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Abstract

Background and objectives: Over the last decade, there has been a surge of studies examining implicit processes underlying addiction. Some implicit measures are assumed to reflect “liking” whereas other implicit measures are assumed to reflect “wanting”. There is, however, little evidence to back up this claim. We examined whether implicit and explicit measures of wanting and of liking are differentially sensitive to manipulations of wanting and expected that these manipulations would affect primarily measures of wanting. *Methods:* Smokers and non-smokers performed both implicit and explicit measures that are assumed to assess wanting and liking for nicotine. Smokers were tested once immediately after smoking, and once after 12 hours of nicotine-deprivation. *Results:* IAT results suggested that smokers showed more implicit liking for nicotine when they were deprived than when they were satiated, whereas there were no differences in wanting. Smokers also seemed to show both more implicit wanting and more implicit liking for nicotine compared to non-smokers. Explicit measures did yield the expected results in that smokers reported to want nicotine more when they were deprived, whereas there were smaller differences in liking. *Conclusions:* We found little support for the assumption that implicit measures of wanting and liking capture different processes. Researchers should thus be cautious in drawing conclusions about wanting and liking on the basis of these measures.

Keywords: Nicotine, Craving, Implicit Association Test, Attentional Blink

1. Introduction

Robinson and Berridge's incentive sensitization theory (e.g., 1993, 2001, 2003, 2008) provides one of the most influential accounts of the development and maintenance of addiction. A central tenet of this model is that wanting and liking are two separable processes and that addiction is driven more by wanting than by liking. Liking refers to the hedonic reaction to drugs, whereas wanting refers to the incentive-motivational properties of drugs and drug-related stimuli. The latter is assumed to be the motivational process that makes drug cues "grab attention" and that triggers drug-use (for a glossary of more elaborate definitions, see Berridge & Kringelbach, 2008). Even though wanting and liking often co-occur, different brain mechanisms are assumed to be at play for each phenomenon. It should thus be possible to find dissociations between the two processes (e.g., to observe wanting in the absence of liking).

Originally, dissociations between wanting and liking have been examined in animals (e.g., Wyvell & Berridge, 2000). Both concepts were operationalized on the basis of facial expressions (liking) and actual consumption (wanting) and the activity of certain brain areas (e.g., Berridge & Kringelbach, 2008). In human research, using the same operationalizations (i.e., facial expressions and actual consumption) that have been used so far in animal research is problematic for several reasons. First, humans can fake facial expressions. Even though there are differences between real and faked facial expressions, these differences are usually very subtle (e.g., Frank, Ekman, & Friesen, 1993; Hill & Craig, 2002). Second, in humans, substance intake and the amount of energy spent to obtain this substance depends on more than merely wanting. As is noted by, for instance, Wiers and Stacy (2006), the impulse to pursue drugs can be inhibited when people are motivated and when they have enough cognitive resources available to do so. Wanting as defined by consumption or willingness to

work may thus be a necessary condition for addictive behaviour to occur, but it is not sufficient.

Another way to examine wanting and liking is on the basis of self-report measures. However, this possibility is problematic too because participants are likely to confuse incentive salience with pleasure (Robinson & Berridge, 1993). Furthermore, both liking and wanting need not be conscious (e.g., Berridge & Kringelbach, 2008). Therefore, researchers have turned to implicit measures to examine wanting and liking, that are assumed to reflect attitudes in an automatic manner (e.g., De Houwer, 2006). It remains an open question, however, whether implicit measures of wanting and liking comply with the normative quality requirements put forward by De Houwer, Teige-Mocigemba, Spruyt, and Moors (2009). They discuss the assumptions that are made when measuring psychological attributes such as liking and wanting. Most importantly, they argue that a measure can be considered as valid only if the to-be-measured attribute causes variation in that measure. Hence, changes in wanting should cause changes in wanting measures whereas changes in liking should affect primarily liking measures. De Houwer and colleagues (2009) suggest also that in addition to validity, the overall quality of the measure should be taken into account. It is important to know whether there are other sources of variation (besides variations in the to-be-measured attribute) that affect the measures. In this paper, we report a study that aimed to test the validity and quality of measures of wanting and liking. We did this by examining whether manipulations of wanting cause more variation in implicit measures of wanting than in implicit measures of liking. Before we describe our studies and results, we first describe a number of measures that have been proposed as implicit measures of wanting and liking.

1.1. Implicit measures of wanting and liking

One procedure that has been used to measure wanting and liking is the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998). Effects in this task are

assumed to be an index of associations between two target concepts and two attributes. The IAT consists of several subsequent blocks, the first of which requires participants to classify target stimuli into one of two target categories (e.g., ~~as~~ “flowers” or “insects”). In a second block, attribute stimuli need to be classified as referring to one of two attributes (e.g., “pleasant” vs. “unpleasant”). Crucially, the same two keys are used as in the first block. During the critical test blocks, then, both target and attribute stimuli are presented. Participants are typically faster when the stimulus-response assignments are compatible with associations in memory (e.g., press one key for “flowers” and “pleasant” and the other key for “insects” and “unpleasant”) than when they are incompatible with associations in memory (e.g., press one key for “insects” and “pleasant” and the other key for “flowers” and “unpleasant”; e.g., Greenwald et al., 1998).

