug consumption in addicts but not in non-addicts.

5.2.2.1. Wanting, Liking, and Approach-Avoid IATs.

Wiers et al. (2002) found a positive correlation between scores on their arousal IAT and alcohol (ab)use (i.e., participants with stronger alcohol-arousal associations used more alcohol), a finding that was replicated with a unipolar IAT (with labels "active" and "neutral" instead of "active" and "passive") as well (e.g., Houben & Wiers, 2006). However, no correlations were found between arousal IATs and explicit arousal ratings. To address the issue of predictive validity, Wiers and colleagues (2002) also measured prospective alcohol use, by asking participants to record their alcohol consumption during one month after participating in the experiment. Results showed that the combined IATs could explain some of the variance in alcohol use. Research with another version of the arousal IAT showed that positive alcohol-arousal associations could predict alcohol use in heavy drinkers (Houben, Rothermund, & Wiers, 2009). In contrast, Van den Wildenberg et al. (2006) found a positive correlation between arousal IAT scores and a decrease in alcohol-induced heart rate (i.e., higher arousal IAT scores were associated with more *relaxation* instead of arousal after an alcohol induction).

Using the valence IAT, Wiers and colleagues (2002) found a negative correlation with alcohol use (i.e., participants with more positive implicit attitudes towards alcohol consumed less alcohol). Similar results have been found, for instance, by Houben and Wiers (2007a) for both the traditional valence IAT and a personalized valence IAT. However, they found no correlations between implicit and explicit valence measures, and no such correlations were found in other studies using similar valence IATs (e.g., Houben & Wiers, 2006). To complicate things even further, other research has shown that valence IATs were positively correlated with prospective alcohol consumption (e.g., Houben & Wiers, 2007a,, 2008). For

the wanting IAT, Tibboel et al. (2011) calculated correlations with explicit measures for deprived and sated smokers. When smokers were deprived, they found positive correlations between the wanting IAT scores and ratings of arousal, valence, and wanting, general smoking urges, and the urge to smoke a cigarette after the session. When smokers were sated, they found correlations with valence ratings, smoking urges, craving, and the urge to smoke after the session. Similar correlations were found for the liking IAT. As the smokers in this study were relatively light smokers, one could argue that for them, "wanting" and "liking" were not yet dissociated, explaining the similarities between the correlations. However, partial correlations, controlling for liking IAT scores, revealed a significant correlation between the wanting IAT and arousal ratings in the deprivation session, and with the urge to smoke a cigarette at the end of the session in the satiation session.

A number of correlational studies have employed the approach/avoid IAT. Lindgren et al. (2015) reported positive correlations between scores several scores reflecting alcohol problems and habitualness of drinking. Palfai and Ostafin (2003) also found positive correlations between scores on the approach/avoid IAT and binge drinking, difficulty to control alcohol consumption, and general sensitivity to positive incentives. Furthermore, participants were asked to rate their urge to drink, affect, and positive expectancies twice: Once during a baseline phase, and once during a cue exposure test. During this test, participants were presented with a glass of beer which they were told they would drink after they filled out the ratings a second time. The IAT score predicted the urge to drink, subjective arousal, and pleasantness ratings during cue exposure. However, after controlling for baseline responding (i.e., responding when they were not yet exposed to the alcohol-cue), the correlation with pleasantness no longer reached significance. The approach IAT score did not correlate with several temptation-related variables, nor with behavioral inhibition. Ostafin, Marlatt, and Greenwald (2008) observed no correlation between the approach IAT and

explicit motivation to drink alcohol, but they did find a positive correlation with alcohol consumption on a taste test. Ostafin, Palfai, and Wechsler (2003) tried to disentangle approach and avoidance by calculating separate approach and avoidance scores. They used an approach-avoid IAT in a sample of social drinkers, who varied in their alcohol consumption. Their results showed that whereas indices of approach associations did not reliably predict binge drinking and alcohol problems, indices of avoidance associations did: Lower avoidance scores were associated with more binge drinking and alcohol problems. Thus, it seems that the avoidance but not the approach component of the approach-avoid IAT is a more important predictor of alcohol-related behavior. This observation suggests, however, that the approach-avoid IAT might not be the best measure to assess "wanting" because IST suggests that "wanting" is driven by approach-related motivational processes rather than by (a lack of) avoidance.

