

Impulsivity related personality traits and cigarette smoking in adults: a meta-analysis using the UPPS-P model of impulsivity and reward sensitivity

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Highlights:

- Reviewed studies assessing six impulsivity-related traits and cigarette smoking.
- Smoking status most associated with lack of premeditation and positive urgency.
- Nicotine dependence most associated with positive urgency.

Abstract

Background: Although there is considerable evidence of an association between impulsivity and cigarette smoking, the magnitude of this association varies across studies. Impulsivity comprises several discrete traits which may influence cigarette use in different ways. The present meta-analysis aims to examine the direction and magnitude of relationships between specific impulsivity-related traits, namely lack of premeditation, lack of perseverance, sensation seeking, negative urgency, positive urgency and reward sensitivity and both smoking status and severity of nicotine dependence in adults across studies and to delineate differences in effects across these relationships.

Methods: Ninety-seven studies were meta-analysed using random-effects models to examine the relationship between impulsivity-related traits and smoking status and severity of nicotine dependence. A number of demographic and methodological variables were also assessed as potential moderators.

Results: Smoking status and severity of nicotine dependence were significantly associated with all impulsivity-related traits except reward sensitivity. Lack of premeditation and positive urgency showed the largest associations with smoking status ($r=0.20$, $r=0.24$ respectively), while positive urgency showed the largest association with severity of nicotine dependence ($r=0.23$). Study design moderated

associations between lack of premeditation and lack of perseverance and smoking status, with larger effects found in cross-sectional compared to prospective studies.

Conclusions: Findings suggest that impulsivity is associated with an increased likelihood of being a smoker and greater nicotine dependence. Specific impulsivity-related traits differentially relate to smoking status and severity of nicotine dependence. Understanding the complexity of impulsivity-related traits in relation to smoking can help to identify potential smokers and could inform cessation treatment.

Keywords: impulsivity; smoking; meta-analysis; UPPS-P model; reward sensitivity

1.0 Introduction

There are currently over a billion smokers worldwide and it is estimated that 80,000 to 100,000 people become addicted to smoking every day (WHO, 2015). Half of all life-long smokers die prematurely and, on average, cigarette smokers lose fifteen years of their life, making smoking the leading cause of premature mortality (WHO, 2015). As such, reducing the prevalence of smoking is one of the major public health goals worldwide.

However, the reinforcing effects of nicotine present a major problem to effective smoking cessation (Hughes, 2001). Current smoking cessation interventions often show limited effectiveness, possibly due to individual differences in the biological and behavioural mechanisms involved in the susceptibility to smoking initiation and maintenance (Sutherland, 2002). Interest in the role played by

personality characteristics, and in particular of impulsivity, in all aspects of smoking behaviour is growing (Bloom et al., 2014). A greater understanding of the influence that impulsivity has on cigarette smoking may result in the improvement of interventions to reduce smoking prevalence, and also aid the development of screening and prevention methods for non-users and escalating smokers.

1.1 Impulsivity and smoking

Impulsivity can be defined as a tendency to engage rapidly in behaviour without adequate consideration of the potential consequences (Evenden, 1999). It seems that individuals with heightened impulsivity are often either unable or unwilling to consider long-term consequences. Unable, because they have difficulty controlling their impulses and resulting actions, and react to immediate environmental stimuli; unwilling, because they get more pleasure from immediately available rewards (Evenden, 1999).

Impulsivity has been assessed in various ways; as a stable personality trait through self-report questionnaires, as a behaviour measured with laboratory based behavioural tests, or as a neurobiological process using tools such as functional magnetic resonance imaging to analyse brain structure and function. The typically modest correlations found in previous research between behavioural and self-report measures of impulsivity suggests that the laboratory-based behavioural tasks are measuring different constructs from self-report personality traits (Cyders & Coskunpinar, 2011). Behavioral tasks usually capture what participants do in a given situation, while self-report questionnaires assess what participants tend to do over time and across situations (Cyders & Coskunpinar, 2011). Laboratory tasks of impulsivity and self-reported impulsivity assessments are weakly correlated or

uncorrelated, but both aspects of impulsivity have been related to specific brain activity (Cyders & Coskunpinar, 2012). The focus of the present study is on the self-report assessment of impulsivity, which is more appropriate for assessing more stable (trait-dependent) aspects of impulsivity.

Research on trait impulsivity and cigarette smoking has found that smokers are typically more impulsive than non-smokers, and that impulsivity is associated with smoking initiation, maintenance, cessation, and nicotine addiction (e.g. Mitchell, 1999; Reynolds et al., 2007; Doran et al., 2009; Perkins et al., 2008). Studies with adolescents suggest that differences between smokers and non-smokers in self-reported impulsivity appear to pre-date smoking initiation (Bloom et al., 2014). Conversely, chronic exposure to nicotine and acute nicotine deprivation may increase impulsivity (Bloom et al., 2014). It has also been suggested that impulsive smokers are less likely to quit because they perceive more benefits from smoking and experience more severe withdrawal symptoms (Doran et al., 2007). However, identifying the role of impulsivity in all stages of tobacco use has been challenging because of variation among studies in how trait impulsivity is defined. Consequently, more integrated research is needed in this area.

Over the last few years, researchers have made considerable progress in deconstructing trait impulsivity into its component constructs through the development of the UPPS-P model of impulsivity (Whiteside & Lynam, 2001; Cyders & Smith, 2008). They have identified five different personality dispositions to engage in rash or impulsive action: negative urgency, which refers to the tendency to act rashly in response to negative mood; positive urgency, the tendency to act rashly when experiencing intensely positive mood; lack of premeditation, the tendency to act without thinking; lack of perseverance, the inability to remain focused on a task;

and sensation seeking, which refers to the tendency to seek out exciting, novel experiences (Whiteside & Lynam, 2001; Cyders & Smith, 2008). Studies have shown that these traits share between 6% and 27% of their variance, with negative and positive urgency sharing the largest proportion of variance (Cyders & Smith, 2007). Measurement of separate aspects of impulsivity using the UPPS-P framework can clarify the variation observed when using more general measures of trait impulsivity. However, one limitation of the UPPS-P framework is that it does not include a measure of reward sensitivity, which refers to an elevated sensitivity to conditioned and unconditioned rewarding stimuli, and has been highlighted as a key component of impulsivity by some authors in the field (Dawe & Loxton, 2004; Dave et al., 2004; Gullo & Dave, 2008). Measures of reward sensitivity were not included in the original factor analysis that generated the UPPS framework (Whiteside & Lynam, 2001). Reward sensitivity is related to the sensation seeking scale from the UPPS-P model, but research has shown that it is distinct from it (Dawe & Loxton, 2004). Reward sensitivity partly reflects individual differences in the functioning of a theorised Behavioural Approach System (BAS; Gray, 1991), and can be measured with personality questionnaires such as the BAS scales (Carver & White, 1994). It is purported by a number of researchers to be a key component of trait impulsivity, and a variable that explains variance in indices of substance use above and beyond other measures of impulsivity (Dawe et al., 2004).

Research using the UPPS-P traits and reward sensitivity has shown that separate traits show different patterns of association and prediction with smoking-related outcomes. For example, whereas sensation seeking predicts initiation of smoking (Lipkus et al., 1994; Perkins et al., 2008) and smoking levels (Flory & Manuck, 2009; Spillane et al., 2010), lack of premeditation and lack of perseverance

often do not, yet, the latter are associated with symptoms of tobacco dependence (Chase & Hogarth, 2011; Flory & Manuck, 2009). Additionally, urgency and reward sensitivity have shown to be related to the development of nicotine dependence and smoking frequency (Spillane et al., 2010; Billieux et al., 2007; Doran et al., 2009; Tapper et al., 2015). However, the relationship between impulsivity-related traits and cigarette smoking varies greatly between studies. Synthesizing the findings from multiple studies to produce summary effect sizes of these associations is therefore a useful research endeavour. Additionally, it would be helpful to understand whether sample characteristics such as age, gender, and ethnicity affect these associations.

1.2 Present study

There are a number of meta-analytic reviews assessing the relationship between trait impulsivity and different substances such as alcohol (Stautz & Cooper, 2013; Coskunpinar et al., 2013) and marijuana (VanderVeen et al., 2016). However, to our knowledge, there has been no quantitative review focused on impulsivity-related traits and their relationship with cigarette smoking. Therefore, the aim of the present study is to review research in order to examine the direction and magnitude of relationships between specific impulsivity-related traits and both smoking status and severity of nicotine dependence in adults across studies, and to delineate differences in effects across these relationships. In addition to the primary analyses, the present study will also test whether age, gender, ethnicity, sample type and study type moderate any relationships. Finally the present meta-analysis aims to highlight gaps in the existing research that future studies could address.

2.0 Method

2.1 Literature search

A literature search was conducted using PubMed, PsychINFO, Medline, EBSCO Academic Search Complete, Elsevier Science Direct and Google Scholar covering articles published up to November 2016. Key words included all possible combinations of two word categories: i) impulsiv*, disinhibition, premeditation, lack of planning, perseverance, boredom proneness, boredom susceptibility, sensation seeking, novelty seeking, urgency, negative urgency, positive urgency, BAS, reward sensitivity, reward drive, behavioural approach, behavioural activation, and ii) smok*, nicotine, cigarette, tobacco. Ten authors with extensive publications on impulsivity and cigarette smoking were also contacted via email with requests for any unpublished data suitable for this meta-analysis which they might have been able to share. No such data were obtained. The reference sections of all eligible articles were also examined to identify further studies that could be included.

