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Implicit beliefs and automatic associations in smoking

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A R T I C L E I N F O

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A B S T R A C T

Background and objectives: Dual process models of addiction suggest that controlled, goal-directed processes prevent drug-use, whereas impulsive, stimulus-driven processes promote drug-use. The most frequently used measure of automatic smoking-related processes, the implicit association test (IAT), has yielded mixed results. We examine the validity of two alternative implicit measures: 1) the affect misattribution procedure (AMP), a measure of automatic evaluations, and 2) the relational responding task (RRT), a measure of implicit beliefs.
Methods: Smokers and non-smokers performed smoking-related versions of the AMP and the RRT and filled in questionnaires for smoking dependence. Smokers participated in two sessions: once after they just smoked, and once after being deprived for 10 h. Smokers also kept a smoking diary for a week after the second session.
Results: We found significant differences between smokers and non-smokers on the RRT, $t\,(86) = 2.86$, $p = .007$, $d = 0.61$, and on the AMP, $F\,(1, 85) = 6.22$, $p = .015$, $_p\eta^2 = 0.07$. Neither the AMP nor the RRT were affected by the deprivation manipulation. Smoking dependence predicted smoking behavior in the following week; the AMP and RRT did not explain additional variance.
Limitations: Possibly, our manipulation was not strong enough to affect the motivational state of participants in a way that it changed their implicit cognitions. Future research should examine the sensitivity of implicit measures to (motivational) context.
Conclusions: We found limited evidence for the validity of the smoking-AMP and the smoking-RRT, highlighting the need for a critical view on implicit measures.

1. Introduction

Many psychologists stress the importance of implicit or automatic processes in the development and maintenance of addiction (e.g., Berridge & Robinson, 1998; Tiffany, 1990; Wiers & Stacy, 2006). Dual-process theories provide a clear-cut hypothesis on why substance-dependent patients continue to use drugs despite being aware of the negative consequences (Deutsch & Strack, 2006, pp. 45–57; Stacy & Wiers, 2010; Wiers, Bartholow, Van Den Wildenberg, Thush, & Engels, 2007). These theories propose that two different types of processes steer behavior: controlled, goal-directed, propositional processes, and automatic, stimulus-driven, associative processes. Whereas drug use starts as a goal-directed action (e.g., I smoke a cigarette because it will make me feel relaxed; I smoke because my peers might appreciate me more), extensive experience with the drug can make the behavior automatic and stimulus-driven (e.g., the sight of a pack of cigarettes can trigger smoking in a habitual smoker). It is assumed that these automatic processes play a more influential role in addiction than controlled processes (e.g., Stacy & Wiers, 2010), and research indeed showed a moderate relationship between implicit cognition and substance use (Rooke, Hine, & Thorsteinsson, 2008).

The most often used implicit measure is the Implicit Association Test (IAT; Greenwald, McGhee, & Schwartz, 1998), which was initially assumed to capture automatic memory associations (but see, for instance, De Houwer, 2006 for an alternative view). In this task, participants are required to categorize concept stimuli (e.g., smoking-related or neutral pictures) using two response keys (e.g., for smoking, press left; for non-smoking, press right) and to categorize attribute stimuli (e.g., pleasant and unpleasant words) using those same response keys (e.g., for pleasant, press left; for unpleasant, press right). In one block, stimulus-response mappings are presented in a way that is congruent with participants' memory associations, whereas in the other block, they are incongruent with participants' memory associations. It is assumed that responses are faster on congruent blocks compared to

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incongruent blocks (e.g., a participant who has a positive implicit attitude towards smoking will be faster when smoking-pictures and pleasant words require the same keypress than when smoking-pictures and negative words require the same key-press).