Wiers, Van Woerden, Smulders, and De Jong (2002) used two different versions of the IAT to examine associations involving alcohol. In a so-called valence IAT, “pleasant” and “unpleasant” were the attribute categories, and “alcohol” and “soda” were the target categories. Wiers et al. also used an arousal IAT in which the same target categories were used, but the attribute categories were “passive” and “active”. Effects in the valence IAT were thought to reflect liking, whereas effects in the arousal IAT were thought to reflect wanting. Wiers et al. found that heavy social drinkers had stronger implicit alcohol-active associations than light drinkers (see De Houwer, Crombez, Koster, & De Beul, 2004, for related results). In contrast, the valence IAT revealed alcohol-negative associations in both heavy and light social drinkers (Wiers et al., 2002; also see De Houwer et al., 2004). In sum, Wiers and his colleagues found a dissociation between measures of wanting and liking, which is in line with the incentive sensitization theory (e.g., Robinson & Berridge, 2003).

Palfai and Ostafin (2003) introduced an approach-avoid IAT in which the concepts “approach” and “avoid” were used as attribute categories. They found that alcohol-approach

associations were related to alcohol use when participants' resources for self-control were depleted (Palfai & Ostafin, 2003). Moreover, heavy drinkers had stronger implicit alcohol-approach associations than light drinkers (Ostafin, Marlatt, & Greenwald, 2008). The effects in the approach-avoid IAT have also been interpreted as an index of wanting.

Performance on another implicit measure, the relevant stimulus-response compatibility (SRC) task, is also assumed to reflect wanting in the context of addiction. During one block of this task, a manikin figure needs to be moved towards drug-cues and away from neutral cues. During another block, the manikin figure needs to be moved away from drug-cues and towards neutral cues (Mogg, Bradley, Field, & De Houwer, 2003; see Rinck & Becker, 2007, Wiers, Rinck, Dictus & Van Den Wildenberg, 2009, for a variant of this task). The difference in RTs between the two blocks is assumed to reflect the relative strength of the tendency to approach drug cues. In the context of nicotine addiction, Mogg and colleagues (2003) found that smokers were faster to approach nicotine-related stimuli and avoid neutral stimuli than to avoid nicotine-related stimuli and approach neutral stimuli. Similarly, Field, Kiernan, Eastwood, and Child (2008) found that heavy drinkers were faster to approach alcohol-related stimuli than to avoid them, whereas light drinkers were not. Importantly, Field, Mogg, and Bradley (2005a) found that approach tendencies towards alcohol-related pictures, as measured with the SRC task, were significantly correlated with the desire to drink alcohol. However, studies in which craving for alcohol (Schoenmakers, Wiers, & Field, 2008) and craving for nicotine (Field, Mogg, and Bradley, 2005b) were manipulated by giving participants a priming dose of alcohol, SRC effects were not affected.

Finally, some researchers have used attention tasks to measure wanting. Given that Robinson and Berridge assume that the incentive salience of drug cues endows them with the power to grab attention (e.g., 2003), addicts' attentional bias toward drug cues is thought to be closely related to wanting (e.g., Field & Cox, 2008). The hypothesized central role of

attentional bias in addiction has become an increasingly popular part of addiction theories (e.g., Kavanagh, Andrade, & May, 2005; McCusker, 2001; Ryan, 2002; for an overview of the relevant research, see Field & Cox, 2008). It is reasoned that attentional bias increases as craving (i.e., an experience of intensely wanting to use the substance; Robinson & Berridge, 1993) becomes stronger. Attentional bias is often defined as the increased likelihood to become aware of drug cues (e.g., Franken, 2003). The most commonly used paradigms are the addiction Stroop paradigm (for an overview, see Cox, Fadardi, & Pothos, 2006) and versions of the dot probe task (e.g., Ehrman et al., 2002). However, at best, such tasks measure the extent to which drug cues consume attentional resources after they have been encoded. They do not measure the efficiency with which drug cues are encoded (e.g., Anderson, 2005). A paradigm that does allow us to draw conclusions about the relative efficiency with which specific salient stimuli are processed is the attentional blink (AB) task (Raymond, Shapiro, & Arnell, 1992). In such a task, participants are presented with a rapid serial visual presentation (RSVP) stream of words. In this stream, two words that stand out because of specific visual properties (e.g., colour) are targets (T1 and T2) that need to be reported at the end of each trial. The common finding is that T1 identification is usually quite good, but that the proportion of correct identifications of T2 depends on the lag between the two targets and the salience of T2. When the lag is short (smaller than 500 ms), this proportion is very low, but it increases with lag. This is called the attentional blink effect. However, there are some exceptions. When T2 is very arousing (e.g., Anderson, 2005) or very relevant (e.g., Shapiro, Caldwell, & Sorensen, 1997) the AB is diminished. Studies in the context of addiction have shown that smokers have a smaller AB for smoking-related than for neutral T2 stimuli (Waters, Heishman, Lerman, & Pickworth, 2007), that opiate dependent patients have a smaller AB for addiction-related T2 stimuli (Liu, Li, Sun, & Ma, 2008), and that heavy social

drinkers have a smaller AB for alcohol-related T2 stimuli (Tibboel, De Houwer, & Field, 2010).