2.2 Inclusion and exclusion criteria

Studies were included in the analysis if they met all of the following criteria: 1) contained empirical measurement of both self-report impulsivity and current smoking status and/or severity of nicotine dependence, 2) used measures of impulsivity that mapped onto the UPPS-P model and reward sensitivity, 3) referred to cigarette use and not any other forms of tobacco use (e.g. cigars, e-cigarettes, hookah etc), 4) used a measure of cigarette smoking that was not combined with alcohol and other drug use, 5) the sample were adults (aged 18 or over), although studies that reported results on college students of 17 years old and older, and where the mean age of the sample was over 18 years old were also retained in the analysis, 6) the sample comprised smokers (dependent, nondependent, chippers) and non-smokers (never-smokers, ex-smokers) for the smoking status analysis or just smokers for the nicotine dependence analysis, 7) were available in English.

Studies were excluded if they reported results on the same population with another study. In such cases, the study with the largest amount of usable data was retained in the analysis. In addition two studies were excluded as they presented non-normally distributed data, possibly indicating a biased sample. There were a number of studies that did not include sufficient data to calculate effect sizes. If the studies had been published within the last ten years (2006 and later), first authors were contacted via email to obtain the necessary information. Figure 1 shows a flowchart of the study selection process including numbers of excluded studies.

2.3 Data extraction

For each study the following data were extracted: Author(s) and year of publication, study design (cross-sectional or prospective), type of sample (normative, such as general population, and college student samples; or non-normative, such as clinical patients), number of smokers (dependent, non dependent smokers, daily, non daily smokers and chippers) and non-smokers (never smokers and ex-smokers), mean age of the sample (in cases where the age range was reported, median value of the range), percentage of the sample that was male, percentage of the sample that was of white ethnicity (as the majority of studies reported samples of white ethnicity), impulsivity trait scale used, nicotine dependence measure used, and the means and standard deviations, F , standardised β values or odds ratio for group comparison studies, and correlation for correlational studies.

Each impulsivity measure used was categorised into trait domains according to each UPPS-P sub-scale and reward sensitivity following previous organisation of existing impulsivity scales (see Stautz & Cooper, 2013). There were eleven studies that used measures that had not previously been categorized in one of the five

UPPS-P impulsivity facets or reward sensitivity; these measures were analysed for content and categorised accordingly (Table 1). Two of the authors independently reviewed these scales and classified each on to a specific UPPS-P trait (there was agreement of rating in all cases). In the present study the Drive and Reward Responsiveness subscales of the BAS measure (Carver & White, 1994) were considered together as a measure of reward sensitivity, as the effect sizes for both subscales were similar for most of the studies that reported results on both subscales. Most of these self-report impulsivity measures showed good reliability as reported in the original studies (Sharma et al., 2014).

Measures of nicotine dependence included: The Fagerström Test for Nicotine Dependence (Heatherton et al., 1991), The Fagerström Tolerance Questionnaire (Fagerström, 1978), number of cigarettes smoked per day/per week and one study that compared daily versus occasional smokers. Even though the last measure is categorical and so differs from the continuous measures of nicotine dependence it was included in the analyses as occasional smokers smoke significantly less cigarettes than daily smokers and they vary greatly in their nicotine dependence compared to daily smokers (Gilpin et al., 1997). All data was coded so that higher values on the measures indicated higher levels of impulsivity.

2.4 Data analyses

The meta-analysis used Pearson's r as the effect size for relationships between personality and smoking status and severity of nicotine dependence as we were interested in differences in patterns of association and wanted to compare the results with previous reviews that have also reported r as the effect size (e.g. Stautz & Cooper, 2013; Coskunpinar et al., 2013; VanderVeen et al., 2016). In the cases

that r was not reported, it was calculated from descriptive statistics (mean and standard deviation), F , odds ratio or standardised β values using traditional formulae (DeCoster, 2004; Lipsey & Wilson, 2001; Peterson & Brown, 2005).

A random effects model was employed for all analyses. The random effects model, as opposed to a fixed effects model, assumes a different underlying effect for each study and takes this into account as an additional source of variation. The random effects model gives more conservative results with wider confidence intervals and the results can be generalised to wider populations. This model was preferred in the present analyses as studies were from different populations and there was substantial variation in the measures used across studies.

All r values were converted to Zr s using Fisher's (1928) r -to- Zr transformation. Resulting effect sizes were weighted by sample size across studies. After performing the meta-analytic calculations, Fisher's Zr values were converted back to Pearson's r using the inverse Zr transformation.

Several articles contributed more than one effect size for the relationship between impulsivity-related traits and smoking status. In these cases the average effect size across all measures of the same outcome was calculated to ensure that every study contributed only one effect size to any one meta-analysis. Multiple effect sizes reported on the same sample from longitudinal studies were also averaged. There were two cases of longitudinal studies (Kvaavik & Rise, 2012; Littlefield & Sher, 2012) that reported results of the same population at two different time points, however the samples size at these two different points was not the same. In this case, only data from the larger sample was retained in the analysis.

Following the recommendations of Tabachnick and Fidell (2001), the effect sizes within each analysis group were examined for univariate outliers by converting to Z scores and assessing whether any values were greater than $Z=3.30$.

The Q and I^2 statistics were calculated for each analysis. The Q statistic reveals how much of the overall heterogeneity can be attributed to true between-studies variation. A statistically significant Q statistic indicates the presence of heterogeneity (Borenstein et al., 2009), while the I^2 statistic is a percentage that indicates the proportion of observed variation that can be attributed to the actual difference between studies rather than within-study variance. Its value ranges from 0-100, with higher values representing higher true heterogeneity (Higgins et al., 2003).

Forest plots were also calculated to illustrate the heterogeneity of the included studies for each analysis (i.e. Figure 2.1, 2.2, 2.3, 2.4).

A fail-safe N (FSN) statistic was estimated on statistically significant mean effects to examine potential publication bias (Orwin, 1983). The FSN estimates the number of unpublished studies with null findings that would cause the effect sizes found in a meta-analysis to fall to non significant levels (Lipsey and Wilson, 2001; Orwin, 1983). Effect sizes of 0.05 were considered very small and this criterion was used in the FSN analysis.

Potential moderating effects of three categorical variables were tested: sample type (normative or non-normative), study type (cross-sectional or prospective) and college sample (yes or no). Potential moderating effects of three continuous variables were also tested: the mean age of sample, percentage of male participants in the sample, and percentage of sample that was of white ethnicity.

Sensitivity analysis was conducted to account for any variation in the self-reported impulsivity scales included in the present meta-analyses and the categorization of smokers and non smokers.

Meta-analyses were conducted in the R statistical environment using 'metafor' (Viechtbauer, 2010) and 'robumental' (Fisher & Tipton, 2015) packages for R (R Development Core Team, 2015).

Due to the large number of analyses conducted, an alpha level of $p=0.01$ was used for significance testing to reduce the likelihood of Type I errors. Any p values less than 0.05 are noted in the tables. Effect sizes were interpreted in accordance with Cohen's (1988) guidelines for small ($r=0.10$), medium ($r=0.30$), and large ($r=0.50$) effects.

3.0 Results

3.1 Study characteristics

A total of 97 studies were eligible for inclusion, 18 studies were included for both the smoking status and nicotine dependence analysis, 67 studies were included for only the smoking status analysis and 12 studies were included for only the nicotine dependence analysis. These studies comprised 93 peer-reviewed journal articles and four doctoral dissertations. Studies reported a total of 198 effect sizes, ranging from $r=-0.10$ to $r=0.79$ (Table 2). The majority of these effect sizes related to sensation seeking ($n=70$, 35.4%) and lack of premeditation ($n=69$, 34.8%). The mean sample size was 466.46 ($SD=798.54$; range 20-5433) and the mean sample age was 30.95 years ($SD=11.00$; range 18-65.30). Samples were, on average, 50.9% male ($SD=23.9$; range 0-100; $k=10$ male only studies), and 77.2% of white ethnicity in 50 studies that reported ethnicity ($SD=24.5$; range 0-100 white, $k=13$

white only ethnicity participants). The majority of samples were normative (k=40 general population, k=40 college students, k=4 schizophrenic patients, k=2 adults with ADHD, k=2 OCD patients, k=2 prisoners, k=2 drug dependents, k=1 bipolar disorder patients, k=1 ulcerative colitis and Crohn's disease patients, k=1 traumatic spinal injury patients, k=1 Parkinson's disease patients, k=1 patients with major depression). Most of the studies were cross-sectional (k=93), and the majority (k=56) were conducted in the US. Included studies were published between 1966 and 2016, with most of the studies having been published in the last decade (k=69). Studies included, on average, 47.8% current smokers (SD=27.3%; range 1.05-100%).

3.2 Univariate Outliers

Two univariate outliers were identified in the meta-analysis of impulsivity traits and smoking status; one for sensation seeking ($Z=4.09$) and one for lack of premeditation ($Z=3.77$). Both came from a single study (Sharma et al., 2012), which reported results in 20 individuals with Obsessive Compulsive Disorder (10 smokers matched on demographic characteristics with 10 non-smokers). Results were very similar with and without this study; therefore, the effect sizes from this study were retained in the analyses.