Initial findings supported the idea that automatic processes play an important role in addiction. For instance, Waters et al. (2007) showed that more positive scores on a valence smoking IAT were associated with more cigarette craving and stronger smoking dependence. Furthermore, non-smokers are shown to have more negative implicit attitudes towards smoking compared to smokers (e.g., De Houwer, Custers, & De Clercq, 2006; Huijding, de Jong, Wiers, & Verkooijen, 2005), deprived smokers have more positive implicit attitudes than when they are sated (e.g., Waters et al., 2007), and heavy smokers have a more positive implicit attitude than light smokers (Sherman, Rose, Koch, Presson, & Chassin, 2003). Studies on other substances have shown that different versions of the IAT yielded results that (at least partly) supported the idea that implicit processes are related to addictive behavior (e.g., De Houwer & De Bruycker, 2007; Houben & Wiers, 2006; Houben & Wiers, 2008; Jajodia & Earleywine, 2003; McCarthy & Thompsen, 2006; Ostafin & Palfai, 2006; Robinson, Meier, Zetocha, & McCaul, 2005). Finally, the meta-analysis by Rooke et al. (2008) showed a consistent small to medium effect size ($r = 0.18$) of the IAT as a predictor of addictive behavior.

However, contrasting findings have been reported as well. Swanson, Rudman, and Greenwald (2001) showed that smokers implicitly showed a consistent preference for non-smoking over smoking. They also failed to find consistent differences between smokers and non-smokers and showed that smokers' explicit beliefs rather than their IAT scores were consistent with their smoking behavior. Furthermore, a smoking IAT used by Spruyt et al. (2015) revealed more negative implicit attitudes in smokers compared to non-smokers. Similarly, studies on other addictive substances have found no or even an opposite relation between addictive behaviour and implicit measures (e.g., Larsen, Engels, Wiers, Granic, & Spijkerman, 2012; Tibboel, De Houwer, Spruyt et al., 2015; Wiers, Houben, & De Kraker, 2007; Wiers et al., 2002) and some studies showed no relationship between IAT scores and craving (Sherman et al., 2003; Tibboel, De Houwer, Dirix, & Spruyt, 2017; Tibboel et al., 2011). Rooke et al. (2008) point out that their meta-analysis also shows conflicting results depending on the type of IAT that is used.

One reason for these diverging findings is that the IAT might not be suitable to measure implicit processes in addiction. During recent years, there has been increasing criticism of the concept validity and the psychometric properties of the IAT both in general (e.g., Fiedler, Messner, & Bluemke, 2010; Schimmack, 2019) as well as within the context of addiction (e.g., Tibboel, De Houwer, & Van Bockstaele, 2015). For instance, the fact that the most often used version of the IAT is a bipolar measure in the sense that it involves contrast categories (i.e., smoking vs. non-smoking; pleasant vs. unpleasant) has been criticized (Blanton & Jaccard, 2006; Rooke et al., 2008) and several studies showed that IAT effects varied depending on the types of target and attribute categories (e.g., Houben & Wiers, 2006; Robinson et al., 2005; Swanson, Swanson, & Greenwald, 2001).

Because of these issues, novel measures were developed to assess the implicit processes that are hypothesized to play a role in addiction. One such task is the Affect Misattribution Procedure (AMP; Payne, Cheng, Govorun, & Stewart, 2005). In this task, participants are presented with a prime stimulus, which is quickly followed by a neutral target stimulus, which is in turn followed by a mask. Participants are required to indicate whether they feel the target stimulus is "pleasant" or "unpleasant". It is reasoned that the affect triggered by the prime stimulus is misattributed to the target stimulus. This leads to positive affective responses when the prime is positive, and negative affective responses when the prime is negative. The AMP is considered a valid and reliable measure of implicit attitudes (e.g., Payne & Lundberg, 2014, but see Teige-Mocigemba, Becker, Sherman, Reichardt, & Klauer, 2017) and the few AMP studies that have been performed in the context of addiction have shown promising results. For instance, daily smokers tend to give more "pleasant" responses when a smoking prime is presented compared to when a neutral prime is presented, whereas this effect is reversed in occasional smokers (Haight, Dickter, & Forestell, 2012). McClernon, and Dobbins (2007) performed an AMP study with smokers, in which they included questions about how recently their participants had smoked. They argued that, since deprivation state affects reactivity to smoking cues (e.g., Payne, Smith, Sturges, & Holleran, 1996), this should also affect implicit cognition. Results indeed showed that AMP scores were more positive as more time had passed since respondents smoked their last cigarette. While these results suggest that the AMP is sensitive to variations in the motivation to smoke, and thus might be a valid alternative to the IAT, Payne et al. (2007) did not experimentally manipulate satiation/deprivation. Such experimental manipulations of the to-be-measured attribute are considered crucial to draw conclusions about the validity of the measure (e.g., Borsboom, Mellenbergh, & van Heerden, 2004).