1.2. The validity and quality of implicit measures of wanting and liking

To sum up, effects in several tasks have been interpreted as measures of wanting, but there is little direct evidence to support the validity of these measures. The strongest evidence to date comes from the study of Wiers et al. (2002) who found that heavy and light drinkers show different effects on an arousal IAT (that is assumed to measure wanting) but not on a valence IAT. However, more recent studies raise doubts about the conclusiveness of these findings. First, several researchers have reported reliable differences between heavy and light drinkers on (variants of) the valence IAT (e.g., De Houwer & De Bruycker, 2006; Houben & Wiers, 2007, Houben & Wiers, 2008; Jajodia & Earlywine, 2003; McCarthy & Thompsen, 2006). Second, in the context of smoking, De Houwer, Custers, and De Clercq (2006) reported data that suggest that smokers and non-smokers differ clearly in both their effects on a valence IAT as well as in their effects on an approach-avoid IAT. Moreover, the two IATs were strongly correlated. Furthermore, it has been shown that manipulations that are thought to increase wanting (e.g., deprivation manipulations) affect implicit liking measures (Waters, Carter, et al., 2007).

Finally, a recent meta-analysis (Field, Munafò, & Franken, 2009) has shown that while the relationship between craving and direct measures of attentional bias (e.g., eye movements and ERPs) is substantial, the relationship between craving and indirect measures of attentional bias (attention tasks) is weak. This casts some doubts on the suggestion that attentional bias tasks provide us with a valid index of wanting. The question thus remains whether implicit measures of wanting truly reflect a different attribute than implicit measures of liking.

1.3. The present study

We report a study examining the assumption that wanting measures indeed reflect wanting (and not liking), and liking measures indeed reflect liking (and not wanting). This is important because we need valid and reliable measures to draw conclusions about the independent contribution of both wanting and liking to addiction and other phenomena. In this experiment, we tested smokers who were deprived of nicotine for twelve hours before one session and who were required to smoke just before another session. Deprivation manipulations have previously been shown to increase craving (e.g., Field, Mogg, & Bradley, 2004). A control group of non-smokers was tested as well. We examined differences between conditions and between groups on several measures. A personalized valence IAT (see De Houwer et al., 2006; Olson & Fazio, 2004) was used to measure liking. We used a personalized version of the valence IAT (with labels “I like” and “I do not like” instead of “positive” and “negative”) in order to increase the likelihood that the IAT would capture liking rather than societal views (see Olson & Fazio, 2004). To measure wanting, we used a personalized wanting IAT (Dewitte & De Houwer, 2008), which is similar to the personalized valence IAT, but now the labels were “I want” and “I do not want” instead of “I like” and “I do not like”. We used this new version of the IAT for two reasons. First, it allowed us to maximize the structural similarity between the implicit wanting measure and implicit liking measure. This ensures that possible differences between the two measures can be attributed to differences in the constructs that they capture. Second, it seems reasonable to argue that the concepts “I want” and “I do n’ot want” are more closely related to the construct “wanting” than the concepts that have been used in previous wanting-IAT (i.e., arousing / calm; approach / avoid). The latter concepts might capture only individual features or correlates of the concept “wanting”. We also used the AB task as a possible wanting measure. In line with the results of Wiers et al. (2002), we expected that the implicit wanting measures would differentiate more clearly between smokers and non-smokers than the implicit liking

measures. With regard to the comparison of deprived and sated smokers, we expected bigger differences in implicit wanting than in implicit liking.

Apart from the main aim of examining the validity of wanting and liking measures, we also examined the reliability of these measures. While researchers often neglect to examine the internal consistency of their measures, it is very important to explore this psychometric property because it reflects the overall quality of the measure (see De Houwer et al., 2009) and helps us decide whether the measure is useful for capturing stable interindividual differences and predicting future behaviour.

2. Method

2.1. Participants.

We tested 49 smokers and 45 non-smokers. All participants were students at various faculties of Ghent University and were recruited via advertisements posted on university websites, asking for smokers who smoked at least ten cigarettes per day, and non-smokers. Smokers participated in two identical sessions and were paid twenty euro after finishing the second session. They were asked not to smoke during twelve hours preceding one session, and to smoke just before the other session. The order of the sessions was counterbalanced. Non-smokers participated in only one session and were paid eight euro.

2.2. Materials and procedure.

Upon arriving at the testing room, participants were provided with instructions and were given the opportunity to ask questions if anything was unclear. They were seated in front of a 19 inch CRT monitor with a refresh rate of 80 Hz, at a distance of approximately 45 cm. We used a standard AZERTY keyboard to record responses. At the beginning of each session, participants' breath carbon monoxide (CO) levels were measured using the Bedfont Smokerlyzer (Bedfont Instruments, Kent, UK). Second, they filled out the brief version of the Questionnaire for Smoking Urges (Cox, Tiffany, & Christen, 2001). This questionnaire

measures two different aspects of smoking urges: the desire to smoke and the extent to which smoking is considered to be rewarding (Factor 1), and the anticipation of relief from negative affect (Factor 2). Participants then performed the AB task. This task was always presented right after the QSU and before the other implicit measures, because we used the same stimuli in the AB and the other measures. We did not want to familiarize participants with the stimuli before the AB task because this could influence the modulation of the AB effect. Moreover, whereas IAT effects are quite robust, this is often not the case in attentional tasks. Another reason to always present the AB in the beginning of the session was to prevent extra noise in the AB that could, for instance, be caused by fatigue. We used the E-prime software package for stimulus presentation and response registration (Schneider, Eschman, & Zuccolotto, 2002a; Schneider, Eschman, & Zuccolotto, 2002b). Each trial started with the presentation of a red fixation cross, that remained on the screen for 1000 ms. This was followed by the RSVP stream, consisting of 13 distractor words in white and two green targets (T1 and T2). All these stimuli were presented for 90 ms in 16 point bold Courier New font against a black background. Participants were instructed to monitor the stream and to remember the green words. At the end of each trial, participants were prompted to type in the two green words. They were encouraged to guess when appropriate. There was no response deadline. T1 could be one of 45 neutral words, with an average word length of 5.91 letters ($SD = 1.06$) and word frequency of 31.96 per million ($SD = 46.03$), as checked with WordGen (Duyck, Desmet, Verbeke, & Brysbaert, 2004). T1 could appear at the third or fifth position in the RSVP-stream. T2 could be one out of 20 nicotine-related words¹ (e.g., tobacco, inhale) or one out of 10 household-related words (e.g., sink, oven). Average word length was 6.40 for the nicotine-related words ($SD = 1.47$), and 6.40 for the neutral words ($SD = 1.90$). Average word frequency was 37.55 ($SD = 54.69$), and 8.80 ($SD = 5.90$) respectively. T2 could appear 2, 4, or 6 lags after T1, reflecting an SOA of 188, 376, or 564 ms respectively. There were 79

