

## REVIEW

# A Systematic Review of the Relationships Between Craving and Smoking Cessation

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## ABSTRACT

**Introduction:** Craving is often portrayed as a defining feature of addiction, but the role of craving in the addictive process is controversial. Particularly contentious is the extent to which drug craving predicts subsequent relapse.

**Methods:** This review synthesizes findings from 62 smoking cessation studies published through December 2011. Eligible studies measured craving for cigarettes in treatment-seeking smokers and related this to subsequent smoking status. The relationships of general craving and cue-specific craving with treatment outcome were examined separately. Further, analyses that related general craving to smoking status were divided into those that used craving data collected before the quit attempt, after the quit attempt, and those that used change in craving over time as a predictor.

**Results:** Results across studies revealed a total of 198 indices of association with 94 (47%) of these being significant. In general, the findings indicated (a) there were only a few cases of significant associations between craving collected as part of cue-reactivity studies and treatment outcome, (b) postquit craving was a stronger predictor of treatment outcome than prequit craving, and (c) several moderators likely influence the relationship between craving and cessation outcome.

**Conclusions:** The overall results suggest that craving is not a necessary condition of relapse. In addition, inconsistent relationships between craving and treatment outcome call into question the value of craving as a target of treatment and underscore limitations in the prognostic utility of craving.

## INTRODUCTION

Craving is often portrayed as a central or defining characteristic of addiction (Anton, 1999; Kassel & Shiffman, 1992; Robinson & Berridge, 1993), but the precise role of craving in the addictive process is controversial. One of the most contentious issues related to craving is the extent to which desire to use a drug predicts subsequent drug use. This question has often been examined in the treatment literature, where predictors of outcome are sought to help identify obstacles to initial cessation success and long-term maintenance of drug abstinence. Although the relationship between craving and cessation outcome is often presented as established knowledge, this association has yet to be evaluated systematically.

Efforts to understand the association between craving and cessation outcome are motivated, in part, by the belief that the utility of the craving construct rests in its ability to predict drug use behavior (Mezinskis, Honos-Webb, Kropp, & Somoza, 2001; Perkins, 2009). Although the significance of craving is not limited to its predictive utility (Tiffany, Warthen, & Goedeker, 2009; Tiffany & Wray, 2009, 2012), there are a number of theoretical and clinical reasons for investigating relationships between craving and drug use.

All major theories of drug dependence propose that craving plays some role in motivating drug use (Drummond, 2001), and many (e.g., conditioning theories, positive expectancy theories, incentive-sensitization theory) suggest that craving and relapse should be tightly coupled (Marlatt, 1985; Robinson & Berridge, 1993; Siegel, 1989). Not all models identify craving as necessary for relapse, and modern theories of addiction seem to be moving away from this convention (e.g., Kavanagh, Andrade, & May, 2005; Tiffany, 1990; see Lowman, Hunt, Litten, & Drummond, 2000 for additional examples). Predictions made by different models about the association between craving and relapse are empirically testable; thus, clarifying the relationships between craving and drug use/relapse has important implications for the evaluation and refinement of addiction theories.

An understanding of the relationships between craving and outcome is also clinically relevant. Craving is widespread among smokers (Tiffany et al., 2009), cited as an obstacle to initiating a quit attempt (Orleans, Rimer, Cristinzio, Keintz, & Fleisher, 1991), and experienced long after successful cessation (Hughes, 2010). Determining the extent of the relationships between craving and smoking relapse has important implications for focusing on craving in intervention efforts.

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## Craving and smoking cessation outcome

Both pharmacological- and psychosocial-based interventions are commonly portrayed as effective because they target craving; however, the hypothesis that craving reduction influences subsequent treatment status is rarely tested explicitly (for exceptions, see Ferguson, Shiffman, & Gwaltney, 2006; McCarthy et al., 2008).

There are several examples of strong assertions in the tobacco literature about the relationship between craving and smoking cessation outcome. These range from statements that there is a well-documented relationship between craving and outcome to those that deny this association. Some authors have focused on the instances in which craving appears to be linked with treatment outcome, making claims such as, “Craving is the most unpleasant consequence of smoking cessation and also the most frequent cause of relapse” (Durcan et al., 2002, p. 548; for other examples, see Bagot, Heishman, & Moolchan, 2007; Businelle et al., 2010; Shiffman, Ferguson, Gwaltney, Balabanis, & Shadel, 2006; Waters et al., 2004). Others have drawn attention to studies that fail to find evidence for this relationship and conclude that “craving is a poor predictor of relapse” (Witkiewitz & Marlatt, 2004, p. 227; for other examples, see Bailey, Hammer, Bryson, Schatzberg, & Killen, 2010; Drummond, Litten, Lowman, & Hunt, 2000).

The conflicting accounts describing this relationship may be driven by a lack of consistent findings across studies. If this is the case, a host of factors related to the variables being measured and the conditions and timing of assessment could be responsible for divergent study results. Such factors might include the time relative to quitting that craving is measured (e.g., prequit vs. postquit), the assessment tool used to measure craving, and the timeframe over which outcome is assessed. An additional consideration when examining possible moderators of the relationship between craving and cessation outcome concerns the type of craving being measured.