Another criticism on the IAT is that it is improbable that we can predict behavior based on IAT scores because they are too unspecific and simple (e.g., Meissner, Grigutsch, Koranyi, Müller, & Rothermund, 2019). Some researchers suggest that automatic behaviors are the result not of associations that the IAT was thought to measure, but of more complex, implicit beliefs (e.g., Meissner et al., 2019; Tibboel et al., 2017). A measure that was specifically designed to examine such implicit beliefs is the Relational Responding Task (De Houwer, Heider, Spruyt, Roets, & Hughes, 2015), a categorization task that is structurally similar to the IAT, except that statements are used instead of single words or pictures. In a recent study Tibboel et al. (2017) used a smoking RRT. In the crucial phases of this task, participants were asked to classify statements (e.g., "A cigarette would taste good now") as "true" or "false" based on a specific response rule. In one block, respondents were asked to respond as if they wanted to smoke a cigarette right at that moment. In another block, respondents were asked to respond as if they did not want to smoke a cigarette at that moment. Participants are assumed to respond faster when the response rule is in line with their personal beliefs than when the response rule is not in line with their personal beliefs (De Houwer et al., 2015). Indeed, Tibboel et al. (2017) found smokers to exhibit stronger positive implicit beliefs when they had been deprived from smoking than when they had just smoked. However, even though the effect was significant, Bayesian analyses showed that the evidence was only "anecdotal". Furthermore, they did not include a control group of non-smokers, which is an important requirement to establish the role of implicit cognition in addiction (Grigutsch, Lewe, Rothermund, & Koranyi, 2019). Finally, they did not yet examine the relationship between RRT scores and actual smoking behavior, despite the clear practical relevance of assessing the predictive validity of implicit measures (e.g., Thush & Wiers, 2007).

In the current study, we aimed to further validate the AMP and the RRT in several ways. First, deprivation and satiation affect the desire and the motivation to smoke (e.g., Sayette, Martin, Hull, Wertz, & Perrott, 2003), we examined whether a deprivation manipulation affected both measures. We hypothesize that scores on both measures would be affected by a deprivation manipulation where smokers were asked to smoke just before one session (satiation) and to abstain from smoking during 10 h before another session (deprivation). In both sessions, smokers performed several explicit measures, the AMP, and the RRT. We expected more positive responses to smoking primes in the AMP when smokers were deprived. We also expected higher RRT scores (i.e., stronger implicit urge to smoke) when smokers were deprived. Second, not only did we expect within-group differences between scores on the implicit measures depending on the motivational state of the smokers, we also expected differences between smokers and non-smokers. We thus compared both AMP and RRT scores between smokers and a control group of non-smokers. In the AMP, we expected smokers to have more positive responses to smoking primes compared to neutral primes, and that this difference was smaller is non-smokers. We also expected that the RRT would show a stronger implicit urge to smoke in smokers compared to non-smokers.

Finally, we would expect correlations between our implicit measures and smoking behavior outside the lab. We thus also examined whether AMP and RRT scores can statistically predict the number of cigarettes smoked during the week after the experiment.

2. Method

2.1. Participants

We tested 44 smokers who smoked at least ten cigarettes per day, and 50 people who identified themselves as non-smokers. Participants were students at our university, who were recruited through the online experiment registration system of the faculty and through word-of-mouth. Smokers were tested in two sessions: once when they were sated and once when they were deprived. There was one week between the two sessions. Non-smokers were only tested once. We aimed to exclude smokers who did not comply with the manipulation. We measured carbon monoxide levels in participants' breath (see paragraph 2.1.3) to examine whether they complied. Our exclusion criterion was that participants with higher levels of carbon monoxide in the deprivation session compared to the satiation session would be excluded. This resulted in no exclusions. We also aimed to exclude non-smokers who did smoke a cigarette in the previous two months and/or experienced craving for cigarettes (as shown by the Questionnaire for Smoking Urges and the Fagerström Test for Nicotine Dependence, see paragraph 2.1.4), which led to twelve exclusions, leading to a final sample of 39 non-smokers.[1] Participants were students who received course credits for their participation. The study was approved by the ethical committee of the faculty.

