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Influence of Affective Manipulations on Cigarette Craving: A Meta-Analysis

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Abstract

Background and Aims—Retrospective self-report and observational studies have yielded inconsistent findings regarding the capacity of negative affect (NA) to increase smoking motivation among dependent smokers. Controlled laboratory studies offer an alternative paradigm for testing the role of affective state upon smoking motivation. The aim of the current study was to quantify cue-provoked cravings produced by affective manipulations in the published literature, and to identify theoretical and methodological moderators.

Methods—We conducted a systematic literature search to identify experimental studies that manipulated NA or positive affect (PA), and assessed post-manipulation craving. Separate random effects meta-analyses examined NA and PA cues as predictors of self-reported craving. Self-reported affect (NA and PA), nicotine deprivation, gender, nicotine dependence, order of cue presentation, single vs. multi-item craving assessment, and affect induction method were tested as moderators of affective cue-induced craving.

Results—NA manipulations produced a medium effect ($g = .47$; $CI = .31 - .63$) on craving, but no main effects were found for PA manipulations ($g = .05$; $CI = -.09 - .20$) on craving. Self-reported NA moderated the extent to which NA and PA manipulations elicited craving (p 's $< .02$ for each). That is, more effective NA manipulations produced greater cravings, and PA manipulations reduced cravings when they reduced NA.

Conclusions—Laboratory studies indicate that negative affect, but not positive affect, is a situational determinant of cravings to smoke among dependent smokers. Adverse emotional states increase craving to smoke among dependent smokers, but positive emotional states do not consistently reduce craving to smoke.

Keywords

tobacco; smoking; craving; conditioned stimuli; affect; cue-reactivity

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Introduction

Affective processes have long been postulated to be essential mechanisms underlying the maintenance of drug consumption (1–8). Although these processes are quite complex (9), affect is generally differentiated in terms of duration (state vs. trait), valence (positive vs. negative), and arousal/activation (low vs. high). Particular attention has been devoted to negative affect (NA), as preclinical, epidemiological, clinical, experimental, observational, and longitudinal studies have attempted to delineate its role across developmental stages of drug use (i.e., initiation, maintenance, and relapse). Qualitative reviews have summarized these research efforts (10–15), but the relationship between controlled affective manipulations and drug use motivation has yet to be systematically quantified. Here we focus specifically on the maintenance phase of tobacco smoking.

Acute Negative Affect and Smoking Motivation

Dependent smokers consistently endorse affect regulation as a primary motive for smoking (16–19), and that NA is a precipitant to relapse (20–29). That is, retrospective self-report studies clearly suggest that NA is an antecedent of smoking during the maintenance and relapse phases. This may occur, in part, because smokers expect smoking to reduce NA, whether or not these reductions actually occur in a given situation (12).

In contrast, observational studies using ecological momentary assessment (EMA) have been equivocal, depending upon the phase of smoking. During a quit attempt, NA is the situational determinant most likely to precede a lapse, and these NA-related lapses most readily progress to relapse (30). However, no relationship between NA and ad lib smoking has been observed in the majority of uncontrolled observational EMA studies (31–33). Thus, there is inconsistency between most EMA findings and other self-report data during the maintenance phase.

Cue-Reactivity Paradigm and Smoking Motivation

Cue-reactivity paradigms are laboratory analogues of drug-seeking behavior (34–37), and perhaps the most widely-utilized method for examining the influence of situational stimuli on smoking motivation (38). A strength of these controlled designs is the experimental manipulation of the cue of interest relative to a neutral comparison condition, thereby eliminating potential confounds and providing an internally valid test of causality. The majority of cue-reactivity studies have focused on responses to environmental stimuli most proximal to the act of smoking (e.g., cigarettes); and the only meta-analysis on this topic found that these exteroceptive cues had small to medium effects ($d = -.07 - .44$) on psychophysiological indices and large effects ($d = 1.18$) on self-reported craving (39).

Given that the most robust response to smoking-related cues appears to occur in subjective reports of craving, it is not surprising that this is the most widely assessed measure of smoking motivation. Commonly operationalized as the desire to use a drug (40), craving has been conceptualized as an expression of drug use motivation that may mediate continued drug use and relapse (41). As such, it serves an integral role within the majority of contemporary models of drug dependence (4, 38, 42–44). Importantly, two types of craving should be distinguished: withdrawal-based or background craving and cue-based or cue-provoked craving (45).