Cohn et al. (2012) performed regression analyses to examine how much variance on the approach/avoid IAT was predicted by temptation to drink alcohol and by alcohol restriction. They found only a significant effect of restriction, but not temptation. The IAT was not correlated with the urge to drink alcohol. Finally, other papers in which the use of the approach/avoid IAT was discussed did not find any correlations with "wanting" measures (e.g., Lindgren et al., 2013; Van den Wildenberg et al., 2006).

To summarize, the arousal IAT has been found to correlate with substance use or substance-related problems (e.g., Wiers et al., 2002), but also with indices of sedation (Van den Wildenberg et al., 2006). For the valence IAT, both positive, negative and no correlations with relevant variables were found (e.g., Houben & Wiers, 2006, 2007a; Wiers et al., 2002). Furthermore, research by Tibboel et al. (2011) provides no clear support for the conclusion that wanting and liking IATs specifically capture "wanting" or "liking", respectively. Finally,

approach-avoid IAT scores tend to correlate with some addiction-related variables, but not with others.

5.2.2.2. Measures of automatic motivational tendencies

Several studies have reported positive correlations between alcohol rSRC effects and alcohol consumption (Christiansen, Cole, Goudie, & Field, 2011; Field, Kiernan, Eastwood, Child et al, 2008). Furthermore, Mogg et al. (2003), also found correlations between their smoking rSRC task and the time participants looked at smoking pictures (as measured with an eye tracker), attentional bias, and pleasantness ratings, but did not find correlations with other criteria (e.g., the number of cigarettes participants smoked on an average day, time since their last cigarette, how long they smoked, etc.).

Clinical studies examining approach bias in actual alcohol-dependent patients revealed contrasting results. Whereas Barkby et al. (2012) report a positive correlation between rSRC scores and alcohol consumption prior to treatment (i.e., supporting IST principles), Spruyt et al. (2012), in contrast, found that alcohol-dependent patients with a stronger alcohol *avoidance* bias were more likely to relapse three months after they were discharged from the hospital. Thus, rSRC scores can correlate positively, negatively, or not at all, with drug-related behaviors. Research with the modified Simon Task is scarce, but so far no significant correlations with drug-related behavior have been found (Field et al., 2011; Van Hemel-Ruiter et al., 2011).

Finally, Wiers et al. (2009) did not find any significant correlations between the AAT and subjective craving (other correlations are not reported). In another study by Wiers and colleagues (2010), regression analyses showed that whether or not participants underwent an approach or avoidance training could explain a significant part of the variance in alcohol consumption during a taste test: participants who had learnt to avoid alcohol drank less than participants who were trained to approach alcohol. However, this was the case only for those

participants for whom approach (or avoidance) training resulted in faster alcohol-approach (or avoid) reaction times. Van Hemel-Ruiter et al. (2011) reported a negative correlation between the AAT score for alcohol-related pictures and alcohol use, but a positive correlation with subjective valence of alcohol (i.e., the stronger participants' approach bias, the less alcohol they used, and the more positively they judged alcohol). Furthermore, in their study concerning cannabis use, Cousijn and colleagues (2011) report that AAT scores correlated negatively with subjective craving (i.e., a stronger approach bias was associated with weaker subjective craving) but they did not find significant correlations with other criteria (e.g., baseline cannabis use, cannabis-related problems, smoking). However, their study did demonstrate predictive validity in the sense that they found a positive relation with cannabis use after six months (i.e., a stronger approach bias was associated with more cannabis consumption). Thus, to summarize, just like rSRC scores, correlations between AAT scores and drug-related behavior can be negative, positive, or non-significant .

5.2.3. Experimental research.

Even though experimental research is the most powerful approach to make claims about validity, studies employing such designs are scarce within the literature on implicit measures of "wanting" and "liking".

5.2.3.1. Wanting, and Approach-Avoid IATs.

First, in addition to examining differences between smokers and non-smokers, Tibboel et al. (2011) performed an experimental manipulation of "wanting". The authors tested a group of smokers in two sessions, once when they were deprived of smoking for 12 hours, and once after they had just smoked. They reasoned that wanting scores should increase when smokers are deprived (e.g., Field, Mogg, & Bradley, 2004). However, contrary to their hypotheses, they found that depriving smokers did not affect scores on the wanting IAT, but

that deprivation caused an increase in scores on the liking IAT. These results are the exact opposite of what IST would propose.