3.3 Meta-analytic findings

3.3.1 Impulsivity traits and smoking status

We conducted six meta-analyses to examine how specific UPPS-P traits and reward sensitivity differentially related to smoking status. The weighted mean effect sizes between smoking status and specific impulsivity traits were all small, but positive, and significantly different from zero, with the exception of reward sensitivity. This relationship was also positive but did not differ from zero ($r=0.01$, $z=0.24$,

$p=0.80$). Lack of premeditation and positive urgency showed the largest associations with smoking status, with weighted mean effect sizes of $r=0.20$ and $r=0.24$, respectively. However, it should be noted that the confidence intervals of these impulsivity-related traits overlap with those of all others except reward sensitivity, suggesting that the difference between traits is not that large and possibly spurious. A FSN analysis for each specific impulsivity trait and smoking status relationship indicated that for the majority of traits, it would take a similar or larger amount of additional studies for each trait with null effects to reduce the mean effect size to $r=0.05$ (Table 3). These findings suggest that the present results are unlikely to be substantially impacted by unpublished data.

3.3.2 Impulsivity traits and severity of nicotine dependence

In respect to specific UPPS-P traits and reward sensitivity, effects sizes for severity of nicotine dependence ranged from $r=0.03$ (for reward sensitivity) to $r=0.23$ (for positive urgency). Most of these effect sizes were not significantly different from zero and did not vary significantly across studies (Table 3). These effect sizes are based on 30 studies and 4145 smokers.

3.4 Moderation

Regarding the meta-analytic findings of impulsivity traits and smoking status, Q values were significant for five out of six meta-analyses that were conducted, indicating the presence of heterogeneity. For five of these, I^2 values were above 75% suggesting that most of the variation between effect sizes was systematic. Although significant heterogeneity was not a condition for conducting moderator analyses, these statistics suggested possible moderation effects. Age, gender (%male) and ethnicity (%white) of the sample were first examined as continuous moderators. No

significant moderating effects were found for gender, ethnicity and mean age on the relationship between each impulsivity related trait and smoking status. Study type, sample type (normative, non-normative) and whether the samples were college students were then considered as categorical moderators. Similar moderation analyses were conducted for each separate impulsivity trait of the UPPS-P model and reward sensitivity. Sample type was tested as a potential moderator of effect size variation for lack of premeditation, lack of perseverance and sensation seeking only. This was due to limited data for the other traits. Subgroups for non-normative samples included a small number of effect sizes ($k < 5$). However no significant effects were found. Study type was only tested as potential moderator for lack of premeditation, lack of perseverance, sensation seeking and negative urgency. There were only four prospective studies in the analyses, therefore power was low in these analyses and results should be interpreted with caution. For lack of premeditation, cross-sectional studies showed larger weighted mean effect sizes, $r = 0.21$ (0.18-0.24) than the prospective studies, $r = 0.07$ (0.01-0.12), and the difference was significant, $Q(1) = 8.33$, $p = 0.004$. Additionally, for lack of perseverance, cross-sectional studies showed larger weighted mean effect sizes, $r = 0.17$ (0.13-0.20) than the one prospective study, which was included in this analysis, with an effect size of $r = 0.02$ and the difference was significant, $Q(1) = 7.79$, $p = 0.005$. No significant moderation effects of study type were found for sensation seeking and negative urgency and smoking status. Lastly, whether the sample was college students or not was tested as a potential moderator of effect size variation for all the separate impulsivity traits, apart from positive urgency due to lack of related studies; again the results showed no significant effect (Table 4).

We did not conduct any moderation analysis for impulsivity traits and severity of nicotine dependence as the number of studies reported was small and the effect size magnitude did not vary significantly across studies.

3.5 Sensitivity analyses

We conducted a number of sensitivity analyses. There were a number of cases where the mapping of a specific scale on to the UPPS-P framework may be somewhat arbitrary or ambiguous. To address this issue, we conducted the analysis removing the scales in which the mapping on to the UPPS-P model was made by the authors. Then, we conducted the analyses only with the studies that used the same scales to measure the impulsivity-related traits. For example, we ran the analyses only with studies that used the UPPS-P scale, then with studies that used only the Sensation Seeking Scale, the BIS and so on. In all these cases the results found were very similar to those when all the studies were included in the analyses.

There were eight cases where the reliability of a scale was not provided in the original study. We performed the analysis excluding these scales. The results found were very similar to those when they were included, so in the analyses reported above we retain these scales.

There was one study that compared daily versus occasional smokers. This measure is categorical and different from the rest of the measures of nicotine dependence. We conducted the analyses with and without this study and the results were similar. So, this study was retained in the analyses.

We combined ex-smokers with non-smokers and heavy smokers with non daily smokers in order to categorize groups as either smokers or non-smokers. We took this approach in fourteen studies. When we conducted the analyses excluding

these fourteen studies, the results did not change. So these studies were also retained in the present meta-analysis.

4.0 Discussion

The aim of this review was to quantify the direction and magnitude of association between impulsivity-related personality traits and two aspects of cigarette smoking - smoking status and severity of nicotine dependence. Meta-analyses of six distinct impulsivity-related traits found that all traits in the UPPS-P model were positively associated both with smoking status and severity of nicotine dependence, while reward sensitivity was not associated with either outcome.

The majority of included studies examined the relationship between sensation seeking and lack of premeditation with smoking status; very few studies have examined the urgency traits and reward sensitivity in this context. Positive urgency and lack of premeditation showed the largest mean associations with smoking status, even though these effect sizes were still small in magnitude, and confidence intervals overlapped with those for all other UPPS-P traits. There appears to be an inconsistency with previous research which suggests that, among impulsivity-related personality traits, sensation seeking best predicts the frequency of engaging in risky behaviours including cigarette smoking (e.g. Zuckerman et al., 1990; O' Connor et al., 2009; Spillane et al., 2010). However the majority of this research is based on adolescents. The present meta-analysis examined studies sampling adults only, with a mean sample age of 31 years old. The discrepancy might therefore be explained by the difference in the age of the samples examined. Younger individuals high in sensation seeking could smoke because of the novelty of the smoking experience and the positive reinforcement they receive from smoking (Clayton et al., 2007). For older smokers, who are likely to have been smoking for a longer time, there is no

element of novelty in smoking and therefore sensation seeking may be less relevant, and other impulsivity traits might be more important in predicting their smoking behaviour. Indeed, the findings of the present study suggest that positive emotion-based impulsivity and lack of planning are better at differentiating smokers from non-smokers. In support of these findings, there is some evidence from previous research suggesting that, among those who try cigarettes, those who become regular smokers are more likely to report higher levels of positive urgency (Cyders & Smith, 2008), and positive affect plays a significant role in the desire to smoke during the course of becoming a regular smoker (Zinser et al., 1992). Nicotine use is also a powerful mood regulator (Brody, 2006; Pomerleau & Pomerleau, 1984), which helps to decrease the intensity and frequency of negative feelings (McGovern et al., 2006). Smokers with high levels of urgency may be prone to smoke impulsively in situations of intense emotion, with smoking becoming conditioned as a negative reinforcer as a result.

Regarding severity of nicotine dependence and its association with specific UPPS-P traits and reward sensitivity, the majority of studies have looked, again, at lack of premeditation and sensation seeking. Based on a small number of eligible studies, positive urgency had the largest association with severity of nicotine dependence, though the effect size was of a small magnitude. This finding is consistent with previous research that suggests that positive urgency is more relevant for predicting the level of nicotine dependence (Spillane et al., 2015). It may be that smokers high in positive urgency, who experience reinforcement from smoking and are more prone than others to react towards their immediate urges, are more likely to smoke more in response to an intense positive mood state (Cyders & Smith, 2008). This preference to smoke when in a heightened emotional state could,

in turn, increase the likelihood of nicotine dependence (Baker et al., 2004). Previous studies have also posited a significant role of negative urgency in predicting the level of nicotine dependence, as it was found that smoking to alleviate negative mood states is a common motivation for smokers (Doran et al., 2009). Indeed, the relationship between negative urgency and severity of nicotine dependence was the second highest in this meta-analysis.

Reward sensitivity was the only impulsivity-related personality trait that showed no association either with smoking status or severity of nicotine dependence. One possible explanation might be that prolonged nicotine use reduces reward sensitivity (Versace et al., 2011; Paelecke-Habermann et al., 2013). It could be the case that the adult smokers in the present analysis had high reward sensitivity when they started smoking, but after a period of smoking, they showed lower levels of reward sensitivity due to inhibitory effects of their nicotine use. Such an explanation would further suggest that reward sensitivity is more relevant to the initiation of smoking than to differentiating smokers from non-smokers. That said, neuroscientific evidence points to a complex pattern of differences between smokers and non-smokers in brain areas related to reward processing (e.g. Martin et al., 2014). It is possible that the self-report scales focused on in this review are not sensitive enough to detect these differences. It should also be noted that reward sensitivity has only been examined in a limited number of studies with small sample sizes. As such, our analysis including this trait was underpowered. However, our results are similar to that found in a previous meta-analysis assessing the relationship between adolescent alcohol use and impulsivity, which showed that reward sensitivity as measured by the BAS scales had weaker associations with adolescent alcohol use than most other impulsivity-related traits (Stautz & Cooper,

2013). Clearly, reward responsiveness's association to smoking status and severity of nicotine dependence warrants further investigation.

We found no evidence of moderation of the association between impulsivity and smoking status by gender, or by age and ethnicity. This finding is consistent with previous research, which has also failed to find any moderation effect of gender on the relationship between specific impulsivity related traits and risk outcomes (Cyders, 2013, Coskunpinar et al., 2013). In the current study, the only moderation effect found was that of study type and lack of premeditation and lack of perseverance. Samples from cross-sectional studies showed significantly larger associations between lack of premeditation, lack of perseverance and smoking status, although these were related to only four and one prospective studies, respectively. These results suggest that the relationship between these traits and smoking might change over time, such that they are stronger correlates than predictors. However, more prospective studies are required in order to verify this idea.