neutral distractors, adapted from Anderson (2005) with an average word length of 12.73 letters ($SD = 2.07$). There were 180 experimental trials, two thirds of which contained a nicotine-related T2 and one third contained a neutral T2. Each of the words was presented once at each of the three lags, for both trials in which T1 appeared at the third position and trials in which T1 appeared at the fifth position, yielding 180 trials. At the beginning of the task, there was a practice block consisting of 18 trials, in which all targets were neutral words².

After this, participants were asked to indicate on a 9 point Likert scale how strongly they felt the urge to smoke. Subsequently, participants performed two IATs, the order of which was counterbalanced over participants but not over sessions (i.e., the order was the same in both sessions): a wanting IAT and a valence IAT. Both IATs were implemented using Inquisit software (Millisecond Software, 2001). There were 10 smoking related words and 10 household related words that were also used in the AB task. Participants were told that they were required to classify these words as either “nicotine” or “household”. In addition, we used 8 positive (e.g., holiday, gift) and 8 negative words (e.g., pain, accident). In line with Olson and Fazio (2004; De Houwer et al., 2006), words were classified as referring to the labels “I like” (“Ik heb graag”) or “I do not like” (“Ik heb niet graag”) in the valence IAT. In line with Dewitte and De Houwer (2008), the labels “I want” (“Ik wil”) or “I do not want” (“Ik wil niet”) were used for these items in the wanting IAT. In both IATs, participants responded by pressing either the left (“a”) or right (“p”) key. The IAT consisted of 7 blocks. The first block consisted of 24 trials on which only positive and negative words were presented. In a second block that also consisted of 24 trials, only nicotine related and household related words were presented. In the third and fourth block, each consisting of 48 trials, words from all categories were presented. For 64 participants (32 smokers), in the first half of both IATs, positive (“I like” and “I want”) words were assigned to the same key as the

nicotine-related words and negative (“I do not like” and “I do not want”) words were assigned to the same key as the household-related words. For the remaining participants, the reverse order was used.⁴ The fifth, sixth and seventh block were identical to the second, third and fourth block respectively except that the assignment for the nicotine and household related words was reversed. If nicotine or household related words were classified incorrectly, a red X appeared for 400 ms. In line with Olson and Fazio (2004) and Dewitte and De Houwer (2008), error feedback was not given for responses to the positive and negative words. The intertrial interval (ITI) was 380 ms. All stimuli were presented randomly, without replacement.

Then, participants were asked to rate the nicotine-related words used in the AB task on 9 point Likert scales for arousal (the word makes me 1 = not aroused at all, 9 = very aroused), valence (the word makes me 1 = very unhappy, 9 = very happy), wanting (1 = I do not want it at all, 9 = I want it very much), and liking (1 = I do not like it at all, 9 = I like it very much). Finally, there was a brief questionnaire containing general questions concerning their smoking behaviour. They were asked whether they smoked, how long they had been smokeeding, how many cigarettes they smoked each day, whether they had any plans to quit smoking, and how much they wanted to quit smoking (on a four-point Likert scale). They were asked also how soon they smoke after getting up in the morning. Finally, they were asked how strongly they felt the urge to smoke at that moment (on a ten-point Likert scale)..

2.3. Data-analysis.

Our design allowed for two separate analyses: one comparing the two different sessions (deprivation, satiation) for smokers only and one comparing smokers with non-smokers (using smokers’ data for the first session only). We discuss these analyses in two separate sections. We calculated correlations only for the smokers, because we did not want to artificially inflate correlations by using two extreme groups (i.e., smokers and non-smokers).

3. Results ⁴

3.1. Smokers: deprivation/satiation.

CO measures, other ratings.

There was a significant difference in CO-level between the deprivation condition, $M = 5.04$ parts per million, $SD = 3.52$, and the satiation condition, $M = 13.65$ parts per million, $SD = 6.86$, $t(45) = 9.78$, $p < .001$, $d = 1.42$. Furthermore, there was a significant difference on the craving Likert-scale between the deprivation condition, $M = 7.00$, $SD = 1.99$, and the satiation condition, $M = 3.93$, $SD = 2.15$, $t(42) = 9.16$, $p < .001$, $d = 1.40$. The urge to smoke at the end of the session differed also between the deprivation condition, $M = 7.89$, $SD = 1.83$, and the satiation condition, $M = 5.40$, $SD = 1.99$, $t(41) = 8.66$, $p < .001$, $d = 1.34$. Finally, t-tests showed that there were differences in arousal ratings between the deprivation condition, $M = 5.35$, $SD = 1.37$, and the satiation condition, $M = 4.59$, $SD = 1.33$, $t(42) = 3.65$, $p < .005$, $d = .56$. There was a difference in valence ratings between the deprivation condition, $M = 5.43$, $SD = .98$, and the satiation condition, $M = 5.06$, $SD = .98$, as well, $t(42) = 2.16$, $p < .05$, $d = .34$.