Craving can be manifest in two primary ways. First, general levels of craving, which can fluctuate relatively slowly over the course of a day, are likely related to the level of deprivation that increases over the interval between cigarettes (Schuh & Stitzer, 1995). Second, cue-specific craving, which reflects responses to smoking-related cues that have previously been paired with drug administration (Carter & Tiffany, 1999; Tiffany et al., 2009), tends to have a fairly fast onset and is more short-lived than changes observed with general levels of craving. The cumulative effect of general craving, especially after a quit attempt, may be related to the likelihood of relapse (Drummond et al., 2000). General craving experienced during a period of “smoking as usual” may not reach peak intensity or be long-lasting, as it is likely alleviated relatively quickly through nicotine administration (i.e., smoking the next cigarette). In contrast, general craving experienced after a quit attempt is likely more intense and longer lasting in nature, and thus may be a stronger predictor of cessation outcome.

Cue-induced craving indexes how responsive a person is to external environmental cues. Presumably, craving experienced as part of a cue-reactivity exposure in a laboratory or clinical setting reflects how an individual will respond to cues in the environment during the quit period. This, in turn, may affect a person’s risk of relapse such that those who are more reactive will have greater difficulty quitting (Drummond et al., 2000; Rohsenow & Monti, 1999). However, there is controversy in the smoking literature about the degree to which cue-induced craving is related to relapse. Some assert that

responses to drug-related cues do predict successful cessation (e.g., Ferguson & Shiffman, 2009), while others have argued that there is scant evidence in the literature of any association between cue-induced craving and relapse (Perkins, 2012).

This review inventoried peer-reviewed journal articles that reported on the relationship between craving and outcome in the context of smoking cessation trials. We intended this review to be inclusive as possible. As a result, the included research addressed a range of questions regarding the nature of the relationships between craving and treatment outcome with statistics representing a wide variety of data analytic strategies. The diversity in statistics and outcome measures reported (e.g., dichotomous outcomes, continuous outcomes, time-to-event data) made collation of the effect sizes into one common metric unfeasible (Deeks, Higgins, & Altman, 2008; Lipsey & Wilson, 2001). Further, a large number of studies did not report statistics or used statistical methods that could not be combined with other studies. Consequently, formal meta-analysis was not used to combine study results. However, effect sizes were aggregated when possible to illustrate the magnitude of the craving–outcome relationship.

## METHODS

A literature search was conducted with the MEDLINE via EBSCO and PsycINFO search engines using the following terms: “smoking,” “treatment,” and “urge” or “craving” or “desire.” Reference lists of articles being reviewed for this paper, articles that discussed craving, and review papers focusing on smoking cessation treatment were examined to identify additional studies that might be appropriate for inclusion.

The following criteria were used to determine eligibility: (a) the sample consisted of current cigarette smokers, (b) participants were treatment seeking (i.e., intending to make a quit attempt at some point during the course of the study), (c) at least one measure of self-report craving was obtained, (d) craving was measured prospectively in relation to outcome, (e) at least one outcome measure related to smoking status was reported (e.g., lapse, relapse, quit status, amount smoking), (f) at least one analysis looking at the relationship between craving and outcome was reported, and (g) the article was published in a peer-reviewed journal no later than December 2011.

All analyses that linked craving and treatment outcome from each study were considered. Analyses were dropped when other factors (e.g., nicotine-dependence score) were covaried out of the craving score, except in cases where this was the only analysis linking craving to treatment outcome (see footnotes in Tables 1–4). Several studies assessed craving at multiple timepoints; in these cases, each analysis was included in the appropriate section of this paper. In cases where multiple analyses using different definitions of abstinence were presented, only analyses using the most stringent abstinence criteria were retained (e.g., continuous abstinence used over 7-day point-prevalence abstinence). Analyses were collapsed in cases where multiple statistics were presented for subgroups of participants (e.g., two analyses comparing early lapsed and late lapsed to abstainers were combined to reflect lapsed vs. abstainers). A cutoff of  $p < .05$  was used to determine statistical significance.

This review examines the predictive utility of cue-induced craving (i.e., measured as part of a cue-reactivity paradigm) and

general (background or tonic) craving. Studies that measured general craving were categorized as measuring craving prequit or postquit, as it has been suggested that the timing of craving assessment may influence its predictive utility (e.g., [Niaura, Shadel, Britt, & Abrams, 2002](#)). Analyses that used change in general craving as the predictor variable were grouped in a fourth category.

## RESULTS

The literature search produced 62,060 articles, 538 of which were reviewed for potential inclusion because they contained at least some required criteria (see [Figure 1](#)). Studies that did not include cigarette smokers interested in quitting, did not measure craving, and/or did not report outcome data were excluded for consideration at this stage. Of the studies that remained, 230 were reviewed to examine whether all inclusion criteria were met. A total of 62 studies were identified as eligible for inclusion. The majority of the remaining 168 studies were excluded because, although craving and cessation outcome were both measured, no analysis was provided linking the two ( $n = 128$ ). A second rater extracted information about the sample size, intervention, craving measurement, outcome variables, and craving–outcome statistics (when available) from each study. Any discrepancies between raters were discussed and reconciled. Agreement was high between the two raters with the percentage agreement for each variable as follows: sample size, 90%; intervention, 97%; craving/outcome measurement and timing of craving/outcome assessments, 100%; and craving–outcome statistics, 97%.