The utility of cue-provoked craving for understanding nicotine dependence remains controversial (see *Addiction*, v. 104, issue 10). Perkins (46) pointed out that minimal evidence supported an association between cue-provoked craving and smoking relapse risk, as this relationship was only observed in one study at that time (47). However, recent

empirical evidence suggests that cue-provoked cravings are clinically meaningful, as additional studies have since found relationships between cue-provoked cravings and smoking cessation outcomes (48–50).

The Perkins review and subsequent discourse also promulgated several areas of future inquiry for cue-reactivity paradigms. For example, Tiffany and Wray (51) pointed out that clarification is needed for many psychometric and methodological issues (e.g., procedural, measurement, sample characteristics). And Shiffman (52) suggested the need to better identify the influence of nonsmoking-specific cues (e.g., NA), which can be considered more distal than smoking-related cues (53). The current study was conducted with these recommendations in mind and to help clarify the equivocal findings on the role of NA as an antecedent of smoking motivation within current, minimally deprived, smokers (i.e., maintenance phase).

Current Study

The primary aim was to quantify the effect size of cue-provoked craving resultant from NA inductions by reviewing existing studies and using meta-analytic methods. Cravings induced by positive affect (PA) manipulations were also explored, given theoretical predictions that PA may increase smoking motivation (54, 55). Finally, we examined variables that may moderate the effects of affective manipulations on craving. Potential moderators were predicated upon their capacity to inform theory and/or cue-reactivity methodology (described below).

Methods

Study Acquisition

As part of a larger effort to identify all cue-reactivity studies the following terms were searched within PsycINFO, PubMed/MEDLINE, and Dissertation Abstracts: (smok* OR nicotine OR tobacco) AND (cue OR stimuli OR reactivity OR conditioned withdrawal OR conditioned responses OR craving OR urge OR stroop OR implicit OR response time OR dot-probe OR priming OR dual-task OR expectancy OR accessibility OR startle OR memory OR cognition OR affect OR mood OR topography OR psychophys* OR fMRI OR ERP). This search concluded in February of 2012 and yielded 7,202 abstracts that were then reviewed to determine relevance to the current study. Bibliographic searches were also conducted within pertinent studies and qualitative reviews.

For a study to be included the following criteria must have been met: 1) sample included smokers; 2) comparison of a neutral cue to an affective cue (PA or NA) devoid of smoking-related content; 3) assessment of post-cue craving; and 4) contained statistics necessary to compute an effect size. Attempts were made to contact authors of relevant studies without the final criterion (five provided this information). An enumerative flow diagram of study selection is presented in Appendix A, and a meta-analysis reporting checklist is presented in Appendix B. When studies included specific subsamples (56–60), each subsample was treated as an individual study.

Moderator Selection

Preliminary analyses tested the assumption that affective manipulations actually induced the intended affective state (i.e., NA or PA). Indeed, NA manipulations produced elevated levels of self-reported NA ($g = .52$, $CI = .36 - .69$) and significant reductions in self-reported PA ($g = -.72$, $CI = -.95 - -.49$). Also as expected, PA manipulations clearly induced PA ($g = .74$, $CI = .31 - 1.18$) and mitigated NA ($g = -.20$, $CI = -.35 - .04$). Effect size estimates for self-reported NA and PA were included as moderators of the craving analyses. Such

moderation would provide additional evidence that these manipulations increased smoking motivation via their impact on affective state (i.e., representing a dose-response relationship).

Additional theoretical moderators included nicotine withdrawal, gender, and nicotine dependence. We hypothesized that nicotine withdrawal would exacerbate cue-reactivity, as it may activate craving networks and make cues more salient (54). A large literature base also suggests that females may be more reactive than males to non-pharmacological aspects of smoking, such as cues (61). Finally, the smoking behavior of those less nicotine dependent has been theorized to be more stimulus bound, and therefore, more reactive to cues (62); however, other theoretical perspectives suggest that cue-reactivity should be positively associated with dependence (43). The current study provided an avenue to clarify this relationship with respect to affective cues.