Using an approach/avoid IAT, Farris and Ostafin (2008) showed that at-risk drinkers had an increased approach bias after consuming alcohol compared to a baseline. However, participants were free to decide how much alcohol they consumed, which implies that some participants might have been sated whereas others were merely primed. This is problematic because priming should increase craving whereas satiation should not (e.g., Christiansen, Rose, Cole, & Field, 2013). Moreover, there was no control group and no placebo condition. Both elements limit the extent to which we can draw solid conclusions. Thus, for both the wanting IAT and the approach/avoid IAT, experimental evidence regarding their validity is limited and unclear.

5.2.3.2. Measures of automatic motivational tendencies

Christiansen et al. (2013) did an elaborate study in which social drinkers were asked to perform an rSRC task in three different sessions. In each session, they were first asked to consume a beverage. In one session, this beverage contained a priming dose of alcohol, in another session the drink was a placebo (i.e., participants were informed that the drink contained alcohol, but in fact it did not), and in another session the beverage was a non-alcoholic control drink (and participants were explicitly told that it did not contain alcohol). Results showed that participants had positive rSRC scores both after consuming alcohol and after consuming the placebo, but not after consuming the control drink. A similar study by Schoenmakers, Wiers, and Field (2008) revealed no difference in rSRC scores after alcohol consumption and placebo consumption either. Thus, it seems that not only the manipulation of "wanting" (i.e., consuming a priming dose of alcohol) but also the manipulation of wanting (i.e., installing the conscious belief that alcohol is consumed) affected rSRC scores,

suggesting that the rSRC is not (only) a measure of "wanting" but also of more conscious processes.

Watson, De Wit, Cousijn, Hommel, and Wiers (2013) have used an AAT to assess "wanting" for nicotine in two groups of smokers. One group was tested just before and after smoking. A control group of smokers performed the AAT twice in a deprived state. Their results showed that AAT scores were positively correlated with craving when smokers were deprived. However, smoking a cigarette led to reduced explicit craving but an increase in AAT scores. For smokers who did not get a chance to smoke, AAT scores remained stable. This is clearly in contrast with the predictions of IST. If AAT scores are an index of "wanting", these scores should be reduced when smokers have just smoked a cigarette.

In their clinical study, Wiers et al. (2011) examined differences in both approach-avoid IAT scores and AAT scores in alcohol-dependent patients before and after treatment. Both the IAT and AAT scores were positive initially, and became negative after treatment. However, the change in IAT and AAT scores (pre and post treatment) could not predict relapse. If one assumes that treatment decreases "wanting", these results partly support the validity of these measures: a decrease in "wanting" causes a decrease in wanting scores. However, if one assumes that relapse is a key indicator of "wanting" (e.g., Robinson & Berridge, 2001), these results are less convincing.

Even though the data are limited, if anything, they seem unable to provide (clear) evidence regarding the validity of these implicit measures.

6. Discussion

Overall, both our theoretical analysis and our review of the empirical evidence provides little support for the validity of different versions of the valence IAT as measures of "liking" (defined as implicit hedonic impact), and of different versions of the arousal IAT, the approach/avoid IAT, the wanting IAT, the AAT, and the rSRC as measures of "wanting"

(defined as implicit incentive salience). Although these doubts stem partly from discrepancies between different definitions and conflicting results (most notable in the IAT studies), they also stem from the lack of studies that allow us to draw clear conclusions regarding the validity of these measures. Given this state of affairs, we conclude that more research is needed that is directed at rectifying a number of shortcomings of the existing literature.

6.1. Experimental designs and longitudinal studies

First, in line with the recommendations of (Borsboom et al., 2004), we suggest that future studies using different implicit measures of "wanting" and "liking" use experimental designs that should aid us in testing a causal relationship between changes in the to-be-measured construct and changes in implicit measures. "Wanting" can be manipulated by, for instance, depriving participants from a substance for a sufficient amount of time (e.g., Tibboel et al., 2011) or by a craving induction (e.g., Dewit & Chutuape, 1993). "Liking", on the other hand, can be manipulated by flavor evaluative conditioning (e.g., Wardle, Mitchell, & Lovibond, 2007). Ideally, researchers should include both implicit measures of "wanting" and implicit measures of "liking" to examine whether these measures are differentially affected by these manipulations and to examine the extent to which each of these measures explains variance on different criterion variables (e.g., drug use, relapse).