Smokers had, on average, smoked for 6.29 years ($SD = 3.80$) and smoked 14.37 cigarettes per day ($SD = 5.65$). On average, they smoked their first cigarette 53.69 minutes after getting up in the morning ($SD = 54.57$). On a scale from 1 (no desire to quit) to 4 (high desire to quit), the mean score on the Likert scale that measured how much they wanted to stop smoking was 2.57 ($SD = .72$). Only 17 percent of the smokers had plans to stop smoking. Of the non-smokers, 20 percent had smoked before. On average, these participants had quit smoking 5.04 months before ($SD = 15.04$). When we excluded the data of these participants from our analyses, results were virtually the same and the conclusions remained unaltered.

AB.

We excluded the data of one participant, because the percentage of correct identifications of T1 ($M = .61$) was more than 3 standard deviations below the group mean, $M = .91$, $SD = .06$. We only analysed data for trials on which T1 was identified correctly. An AB survival score was calculated for nicotine and neutral words by subtracting the proportion of correct responses at Lag 2 from the proportion of correct responses at Lag 6. We subsequently subtracted the AB score for the neutral words from the AB score for the nicotine-related words to obtain an index of the relative attentional bias for nicotine-related words compared to neutral words. Positive scores thus reflected more AB survival for nicotine-related than for neutral words. The difference between the deprivation ($M = 3.78$, $SD = 14.43$) and the satiation condition ($M = 1.17$, $SD = 20.58$) was not significant, $t < 1$, $d = .11$. The AB index tended to differ from zero only in the deprivation condition, $t(46) = 1.79$, $p = .08$, but not in the satiation condition, $t < 1$.

IATs.

For the IATs, we calculated effects on the basis of the D600 measure (Greenwald, Nosek, & Banaji, 2003). An ANOVA with condition (deprivation and satiation) and IAT (wanting and liking) as within-subjects factors failed to yield a significant interaction between condition and IAT, $F = 1.48$. The main effects did not reach significance either, $F_s < 1.91$. A priori t-tests revealed that there was no difference between the deprivation condition, $M = .01$, $SD = .45$, and the satiation condition, $M = -.00$, $SD = .41$, $t < 1$, $d = .02$, on the wanting IAT. However, scores on the valence IAT were significantly lower (indicating less liking for smoking) in the satiation condition, $M = -.08$, $SD = .31$, than in the deprivation condition, $M = .00$, $SD = .37$, $t(43) = 2.10$, $p < .05$, $d = .31$. None of the IAT scores differed from zero, $t < 1$, except for the valence IAT in the satiation condition, $t(44) = 1.64$, $p = .11$, $d = .26$.

QSU.

An ANOVA with condition (deprivation and satiation) and QSU factor (1: reward and 2: avoidance of negative affect) as within-subjects factors revealed a significant main effect for condition, $F(1, 43) = 161.02, p < .001$, and for factor, $F(1, 43) = 237.47, p < .001$, showing higher scores in the deprivation condition than in the satiation condition, and higher scores on Factor 1, the factor that reflects the rewarding value of smoking than on Factor 2, the factor that reflects the tendency to smoke to avoid negative affect. Most importantly, there was a significant interaction between condition and factor, $F(1, 43) = 27.09, p < .001$. There was a significant difference between the deprivation condition and the satiation condition on both Factor 1, $t(43) = 12.87, p < .001, d = 2.49, M = 4.23, SD = .83$, and $M = 2.17, SD = 1.11$, respectively, and Factor 2, $t(43) = 8.15, p < .001, d = 1.51, M = 2.41, SD = 1.13$, and $M = 1.22, SD = .66$ respectively. The interaction shows that the difference between conditions was larger for QSU Factor 1.

Explicit wanting and liking.

An ANOVA with condition (deprivation and satiation) and type of rating (wanting and liking) as within-subjects factors revealed a significant main effect for condition, $F(1, 42) = 30.77, p < .001$, showing higher ratings in the deprivation condition than in the satiation condition. Importantly, there was also an interaction between condition and type of rating, $F(1, 42) = 4.30, p < .05$. Liking ratings were higher in the deprivation condition, $M = 5.85, SD = 1.06$, than in the satiation condition, $M = 5.19, SD = 1.13, t(42) = 4.36, p < .001, d = .60$. Similarly, wanting ratings were higher in the deprivation condition, $M = 6.03, SD = .97$, than in the satiation condition, $M = 5.15, SD = 1.15, t(42) = 5.93, p < .001, d = .83$. However, in the deprivation condition, participants experienced more wanting than liking, $t(45) = 2.06, p < .05, d = .27$, but in the satiation condition there was no difference between wanting and liking, $t < 1, d = .05$. There was no main effect of type of rating, $F < 1.33$.

Correlations.

Deprivation/Satiation.

There was no significant correlation between the AB index for the deprivation condition and the AB index for the satiation condition, $r(45) = .08$. Performance on the wanting IAT in the deprivation condition was correlated with performance on the wanting IAT in the satiation condition, $r(44) = .57, p < .001$, and performance on the valence IAT in the deprivation condition was correlated with performance on the valence IAT in the satiation condition, $r(44) = .73, p < .001$.