4.1 Implications

Results from this review suggest that impulsivity-related traits are more strongly associated with smoking status than severity of nicotine dependence. This pattern of findings suggests a non-linear relationship between impulsivity-related traits and smoking behaviour, such that these traits better help to explain differences between non-smokers and smokers than differences between lighter smokers and heavier (i.e. more dependent) smokers. Attempts to reduce cigarette smoking by targeting impulsivity-related traits may therefore be best aimed at individuals at risk of smoking. Moreover, given that differential patterns of relationships between impulsivity-related personality traits and smoking status and severity of nicotine

dependence were found, it could be suggested that different factors should be targeted for preventing initiation of cigarette smoking and for interventions of quitting smoking. If different traits relate to different aspects of the risk process, it is useful for both researchers and clinicians to understand the role of specific traits and their associated patterns of affect, behaviour, and cognition in relation to smoking. This understanding could help to identify individuals at greater risk of becoming smokers and nicotine dependents, and by extension has the potential to inform individualised treatment plans and decisions.

This study also highlights where further research is needed in examining the relationship between discrete impulsivity-related traits and smoking status and severity of nicotine dependence. Specifically, there is a lack of research examining smoking status and severity of nicotine dependence with positive urgency and reward sensitivity. Generally, more research is needed that include multiple impulsivity-related traits in the same study, to account for shared variance between traits. We recommend that researchers interested in the relationship between impulsivity and smoking behaviour use a multidimensional approach to measuring impulsivity-related traits, based on current understanding of the structure of the impulsivity construct (see Sharma et al., 2014; Sperry et al., 2017; Stautz et al., 2017).

The present review found patterns of small effects for lack of premeditation and positive and negative urgency on smoking status and severity of nicotine dependence. Even though data on positive and negative urgency on both smoking status and severity of nicotine dependence were limited, these results may offer one reason why many smokers are relatively unaffected by campaigns that focus on the health consequences of smoking and the benefits of quitting (NHS, 2017). In addition

to present prevention campaigns, smokers high in urgency could benefit from interventions that involve learning to identify behavioural patterns that lead to acting rashly in response to intense emotions, for example relaxation training and distress tolerance (Zapolski et al., 2010). Smokers high in lack of premeditation could benefit from organization and cognitive remediation training, and learning how to break tasks down into manageable steps along with sticking to long-term goals. In addition to these individualised approaches, interventions that focus on changing or removing environmental cues that promote smoking, such as switching to standardised cigarette packaging or legislating that vendors must place cigarettes behind opaque covers, could be particularly helpful for smokers high in impulsivity-related traits.

4.2 Strengths and limitations

To the best of our knowledge this is the first empirical review and quantitative synthesis to focus on trait impulsivity and smoking. Our analysis considered six distinct impulsivity-related personality traits and two smoking outcomes – smoking status and severity of nicotine dependence. We also considered a number of demographic and study-level factors that might moderate any associations.

Despite these strengths, several limitations might affect the generalizability of the findings. First, there were limited data for a number of traits analysed. With regards to positive urgency, only three studies assessed this trait with smoking status and severity of nicotine dependence, and there were only four studies assessing reward sensitivity and severity of nicotine dependence. Our analysis is therefore likely underpowered to detect the true associations of these traits with smoking status and severity of nicotine dependence, if any. Also, in these meta-analyses we have examined bivariate relationships between the impulsivity traits and

smoking status and severity of nicotine dependence. It is possible effect sizes will differ from those reported here for the specific impulsivity traits when controlling for their overlap with the other impulsivity traits

Second, a wide range of impulsivity measures were included. It is likely that this introduced substantial heterogeneity between effect sizes. However, we tried to ensure that all the measures included were categorised according to the relevant impulsivity-related trait and followed the categorization reported in previous research (Stautz & Cooper, 2013; Coskunpinar, et al., 2013). Additionally we employed a random effects model to deal with the differences in effect sizes across studies.

Third, there was variation in the categorization of smoking status used across the studies included in the meta-analysis. In some studies, we had to combine ex-smokers with non-smokers as there is some evidence that ex-smokers do not differ significantly from non-smokers in self-report measures of impulsivity (Bickel et al, 1999), and heavy smokers with non daily smokers, in order to categorize groups as either smokers or non-smokers. This approach may have lead to some inconsistencies across studies. However, we took this approach only in fourteen studies and we also examined differences in impulsivity and differences in severity of nicotine dependence within the smoking group. Moreover, the sensitivity analysis showed no substance difference in results when excluding these fourteen studies from the meta-analysis.

Fourth, the majority of studies reviewed were cross-sectional. Research suggest that heightened impulsivity seems to precede smoking initiation and be a consequence of greater smoking (Bloom et al., 2014). The current analysis do not allow us to delineate these relationships, but prospective studies suggest that two of

the impulsivity-related traits (lack of premeditation and lack of perseverance) are weaker predictors than correlates. More prospective studies are needed to shed light on the changes of impulsivity-related traits and smoking status and severity of nicotine dependence over time.

Most of the included studies sampled from non-clinical populations, limiting the generalizability of findings to clinical populations. Additionally data included in the present meta-analysis was self-reported. Self-reported measures of cigarette use underestimate the true smoking prevalence compared to measures of biological samples (Corbet et al., 2009). In the present analysis there were only eighteen studies that reported biological samples of nicotine use to validate self-report measures.

4.3 Conclusion

The present review is the first to synthesise data on separable impulsivity-related traits and smoking status and severity of nicotine dependence in adults. It suggests that smokers are more impulsive than non-smokers, impulsivity is positively associated with severity of nicotine dependence, and that unique impulsivity-related traits show modest differences in patterns of association with smoking status and severity of nicotine dependence in adults. Smoking status is most associated with positive urgency and lack of planning. Severity of nicotine dependence appears also to be most associated with positive urgency. Reward sensitivity was the only trait that was not related to either smoking status or severity of nicotine dependence, though was examined in very few studies.

Understanding the complexity of impulsivity-related traits in relation to smoking status and severity of nicotine dependence will help to inform screening and prevention efforts aimed at reducing the number of adult smokers.

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Table 1. Impulsivity-related trait categories and measures.

Lack of premeditation	Barratt Impulsivity Scale – Nonplanning and Motor Impulsivity (Patton et al., 1995)
	Barratt Impulsivity Scale –Total score (Patton et al., 1995)
	I-7 Impulsiveness (Eysenck et al., 1985)
	Impulsivity Control Scale (Plutchik & Van Praag, 1978)
	Karolinska Scales of Personality – Impulsiveness (Schalling, 1978)
	Substance Use Risk Profile Scale – Impulsivity (Woicik et al., 2009)
	UPPS – Lack of Premeditation (Whiteside & Lynam, 2001)
	Zuckerman-Kuhlman Personality Questionnaire – Impulsivity (Zuckerman et al., 1993)
	^a The Personality Inventory (BUPI)- Impetuousness (Hathaway & McKinlet, 1951)
	^a Dickman Impulsiveness Inventory- Dysfunctional Impulsivity (Dickman, 1990)
	^a 10 item Impulsivity scale (Littlefield, Sher & Wood, 2009)
	^a Impulsive Behaviour scale (Morean et al., 2014)
	^a Eysenck Personality Inventory (EPI)- Extraversion-Impulsivity Subscale (Eysenck and Eysenck 1968)
^a EPQ- Eysenck Personality Questionnaire (Eysenck and Eysenck 1978)	
Lack of perseverance	Sensation Seeking Scale – Boredom susceptibility, Disinhibition (Zuckerman, 1994)
	UPPS – Lack of perseverance (Whiteside & Lynam, 2001)
	^a Emotionality, Activity, Sociability and Impulsivity Temperament Survey III- Inhibitory Control Subscale (Buss & Plomin, 1975)
	^a Frontal Systems Behavior Scale -scale Disinhibition (Grace & Malloy, 2001)
Sensation seeking	BIS/BAS Scales – Fun Seeking (Carver & White, 1994)
	Brief Sensation Seeking Scale (Hoyle et al., 2002)
	I-7 Venturesomeness (Eysenck et al., 1984)
	TCI – Novelty Seeking (Cloninger et al., 1994)
	TPQ – Novelty Seeking (Cloninger, 1989)
	Sensation Seeking Scale – Thrill and adventure seeking (Zuckerman, 1994)
	Sensation Seeking Scale – Total score (Zuckerman, 1994)
	Substance Use Risk Profile Scale – Sensation seeking (Woicik et al., 2009)
	UPPS- Sensation Seeking (Whiteside & Lynam, 2001)
	Zuckerman – Kuhlman Personality Questionnaire – Sensation Seeking (Zuckerman et al., 1993)
	^a Values, Attitudes and Lifestyles- Novelty seeking (Strategic insight, 2005)
	^a Domain-specific Risk attitude scale (Weber, Blais & Betz, 2002)
	^a The Personality Inventory (BUPI)- Thrill and danger seeking (Hathaway & McKinlet, 1951)
^a Two item risk taking scale (Peltzer, Malaka & Phaswana, 2001)	
Negative urgency	Barratt Impulsivity Scale – Attentional Impulsivity (Patton et al., 1995)
	NEO-PI-R Impulsiveness (Costa & McCrae, 1992)
	UPPS – Urgency (Whiteside & Lynam, 2001)
Positive Urgency	UPPS-P Positive Urgency (Cyders et al., 2007)
Reward Sensitivity	BIS/BAS Scales – Drive and Reward Responsiveness (Carver & White, 1994)
	SPSRQ – Sensitivity to Reward (Torrubia et al., 2001)