Order of cue presentation and how craving was assessed were methodological characteristics we hypothesized as potential moderators. Given the likelihood of carryover effects that may blur differences between neutral and smoking-related cues (63), we expected studies that employed fixed order cue presentation (neutral first) would evince higher magnitude effect sizes than other cue presentations (counterbalanced or randomized). It was also predicted that larger effect sizes would be observed for studies that assessed craving with validated multi-item measures, relative to those that used single items. This was based on the assumption that elevated reliability increases the power to detect craving fluctuations in response to experimental manipulations (40). Exploratory analyses were conducted for modality of affective induction (e.g., picture, mental imagery).

Study Codification

To conduct theoretical moderation analyses the following study characteristics were extracted, when available: post manipulation self-reported affect (PA and NA); hours of nicotine deprivation (via pre-session smoking instructional set); gender composition (calculated as percent male); nicotine dependence (via cigarettes per day [CPD] and Fagerström Test of Nicotine Dependence scores [FTND]; 64). Methodological moderator variables were dummy coded as follows: cue presentation (fixed vs. other); craving assessment (multi-item vs. single item measure); and cue presentation modality (picture vs. mental imagery).

We also codified various demographics and other aspects of the study (e.g., task duration), but these were generally unable to be analyzed (e.g., inadequate reporting, insufficient variability). The methodological quality (i.e., validity or risk of bias) for each study was scored using a modified scale informed by Cochrane, PRISMA, and PEDro guidelines. The scale consisted of 14 dichotomous items specific to procedural (e.g., randomization, sample size justification, description of inclusion criteria, manipulation check) and statistical (e.g., description of analyses, selective reporting) aspects of the study, with higher scores representing higher quality designs. The second and third authors independently coded each study (90% agreement), with any discrepancies resolved through discussion with the first author.

In the few cases where a single study implemented multiple affect manipulations (65, 66) or affect/craving assessments (i.e., subscales; 66, 67, 68) a composite score was computed across affective manipulations or measures (which was then used to calculate study effect sizes). However, when both multi- and single item craving indices were included, only the former was used (69, 70).

Quantitative Data Synthesis

Comprehensive Meta-Analysis (71) was used to calculate individual study effect sizes and meta-analytic statistics. Separate meta-analyses were conducted to assess experimental manipulations of NA and PA upon craving (56–60, 65–70, 72–82). Hedge's g was calculated for all studies through the use of post-affective cue responses relative to post-neutral cue responses. As recommended by Rosenthal (83), a conservative correlation (.7) was assumed when calculating matched group effect sizes.

Primary Analyses—Summary statistics for each of the 2 primary meta-analyses (i.e., IV's = PA and NA manipulations; DV = craving) were computed using a random effects approach. The Q statistic and I^2 were used to explore heterogeneity between effect sizes. Multiple indices were utilized to examine the impact of publication bias. These included the classic fail-safe N , Orwin's fail-safe N (trivial effect size set at .2 or $-.2$ and effect size of missing studies set at 0), Begg–Mazumdar rank correlation test (84), Egger's test (85), and Duval and Tweedie's trim and fill approach (86). Funnel plots were also visually inspected.

Moderation Analyses—All three methodological moderators (craving assessment, affect manipulation modality, and presentation order) were categorical and examined using mixed effects analyses. Meta-regression analyses (via method-of-moments parameter estimation) were conducted for the six continuous theoretical moderators (NA, PA, FTND, CPD, nicotine deprivation, and gender composition) and study quality scores. Thus, 10 single-predictor moderation analyses were conducted for each type of the affective cue (i.e., PA and NA).

Results

Sample Characteristics

Study characteristics are shown in Table 1. The entire sample consisted of 27 studies ($N = 1,412$), several of which contributed to multiple analyses (see Figures 1–2). Overall, the large majority of studies used within-subjects designs (93%) and few used fixed order cue presentation (12%). On average, study samples were 31.30 years of age, 57% male, smoked 20.60 CPD, and were moderately nicotine dependent ($FTND = 5.26$). There was a wide range of pre-session nicotine deprivation (0–18 hours), with a mean of 2.36 hours (median = 0 hours). Considerable variability was observed for type of affective manipulation employed, along with how affect and smoking motivation were assessed. No study reached the maximum methodological quality score, which averaged to 73% across studies (range = 64 – 86%).