The average sample size of the 62 studies included in this review was 348 (the largest sample size used for any analysis reported by a given study was used to derive this average,  $SD = 503$ , median = 167, range  $n = 20$ –2,645); the total number of participants was 21,547. Mean participant age was 40 years ( $SD = 7$ , median = 41, range 15–49; mean participant age weighted by sample size = 42 years) and mean number of cigarettes per day (CPD) was 23 ( $SD = 4.5$ , median = 22, range 12–36; mean CPD weighted by sample size = 22). Just under half of the studies (45%) assessed nicotine dependence

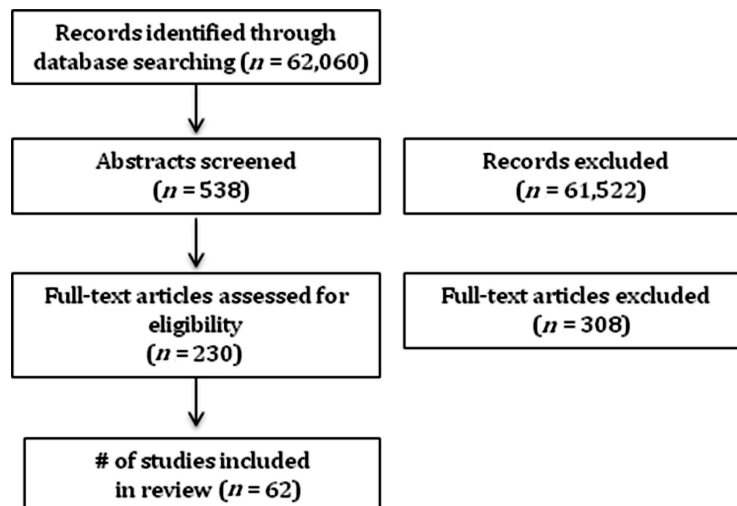
using the Fagerström Test for Nicotine Dependence (FTND; [Heatherton, Kozlowski, Frecker, & Fagerström, 1991](#)); the average reported FTND score out of a possible score of 10 was 5.20 ( $SD = 0.76$ , median = 5.3, range 3.53–6.67; mean FTND score weighted by sample size = 5). Cessation outcome was measured as close as 24hr postcessation to as far as 2 years postquit (see [Tables 1–4](#)).

The treatments implemented in these 62 studies included psychosocial-based interventions ( $k = 18$ ), pharmacological interventions ( $k = 4$ ), a combination of psychosocial and pharmacological treatment ( $k = 28$ ), and no formal treatment beyond asking participants to make at least one quit attempt ( $k = 12$ ).

### What Is the Overall Relationship Between Craving and Smoking Cessation Treatment Outcome?

A total of 198 analyses were extracted from the 62 studies that were included in this review. A lack of significant association between craving and treatment outcome was reported in 104 analyses (52.5%), while 94 analyses (47.5%) found significant support for this association. Across all 62 studies, 26 found significant relationships between craving and outcome in each analysis conducted, 18 reported nonsignificant relationships between craving and outcome in each analysis conducted, and 18 found mixed results depending on the craving or outcome measure used in the analysis.

The 94 analyses that identified a statistically significant relationship between craving and treatment outcome were extracted and combined when possible to determine the magnitude of these effects. Statistics were converted to correlations when possible, and the inverse of odds ratios ( $ORs$ ) < 1.0 were taken to allow for averaging across  $ORs$ . Averages were weighted by sample size by multiplying the effect size by sample size, summing these values in a given category, and dividing that sum by the total number of participants included in those analyses. The average significant correlation between craving and treatment outcome (which combined 27 analyses) was  $r = .19$ , indicating a small-to-medium effect size ([Cohen, 1992](#)). The average significant  $OR$  reported was  $OR = 1.54$  ( $n = 28$ ), suggesting that the odds of relapse for participants



**Figure 1.** Preferred reporting items for systematic reviews and meta-analyses flow chart.

**Table 1. Smoking Cessation Studies Reporting Findings Relating Cue Reactivity and Treatment Outcome Data**

Article	n	Definition of cue reactivity	Craving measure	When craving measured	Outcome measure	Significant craving–outcome association (y = yes, n = n <sup>a</sup> )
Abrams et al. (1988)	48	Post smoking cue craving	1 item	Prequit	(1) Abstinence 6 months postquit	(1) n, r = -.03
Niaura et al. (1989b)	47	Post smoking cue minus baseline	1 item	Prequit	(2) EOT (3) 6 months postquit status	(2) n, r = -.13 (3) n
Niaura et al. (1989a)	20	Post smoking cue craving	1 item	Postquit	(4) 6 months postquit status	(4) y, r = .33
Payne et al. (2006)	62	Post smoking cue craving <sup>b</sup>	1 item	Prequit	(5) 3 months postquit status	(5) n, r = .28
Pomerleau et al.(2005)	67	Post smoking cue minus baseline <sup>c</sup>	1 item	Prequit <sup>d</sup>	(6) EOT status	(6) n
					(7) CPD 11 days postquit (8) days to lapse 11 days postquit (9) likelihood of quit	(7) n (8) n (9) n
Powell et al. (2010)	141	Post smoking cue minus post neutral cue	1 item	On TQD <sup>e</sup>	(10) 1 week (11) 1 month (12) 3 months postquit abstinence	(10) y, r = -.19 (11) y, r = -.22 (12) y, r = -.21
Shadel et al. (1998)	183	Post smoking cue minus baseline	1 item	Prequit	(13) 7 days (14) 14 days (15) 30 days postquit status	(13) n (14) n (15) n
Waters et al. (2004)	122	Post smoking cue craving	1 item	On TQD	(16) lapse 1 week postquit (17) time to first lapse	(16) y, OR = 1.24 (17) y, HR = 1.12
		Post smoking cue craving minus baseline			(18) lapse 1 week postquit (19) time to first lapse	(18) n, OR = 1.26 (19) n, HR = 1.10

Note. CPD = cigarettes per day; EOT = end of treatment; FTQ = Fagerström Tolerance Questionnaire; HR = hazard ratio; n = sample size; OR = odds ratio; r = correlation coefficient; TQD = target quit date.