Deprivation.

The AB index did not correlate with any other implicit wanting or liking measure, nor did it correlate with any of the other relevant variables. The wanting IAT was correlated with the valence IAT, $r(46) = .78, p < .001$, both Factor 1, $r(46) = .32, p < .05$, and Factor 2 of the QSU, $r(46) = .34, p < .05$, and arousal, valence, and wanting ratings for the nicotine-related words, $r(46) = .44, p < .005$, $r(46) = .31, p < .05$ and $r(46) = .32, p < .05$, respectively, but not with liking ratings, $r(46) = .26, p = .07$. It was also correlated with the urge to smoke at the end of the session, $r(46) = .32, p < .05$.

The valence IAT was correlated with arousal, valence, wanting, and liking ratings for the nicotine-related words, $r(45) = .33, p < .05$, $r(45) = .43, p < .005$, $r(45) = .34, p < .05$, and $r(45) = .32, p < .05$, respectively.

When we controlled for the valence IAT, the wanting IAT was still correlated with arousal ratings for nicotine-related words, $r(41) = .32, p < .05$. There were no other correlations, $-.12 < r_s < .24$. When we controlled for the wanting IAT, the valence IAT was still significantly correlated with valence ratings for nicotine-related words, $r(41) = .31, p < .05$. Other correlations were not significant, $-.15 < r_s < .21$.

Satiation.

The AB index did not correlate with any other implicit wanting or liking measure, nor did it correlate with any of the other relevant variables. The wanting IAT was correlated with the valence IAT, $r(45) = .77, p < .001$, Factor 1 of the QSU, $r(43) = .41, p < .01$, and the craving Likert, $r(44) = .40, p < .01$. There was also a correlation with the urge to smoke at the end of the session, $r(42) = .45, p < .005$.

There was a significant correlation between the valence IAT and both Factor 1, $r(43) = .42, p < .01$, and Factor 2 of the QSU, $r(43) = .37, p < .05$, and the craving Likert, $r(44) = .36, p < .05$. Moreover, the wanting IAT was correlated with valence ratings for the nicotine words, $r(44) = .31, p < .05$. There was also a correlation with the urge to smoke at the end of the session, $r(42) = .34, p < .05$.

When we controlled for performance on the valence IAT, the wanting IAT was still significantly correlated with the urge to smoke at the end of the session, $r(37) = .34, p < .05$. There were no other correlations, $-.12 < r_s < .27$. When we controlled for performance on the wanting IAT, the valence IAT was no longer significantly correlated ~~to~~with any of the other variables, $-.11 < r_s < .22$.

Split-half reliability.

Deprivation condition.

In the deprivation condition, there was no correlation between the AB effect on even and uneven trials, $r(47) = -.06$. Split-half reliability was high for both the wanting IAT, $r(47) = .88, p < .001$, and the valence IAT, $r(47) = .84, p < .001$.

Satiation condition.

For the AB, there was a significant but relatively small correlation between the effect on even and uneven trials, $r(47) = .42, p < .005$. Split-half reliability was high for both the wanting IAT, $r(45) = .88, p < .001$, and the valence IAT, $r(45) = .75, p < .001$.

Power analysis.

We performed power analyses with G-power (Buchner, Erdfelder, & Faul, 1997). These analyses show that we would be able to capture effects with a minimal effect size of $d = .36$. We thus had enough statistical power to detect relatively small effects. However, the possibility remains that our power was still insufficient, because for the paired samples t-tests comparing smokers over the two sessions, effect sizes for the AB, the wanting IAT, and the valence IAT were even smaller: .11, .02, and .31, respectively.

3.2. Smokers/non-smokers.

CO measures, other ratings.

There were significant differences for CO-levels of smokers, $M = 8.98$, $SD = 6.99$, and non-smokers, $M = .69$, $SD = .87$, $t(92) = 8.23$, $p < .001$, $d = 1.66$. There were also significant differences between smokers, $M = 5.70$, $SD = 2.36$, and non-smokers, $M = 1.20$, $SD = .81$, on the craving Likert-scale, $t(90) = 12.34$, $p < .001$, $d = 2.55$. T-tests on the arousal ratings for the nicotine-related words revealed differences between smokers, $M = 4.91$, $SD = 1.39$, and non-smokers, $M = 3.68$, $SD = 1.54$, $t(87) = 3.96$, $p < .001$, $d = .41$. Similarly, there were differences in valence ratings for nicotine-related words between smokers, $M = 5.33$, $SD = .87$, and non-smokers, $M = 3.48$, $SD = .88$, $t(87) = 9.98$, $p < .001$, $d = 2.11$.

AB.

We again calculated a relative attentional bias index (subtracting the AB index for household words from the index for nicotine-related words) and examined differences between smokers and non-smokers with an independent samples t-test. There was no significant difference between smokers, $M = 4.67$, $SD = 16.49$, and non-smokers, $M = -.00$, $SD = 19.01$, $t < 1.25$, $d = .26$. Only for smokers, the index differed from zero, $t(48) = 1.96$, $p = .07$, but only marginally so. For non-smokers, there was no difference from zero, $t < 1$.

IATs.