2.2. Materials

2.2.1. Relational responding task (RRT)

We used the same RRT as Tibboel et al. (2017). We used E-Prime (Schneider, Eschman, & Zuccolotto, 2002a, 2002b) for stimulus presentation and response registration. There were ten different inducer words. Five words were synonyms for "true" (Dutch translations of "good", "accurate", "correct", "exact", "okay") and five words were synonyms for "false" (Dutch translations of "wrong", "untrue", "incorrect", "faulty", "mistaken"). These inducer words were included to ensure that participants encoded the two responses as "true" and "false" (De Houwer et al., 2015). There were 24 target statements (see Appendix A for all stimuli). Half of these statements referred to positive beliefs regarding smoking, whereas others referred to negative beliefs regarding smoking. Inducer statements were always presented in yellow (255, 255, 0 in RGB), and target statements were always presented in blue (0, 0, 255 in RGB). All stimuli were presented in 18 point Verdana font.

Participants were instructed to categorize words and statements presented on the screen as either "true" or "not true" by pressing the Q or P keys. In a first practice block, each of the 10 inducer words was presented 4 times, resulting in 40 trials. In the second practice block of 48 trials, each of the 24 target statements was presented twice. Participants were required to respond as if they felt the urge to smoke a cigarette at that moment. In the third block, target and inducer trials were presented intermixed. In each block, each inducer statement was presented four times, and each target statement was presented twice, resulting in 88 trials. Participants were required to respond in the same manner as they did during the practice blocks. The fourth block was another practice block in which the 24 target statements were again presented twice each. However, now the response rule was reversed: participants were instructed to respond as if they did not feel the urge to smoke a cigarette at that moment. In the fifth block, with the same response rule as block 4, was another critical test block in which 88 target and inducer trials were presented intermixed. In line with De Houwer et al. (2015) and Tibboel, De Houwer, Dirix, and Spruyt (2017) we did not counterbalance the order of the blocks, to avoid inflation of error variance.

Inducer words and target statements were presented in the center of the screen. They remained on the screen until a response was given. If a response was incorrect, a red X appeared in the center of the screen. It remained there until participants gave the correct response. The inter-trial interval was 750 ms. Implicit smoking beliefs were operationalized as the difference in reaction times between the test block in which participants responded as if they felt the urge to smoke versus the test block in which they responded as if they did not feel the urge to smoke.

2.2.2. Affect misattribution procedure (AMP)

We used a procedure like the one used by Payne et al. (2007). There were 50 smoking-related prime stimuli (e.g., pictures of people smoking or of smoking-related objects) and 50 visually matched control stimuli (e.g., a pencil). Pictures were taken from Luijten, Littel, and Franken (2011). There were 100 Chinese ideographs from a study of Van Dessel, Mertens, Tucker, and De Houwer (2017). Prime stimuli were presented for 75 ms, followed by a blank screen for 125 ms. Then, a mask appeared for 100 ms, followed by the target picture. This remained on the screen until participants gave a response by pressing either the "N" key if they found the target picture unpleasant, or the "M" key if they found it pleasant. Each prime and target stimulus was presented only once, yielding 100 trials in total.

In line with the study of Payne et al. (2007). Participants were instructed not to let the prime pictures influence their responses to the target pictures, and to merely evaluate the Chinese ideographs without influence from the preceding pictures.

2.2.3. Carbon monoxide

We measured smokers' breath carbon monoxide (CO) levels using the Bedfont Smokerlyzer (Bedfont Instruments, Kent, UK). The smokerlyzer returns two values, i.e., parts per million and the percentage of Carboxyhemoglobine (COhb). We used the latter for our analyses.