<sup>a</sup>Effect sizes listed when they were able to be extracted from the article.

<sup>b</sup>Duration of deprivation from smoking, FTQ score, and baseline craving entered into the regression model before postcue craving.

<sup>c</sup>Analyses controlled for dependence, depression, and gender.

<sup>d</sup>Cue-reactivity trials followed 4 days mandatory abstinence but preceded participants' quit attempt.

<sup>e</sup>Required 12 hr overnight abstinence.

**Table 2. Studies That Examine the Relationship Between Prequit Craving and Treatment Outcome**

Article	n	Craving measure	Outcome measure	Significant craving–outcome association (y = yes, n = no <sup>a</sup> )
**al'Absi et al. (2004)	72	(1) 1 item (2) QSU-b1 (3) QSU-b2	1 week postquit status	(1) y (2) y (3) y
al'Absi et al. (2005)	72	(4) QSU-b1 (5) QSU-b2	Time to relapse 4 weeks post-TQD	(4) y, HR = 1.03 (5) y, HR = 1.03
**Allen et al. (2008b)	137	(6) 1 item (7) QSU-b1 (8) QSU-b2	Smoking status 30 days postquit	(6) n, r = .05 (7) n, r = .08 (8) n, r = .23
Allen et al. (2009)	38	1 item at: (9) waking (10) 1 hr postwaking (11) 10 a.m. (12) 8 p.m. (13) bedtime <sup>b</sup>	Time to relapse over 4 weeks postquit	(9) y (10) n (11) n (12) n (13) n
Bagot et al. (2007)	44	(14) QSU-b	11 weeks postquit status	(14) n, r = .16
Bailey et al. (2010)	301	(15) 2 items	52 weeks postquit status	(15) n
Dorner et al. (2011)	1076	1 item	Postquit status for those attending (16) 2 (17) 3 (18) 4 or (19) 5 tx sessions (time of assessment varied)	(16) n (17) n (18) y, OR = 1.01 (19) n
Killen et al. (2006)	362	2 items	(20) 11 weeks (21) 26 weeks (22) 52 weeks postquit status	(20) y, OR = 1.22 (21) y, OR = 1.27 (22) y, OR = 1.28
Persico (1992)	24	(23) 1 item	6 months postquit status	(23) n, r = .16
**McCarthy et al. (2008)	400	Random prompt craving (24) <sup>c</sup> 1 week before start of tx (25) 1 week prequit. Evening report craving (26) 1 week prequit	1 month postquit status	(24) n, OR = 1.03 (25) n, OR = 1.03 (26) n
Niaura et al. (2002)	76	(27) 1 item <sup>d</sup>	3 months postquit status	(27) n, OR = 1.09
Payne et al. (2006)	62	(28) 1 item	EOT status	(28) n
Powell et al. (2010)	141	1 item <sup>e</sup>	(29) 1 week (30) 1 month (31) 3 months postquit status	(29) n, r = .14 (30) n, r = .07 (31) n, r = .14
Raw and Russell (1980)	49	1 item	Consumption at (32) EOT (33) 1 year postquit	(32) y, r = .29 (33) n, r = .01
Shadel et al. (2011)	63	(34) 5 items	Time to relapse over 14 days postquit	(34) n, HR = 1.18
**Strong et al. (2011)	183	1 item (35) measured after 12 hr of abstinence (36) measured after <i>ad-lib</i> smoking	Time to relapse over 30 days postquit	(35) n (36) n
Van Gucht et al. (2010)	88	1 item	(37) TQD abstinence. Status (38) 1 (39) 2 (40) 6 (41) 12 months postquit	(37) n (38) n (39) n (40) n (41) n, r = .50
**Van Zundert et al. (2009)	126	2 items	(42) 3 weeks (43) 8 weeks postquit status	(42) y, OR = 1.59(43) n, OR = 1.10
Van Zundert et al. (2011)	149	5 items	(44) time to first lapse (45) time to relapse over 3 weeks postquit	(44) n, HR = 1.04(45) n, HR = 1.19
Zhou et al. (2009)	2,431	1 item (yes/no)	(46) postquit lapse over 18 months	(46) n, OR = 1.38

Note. \*\* = studies that include both pre- and postquit measures of craving; EOT = end of treatment; FTND = Fagerström Test for Nicotine Dependence; HR = hazard ratio; n = sample size; OR = odds ratio; QSU(-b,1,2) = Questionnaire on Smoking Urges (-brief, Factor 1, Factor 2); r = correlation coefficient; TQD = target quit date, tx = treatment.

<sup>a</sup>Effect sizes listed when they were able to be extracted from the article.

<sup>b</sup>All craving scores in this study control for baseline FTND score.

<sup>c</sup>Example items are provided in supplemental material but the number of craving items per assessment is unknown.

<sup>d</sup>Craving measured after a manipulation used to induce anxiety and after 1 hr abstinence.

<sup>e</sup>Craving measured after 12 hr of abstinence.