On a related note, it is important to examine the development of substance (ab)use over time and the influence of interventions and therapies on substance (ab)use. In this respect, longitudinal studies examining the development of substance (ab)use over time are invaluable. A serious shortcoming of the existing literature is the paucity of longitudinal studies that examine the development of addiction and the changes in scores on implicit measures of "wanting" and "liking". Researchers could, for instance, repeatedly test youths who are at risk for developing addiction on both "wanting" and "liking" measures. If these measures are valid, "liking" scores should decrease, whereas "wanting" scores should

increase when casual drug use develops into an addiction. One recommendable study was performed by Peeters et al. (2013). They tested a large group of adolescents who were at risk for developing substance abuse problems at two points in time, with an interval of six months. One of their most important findings was that in adolescents with weak inhibition skills, higher AAT scores at T1 were related to more self-reported alcohol use at T2. Similarly, more intervention studies are needed, in which participants perform "wanting" and "liking" tests both before and after treatment (see Wiers et al., 2011, for an important exception). It might, however, be less straightforward to formulate hypotheses for these intervention studies because IST postulates that sensitized "wanting" persists for a long time even after withdrawal symptoms have disappeared.

6.2. Sample selection and context effects

This brings us to a second issue that is often overlooked in the existing literature on implicit measures of "wanting" and "liking", and that may explain some of the discrepant findings: IST assumes that there are differences between drug users and drug addicts. According to the theory, both "liking" and "wanting" initially play an important role in drug pursuit. The "wanting" system becomes sensitized and the role of "liking" diminishes only after frequent drug use (e.g., Robinson & Berridge, 1993). Researchers should take this into account when they choose their sample. For instance, the drinking behavior of a heavy social drinker may be driven by both "liking" and "wanting", whereas only "wanting" might play a role in clinical levels of alcoholism. Moreover, a sample of participants who classify as heavy social drinkers might contain both drinkers who are in the earlier developmental stage of addiction (i.e., the stadium that involves both "wanting" and "liking") as well as drinkers who are in later stages (i.e., stages in which "liking" no longer influences their behavior). Contrasting findings and null-results could thus be due to both hidden across- and within-study variability in the selection of participants.

On a related note, the contrasting results we reviewed in this paper might be due to another sample-related question. Whereas IST suggests that "wanting" plays a crucial role in the development and maintenance of all kinds of substance abuse, research has shown that different types of reinforcement play different roles in different types of substance abuse. For instance, intoxication and bingeing play an important role in psychostimulant addiction, whereas they play a considerably less crucial role in nicotine addiction (in which negative affect and withdrawal are the most important motivators for continuing drug use; e.g., Koob & Volkow, 2010). Furthermore, it is possible that the weight of these different processes changes with the development of an addiction. For instance, whereas alcohol abuse might start with an emphasis on the motivation to become intoxicated, this might change gradually in a motivation to avoid the negative consequences of withdrawal. Note that this can differ between individuals as well (e.g., Koob & Le Moal, 2008). In other words, it is possible that some substances automatically trigger memories or expectations regarding the appetitive characteristics of drugs, whereas others substances are associated more with their negative effects. Importantly, implicit measures of "wanting" and "liking" might be sensitive to these different drug-effects. It is possible that our "wanting" and "liking" measures are not valid measures of "wanting" and "liking" but instead reflect the automatically activated expectations regarding specific drug effects.

Similarly, substance abusers might differ in their reactions depending on the context they are tested in. Research has shown that generally, implicit measures are malleable (see Han, Czellar, Olson & Fazio, 2010, for a review and some interesting considerations). Hence, the results of studies on addiction might be influenced by the circumstances under which participants were tested. For instance, a treatment context might trigger only negative affect and avoidance tendencies, whereas another (e.g., social) context might trigger more positive affect and approach tendencies (e.g., Barkby et al., 2012; Dickson et al., 2013; Spruyt et al.,

2012). Future research should examine the influence of these factors more thoroughly. Note, however, that if effects indeed differ according to the context, this adds further evidence for our hypothesis that the implicit measures we address in this paper are not valid "wanting" and "liking" measures: "wanting" and "liking" are assumed to be more hard-wired and stable (see Field, Mogg, Mann, Bennett & Bradley, 2013, for similar arguments regarding the role of attentional bias in alcohol abuse) and should not be affected by one's surroundings.