For the IATs, we calculated effects on the basis of the D600 measure (Greenwald et al., 2003) and then performed an ANOVA with type of IAT (wanting and liking) as within-subjects factor and group (smokers and non-smokers) as between subjects factors. This revealed a main effect for group, $F(1, 89) = 50.47, p < .001$, showing more negative scores for non-smokers. Furthermore, and most importantly, it revealed an interaction between type of IAT and group that approached significance, $F(1, 89) = 3.67, p = .06$. On the wanting IAT, non-smokers, $M = -.49, SD = .35$, had a more negative score (which might indicate less implicit wanting) than smokers, $M = .08, SD = .45, t(90) = 6.73, p < .001, d = 1.41$. On the valence IAT, non-smokers, $M = -.47, SD = .34$, were more negative (which might indicate less implicit liking) than smokers, $M = -.01, SD = .37$, as well, $t(89) = 6.11, p < .001, d = 1.29$. One-sample t-tests showed that for non-smokers, values differed significantly from zero for both the wanting IAT, $t(44) = 9.41, p < .001, d = 1.40$, and the valence IAT, $t(43) = 9.19, p < .001, d = 1.38$. For smokers, this was not the case, both $ts < 1.18$.

For smokers there was a marginally significant difference between the wanting and the valence IAT, $t(46) = 1.99, p = .05, d = .29$. They had more positive scores on the wanting IAT than on the valence IAT (which might indicate stronger implicit wanting than implicit liking). For non-smokers, there was no difference, $t < 1$.

Explicit wanting and liking.

An ANOVA with rating type (wanting and liking) as within-subjects factor and group (smokers and non-smokers) as between subjects factors revealed only a significant main effect for group, $F(1, 90) = 314.86, p < .001$. Other effects did not reach significance, $F < 1.20$. Exploratory t-tests show that explicit wanting was higher in smokers, $M = 5.63, SD = .96$, than in non-smokers, $M = 2.26, SD = .85, t(87) = 17.45, p < .001, d = 3.72$. Furthermore, explicit liking was higher in smokers, $M = 5.60, SD = 1.02$, than in non-smokers, $M = 2.34, SD = .86, t(87) = 16.30, p < .001, d = 3.46$.

QSU.

An ANOVA with factor (1: reward and 2: avoidance of negative affect) as within-subjects factor and group (smokers and non-smokers) as between subjects factors revealed a significant main effect ~~for~~of group, $F(1, 91) = 113.60, p < .001$, showing higher scores for smokers than for non-smokers, and a significant effect ~~for~~of factor, $F(1, 91) = 123.49, p < .001$, showing higher scores on Factor 1. Most importantly, there was also a significant interaction between group and factor, $F(1, 91) = 108.56, p < .001$. Smokers scored higher than non-smokers on both Factor 1, the “reward” factor, $t(91) = 13.06, p < .001, d = 2.67, M = 3.28, SD = 1.30$, and $M = .78, SD = .26$, respectively, and on Factor 2, the “avoidance of negative affect” factor, $t(91) = 6.77, p < .001, d = 1.93, M = 1.80, SD = 1.09$, and $M = .73, SD = .06$, respectively. The difference between groups was more pronounced for Factor 1.

Power analysis.

Again we computed the effect size that we should be able to capture, which yielded an effect size of $d = .52$. For the independent t-tests comparing smokers and non-smokers, effect sizes for the AB, the wanting IAT, and the valence IAT were .26, 1.41, and 1.29 respectively. Thus power was good for both IATs, but the possibility remains that our null-finding with the AB task was due to the fact that we had insufficient statistical power to capture small effects.

4. Discussion

In this study we tested the assumption that the wanting IAT and the AB task are valid measures of wanting (and not of liking). We did this by examining whether these wanting measures are sensitive to a wanting manipulation and whether this sensitivity is specific for wanting measures and not liking measures. On the basis of incentive sensitization theory (e.g., Robinson & Berridge, 2001) we expected that ~~that~~ smokers would show more implicit wanting for nicotine when they were deprived than when they were satiated, and that their liking would be less affected by this manipulation. Finally, on the basis on previous findings

(e.g., Wiers et al., 2002) we expected that wanting measures could differentiate between smokers and non-smokers better than liking measures. Our manipulations of craving were highly successful as indexed by the large effect of deprivation/satiation on QSU and self-reported urge to smoke. Nevertheless, we failed to obtain a stronger effect of craving manipulations on implicit measures designed to capture wanting than on implicit measures designed to capture liking of smoking. Opposite to what was predicted, the deprivation manipulation did not affect the presumed implicit measures of wanting (i.e., wanting IAT and the AB task). Instead, the manipulation did cause smokers to be less negative towards nicotine as indexed by the valence IAT. The fact that our manipulation did affect the liking IAT also suggests that lack of support for the validity of the wanting measures is not simply due to insufficient test power or the use of ineffective craving manipulations.

Our findings are in line with previous research showing that the valence IAT can differentiate between smokers and non-smokers (De Houwer et al., 2006) and that abstinence counteracts negative implicit liking (Waters, Carter, et al., 2007). However, it is inconsistent with the results of Wiers et al. (2002). Whereas Wiers et al. found that only an implicit measure of wanting but not an implicit measure of liking could differentiate between heavy and light drinkers, we observed a difference between smokers and non-smokers on implicit measures of both wanting and liking. With regard to the comparison of our study with that of Wiers et al., we must note that different processes might underlie drinking and smoking. However, according to incentive sensitization theory, we would expect that the underlying wanting and liking processes should be highly similar (e.g., Robinson & Berridge, 2003). Moreover, we used a different implicit measure of wanting (i.e., effects on the wanting IAT) than Wiers et al. (i.e., effects on the arousal IAT). However, both are designed to measure (aspects) of incentive sensitization. Furthermore, the wanting IAT scores correlated with arousal ratings, suggesting a strong link between arousal and wanting.