^a Scales categorised by authors

Table 2. Studies included in the meta-analyses

Author(s)(year)	N	Age	%male	% white	sample	Desi gn	Scale used	Trait	Smoking measure	r
Addicott et al (2013)	18 S 17 NS	34	42.86	45.71	Community	CS	SS-TAS BIS-NP/MI SSS-BS/DI	SS Prem Pers	ST	0.16 0.26 0.13
Addicott et al	18S	36	44.44	38.9	Community	CS	SS-TAS	SS	ND	-0.09

(2013)							BIS-NP/MI SSS-BS/DI	Prem Pers		0.22 -0.0005
Bailey (2011)	229	18- 20	52	81	College	PR	UPPS	SS NU	ST	0.090.13
Balevich, Wein & Flory (2013)	141 S 102 NS	19.4	46.5	62.55	College	CS	SS-TAS BIS-NP/MI SSS-BS/DI	SS Prem Pers	ST	0.26 0.16 0.30
Baumann et al (2014)	950 S 891 NS		44.67	80.92	College	CS	BIS/BAS BIS/BAS	SS RS	ST	0.02 -0.03
Beaton, Abdi & Fidley (2014)	82 S 37 NS	30.1 9	49.58		Community	CS	ZKPQ-SS BIS-T	SS Prem	ST	0.33 0.32
Bejerot, Knorrning & Ekselius (2000)	13 S 51 NS	42	46.88		OCD patients	CS	KSP-I	Prem	ST	0.38
Berg et al (2016)	455 S 2963 NS	20.5 5	35.55	62.4	College	CS	VAL-NS	SS	ST	-0.07
Bernow et al (2011)	82 S 119 NS	43.2 1	25.37		Community	CS	I-7 Vert I-7 Imp	SS Prem	ST	0.25 0.27
Bickel, Odum & Madden (1999)	23 S 43 NS	33.9 7	39.3		Community	CS	EPQ	Prem	ST	0.23
Carton, Jouvent & Widlocher (1994)	96 S 68 NS	35.1 1	64		Community	CS	SS-TAS SSS-BS/DI	SS Pers	ST	0.14 0.21
Chives et al (2016)	400 S 400 NS	31.2 4	0	76.8	Community	CS	BIS-NP/MI	Prem	ST	0.16
Cui et al. (2015)	272 S	44.4	59.9	75.7	Community	CS	BIS/BASFBS BIS/BAS D, R	SS RD	ND	0.35 -0.014
Dervaux et al (2004)	67S 33 NS	34.7 2	68		Schizophre nic patients	CS	SS-TAS BIS-NP/MI SSS-BS/DI	SS Prem Pers	ST	0.23 0.13 0.27
Dinn, Aycicegi & Harris (2004)	23 S 116 NS	18.6	29.85		College	CS	TPQ-NS/I-7 I-7 Imp	SS Prem	ST	0.28 0.27
Doran et al. (2006)	70 S	29.9	49		Community	CS	BIS-T	Prem	ND	-0.15
Doran et al (2013)	73 S 327NS	18.3	45	40	College	PR	UPPS	SS Prem Pers NU	ST	0.14 0.01 0.03 0.12
Downey, Pomerleau & Pomerleau (1996)	35 S 17 NS	30.2	100	100	Adults with ADHD	CS	TCI-NS	SS	ST	-0.11
Durazzo et al (2015)	35 S 30 NS	48.8 3	88	67	Community	CS	BIS	Prem	ST	0.34
Dvorak, Simons & Wray (2011)	53 S	20.2 6	20.75	90.57	College	CS	I-7 Imp	Prem	ND	-0.18
Etter (2010)	1593 S 1388 NS	33.1	36.2		Community	CS	TCI-NS	SS	ST	0.08
Evans et al (2015)	97 S 115 NS	65.3	61.32	100	Parkinson's patients/ Community	CS	Short-SS	SS	ST	0.18

Fairweather-Schmidt & Wade (2014)	21 S 63 NS	33.5	0		Community	CS	BIS-T	Prem	ST	0.10
Gau et al (2009)	263 S 2655 NS	19.3	45.5		College	CS	TCI-NS	SS	ST	0.13
Glicksohn & Nahari (2007)	121 S 111 NS	20-34	45.26		Community	CS	I-7 V I-7 Imp/ BIS-T SSS-BS/DI	SS Prem Pers	ST	0.17 0.31 0.28
Glicksohn & Nahari (2007)	121 S	20-34	50.4		Community	CS	I-7 Imp/ BIS-T	Prem	ND	0.31
Golding, Harpur & Brent-Smith (1983)	56 S 122 NS	18-22	61.8		College	CS	SS	SS	ST	0.24
Golding, Harpur & Brent-Smith (1983)	56 S	18-22			College	CS	SS	SS	ND	0.32
Grano et al (2004)	57 S 5376 NS	43.3	11.06		Community	PR	KSP-I	Prem	ST	0.06
Greenbaum et al (2006)	242 S 142 NS	23.8 9	0	100	College	CS	TCI-NS	SS	ST	0.28
Greenbaum et al (2006)	242 S	24.3	0	100	College	CS	TCI-NS	SS	ND	0.12
Guillot, Pang & Leventhal (2014)	205 S	44.4	66.3	37.1	Community	CS	UPPS	NU	ND	0.14
Gurpegui et al (2007)	174 S 324 NS	45.1	42		Community	CS	TCI-NS	SS	ST	0.17
Heyman, Dunn & Mignone (2014)	184	40.7	43	73	Drug users/ Community	CS	BIS-T	Prem	ST	0.25
Hogarth, Chase & Baess (2010)	64 S	21.1 5	50		College	CS	BIS-T	Prem	ND	0.10
Holmes et al (2016)	1015	21.3 8	47.1	100	College	CS	TCI-NS BIS/BASF RAS BIS-MI	SS Prem	ST	0.13 0.05
Hudspith (2012)	58 S 111 NS	19.4 4	50.3	88.2	College	CS	SS	SS	ST	0.30
Hudspith (2012)	58 S				College	CS	SS	SS	ND	0.11
Hyphantis et al (2010)	56 S 129 NS	47.9	63.2		Ulcerative Colitis and Crohn's disease patients	CS	ZKPQ-Imp	Prem	ST	0.115
Iancu et al (2006)	24 S 37 NS	41.1 9	57.5		Schizophre nic patients	CS	ICS	Prem	ST	0.26
Jacobs et al (1966)	54 S 80 NS	26	100		Community	CS	BUPI	SS Prem	ST	0.13 0.28
Jacobs et al (1966)	54 S		100		Community	CS	BUPI	SS Prem	ND	0.06 -0.04
Jacobs & Spilken (1971)	42 S 108 NS	19	100		College	CS	BUPI	Prem	ST	0.29

Kao et al (2011)	62 S 33 NS	35.8 7	47.4		Schizophrenic patients	CS	BIS-NP/MI	Prem	ST	0.20
Kassel et al (1994)	137 S 70 NS	39.9 9	28.6	100	Community	CS	SS EPI SSS-BS/DI, EASIT- Inh.C	SS Prem Pers	ST	0.22 0.13 0.12
Kassel et al (1994)	137 S	39.3 2	30.66	100	Community	CS	SS EPI EASIT- Inh.C	SS Prem Pers	ND	-0.09 -0.03 -0.12
Kertzman et al (2013)	39 S 81 NS	28.4 1	0		Community	CS	BIS-T	Prem	ST	0.30
Knorrning & Oreland (1985)	601 S 481 NS	18	100	100	Community	CS	SS-TAS EPI SSS-BS	SS Prem Pers	ST	0.08 0.15 0.15
Knorrning & Oreland (1985)	601 S	18	100	100	Community	CS	SS-TAS EPI SSS-BS	SS Prem Pers	ND	-0.02 0.17 0.05
Kohn & Coulas (1985)	78	18.5	23.08		College	CS	SS SSS-DI	SS Pers	ST	0.21 0.22
Krause et al (2015)	198 S 326 NS	33.5	79.4	69.5	Traumatic spinal cord patients	CS	ZKPQ-IMP	Prem	ST	0.16
Kvaavik & Rise (2012)	523 S 1253 NS	22.3	41.8	100	Community	CS	EPQ BIS-T	Prem	ST	0.28
Kvaavik & Rise (2012)	523 S	22.1	36.3	100	Community	CS	EPQ BIS-T	Prem	ND	0.08
Lee et al (2015)	41 S 399 NS	18.4 9	48	82.8	College	CS	UPPS-P	SS Prem Pers NU PU	ST	0.14 0.24 0.15 0.28 0.25
Lee et al (2015)	41 S				College	CS	UPPS-P	SS Prem Pers NU PU	ND	0.11 0.11 0.11 0.26 0.24
Lejuez et al (2003)	26 S 34 NS	20.1	50	68	College	CS	SS I-7 Imp	SS Prem	ST	0.43 0.28
Leventhal (2007)	120 S 59 NS	24.0 2	32	64.5	College	CS	DII-DS	Prem	ST	0.08
Littlefield & Sher (2012)	86 S 316 NS	18.2	46		College	PR	10-ITEM	Prem	ST	0.14
Litvin & Brandon (2010)	175 S	39.2 6	52	71.3	Community	CS	BIS-T	Prem	ND	0.35
Livaditis et al (2001)	86 S 101 NS		54.01	89.8	College	CS	TPQ-NS	SS	ST	0.16
Livaditis et al (2001)	86 S		56.25	84.36	College	CS	TPS-NS	SS	ND	0.11
Luijten, Van Meel & Franken (2011)	13 S 14 NS	21.0 6	70.37		College	CS	I-7 Imp	Prem	ST	0.39
MacKillop & Kahler (2009)	57 S	41.3 8	61	90	Community	CS	BSSS	SS	ND	0.11
McChargue et	128 S	40.8	56	40.6	Patients	CS	BIS-T	Prem	ND	0.11