NA-Induced Craving Analyses

Primary—NA manipulations yielded medium effects for inducing cravings to smoke (see Table 2 and Figure 1). There was substantial heterogeneity in effect sizes, as seen by the significant Q statistic and large amount of true variance accounted for (i.e., I^2). Of the five publication bias indices, only the trim and fill method indicated potential bias, and adjusting for imputed studies had little impact on the summary statistic (adjusted $g = .35$, $CI = .18 - .52$).

Moderators—Self-reported NA significantly moderated the effects of the NA manipulations on craving ratings (slope = .74, $p = .003$), whereas moderation was not observed for self-reported PA (slope = $-.21$, $p = .25$). None of the other planned theoretical moderator analyses reached significance (i.e., gender, nicotine deprivation, nicotine dependence, or CPD; p 's $> .10$).

Modality was the only significant methodological moderator. Mental imagery manipulations produced large effect sizes, while picture presentation produced small effect sizes that did not reach statistical significance. Although not significant, studies that utilized single-item craving indices showed larger cue-provoked cravings than those with multi-item measures. Order of cue presentation and study quality scores were unrelated to NA-provoked craving.

PA-Induced Craving Analyses

Primary—No effect or publication bias was observed for PA inductions (see Table 3 and Figure 2). The Q statistic and I^2 suggested heterogeneity across studies.

Moderators—Again, self-reported NA significantly moderated craving ratings (slope = .71, $p = .03$), but self-reported PA did not (slope = .08, $p = .62$). That is, PA manipulations were found to reduce cravings as a function of their ability to reduce NA. No evidence of moderation was observed for gender, nicotine deprivation, nicotine dependence, or CPD (p 's > .34).

In contrast to the findings for NA inductions, PA mental imagery studies had little to no impact on craving. This was significantly different from the small positive effect size obtained by studies that used picture presentations. Craving assessment was also a significant moderator, as multi-item measures were associated with reductions in post-cue craving ratings, whereas single-item assessments tended to show craving increases. Additionally, PA-provoked craving was moderated by study quality scores (slope = $-.11$, $p = .054$), suggesting that PA decreased craving within higher quality studies.

Discussion

Affective Cues and Craving

To characterize the effects of affective stimuli on smoking motivation we quantitatively synthesized affective cue-reactivity studies that measured self-reported craving. With respect to controlled laboratory manipulations of NA (relative to neutral), as expected, we observed a clear cause-effect relationship with smoking motivation. Based on the quality and number of studies, there was strong evidence that NA inductions evoked cravings to smoke. Although NA manipulations increased cravings to smoke, it is noteworthy that the overall effect size was smaller than that previously reported for smoking-specific cue presentations (39). This is not surprising, as negative affect can be considered a distal cue to smoke, compared to the more proximal cues involving smoking-specific stimuli (53).

PA inductions did not have consistent effects on craving (although the methodologically stronger studies were more supportive of craving reduction). Thus, PA did not appear to act as a conditioned interoceptive stimulus for the maintenance of smoking motivation. This is at odds with addiction models that emphasize the role of PA, non-specific to drug use, as a motive for continued substance use (e.g., 54). The negligible role of PA found here converges with evidence that heightened PA is associated with a small proportion of smoking relapse (87).

Moderators

The relative importance of NA was further substantiated by analyses that tested self-reported affect as moderators for cue-provoked cravings. NA ratings were found to moderate the influence of NA and PA cues, such that craving was dependent upon the degree to which these stimuli altered NA. Although affective cues also had large effects on PA ratings, these did not modulate craving responses. That self-reported NA predicted cue-provoked cravings, regardless of cue type, supports the supposition that the interoceptive state of NA is a

primary mechanism involved in the maintenance of drug dependence, including smoking (1). However, the interpretation of these analyses was limited by the number of studies that contributed both affective and craving outcomes.