6.3. Behavioral manifestations of "wanting" and "liking"

Third, we also need clearer hypotheses regarding the behavioral manifestations of "wanting" and "liking". Without such hypotheses, it is impossible to determine the criterion variables that implicit measures of "wanting" and "liking" should relate to. For instance, it would be helpful to know whether and when one should expect correlations between implicit and explicit measures (e.g., subjective pleasantness or craving ratings). According to IST (e.g., Berridge, 2010) "wanting" and "liking" are independent of conscious wanting and liking, suggesting that implicit measures and explicit measures should not correlate. However, many researchers do calculate these correlations and draw conclusions on the basis of these correlations (e.g., Houben & Wiers, 2007a; 2007b; 2008). Furthermore, clarity is obscured by the tendency of addiction researchers to include in their studies a large range of explicit ratings and questionnaires. For instance, studies on alcohol consumption often incorporate questionnaires to assess alcohol problems such as the Rutgers Alcohol Problem Index (White & Labouvie, 1989) and the Alcohol Use Disorders Identification Test (Babor, Higgings-Biddle, Saunders, & Monteiro, 2006), alcohol craving questionnaires such as the Desire for Alcohol Questionnaire (Love, James, & Willner, 1998), alcohol consumption questionnaires such as the Alcohol Timeline Follow Back (Sobell, & Sobell, 1995), Likert scales concerning alcohol expectancies (e.g., Houben et al., 2009), as well as other measures of explicit alcohol attitudes (e.g., Houben & Wiers, 2006). Commonly, correlations are found for only a (small)

subset of criterion measures, but which correlations are significant varies between studies. Hence, when correlations are observed, they might well be spurious, especially because it is uncommon to correct for multiple statistical tests. If these correlations are not spurious, the question remains why results are inconsistent across studies. In order to advance, researchers need to make clear *a priori* predictions regarding correlations between implicit measures and criterion measures and subsequently report the results concerning all tested hypotheses. Exploratory analyses remain useful but should be acknowledged as such.

In this context, it is also important to note that the reasons behind the difficulty to specify criterion variables for implicit measures of "wanting" and "liking" might be related to the manner in which IST has been developed. Berridge (1996) stressed the benefits of the volatile definitions of "wanting" and "liking" because there should be room for these definitions to grow with the increasing amount of research findings. However, to be able to test a theory, strict definitions and clear hypotheses are needed, because these are the only kinds of hypotheses that are falsifiable (e.g., Kuhn, 1962). From this perspective, it is troublesome that IST does not clearly commit itself to the possibility that "wanting" and "liking" (as mental processes) could be measured behaviorally in humans. This raises the question whether adopting other definitions allows for more straightforward hypothesis-testing. Whereas the effect definition might present a too simplified image of drug use for human subjects (e.g., Wiers et al., 2007), and the utility definition is currently restrained to theoretical work (e.g., Berridge & Aldridge, 2008), the neurological definition might offer some perspective. For instance, in some papers (e.g., Berridge, 2004) "liking" is reduced to a brain reaction that leads to an experience of pleasure that is not linked to an object of desire. This means that we cannot measure "liking" *for* a substance, as "liking" is per definition not linked to any object at all. If this assumption is correct, this leaves only possibilities for neuropsychological research to shed more light on the IST hypotheses: it suggests that the

only possible way to assess "liking" is to examine brain activity in hedonic hotspots exactly when a participant consumes a substance. Although such a theoretical conceptualization might have merit, it does seriously constrain the possibility of constructing implicit or other behavioral measures of "liking".

6.4. Neural manifestations of "wanting" and "liking"

This leads us to a final point that neural manifestations of "wanting" and "liking" might eventually provide the best criterion variable to assess the validity of implicit (behavioral) measures of "wanting" and "liking". Whereas IST is not perfectly clear concerning the behavioral manifestations of "wanting" and "liking", it does make more specific hypotheses concerning the neural manifestation of these processes (e.g., Berridge, 2010; Berridge & Kringelbach, 2008). Cognitive neuroscience could provide us with the tools to test the hypotheses of IST and lend a helping hand in examining the validity of implicit measures of "wanting" and "liking". Two examples of studies that could further our understanding of neuropsychological mechanisms that underlie drug abuse and their relation to implicit measures were performed by Cousijn et al. (2012) and Korucuoglu, Gladwin, and Wiers (2014). Cousijn and colleagues asked a group of heavy cannabis users and a group of controls to perform an rSRC task in the fMRI scanner. Their results did not reveal differences in rSRC scored between groups, but they did show that in heavy cannabis users, approach bias activations in several fronto-limbic areas were associated with cannabis use, and that approach bias activations in the dorsolateral prefrontal cortex and anterior cingulate cortex could predict cannabis problem severity six months after testing. In a recent EEG study, Korucuoglu et al. (2014) examined the influence of a priming dose of alcohol or a placebo on