al. (2011)		1			with major depression					
Meil et al (2016)	138 S 183 NS	18-19	41.4	78.2	College	CS	SS	SS	ST	0.45
Mitchell (1999)	20 S 20 NS	21.5 5	50		College	CS	TCI-NS SS-TAS BIS-NP, MI, EPQ SSS-BS/DI BIS-AI	SS Prem Pers NU	ST	0.34 0.33 0.29 0
Morean et al (2014)	779 S 658 NS	33.5 6	51.08	70.84	Community	CS	BIS/BASF IBS BIS/BAS	SS Prem RS	ST	0.05 0.03 0.01
Munyon (2014)	63 S 63 NS				College	CS	UPPS-P	SS Prem Pers NU PU	ST	0.24 0.12 0.16 0.21 0.29
Nieva et al. (2011)	103 S	47.1	53.4		Community	CS	ZKPQ	SS Prem	ND	-0.06 0.13
O'Connor, Stewart & Watt (2009)	112 S 421 NS	18.9	32.27	58	College	CS	BIS/BASF BIS/BAS	SS RS	ST	0.16 0.08
O'Connor, Stewart & Watt (2009)	112 S				College	CS	BIS/BASF BIS/BAS	SS RS	ND	-0.08 0.005
Omiya et al (2015)	182	19.9 9	28.57	0	College	CS	BIS/BASF SURPS	SS Prem	ST	0.17 0.09
Ostacher et al (2009)	31 S 85 NS	45	40	95	Bipolar Disorder patients	CS	BIS-T	Prem	ST	0.17
Pang et al. (2014)	207 S	44.5 4	66.7		Community	CS	UPPS-P	NU PU	ND	0.15 0.16
Papadodima et al (2009)	116 S 57 NS	41.7	100	95	Prisoners	CS	BIS-T	Prem	ST	0.37
Park et al. (2016)	180 S	44.5	68.3	37.4	Community	CS	UPPS-P	NU	ND	0.13
Patkar et al (2003)	26 S 30 NS	31.3 2	61.55	0	Community	CS	BIS-NP, MI	Prem	ST	0.29
Peltzer, Malaka & Phaswana (2001)	104 S 695 NS	20.1 2	55.2		College	CS	RTS	SS	ST	0.06
Perkins et al (2000)	55 S 37 NS	31.1 3	48		Community	CS	SSS-TAS SSS-BS/DI	SS Pers	ST	0.08 0.22
Pomerleau et al (1992)	240 S 676 NS	42.1 2	48.8		Community	CS	TCI-NS	SS	ST	0.30
Pripfl et al (2013)	18 S 18 NS	21.7	30.56		College	CS	SURPS-SS SURPS, BIS-T	SS Prem	ST	0.55 0.46
Rass, Ahn & O' Donnell (2015)	53 S 30 NS	25.2 5	47	74.7	Community	CS	SS-TAS BIS-NP, MI SSS-BS/DI BIS-AI	SS Prem Pers NU	ST	0.23 0.23 0.20 0.12
Rass, Ahn & O' Donnell (2015)	53 S	25.2 5	48.01	80.77	Community	CS	SS-TAS BIS-NP, MI SSS-BS/DI BIS-AI	SS Prem Pers NU	ND	0.11 0.19 0.10 0.03
Rezvanfard et	59 S	24.3	100		College	CS	I-7 V	SS	ST	0.32

al (2010)	30 NS	6					SS-TAS TCI-NS BIS-NP, MI I-7 Imp SSS-BS/DI	Prem Pers		0.19 -0.02
Rezvanfard et al (2010)	59 S	24.1 2	100		College	CS	I-7 V SS-TAS TCI-NS BIS-NP, MI I-7 Imp SSS-BS/DI	SS Prem Pers	ND	0.43 0.24 0.25
Ristache & Rotarescu (2015)	55 S 115 NS	25.7 6	10.1		College	CS	TPQ-NS	SS	ST	0.33
Roberts et al (2014)	74 S 287 NS	21.4	49.2	82.8	College	CS	UPPS-P	SS Prem Pers NU PU	ST	0.09 0.19 0.14 0.3 0.22
Schiep & Cieslik (2011)	149 S 146 NS	42.8 4	55.25		Community	CS	TCI-NS	SS	ST	0.28
Schiep & Cieslik (2011)	149 S	42.1	57		Community	CS	TCI-NS	SS	ND	0.16
Sharma, Gale & Fineberg (2012)	10 S 10 NS		50		Adults with OCD	CS	TCI-NS BIS-T	SS Prem	ST	0.79 0.71
Shokrgozar et al (2015)	50 S 50 NS	33.6 7	79		Schizophre nic patients	CS	BIS-NP, MI	Prem	ST	0.51
Skinner, Aubin & Berlin (2004)	326 S 74 NS	43.3 3	66.75	90	Alcohol dependents	CS	BIS-NP, MI	Prem	ST	0.22
Sousa et al (2011)	181 S 241 NS	34.1 2	51.66	100	Adults with ADHD	CS	TCI-NS	SS	ST	0.22
Spielberger et al (2004)	225 S 490 NS	41.5	100	100	Community	CS	NEO-PI-R	NU	ST	0.09
Spillane, Smith & Kahler (2010)	139 S 87 NS	18.9 7	41.5		College	CS	UPPS-P	SS Prem Pers NU PU	ST	0.21 0.16 0.16 0.21 0.21
Spillane, Smith & Kahler (2010)	139 S				College	CS	UPPS-P	PU	ND	0.32
Spinella (2002)	30	31.1 7	36.67		Community	CS	BIS-NP, MI	Prem	ST	0.21
Spinella (2003)	26 S 64 NS	29.9 2	40		Community -dwelling adults	CS	FSBS-DI	Pers	ST	0.46
Stephenson et al (2007)	789	24.4	39.5	100	Community	CS	BSSS	SS	ST	0.19
Stoltenberg, Batién & Birgenheir (2008)	31 S 169 NS	22.6 7	37.06	95.9	College	CS	BIS-NP, MI	Prem	ST	0.11
Stoltenberg et al (2011)	101 S 373 NS	22.4 9	35.3	100	College	CS	BIS-NP, MI	Prem	ST	0.24
Stuart et al (2006)	212 S 148 NS	33.1	100	79	Prisoners	CS	I-7 Imp	Prem	ST	0.19
Tapper et al (2015)	46 S 138 NS	33	0	92	Community	CS	BIS/BASFS BIS/BAS	SS RS	ST	0.32 0.0005

Tapper et al (2015)	46 S		0		Community	CS	BIS/BASF BIS/BAS	SS RD	ND	0.16 0.30
Terracciano & Costa (2004)	116 S 1638 NS	60.3	50		Community	CS	NEO-PI-R	NU	ST	0.12
Terracciano et al (2008)	318 S 770 NS	56.6 4	38	63	Community	CS	NEO-PI-R	NU	ST	0.31
Vanderveen et al. (2008)	50 S	22.7 2	68	88	College	CS	BIS-T	Prem	ND	-0.13
Vasconcelos et al (2015)	235 S 435 NS	39.5	43.9		Community	CS	BIS-T	Prem	ST	0.28
Voigt et al (2009)	976	20.8 5	41.6		College	CS	BIS/BASF BIS/BAS	SS RS	ST	0.13 -0.01
Voracek, Pum & Dressler (2010)	49 S 85 NS	36.3	100	100	Community	CS	SS-TAS SSS-BS/DI	SS Pers	ST	0.11 0.21
Ward et al (1987)	18 S 69 NS	19.6	65.52		College	CS	SS-TAS SSS-BS/DI	SS Pers	ST	0.15 0.17
White et al (2011)	47 S 85 NS	19.4 4	53.03	100	College	CS	BIS-T	Prem RS	ST	0.21 0.11
White et al (2011)	47 S		57.5	100	College	CS	BIS-T SPSRQ	Prem RS	ND	0.02 0.07
Zuckerman, Ball & Black (1990)	150 S 921 NS	17- 21	39.4		College	CS	SS	SS	ST	0.19
Zuckerman & Kuhlman (2000)	260		38.85		College	CS	ZKPQ-SS	SS	ST	0.25

Age=mean unless otherwise noted; r=r value before transformations; S=smokers; NS=non-smokers; CS=cross-sectional; PR=prospective; Prem=lack of premeditation; Pers=lack of perseverance; SS=sensation seeking; NU=negative urgency; PU=positive urgency; RS=reward sensitivity; ST=smoking status, ND=nicotine dependence

Table 3. Meta-analyses

	k	N	r	CI	Z	SE	Q	I ²	FSN
Smoking Status									
Lack of premeditation	52	20,129	0.20	0.17-0.24	12.65***	0.02	224.17***	72.03	163
Lack of perseverance	20	4443	0.18	0.14-0.22	8.29***	0.02	30.47*	40.29	51
Sensation Seeking	53	27,566	0.19	0.16-0.22	11.34***	0.02	377.93***	83.30	149
Negative Urgency	11	5498	0.19	0.13-0.25	6.17***	0.03	48.07***	75.41	28
Positive Urgency	4	1305	0.24	0.18-0.29	8.62***	0.03	0.89	0	16
Reward Sensitivity	6	5140	0.01	-0.04-0.06	0.24	0.03	13.06*	60.18	0
All traits	85	44,049	0.19	0.17-0.22	15.03***	0.01	588.83***	82.13	251
Nicotine									