None of the other moderation hypotheses was supported, but the power of these tests was limited by the few available studies. For example, fixed order of cue presentation was only used by four studies that investigated NA manipulations and one study that examined PA inductions. No clear pattern emerged across affective cues with respect to the use of single-item vs. multi-item craving assessments, but larger PA-induced cravings were observed when assessed via single-item scales. However, assessment approach may have been confounded with other design and methodological characteristics. For instance, five of the six studies that used multi-item craving measures also used mental imagery to induce PA, whereas this was only the case for two of the eight studies that assessed craving with a single-item. Thus, the induction modality may have driven the effects observed for craving assessment method, a possibility that a more highly powered study might be able to disentangle through multi-moderator analyses.

Indeed, significant differences were found when we explored which affective induction methods were most potent for inducing craving. Across affective cues, picture presentation produced small effect sizes. Mental imagery had no discernible impact as a PA cue, but was a more effective NA cue than were pictures. Although there were other types of NA manipulations, they were too sparsely used to be included within moderation analyses. However, pain induction and the Trier Social Stress Test (88) also appeared to have large effects. Thus, it seems as though active engagement in NA inductions (compared to passive viewing of pictures) results in higher smoking motivation.

Clinical Implications

The findings indicating a causal role of NA upon smoking motivation suggest that cessation treatments might benefit by including strategies that: 1) prevent NA or 2) extinguish the relationship between NA and drug seeking. The importance of targeting reactivity to NA is further highlighted by studies that indicate that NA-induced cravings predict ad lib smoking behavior and cocaine relapse better than cravings produced by drug-specific stimuli (73, 89). This may occur because cue-provoked cravings from drug-specific stimuli may extinguish rather quickly following cessation (90, 91), whereas reactivity to NA may be more resistant to change (92). Additionally, it may be more difficult to avoid internal cues that are devoid of environmental constraints (i.e., NA), relative to external cues that only occur in circumscribed environments (i.e., drug-specific stimuli). Therefore, the reduction of NA-induced cravings might serve as a proxy for treatment efficacy, and the cue-reactivity paradigm may offer a laboratory model for testing treatment effects (93) and explicating NA-related pathophysiology (14).

However, it is unclear to what extent our findings extend to relapse processes, as 90% of participants in the constituent studies were not attempting to quit smoking. Additionally, few studies examined affective cues in the context of extended nicotine deprivation. Manipulation of these sample characteristics may be a fruitful area for further exploration, and serve to establish more representative cessation laboratory analogues. Furthermore, it is imperative that laboratory models include ad lib smoking behavior (in addition to craving) as a dependent variable (94).

Limitations and Future Directions

The degree to which our results generalize to naturalistic settings is inherently limited by the cue-reactivity paradigms employed by the constituent studies. Examination of contrived

affective manipulations in controlled environments thereby sacrificed external validity, but maximized internal validity and the ability to make causal inferences. These tradeoffs may, in part, account for the divergence between our findings and those of EMA studies that investigated smoking motivation via ad lib smoking. Alternatively, EMA studies may not detect a relationship between self-reported NA and smoking because naturalistic smoking may precede, and prevent, conscious awareness of NA (1).

Additionally, we could not delineate the influence of low arousal states of NA (e.g., sadness), or discrete aversive emotions (e.g., disgust, shame) upon smoking motivation, as all but one of the NA manipulations incorporated an element of high arousal (e.g., stress) and were nonspecific. Future studies may wish to consider the use of video presentations, which are evocative stimuli that have been validated to induce various forms of NA (95). A unique, and potentially informative, design would be to examine all combinations of valence and arousal within a single experimental study.

Central to the current study, and all cue-reactivity studies, is how cue-provoked craving is operationalized. We focused on studies in which responses to neutral cues could be compared to those of affective cues. Thus, we did not capture studies that examined only changes from baseline to post-cue. Our approach was designed to isolate cue-provoked craving from background craving, but methods that investigate these in conjunction may be more appropriate for understanding relapse processes (96).

An additional limitation of the current study is the large number of analyses conducted (2 primary analyses and 20 moderation analyses), without formal correction of statistical significance. Indeed, our approach may have increased the likelihood for Type I error and reduced the degree to which our results reflect “true” population values. However, we chose this approach because our primary aim was to investigate the role of affective manipulations on craving (only 2 analyses), and our moderation analyses were informed by previous theory or qualitative reviews. With the intention of guiding future research, we did not want to diminish the capacity to detect potential signals that may influence affective cue-provoked cravings (i.e., increase Type II error). As more studies accumulate, future meta-analyses will be better powered to use multi-predictor moderation analyses.