2.2.4. Explicit measures

Both smokers and non-smokers completed the brief version of the Questionnaire for Smoking Urges (QSU; Cox, Tiffany, & Christen, 2001; Tiffany & Drobes, 1991). This 10-item 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). The internal consistency of this measure was good in our study ($\alpha = 0.77$). Smokers also filled in the Fagerström Test for Nicotine Dependence, which measures the degree of physical smoking dependence (Heatherton, Kozlowski, Frecker, & Fagerstrom, 1991). Internal consistency in our study was low ($\alpha = 0.18$); a Timeline Followback questionnaire, in which they indicated for each day of the previous week how many cigarettes they smoked. This questionnaire was based on the 7-day version of the Timeline Followback questionnaire for alcohol consumption (Sobell & Sobell, 1992), adapted by the authors. It had high internal consistency ($\alpha = 0.97$); a brief questionnaire with 5 smoking-related questions: "how long have you smoked", "how many cigarettes do you smoke each day", "do you have plans to quit smoking", "how much would you like to quit smoking", and "how much time passes between the hour of waking and lighting your first cigarette". Non-smokers answered four other smoking related questions: "did you ever smoke a cigarette", "when was the last time you smoked a cigarette", "how many cigarettes have you smoked", and "did you ever experience craving for a cigarette".

2.3. Procedure

Smokers were tested in two sessions, the order of which was

[1] Excluding these participants did not affect the results.

counterbalanced. Participants were asked not to smoke during 10 h preceding one session (the deprivation condition) and they were asked to smoke a cigarette just before the other session (the satiation condition). Non-smokers were tested only once.

Participants were seated in a testing room in front of desktop computer with a 19-inch screen. We used a standard QWERTY keyboard to record responses. Participants were instructed about the procedure and gave informed consent. For the smokers, we then measured carbon monoxide (CO) levels in their breath using the Bedfont Smokerlyzer (Bedfont Instruments, Kent, UK). Subsequently, they performed the RRT, followed by a questionnaire (the Fagerstrom questionnaire in the first session; the five-item general smoking questionnaire in the second session), and then they performed the AMP. Because different implicit measures might affect each other, it is common to counterbalance the order of the tasks. However, in this experiment we instead reduced such contamination effects by asking our participants to fill in questionnaires in between the two tasks. Subsequently, participants filled in the QSU. Finally, at the end of each session, smokers filled in the Timeline Followback Questionnaire. This was done in order to familiarize smokers with tracking their cigarette use. Finally, they also filled in the Timeline Followback questionnaire one week after the last session. Only these data were used in the analyses.

For non-smokers, the procedure was similar: after giving informed consent, they immediately started with the RRT, followed by the QSU. Subsequently, participants performed the AMP, which was followed by the four item questionnaire.

3. Results

3.1. Scoring and analytical approach

For our analyses of the RRT data, we first excluded filler trials and then calculated dRRT scores using the D1 algorithm of Greenwald, Nosek, &Banaji (2003; see also De Houwer et al., 2015). Positive dRRT scores reflect a stronger implicit urge to smoke. For our analyses of the AMP, we calculated the proportion of "pleasant" responses for trials in which smoking pictures or control pictures were presented, in line with Payne et al. (2007). For the regression analyses we subtracted the proportions of pleasant responses on control trials from pleasant responses on smoking trials (Payne et al., 2007), where positive scores thus indicate a more positive implicit attitude. We report scaled Jeffreys–Zellner–Siow Bayes factors to allow for conclusions about the strengths of effects and null effects (Beard, Dienes, Muirhead, & West, 2016; Rouder, Speckman, Sun, Morey, & Iverson, 2009).

For both the regression analyses and the comparison of smokers and non-smokers, we used the smokers' data for Session 1. We chose this option in line with Tibboel et al. (2011) so all participants were equally experienced in performing the tasks. The downside of this option is that this means that the data contained both deprived and satiated smokers. However, re-analyzing the data using either the deprivation or the satiation session yielded similar results.

3.2. Participant characteristics

The smokers on average had been smoking for 6.08 years (SD = 0.71), they smoked M = 12.25 cigarettes per day (SD = 5.60), and smoked their first cigarette 94.20 min after waking up (SD = 76.79). On a four-point scale, the desire to quit smoking was $M = 2.79$, $SD = 0.71$. Sixteen smokers indicated that they had plans to quit. The average score on the Fagerstrom Questionnaire was 5.27, SD = 2.29, indicating a moderate nicotine dependance.