Dependence									
Lack of Premeditation	17	2358	0.10	0.03-0.17	2.65**	0.04	35.52**	60.30	18
Lack of perseverance	6	970	0.05	-0.05-0.15	1.03	0.05	6.78	32.73	0
Sensation Seeking	17	2183	0.11	0.03-0.19	2.65**	0.04	50.80***	67.24	20
Negative Urgency	5	747	0.15	0.08-0.22	4.08***	0.04	2.18	0	11
Positive Urgency	3	449	0.23	0.13-0.33	4.29***	0.06	2.38	23.24	12
Reward Sensitivity	4	477	0.03	-0.06-0.12	0.58	0.05	3.71	0.02	0
All traits	30	4145	0.12	0.08-0.17	5.17***	0.02	51.80**	46.55	43

K=no. of studies; N=aggregate sample size; r=mean weighted size; CI=95% confidence interval; Z=Z-test of the mean effect size; SE=standard error; Q=heterogeneity statistic; I²=true heterogeneity percentage; FSN=no. Of studies with average effect size of 0 required to reduce the observed mean effect size to r=0.05.

* p<0.05

** p<0.01

***p<0.001

Table 4. Moderator subgroup analyses (Impulsivity traits and smoking)

	K	Q	P
Lack of premeditation			
Age	50	0.73	0.39
Ethnicity	26	1.52	0.22
Gender	51	2.70	0.10
Sample type	52	2.60	0.11
College students	52	2.51	0.11
Study type	52	8.33	0.004
Lack of perseverance			
Age	18	0.62	0.43
Ethnicity	9	0.60	0.44
Gender	19	0.14	0.70
Sample type	20	0.69	0.41
College students	20	2.26	0.13
Study type	20	7.79	0.005
Sensation Seeking			
Age	48	0.15	0.69
Ethnicity	26	0.08	0.77
Gender	52	3.59	0.06
Sample type	53	0.20	0.65
College students	53	0.02	0.88
Study type	53	0.79	0.37
Negative Urgency			
Age	10	0.002	0.97
Ethnicity	7	0.02	0.87

Gender	10	2.27	0.10
Sample type		No results	
College students	11	0.31	0.58
Study type	11	0.97	0.32
Positive Urgency			
Age	3	0.09	0.76
Ethnicity		No results	
Gender	3	0.13	0.72
Sample type		No results	
College students		No results	
Study type		No results	
Reward Sensitivity			
Age	5	2.05	0.15
Ethnicity	5	0.01	0.93
Gender	6	0.01	0.93
Sample type		No results	
College students	6	0.04	0.83
Study type		No results	
All traits			
Age	79	0.69	0.41
Ethnicity	42	0.22	0.64
Gender	84	0.06	0.80
Sample type	85	2.11	0.15
College students	85	1.64	0.20
Study type	85	4.08	0.04

K=no. of studies; Q=heterogeneity statistic; p=alpha level

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Figure 1. Flowchart for study selection

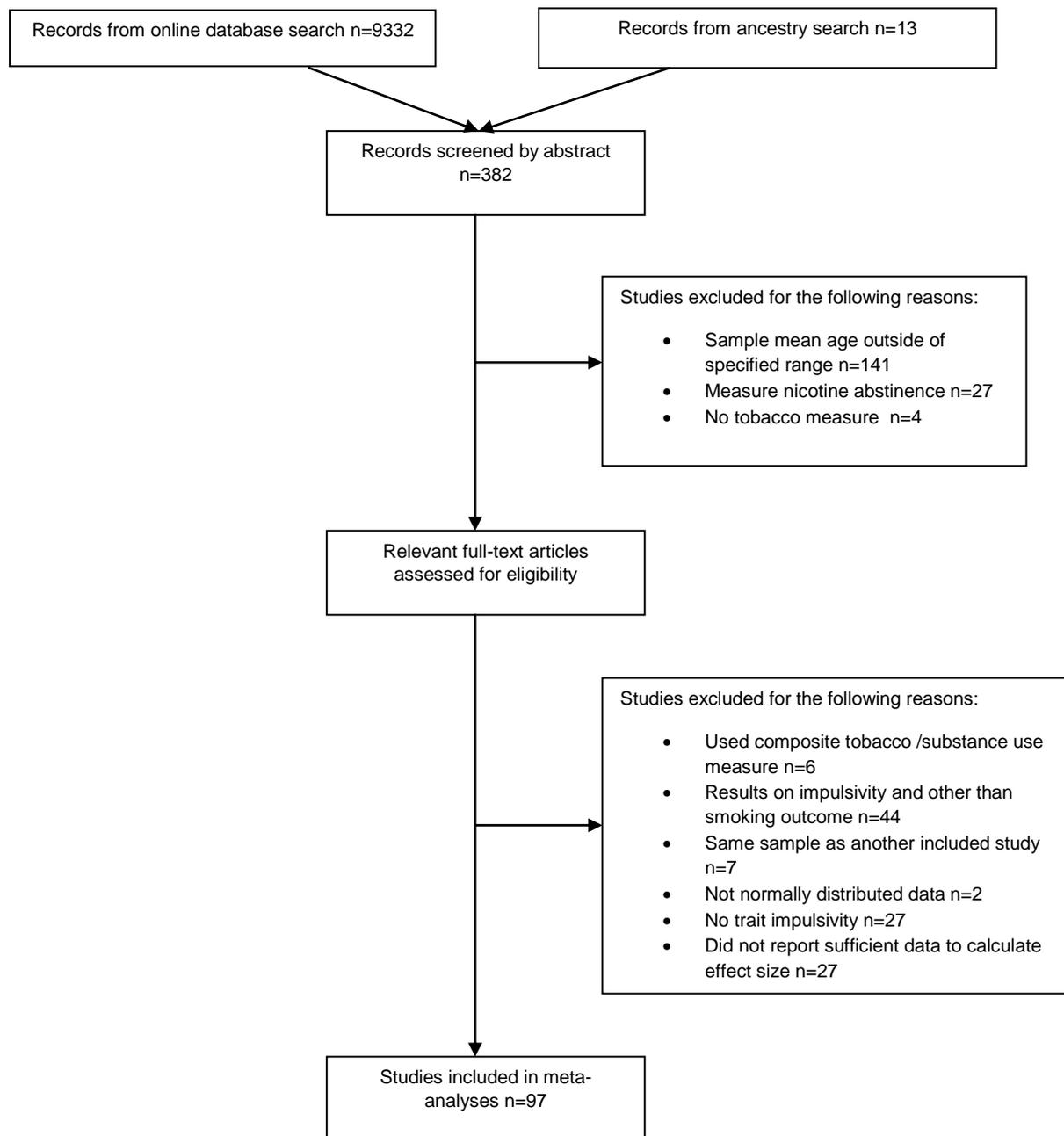


Figure 2.1: Forest plot lack of premeditation and smoking status.