**Table 3. Studies That Examine the Relationship Between Postquit Craving and Treatment Outcome**

Article	n	Craving measure	Outcome measure	Significant craving–outcome association (y = yes, n = no) <sup>a</sup>
**al/Absi et al. (2004)	72	(1) 1 item (2) QSU-b1 (3) QSU-b2 <sup>b</sup>	1 week postquit status	(1) y (2) y (3) y
Allen et al. (2008a)	202	(4) 1 item (5) QSU 1 (6) QSU 2	1 week postquit status	(4) y, r = .23 (5) y, r = .34 (6) y, r = .28
**Allen et al. (2008b)	137	(7) 1 item (8) QSU 1 (9) QSU 2	30 days postquit status	(7) y, r = .27 (8) y, r = .35 (9) y, r = .40
Allen et al. (2010)	202	(10) 1 item QSU 1 QSU 2	30 days postquit status (11) 14 days (12) 30 days postquit status (13) 14 days (14) 30 days postquit status (15) amount smoked next day over 4 weeks postquit 4 weeks postquit status	(10) y, OR = 1.67 (11) y, OR = 1.88 (12) y, OR = 1.92 (13) y, OR = 1.78 (14) y, OR = 1.62 (15) y (16) n, r = -.01 (17) n, r = -.05 (18) n, r = -.004 (19) n, r = -.01 <sup>c</sup> (20) n, OR = 1.10 (21) n, OR = 1.12
Berkman et al. (2011)	27	1 item		
Businelle et al. (2010)	424	WSWS (16) urge (17) desire (18) thoughts (19) focus items	(20) 1 week (21) 2 weeks postquit continuous abstinence	
Castro et al. (2011)	424	WSWS craving items		
Cofta-Woerpel et al. (2011)	300	1 item	(22) lapse over 4 weeks postquit	(22) y
Cooney et al. (2007)	102	1 item	(23) <sup>d</sup> 14 days postquit status	(23) y, OR = 1.19
Doherty et al. (1995) <sup>e</sup>	215	5 items on day 1 postquit 5 items on day 7 postquit 5 items on day 14 postquit 5 items on day 30 postquit	(24) 7 days postquit status (25) 14 days postquit status (26) 30 days postquit status (27) 60 days postquit status	(24) y (25) y (26) n (27) y
Ferguson et al. (2006)	324	1 item (28) on TQD (29) over 6 weeks postquit	Status over 6 weeks postquit	(28) y, HR = 1.43 (29) y, HR = 1.65
Holt et al. (2011)	48	1 item	(30) lapse over 2 weeks post	(30) y, OR = 1.48
Javitz et al. (2011)	935	2 items	(31) 8 weeks (32) 6 months postquit status	(31) y, OR = 1.64 (32) y, OR = 1.54
Juliano et al. (2006)	67	3 items	(33) 2 weeks postquit status	(33) y, r = 0.27
Killen et al. (1992)	618	2 items	(34) 1 year (35) 2 years postquit status	(34) y, r = 0.18 (35) y, r = .15
Killen and Fortmann (1994)	521	2 items	(36) 12 months postquit status. Time to relapse (37) 30 days (38) 1 year postquit	(36) y, r = .21 (37) n (38) n
Killen and Fortmann (1997)	1,202 1,040	2 items <sup>g</sup>	12 months postquit (39) status (40) survival 12 months postquit (41) status (42) survival 12 months postquit (43) status (44) survival (45) 12 months postquit survival 4 weeks postquit status	(39) y, r = .10 (40) y (41) y, r = .17 (42) y (43) y, r = .17 (44) y (45) y, HR = 1.15 (46) n, OR = 1.10 (47) y, r = .12
Killen et al. (1999)	403 408	2 items		
**McCarthy et al. (2008)	400	(46) random prompt craving (47) evening report craving		
Norregaard et al. (1993)	289	1 item week 1 1 item week 2 1 item week 3 (58) 1 item week 2 (59) week 3	End of week (48) 1 (49) 3 (50) 6 (51) 12 status End of week (52) 3 (53) 6 (54) 12 status End of week (55) 3 (56) 6 (57) 12 status End of week 12 status (60) 1 week (61) EOT (62) 6 months postquit status	(48) y <sup>h</sup> (49) n (50) n (51) n (52) n (53) n (54) n (55) n (56) n (57) n (58) y (59) y (60) y, r = .34 (61) y, r = .25 (62) y, r = .27
Piper et al. (2008)	608	1 item		

(Continued)