3.3. Smokers: manipulation check

Smokers had higher COhb percentages when they had just smoked, $M = 2.40$, $SD = 1.00$ compared to when they had been deprived for 10 h, $M = 1.30$, $SD = 0.44$, $t\,(43) = 8.61$, $p < .001$, $d = 1.30$, $BF_1 > 100$. QSU scores were higher in the deprivation condition, $M = 45.50$, $SD = 17.46$, as compared to the satiation condition, $M = 30.61$, $SD = 11.79$, $t\,(43) = 6.55$, $p < .001$, $d = 0.99$, $BF_1 > 100$. This suggests that the manipulation affected both objective deprivation as well as the subjective experience of craving.

3.4. Smokers: deprivation versus satiation

3.4.1. RRT

A paired-samples t-test revealed no significant difference in RRT d-scores between the deprivation condition and the satiation condition, $t\,(43) = 0.18$, $p = .86$, $d = 0.02$, $BF_0 = 6.03$. All means can be found in Table 1.[2]

3.4.2. AMP

A repeated measures ANOVA with trial type (neutral vs. control) and condition (deprivation vs. satiation) as within-subjects factors revealed no significant interaction between condition and trial type, $F\,(1, 42) = 0.09$, $p = .77$, $_p\eta^2 = 0.00$, $BF_0 = 6.04$. We also find no significant main effects for condition, $F\,(1, 42) = 1.01$, $p = .32$, $_p\eta^2 = 0.02$, $BF_0 = 3.76$, or trial type, $F\,(1, 42) = 0.21$, $p = .65$, $_p\eta^2 = 0.01$, $BF_0 = 5.94$. Means can be found in Table 1.[3]

3.5. Smokers: smoking diary

In order to predict smoking behavior during the week after the experiment, we calculated the total number of cigarettes smoked for each participant. The mean was $M = 84.33$, $SD = 37.98$. We used a hierarchical linear regression model in which we included scores on the Fagerstrom questionnaire in a first step, followed by the dRRT and the AMP scores that we obtained in the first session in a second step. We first calculated correlations between each of the measures used in the model. Only the correlation between the Fagerstrom questionnaire and the number of cigarettes smoked was significant, $r\,(43) = 0.61$, $p < .001$. All other rs < 0.14.

Because regression models are prone to be affected by outliers, we followed the guidelines of Aguinis, Gottfredson, and Joo (2013) to identify potential model fit outliers and potential prediction outliers. Excluding the six outliers we identified did not affect the results. The model including all participants is described below.

The first model significantly predicted smoking behavior, $R^2 = 0.38$, $F\,(1, 40) = 24.43$, $p < .001$, $BF_1 = 109.26$, showing that the Fagerstrom questionnaire was a significant predictor, $\beta = 0.62$, $p < .001$. The second model did not improve predictive power, R^2 change <0.001, $BF_0 > 100$. Neither the dRRT, $t\,(38) = 0.16$, $p = .88$, $BF_0 = 5.99$, nor the AMP, $t\,(38)$

Table 1
dRRT-scores and proportion of "pleasant" responses on AMP smoking and control trials for each condition.

	Smokers - Deprivation		Smokers - Satiation		Smokers - Session 1		Nonsmokers	
Score	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
RRT	.17	.35	.18	.31	.19	.33	.00	.29
AMP_control	.58	.17	.57	.16	.57	.18	.62	.20
AMP_smoking	.60	.19	.58	.17	.60	.18	.55	.22

[2] When we performed a between-group comparison for deprived and satiated smokers in the first session, we also did not find a significant difference, $t(42) = -1.0$, $p = .30$.

[3] When we performed a between-group comparison for deprived and satiated smokers for the first session only, we also did not find a significant interaction between trial type and condition, $F(41) = 2.28$, $p = .14$.

$= 0.01$, $p = .99$, $BF_0 = 6.06$, predicted the number of cigarettes smoked.[4]

All correlations can be found in Appendix B.

3.6. Smokers versus non-smokers

3.6.1. RRT

An independent *t*-test revealed a significant difference between smokers in Session 1 and non-smokers in RRT d-scores, t (86) $= 2.86$, $p = .007$, $d = 0.61$, $BF_1 = 5.24$. All means can be found in Table 1.