AAT[7] performance and its influence on event-related desynchronization in the beta band (beta band ERD) which is assumed to provide an index of advanced response preparation. Whereas their behavioral data only showed a (marginal) AAT effect, and no effect of priming dose, their EEG data showed an interesting pattern: Beta band ERD was higher in the congruent block (i.e., approach alcohol; avoid soft drink) in the alcohol condition compared to the placebo condition. Moreover, within the alcohol condition, beta band ERD was higher for approach alcohol trials compared to avoid alcohol trials, and higher for avoid soft drink trials compared to approach soft drink trials. Both studies show that implicit measures alone might not be sensitive enough to pick up on differences between groups or conditions, but they might still be related to neuropsychological processes that play a role in incentive salience attribution. These studies provide us with new and exciting ways to gain more insight into the questions raised in this paper.

7. Conclusion

In this paper, we evaluated existing efforts to measure the mental processes of "wanting" and "liking" in implicit ways and uncovered several inconsistencies that need to be addressed in future research. Of course, these problems do not detract from the value of IST. This theory has given impetus to groundbreaking research with non-human (e.g., Wyvell & Berridge, 2000) and human (e.g., Wiers & Stacy, 2006) subjects, on behavioral and neuropsychological levels (e.g., Evans et al., 2006), and has impacted a wide range of impulse control disorders (e.g., Noël, Brevers, & Bechara, 2013). It has redefined the role of dopamine in incentive salience attribution, and it has thereby redefined reward in general (e.g., Berridge & Robinson, 1998). These developments have led to an increasingly better understanding of

[7] It must be noted that the task used in this study was not a regular AAT, because it required that stimuli were judged on the relevant stimulus dimension (i.e., alcohol or soft drinks) whereas in most AATs, stimuli are judged on a different dimension (e.g., portrait or landscape).

the role of reward and affect in the development and maintenance of addiction. However, it is important to note that even though the way is paved, we have not yet arrived at our destination, in particular with regard to the definition and (implicit) measurement of the core concepts of “wanting” and “liking” in humans. We therefore hope that our recommendations can further improve both empirical and theoretical insights into incentive sensitization and its role in addiction.

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Table 1. Overview of different definitions of “wanting” and “liking”

Definition type	"Wanting"	"Liking"
Mental process	(preconscious) craving; (the result of) incentive salience; drug administration itself; mechanism that relates the hedonic experience (“liking”) to an object of desire	(preconscious) pleasure; core hedonic impact; affective state; brain reaction without an object of desire
Effect	the “motivational magnet” feature the cue-triggered US “wanting” feature the conditioned reinforcer feature	None
Utility	decision utility: the essence of the decision to pursue a reward at the moment it is made	experienced utility: the hedonic experience by the reward after it is obtained
Neurological	activity in mesolimbic dopamine-systems, affected by dopamine, opioids, and GABA	activity in subcortical hedonic hotspots, affected only by opioids

Table 2. Overview of different implicit measures of “wanting” and “liking”

Liking measures	To-be-measured attribute	Task summary
Implicit Association Test (IAT)	Liking	Categorization task of attributes ("I like" vs. "I do not like") and targets (drug-related vs. control)
	Valence	Categorization task of attributes ("pleasant (positive)" vs. "unpleasant (negative)") and targets (drug-related vs. control)
Wanting measures		
Implicit Association Test (IAT)	Wanting	Categorization task of attributes ("I want" vs. "I do not want") and targets (drug-related vs. control)
	Approach/avoidance tendencies	Categorization task of attributes ("Approach" vs. "Avoid") and targets (drug-related vs. control)
	Arousal/sedation	Categorization task of attributes ("Active" vs. "Passive") and targets (drug-related vs. control)
relevant Stimulus Response Compatibility Test (rSRC)	Approach/avoidance tendencies	Approach or avoid pictures on the basis of relevant (drug-related) dimension using a mannikin
Affective Simon Task (AST)	Approach/avoidance tendencies	Approach or avoid pictures on the basis of irrelevant (not drug-related) dimension using a mannikin
Approach/avoidance task (AAT)	Approach/avoidance tendencies	Approach or avoid pictures on the basis of irrelevant (not drug-related) dimension using a joystick