The fact that our manipulation did not affect the AB effect is also consistent with previous research. Importantly, Waters et al. (2007) conducted a **highly** similar study in which smokers performed an AB task once when they were deprived, and once when they were sated. Their results were similar **as to** ours in that they showed that the AB was smaller for nicotine-related words, but that this was not affected by abstinence. Unfortunately, Waters and colleagues did not test a control group of non-smokers. Hence, there are no previous results concerning the difference between non-smokers and smokers in the AB for nicotine-related words. Nevertheless, our findings are in line with other studies that showed that initial encoding of addiction-related information is only weakly related to craving (Field et al., 2009).

Another important finding was that the wanting and liking IAT were correlated very highly, almost as highly as their internal consistency would allow for. This raises serious questions about the extent to which these measures can capture different constructs. However, the correlational analyses also provided some evidence that the wanting and liking measures captured different constructs. Most importantly, we found significant correlations between wanting measures and wanting-relevant constructs, even after controlling for liking. Conversely, we found correlations between liking measures and liking-relevant constructs, even after controlling for wanting. Nevertheless, these correlations were numerically small and no longer significant when correcting for multiple statistical tests.

Of course, as we only used the AB and the wanting IAT, we must be careful in generalizing our findings to other implicit wanting measures. We cannot exclude the possibility that there are measures of implicit wanting other than the AB and wanting IAT that do capture wanting rather than liking. Furthermore, we cannot dismiss the AB and the wanting IAT completely because we cannot exclude the possibility that even these measures might be sensitive to even more extreme manipulations of wanting. However, our results do

raise questions about whether in most typical situations, implicit wanting measures capture something else than implicit liking measures. Until more evidence is available showing that implicit wanting measures capture wanting under at least some conditions, researchers should remain cautious when drawing conclusions about differences between wanting and liking on the basis of so-called implicit measures of wanting.

The question remains if there are any measurement procedures that would provide us with more valid indices of wanting and liking processes. One option is to use explicit measures. In this study, explicit measures have shown to be very promising. They yielded the expected results: smokers experienced more wanting and liking when they were deprived than when they were sated, but this difference was larger for wanting. This is illustrated by both the explicit ratings as well as by the QSU data. Explicit measures of wanting and liking have previously revealed dissociations between wanting and liking. Epstein, Truesdale, Wojcik, Paluch, and Raynor (2003) found that participants showed more wanting for food when they were deprived, while this was not the case for liking. Finlayson, King and Blundell (2007) found that participants' wanting and liking for food was differentially affected by deprivation, but that this was in turn affected by fat content and taste. However, as mentioned in the introduction, both wanting and liking do not need to be conscious (e.g., Berridge & Kringelbach, 2008) and even if it is conscious, it is likely that subjects confuse these feelings (Robinson and Berridge, 1993). It is unlikely that their conception of "wanting" and "liking" corresponds with the definitions provided by, for instance, Berridge and Kringelbach (2008). Moreover, it is possible that responses on explicit measures may be affected by demand characteristics. Participants may form their own hypotheses about the goal of the experiment and they may feel the need to respond in a socially desirable way.

There are thus important drawbacks to both implicit and explicit measures. Because objective wanting and liking are defined in terms of brain activity, another option is to use

brain imaging techniques. This could help us also to determine whether implicit measures of wanting and liking are valid. If activity in hedonic hotspots is associated with increased effects on a valence IAT but not with effects on an SRC task and arousal, approach, and wanting IATs, and activity in mesolimbic reward structures is associated with increases effects on an SRC task or wanting, arousal, or approach IATs, but not on a valence IAT, this would provide us with more convincing reasons to believe that these implicit measures actually do mirror objective wanting and liking. In the context of racial prejudice, the combination of implicit measures and brain imaging has already proven to be promising. Phelps and colleagues (2000) for instance, have used fMRI to examine amygdala activity of subjects who viewed Black and White faces. Their participants also performed an IAT that was designed to measure the unconscious evaluation of Black and White social groups. Phelps and colleagues found that the strength of amygdala activity was associated with the IAT effect. Similar studies could prove useful for the development and validation of measures of wanting and liking.

To sum up, we found no evidence that implicit wanting measures and implicit liking measures capture different processes. Our results call for caution in interpreting data of studies in which such measures are used.

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Footnotes

¹ For exploratory purposes, half of the nicotine-related words were clearly related to nicotine (e.g., “ashtray”) and half of the words were more ambiguous (e.g., “packet”). None of the conclusions were affected by the ambiguity of the nicotine-related word.

² For exploratory purposes, there was a brief categorization task after the AB. In this task, all T2 stimuli were shown simultaneously and participants were asked to decide what coherent category of words they felt stood out. They were asked to press a key to indicate that they had reached a decision, and were subsequently asked to type in the name of this category. Then, they were shown the list of words again, and were asked to use the mouse to click on each word belonging to that category. Because this task is not relevant for the current discussion, we do not report the results.

³ We initially counterbalanced the order of the blocks, but later decided to test participants only on an IAT starting with the block in which positive and nicotine-related words were assigned to the same key, and negative and household-related words to the other key. We did this because compatibility order strongly affects IAT effects (e.g., Greenwald et al., 1998) and thus increases variance in the IAT effects. We included all the data in our analyses, and when we included block order as a factor this did not yield significant effects.

⁴ Because some participants made too many errors on some tasks, or they did not answer all questions, degrees of freedom may differ across different tasks.