3.6.2. AMP

A mixed measures ANOVA with trial type (neutral vs. control) as within-, and group (smokers in Session 1 vs. non-smokers) as between-subjects factor revealed a significant interaction between trial type and group, $F\,(1, 85) = 6.22$, $p = .015$, ${}_p\eta^2 = 0.07$, $BF_1 = 2.11$. There was no significant main effect of trial type, $F\,(1, 85) = 1.67$, $p = .20$, ${}_p\eta^2 = 0.02$, nor of Group, $F\,(1, 85) = 0.002$, $p = .96$, ${}_p\eta^2 = 0.00$. Paired-samples t-tests revealed a significant difference between smoking and control trials in non-smokers, $t\,(44) = 4.05$, $p < .001$, $BF_1 = 120.81$, but not for smokers, $t\,(43) = 0.67$, $p = .51$, $d = 0.25$, $BF_0 = 4.91$. However, independent t-tests revealed no difference between smokers and non-smokers on smoking trials, $t\,(85) = 1.05$, $p = .30$, $BF_0 = 4.97$, nor on control trials, $t\,(85) = 1.21$, $p = .23$, $d = 0.26$, $BF_0 = 4.18$. Means can be found in Table 1.

4. Discussion

The aim of the current paper was to validate the AMP as a measure of implicit affect misattribution and the RRT as a measure of implicit beliefs in the context of smoking addiction. To that end, we (a) we employed an experimental design in which we manipulated craving by depriving smokers for 10 h, (b) tried to predict smoking during the week following the experiment; and (c) used a control group of non-smokers to examine between-group differences. Despite previous data suggesting that RRT and AMP effects depend on craving intensity (Tibboel et al., 2017 and Payne et al., 2007; respectively), and even though our deprivation manipulation was successful, we found no evidence that this manipulation affected the RRT and AMP scores. In fact, Bayesian analyses showed moderate support for the *absence* of an effect of the manipulation on these implicit measures. This suggests that neither the RRT nor the AMP are valid measures of implicit processes that play a role in smoking addiction.

Different theories suggest that motivational states should affect automatic processes (e.g., Cox, Fadardi, & Klinger, 2006; Franken, 2003; Stacy & Wiers, 2010), and a range of studies did reveal a link between deprivation and craving and automatic processes (e.g., Carter & Tiffany, 1999; Field, Munafò, & Franken, 2009; Payne et al., 2007; Sherman et al., 2003; Tibboel et al., 2017). It has also been suggested, however, that implicit measures, such as the IAT, may fail to tap into the attribute that we manipulated, i.e., craving. For instance, in a recent study, Grigutsch et al. (2019) asked smokers to perform several IATs to measure different implicit processes assumed to play a role in addiction. Importantly, they showed that scores on a so-called Wanting-IAT were not affected by the same deprivation manipulation used here. They reasoned that the chronic nature of addiction causes stable changes in smokers' implicit attitudes that are not likely to be affected by contextual factors such as the smokers' motivational state. This suggests that we should not focus on intra-individual differences in implicit attitudes, but instead look at steady differences between groups of smokers and non-smokers. From this perspective, we do have moderate evidence for the validity of the RRT: We found significantly higher RRT scores, in smokers compared to non-smokers. Moreover, we found anecdotal evidence for the validity of the AMP, in which non-smokers showed more negative automatic reactions to smoking-related images compared to control images.

In order to get a better understanding of the circumstances in which we can find differences within an individual, more research is needed examining which implicit measures are more sensitive to context and motivational factors (Sherman et al., 2003). Measures that tap into processes related to long-lasting brain changes such as sensitization of reward-areas (e.g., Robinson & Berridge, 2008), might be less dependent on context than measures that are related to more fleeting processes such as cue-elicited craving (e.g., Carter & Tiffany, 1999).

A further complexity that is often overlooked within dual process models of addiction, is that automaticity is multi-faceted (e.g., Moors, 2016; Moors & De Houwer, 2006). Several prominent theories mention a range of automaticity criteria (e.g., Gladwin, Wiers, & Wiers, 2017; Wiers et al., 2007; Wiers & Stacy, 2006) but no thorough theoretical exploration has been done to examine how exactly which components of automaticity affect different addictive behaviors. Because different implicit measures are thought to be sensitive to pick up on different automaticity criteria (e.g., Van Dessel et al., 2020) such a theoretical step would allow us to test specific hypotheses with the best-suited implicit measures.