Table 3. Continued

Article	<i>n</i>	Craving measure	Outcome measure	Significant craving–outcome association ( <i>y</i> = yes, <i>n</i> = no) <sup>a</sup>
Robinson et al. (2011)	111	(63) 1 item <sup>i</sup> (64) WSWS items	EOT status (10–14 days postquit)	(63) <i>n</i> (64) <i>n</i>
Segan and Borland (2011)	698	1 item	(65) 4 (66) 12 months postquit status	(65) <i>n</i> , <i>OR</i> = 1.60 (66) <i>n</i>
Shiffman et al. (1997)	214	(67–68) TQD waking urge (baseline urge covariate) (69–70) TQD random urge (baseline urge covariate) (71–72) TQD peak urge during temptation (baseline urge covariate) (73) post-TQD waking urge (74) post-TQD random assess urge (75) post-TQD peak urge during temptation	Subsequent lapse over 26 days postquit	(67) <i>n</i> , <i>HR</i> = 1.01 (68) <i>n</i> , <i>HR</i> = 1.01 (69) <i>n</i> , <i>HR</i> = 1.03 (70) <i>n</i> , <i>HR</i> = 1.05 (71) <i>n</i> , <i>HR</i> = 1.03 (72) <i>n</i> , <i>HR</i> = 1.06 (73) <i>y</i> , <i>HR</i> = 1.08 (74) <i>n</i> , <i>HR</i> = 1.06 (75) <i>n</i> , <i>HR</i> = 1.09
Shiffman (2008)	1,144	1 item (76) week 1 (77) week 2	Week 6 postquit status	(76) <i>y</i> (77) <i>y</i>
**Strong et al. (2011)	183	(78) 1 item	Time to relapse over 30 days postquit	(78) <i>y</i>
**Van Zundert et al. (2009)	126	2 WSWS items	(79) 3 weeks (80) 8 weeks postquit status	(79) <i>y</i> , <i>OR</i> = 1.69 (80) <i>n</i> , <i>OR</i> = 1.45
Waters et al. (2003)	158	1 item	(81) week 1 postquit status (82) time to first lapse over 3 months postquit	(81) <i>y</i> , <i>OR</i> = 1.75 (82) <i>y</i> , <i>HR</i> = 1.32
Westman et al. (1997)	159	(83) SJWSS craving subscale items on TQD (84) end of week 1 (85) week 2 postquit (86–91) individual SJWSS craving subscale items	6 months postquit status	(83) <i>y</i> , <i>OR</i> = 1.67 (84) <i>y</i> , <i>OR</i> = 1.67 (85) <i>y</i> , <i>OR</i> = 2.00 (86) <i>y</i> , <i>r</i> = .19 (87) <i>y</i> , <i>r</i> = .21 (88) <i>n</i> (89) <i>n</i> (90) <i>n</i> (91) <i>n</i>
West et al. (1989)	227	(92–94) 1 item week 1 (95–97) 1 item week 2 (98–100) 1 item week 3	Week 2 postquit status	(92) <i>y</i> , <i>r</i> = .22 (93) <i>y</i> , <i>r</i> = .29 (94) <i>n</i> , <i>r</i> = .12
			Week 3 postquit status	(95) <i>n</i> , <i>r</i> = .14 (96) <i>y</i> , <i>r</i> = .22 (97) <i>n</i> , <i>r</i> = .16
			Week 4 postquit status	(98) <i>n</i> , <i>r</i> = .05 (99) <i>n</i> , <i>r</i> = .11 (100) <i>n</i> , <i>r</i> = .08
Zelman et al. (1992)	126	1 item	(101) 1 month (102) 3 months (103) 6 months (104) 12 months postquit survival	(101) <i>y</i> (102) <i>y</i> (103) <i>y</i> (104) <i>y</i>

*Note.* \*\* = studies that include both pre- and postquit measures of craving; EOT = end of treatment; HR = hazard ratio; *n* = sample size; *OR* = odds ratio; QSU(-b,1,2) = Questionnaire on Smoking Urges (-brief, Factor 1, Factor 2); *r* = correlation coefficient; SJWSS = Shiffman–Jarvik Withdrawal Symptom Scale; TQD = target quit date; WSWS = Wisconsin Smoking Withdrawal Scale.

<sup>a</sup>Effect sizes listed when they were able to be extracted from the article.

<sup>b</sup>Collected after 24 hr abstinence.

<sup>c</sup>Both analyses controlled for age, education, employment status, gender, and income.

<sup>d</sup>Collected craving ratings in natural environment over 2 weeks postquit and used assessment most proximately preceding lapse.

<sup>e</sup>The 32% of participants who relapsed within the first 24 hr after quitting were not included in these analyses. Urge data for the reported analyses were collected from 147 participants who remained abstinent at day 7, 87 participants who remained abstinent at day 14, and 76 participants who remained abstinent at day 30.

<sup>f</sup>Analysis controlled for recording day, time of day, day × time, and baseline QSU score.

<sup>g</sup>Controlled for level of dependence.

<sup>h</sup>Analyses 48–57 included complete abstainers only; analyses 58–59 included complete abstainers and abstainers with slips.

<sup>i</sup>Craving ratings collected after smoking, neutral, positive mood, and negative mood cues collapsed into one craving score.

**Table 4. Studies That Examine the Relationship Between Change in Craving and Treatment Outcome**

Article	n	Craving measure	Change in craving	Outcome measure	Significant craving–outcome association (y = yes, n = no <sup>a</sup> )
Cofta-Woerpel et al. (2011)	300	1 item	(1) slope over first week postquit	Lapse 4 weeks postquit	(1) n
Doran et al. (2004)	45	QSU	(2) baseline to 48 hr postquit	Time to relapse 4 weeks postquit	(2) n
Hughes (1992)	178	1 item	(3) baseline to 2 days postquit	7 days postquit status	(3) n
			(4) baseline to 7 days postquit	14 days postquit status	(4) n
			(5) baseline to 14 days postquit	30 days postquit status	(5) n
			(6) baseline to 30 days postquit	180 days postquit status	(6) n
Javitz et al. (2011)	935	2 items	Slope of craving over 1 week postquit	(7) 8 weeks (8) 6 months postquit status	(7) y, OR = 1.30 (8) y, OR = 1.32
Kaufmann et al. (2004)	175	2 items	(9) 1 week prequit to 1 week postquit	6 months postquit	(9) y, OR = 1.49
Lerman et al. (2002)	426	2 items	(10) 1 week prequit to 1 week postquit	Abstinence <sup>b</sup>	(10) y, OR = 1.23
McCarthy et al. (2006)	70	2 items	(11) prequit to quit date	3 months postquit	(11) y <sup>c</sup> , OR = 2.38
McCarthy et al. (2008)	400	Random prompt craving	Change in craving (12) over first week of tx (13) 1 week prequit (14) over first week of quit attempt	1 month postquit status	(12) n, OR = 1.64 (13) n, OR = 1.83 (14) y, OR = 4.55
Piasecki et al. (2000)	159	Evening report craving	(15) postquit slope	Day 30 postquit status	(15) n
		6 items	(16) prototypical postquit change in craving vs. atypical trajectory		(16) y, OR = 3.93
Piper et al. (2011)	1,504	2 items	(17) change in craving from pre- to postquit	Cessation outcome 8 weeks postquit	(17) y, OR = 1.12
Robinson et al. (2011)	111	WSWS craving items	(18) postquit slope	EOT status (10–14 days postquit)	(18) y
Schnoll et al. (2011)	642	QSU-b	2 weeks prequit to 2 weeks postquit	Abstinence (19) 15 weeks (20) 27 weeks postquit	<sup>d</sup> (19) n, r = .02 (20) n, r = .01
Strong et al. (2011)	183	1 item	(21) postquit linear slope	Time to relapse over 30 days postquit	(21) y
Swan et al. (1996)	64	SJWSS craving items	(22) prequit (1 assessment) to postquit (5 assessments)	Time to relapse over 28 days postquit	(22) y, HR = 1.31
Tonnesen et al. (2003)	707	4 WSWS craving items	(23) prequit to 2 weeks postquit	Weeks 4–7 postquit status	(23) y <sup>e</sup>
Van Zundert et al. (2009)	126	2 WSWS craving items	Change in craving 1 week before quit	(24) 3 weeks (25) 8 weeks postquit status	(24) n, OR = 1.11 (25) n, OR = 1.11
			Change in craving over 3 weeks postquit	(26) 3 weeks (27) 8 weeks postquit status	(26) n, OR = 1.11 (27) n, OR = 1.52
Van Zundert et al. (2011)	149	2 WSWS craving items	Postquit increments in daily craving	(28) first lapse on subsequent day (29) relapse on subsequent day	(28) y, HR = 1.24 (29) y, HR = 1.57