Conclusions

With the caveat that included studies focused primarily on the effects of high arousal NA upon dependent smokers, we found that NA inductions increase cravings to smoke. Consistent with previous theory and retrospective self-report findings, our analyses provide strong quantitative evidence in support of a causal relationship between NA and smoking motivation. This relationship is more readily observed when NA is induced via mental imagery, relative to picture presentation. The only theoretical moderator observed was self-reported NA, which influenced craving responses to NA and PA cues. These findings support negative reinforcement models of addiction that emphasize the role of aversive states upon drug-seeking behavior.

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*denotes studies included within the meta-analyses

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Appendix A. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Flow Diagram

Appendix B. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			

Section/topic	#	Checklist item	Reported on page #
Rationale	3	Describe the rationale for the review in the context of what is already known.	3–5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	n/a
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5–6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	5–6
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7–8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7–8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	8
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	8
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	9
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	6, 31
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	9, 24–26
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	10–11
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention	29–30

Section/topic	#	Checklist item	Reported on page #
		group (b) effect estimates and confidence intervals, ideally with a forest plot.	
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	27–28
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	10–11
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	10–11, 27–28
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	11–12
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	14–15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	15–16
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	1

Figure 1.

Forest plot for comparisons of post-NA cue to post-neutral cue self-reported craving. This includes effect sizes (g), standard errors, variances, 95% confidence intervals, Z scores, and p -values. Effect sizes to the right of zero indicate larger craving in response to NA cues, relative to neutral cues. Confidence intervals that do not include zero reflect significant differences. Summary statistics are reported in the final row, computed via random effects meta-analysis.

Figure 2.

Forest plot for comparisons of post-PA cue to post-neutral cue self-reported craving. This includes effect sizes (g), standard errors, variances, 95% confidence intervals, Z scores, and p -values. Effect sizes to the right of zero indicate larger craving in response to PA cues, relative to neutral cues. Confidence intervals that do not include zero reflect significant differences. Summary statistics are reported in the final row, computed via random effects meta-analysis.

Table 1

Study characteristics

Study	N	NA cue	PA cue	Neutral Cue	Smoking Motivation Assessment(s)
al' Absi et al. (2003; non-deprived)	17	Public-speaking	n/a	Rest (video/magazine)	Single item (desire to smoke)
al' Absi et al. (2003; deprived)	21	Public-speaking	n/a	Rest (video/magazine)	Single item (desire to smoke)
Beckham (1996)	25	Words (anxiety)	n/a	Words	5-item craving subscale (SWQ)
Bradley et al. (2007)	12	Personal imagery & music (sad)	n/a	Personal imagery & music	QSU
Carpenter et al. (2009)	78	Personal imagery (stressful)	Personal imagery (relaxed)	In vivo (pencil and eraser)	QSU-B
Carter et al. (2006)	63	IAPS (high arousal)	IAPS (high arousal)	IAPS (low arousal)	Single item (craving)
Childs & de Wit (2010)	17	TSST	n/a	Describe book or film and computer game; no camera	VAS (craving)
Colamussi et al. (2007; males)	72	Standard imagery (stressful)	n/a	Standard imagery	5-item (validated)
Colamussi et al. (2007; females)	88	Standard imagery (stressful)	n/a	Standard imagery	5-item (validated)
Conklin & Tiffany (2001)	60	n/a	Composite imagery: standard; personal; other	Composite imagery: standard; personal; other	QSU-B
Ditre & Brandon (2008)	66	Cold pressor	n/a	Room temperature water	QSU-B
Drobes (2002; non-alcoholic)	19	Pictures (unpleasant)	Pictures (pleasant)	Pictures	VAS (craving)
Drobes (2002; alcoholic)	21	Pictures (unpleasant)	Pictures (pleasant)	Pictures	VAS (craving)
Elash et al. (1995)	36	Standard imagery	Standard imagery (relaxed)	Standard imagery	QSU-B
Litvin & Brandon (2010)	88	Speech preparation	n/a	Rate art (landscapes)	QSU-B
Maude-Griffin & Tiffany (1996; non-deprived)	49	Standard imagery	Standard imagery (relaxed)	Standard imagery	Single item (urge)
Maude-Griffin & Tiffany (1996; deprived)	51	Standard imagery	Standard imagery (relaxed)	Standard imagery	Single item (urge)
McKee et al. (2011)	37	Personal imagery (stressful)	n/a	Personal imagery (relaxing/neutral)	QSU-B
Perkins et al. (2008)	200	IAPS & music (high arousal)	IAPS & music (high arousal)	IAPS & music (low arousal)	QSU-4 item
Perkins et al. (2010)	104	Composite: digit recall; public-speaking; IAPS (high arousal)	n/a	IAPS (neutral)	QSU-B
Perkins & Grobe (1992)-(non-deprived)	16	Difficult digit recall	n/a	Simple digit recognition	VAS (desire to smoke)
Perkins & Grobe (1992)-(deprived)	16	Difficult digit recall	n/a	Simple digit recognition	VAS (desire to smoke)
Rehme et al. (2009)*	36	IAPS (high arousal)	IAPS (high arousal)	IAPS	VAS (desire to smoke)
Robinson et al. (2011)	111	IAPS (high arousal)	IAPS (high arousal)	IAPS (low arousal)	Single item (craving)
Taylor et al. (2000)	18	Standard imagery	Standard imagery	Standard imagery	QSU-B
Tiffany & Drobes (1990)	60	Standard imagery	Standard imagery	Standard imagery	2 items (urge and craving)