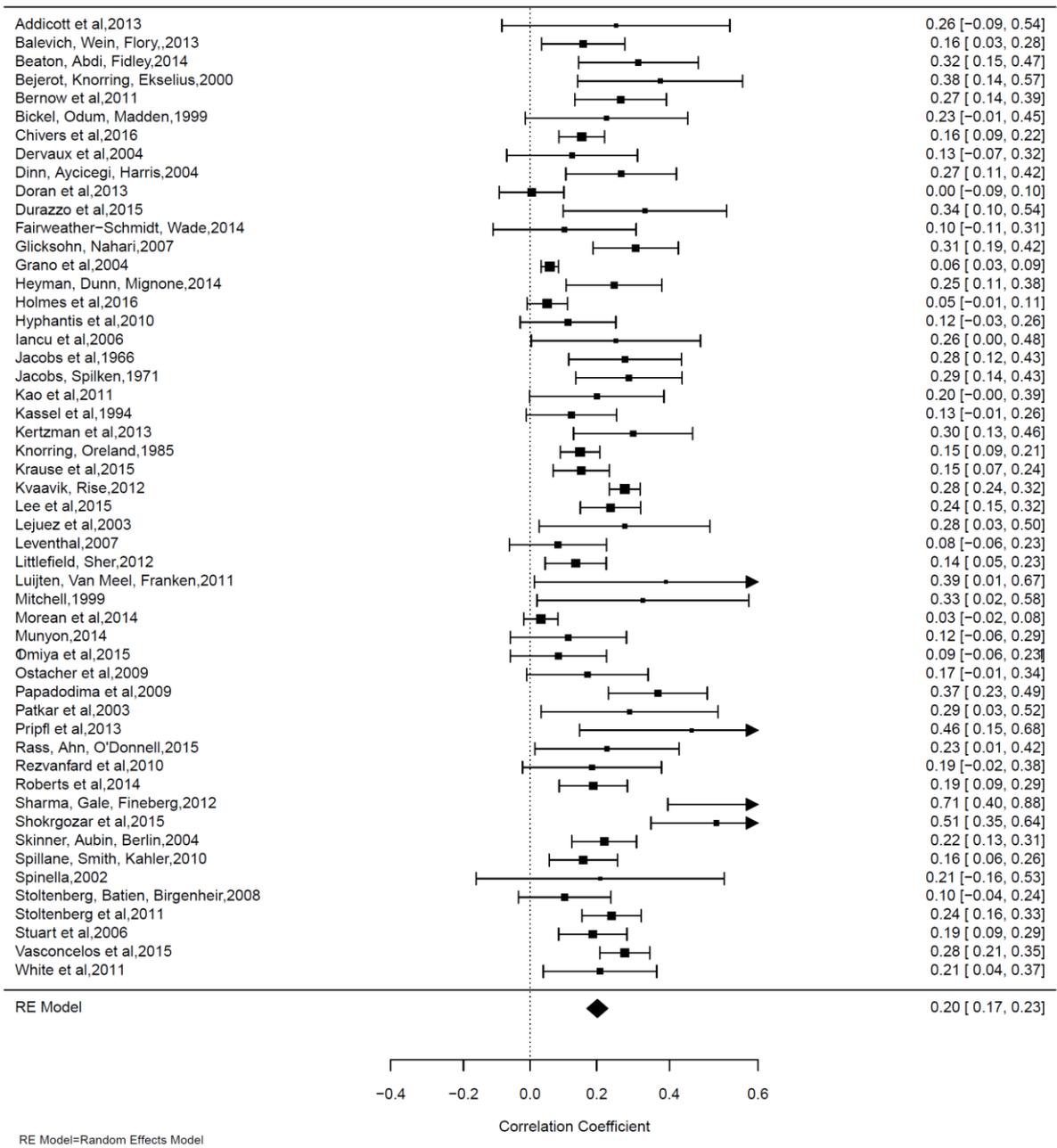


Figure 2.2.: Forest plot lack of premeditation and severity of nicotine dependence

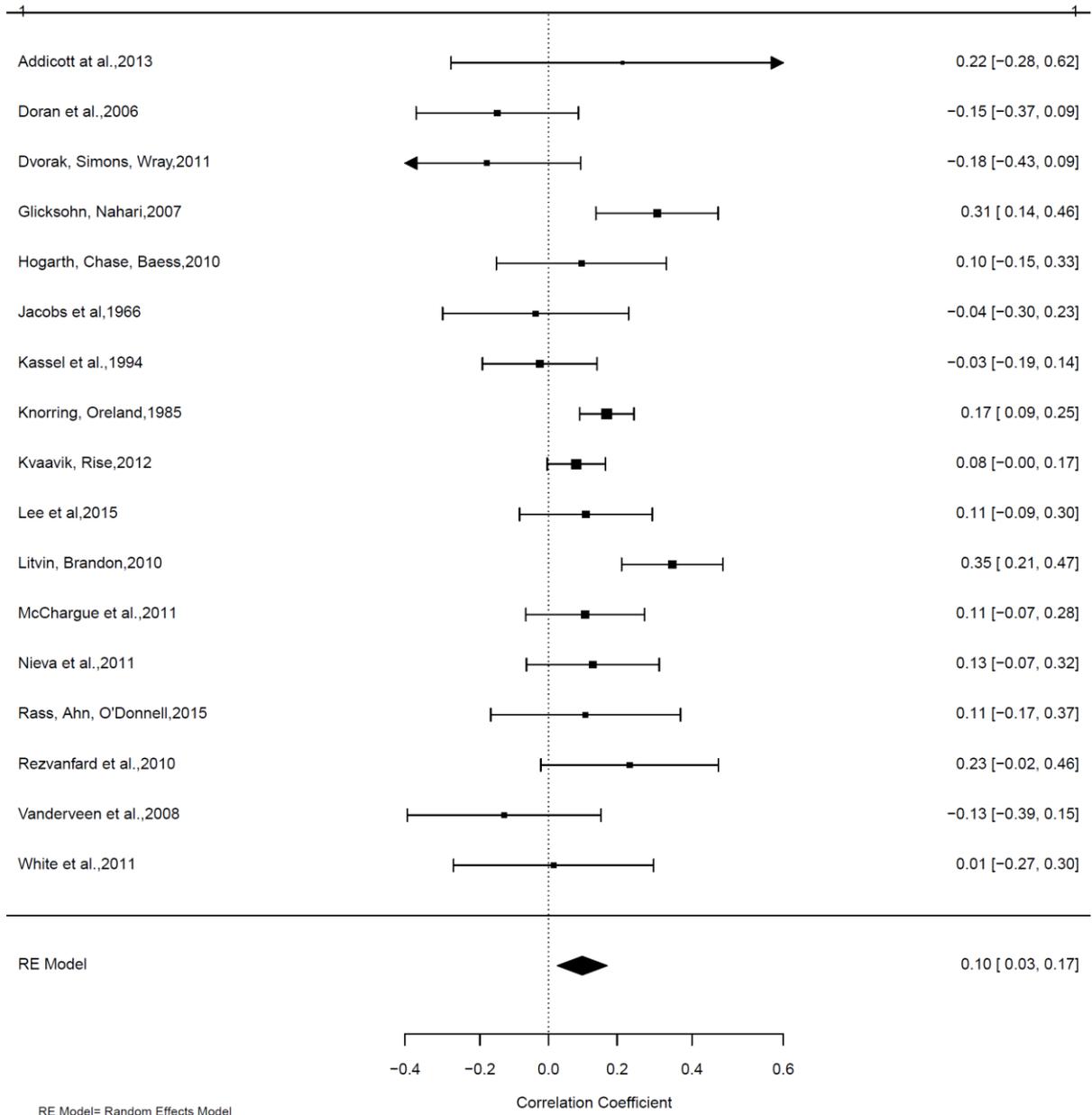


Figure 2.3: Forest plot sensation seeking and smoking status

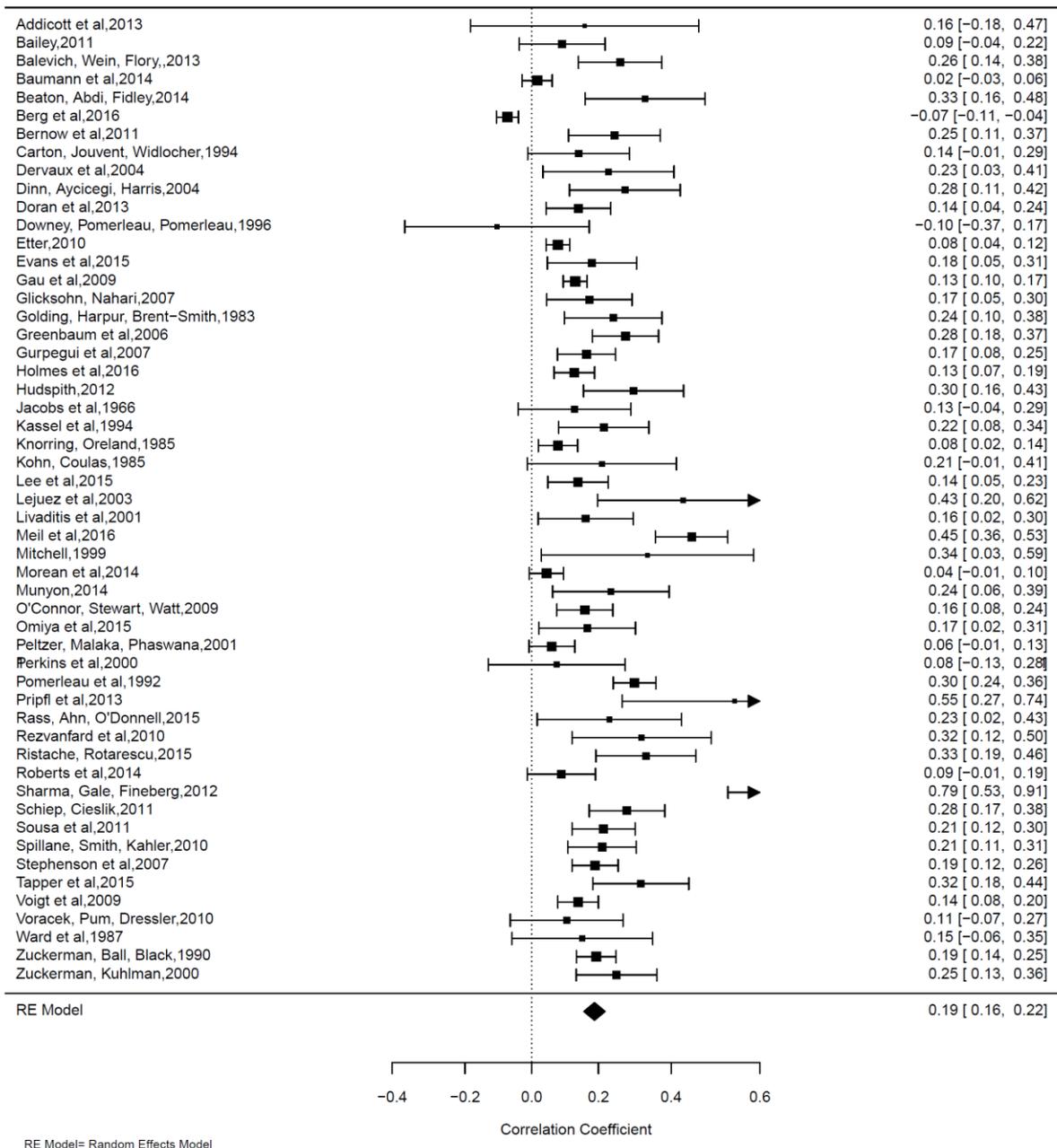


Figure 2.4: Forest plot sensation seeking and severity of nicotine dependence