Note. EOT = end of treatment; HR = hazard ratio; n = sample size; OR = odds ratio; QSU(-b) = Questionnaire on Smoking Urges (-brief); SJWSS = Shiffman–Jarvik Withdrawal Symptom Scale; tx = treatment; WSWS = Wisconsin Smoking Withdrawal Scale.

<sup>a</sup>Effect sizes listed when they were able to be extracted from the article.

<sup>b</sup>Analysis controlled for sex, treatment, and baseline level of nicotine dependence. Results were unclear as to whether follow up was at end of treatment or 6 months postquit.

<sup>c</sup>Analysis controlled for prequit craving levels and pre- and postquit growth.

<sup>d</sup>Age, gender, and level of dependence included as covariates in regression models.

<sup>e</sup>Analysis controlled for baseline craving, center, treatment group, and continuous abstinence during weeks 4–7.



reporting higher craving were 1.54 times greater than for those with lower craving. The average significant hazard ratio (HR) reported was  $HR = 1.31$  ( $n = 11$ ).

We also calculated average relationships across all analyses (weighted by sample size) by substituting 0.0 for correlation coefficients and 1.0 for ORs or HRs that were reported as non-significant with no corresponding statistic described. A total of 28 significant analyses could not be included in these data because significant associations were reported but analyses were not compatible with correlations, ORs, or HRs or because no corresponding statistics were reported. This approach generated average correlation coefficients of .10 ( $n = 88$ ), ORs of 1.35 ( $n = 55$ ), and HRs of 1.14 ( $n = 27$ ).

### Magnitude of Craving

Descriptive statistics reporting the mean score on craving measures taken before the quit attempt up through 1 week postcessation were extracted from papers when available. In order to compare ratings across studies, the mean craving rating was divided by the upper limit of the scale to arrive at a relative percentage of the scale. The average prequit craving score percentage was 48.9% ( $n = 19$ ) and the average postquit craving score percentage (over the first week of cessation) was 56.0% ( $n = 24$ ). Craving tended to be of approximately the same magnitude on the target quit date (TQD) as it was leading up to the quit date (47.9%;  $n = 5$ ), but was higher over the first 24 and 48 hr of cessation (56.0%,  $n = 2$ , and 63.2%,  $n = 5$ , respectively).

### What Is the Relationship Between Cue-Induced Craving and Treatment Outcome?

The relationship between cue-specific craving and treatment outcome was assessed by eight studies (median sample size = 65) in a number of ways (i.e., post smoking cue craving only, post smoking cue craving minus baseline craving, or post smoking cue craving minus post neutral cue craving). Nineteen analyses that fit study criteria were reported across these studies (see Table 1), with 13 (68%) indicating a lack of a significant relationship between cue-reactivity scores and cessation outcome.

The timing of the cue-reactivity procedure in relation to the quit attempt included assessments collected before, on, or after the TQD. Significant relationships between cue-induced craving and treatment outcome (6/19 analyses) were only obtained in studies that conducted the cue-reactivity part of the study on (Powell, Dawkins, West, Powell, & Pickering, 2011; Waters et al., 2004) or after (Niaura, Abrams, Monti, & Pedraza, 1989b) the TQD. Three analyses (all from the same study) reported a significant relationship between cue-induced craving and treatment outcome that was in the opposite direction from what would be expected (Powell et al., 2011) such that those who were *more* reactive to cues were less likely to relapse.

### What Is the Relationship Between Prequit General Craving and Treatment Outcome?

The relationship between general craving measured before the TQD and subsequent outcome was examined in 20 studies (median sample size = 107; see Table 2). Of these studies, 13 reported nonsignificant associations between craving and outcome, 3 found significant relationships, and 4 reported mixed

results. A total of 46 analyses were extracted from these 20 studies; of these, 34 (74%) reported a lack of association between craving and outcome, while 12 (26%) found a significant relationship. Of the studies that found a significant relationship between craving and outcome, 66% of the analyses used a multi-item craving measure. In contrast, only 26% of the studies reporting a nonsignificant relationship between prequit craving and outcome used a multi-item measure.