Study	N	NA cue	PA cue	Neutral Cue	Smoking Motivation Assessment(s)
Watson et al. (2010)	90	Personal imagery (stressful)	Personal imagery (relaxed)	In vivo (pencil and eraser)	QSU-B

Table 2

Meta-analyses of negative affect inductions on self-reported craving.

	k	g	LL	UL	Z	p_Z	Q	p_Q	I²
Overall Sample	26	0.47	0.31	0.63	5.78	0.000	281.40	0.000	91.12
Moderators									
<i>Craving Assessment</i>	-	-	-	-	-	-	1.82	0.177	-
Multi-item	12	0.35	0.11	0.58	2.90	0.004	147.57	0.000	92.55
Single-item	14	0.57	0.35	0.79	5.09	0.000	120.75	0.000	89.23
<i>Induction Modality</i>	-	-	-	-	-	-	3.97	0.046	-
Picture	6	0.23	-0.08	0.53	1.46	0.143	18.81	0.002	73.42
Mental imagery	11	0.61	0.38	0.83	5.29	0.000	152.57	0.000	93.45
<i>Cue Order</i>	-	-	-	-	-	-	0.10	0.748	-
Fixed	4	0.54	0.14	0.95	2.62	0.009	97.65	0.000	96.93
Other	20	0.47	0.28	0.66	4.90	0.000	170.24	0.000	91.42

Table 3

Meta-analyses of positive affect inductions on self-reported craving.

	k	g	LL	UL	Z	p_Z	Q	p_Q	I²
Overall Sample	14	0.05	-0.09	0.20	0.74	0.461	94.90	0.000	86.30
Moderators									
<i>Craving Assessment</i>	-	-	-	-	-	-	21.59	0.000	-
Multi-item	6	-0.22	-0.37	-0.06	-2.79	0.005	19.05	0.002	73.50
Single-item	8	0.27	0.13	0.41	3.84	0.000	22.05	0.002	68.25
<i>Induction Modality</i>	-	-	-	-	-	-	4.68	0.031	-
Picture	6	0.24	0.02	0.47	2.12	0.034	32.70	0.000	84.71
Mental imagery	8	-0.08	-0.28	0.11	-0.85	0.394	52.49	0.000	86.66
<i>Cue Order</i>	-	-	-	-	-	-	0.18	0.676	-
Fixed	1	-0.06	-0.62	0.50	-0.21	0.836	0.00	1.000	0.00
Other	13	0.07	-0.10	0.23	0.77	0.442	91.80	0.000	86.93