Others have proposed to take a more pragmatic stance and focus on how these measures relate to actual behavior (e.g., Nosek & Greenwald, 2009). The current study was the first to examine whether scores on the AMP and the RRT could reliably predict smoking behavior in the week following the second session. Whereas the Fagerstrom questionnaire did predict smoking behavior, we found moderate evidence for the *absence* of an effect of our implicit measures. In general, studies that examine whether implicit measures can predict future smoking behavior are scarce, and the results have not been straightforward. For instance, Spruyt et al. (2015) found that scores on the evaluative priming task (EPT) but not on the IAT could predict relapse in a sample of people who just quit smoking. However, others have found that IAT scores could, to some extent, predict relapse (e.g., Chassin et al., 2010; Lee et al., 2018) and the initiation of smoking (Sherman, Chassin, Presson, Seo, & Macy, 2009).

These discrepancies can be due to a myriad of factors. First, in previous studies, the behavioral outcome was relapse in samples of smokers who had the intention of quitting smoking. In our study, we did not select participants with an intention to quit smoking. It is possible that for our sample, implicit measures do not reliably explain additional variance over the explicit measure because there is no discrepancy between their rational, controlled processes (e.g., "I want to keep smoking") and their (automatic) smoking behavior. When automatic processes strongly push people to behave in a way that is opposite to their explicit goals, implicit measures might be a more reliable predictor of behavior (e.g., Greenwald, Poehlman, Uhlmann, & Banaji, 2009). Second, we asked participants to keep a smoking diary, whereas other studies looked at effects on smoking cessation or initiation. Even though we aimed to measure smoking behavior in a naturalistic way, it is likely that asking participants to track their cigarette use changed their smoking behavior. Third, several moderators have been shown to affect the predictive validity of different implicit measures and might have an effect on the RRT and AMP as well such as attentional control levels (Spruyt et al., 2015) or the intention to quit smoking (Chassin et al., 2010). Possibly, accounting for these factors could have improved the predictive validity of the measures used in our study.

It is important to note that our study has several limitations. Smokers were not heavy smokers, and our manipulation might not have been strong enough to pick up on differences in RRT and AMP scores within smokers over the two sessions. On a similar note, our sample was smaller (44 smokers and 50 non-smokers) compared to the study of Tibboel, De

[4] When we included not only the Fagerstrom but also the AMP and the RRT in the first step, this yielded similar results: whereas the Fagerstrom was a highly significant predictor, $p < .001$, the AMP and RRT were not, $ps > .87$.There were no significant correlations between the RRT nor the AMP with the number of smoked cigarettes either, $ps > .41$.

Houwer, Dirix, & Spruyt, 2017, p. 50 smokers and power might have been insufficient to pick up on relatively subtle effects on implicit measures. Using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), we performed post-hoc sensitivity analyses with a conventional power of .80. These analyses showed that the sample size was large enough to detect medium to large effects for the paired samples t-tests, $f^2 = 0.38$, the repeated measures ANOVA, $f^2 = 0.25$, and the regression analyses, $f^2 = 0.27$, that were used to examine within-group differences and the predication of smoking behavior in the sample of smokers.

5. Conclusion

The past few decades have seen the development of a range of implicit measures with the intent to shed light on the role implicit processes play in different types of behaviors, such as smoking addiction, and to use these measures in applied settings. Regarding the latter, our study shows that it is important to regard clinical applications of implicit measures with caution. Several researchers have already put forward specific characteristics that implicit measures should meet to have clinical relevance (Waters & Leventhal, 2006), but so far, these criteria have not been met consistently by the measures we have used in our study. Regarding the former, our study provides only limited evidence regarding the role of implicit measures in smoking addiction. Whereas we did find differences on both the RRT and the AMP between smokers and non-smokers, our deprivation manipulation and regression analyses provided no support for this. However, other research using different implicit measures (e.g., Spruyt et al., 2015) has provided convincing evidence that implicit measures do play a role in smoking addiction. We suggest that more research is needed to solidify the methodology.

CRediT authorship contribution statement

Helen Tibboel: Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Bram Van Bockstaele:** Writing – review & editing, Conceptualization. **Adriaan Spruyt:** Writing – review & editing, Conceptualization. **Ingmar Franken:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors report to have no conflict of interest.

Data availability

Data are available at the Open Science Framework, upon request.

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Appendix A. Supplementary data

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