The time that craving was measured ranged from very proximal to the quit attempt (i.e., on the TQD just before the quit attempt was made) to up to 3 months before the TQD. A variety of treatment outcomes were assessed (e.g., abstinent vs. smoking, time to lapse, likelihood of lapse) over a wide range of timepoints (from as early as the TQD to as long as 1 year postquit). Overall, prequit craving did not appear to be tightly coupled to treatment outcome.

### What Is the Relationship Between Postquit Craving and Treatment Outcome?

The relationship between general craving assessed after a quit attempt and subsequent treatment outcome was examined in 31 studies (median sample size = 214) yielding a total of 104 analyses (see Table 3). Of these studies, 4 reported nonsignificant associations between craving and outcome, 19 found significant relationships, and 8 reported mixed results. Of these analyses, 62 (60%) reported a statistically significant relationship between craving and outcome and 42 (40%) reported nonsignificant results. Timing of the craving assessment in relation to participants' quit date ranged from as early as on the quit day up to 6 weeks after the cessation attempt. The time period during which treatment outcome was assessed also varied considerably within this subset of studies, ranging from the quit date to as long as 2 years postquit. Overall, postquit craving showed an inconsistent relationship with treatment outcome.

### Studies That Related Both Prequit and Postquit Craving to Outcome

Several studies assessed both pre- and postquit craving and related those measures to treatment outcome ( $k = 5$ ). Of this small group of studies, only one (al'Absi, Hatsukami, Davis, & Wittmers, 2004) reported a significant relationship between *both* pre- and postquit measures of craving and treatment outcome. The remaining studies reported mixed results; of note is that three of these four studies (Allen, Bade, Hatsukami, & Center, 2008b; McCarthy et al., 2008; Strong et al., 2011) found that postquit craving was significantly associated with cessation whereas prequit craving was not.

### Studies That Related Craving to Outcomes at Multiple Timepoints

Two studies reported mixed findings when relating a prequit measurement of craving to treatment outcome at multiple timepoints. In both studies, more proximal outcome assessments (1 week and 3 weeks post-TQD) were significantly associated with prequit craving when more distal outcome assessments (52 weeks and 8 weeks post-TQD) were not (Raw & Russell, 1980; Van Zundert, Boogerd, Vermulst, & Engels, 2009).

Much like the pattern seen with prequit craving and outcome assessed at different points in time, postquit craving

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appeared to be more strongly related to more proximal measures of treatment status (see Van Zundert et al., 2009, 3 weeks post-TQD status vs. 8 weeks post-TQD status; West, Hajek, & Belcher, 1989, week 2 post-TQD status vs. week 4 post-TQD status). These combined results suggest that craving may have stronger predictive validity for outcomes assessed more proximal to the quit attempt.

### What Is the Relationship Between Change in Craving and Treatment Outcome?

The relationship between change in craving and subsequent treatment outcome was assessed in 17 studies (median sample size = 178; see Table 4). Of the 29 analyses extracted from these studies, 15 (52%) indicated a nonsignificant relationship. Change in craving was most commonly defined as either (a) the slope of a participants' craving trajectory derived from multiple assessment points through hierarchical linear models or (b) a change score from craving at time A to craving at time B. Analyses that examined the relationship between craving slope (either before or after the quit attempt;  $n = 16$ ) demonstrated a significant relationship between craving slope and treatment outcome half the time. These studies reported that a faster decline in craving predicted abstinence. Of note is that change in *postquit* slope was found to be related to treatment outcome 66% of the time, while change in *prequit* slope was not found to be related to treatment outcome in any analysis (0/4). Analyses that defined change in craving as the difference from pre- to postquit also found a significant relationship between that change and treatment outcome about half of the time ( $n = 13$ , 46% significant). For example, larger increases in craving from pre- to postquit were significantly associated with shorter time to relapse (Swan, Ward, & Jack, 1996), and increases in craving from prequit to quit day were significantly and inversely associated with likelihood of abstinence (McCarthy, Piasecki, Fiore, & Baker, 2006).

## CONCLUSIONS

This is the first systematic evaluation of the literature assessing relationships between craving measured during smoking cessation studies and treatment outcomes. The results highlight why the nature of this relationship has been subject to debate—overall, three decades of research suggest craving and treatment outcome are significantly associated just about as often as they are unrelated. While these varied findings may appear to offset each other, it is worth noting that if there were no link between these variables, significant findings would only be expected to occur once for every 20 studies rather than for half of the studies.

Several themes emerged with regard to the conditions under which this association could be detected. The most salient condition appeared to be related to the timing of the craving assessment relative to the quit attempt. Analyses that used postquit general craving measures were more likely to find a relationship between craving and outcome than those using a prequit general craving measure. In addition, several studies that included both pre- and postquit assessments of craving found significant associations when using postquit (but not prequit) assessments.

## Findings Related to the Timing of Craving Assessment

There are several reasons why craving measures collected after as opposed to before the quit attempt may be more likely to predict treatment outcome. As participants in treatment studies are likely smoking at regular rates before attempting to quit, it is conceivable that they would be reporting low levels of general craving. Consequently, measurements of prequit craving may be subject to floor effects (e.g., Mash et al., 2000; O'Malley, Croop, Wroblewski, Labriola, & Volpicelli, 1995; Powell, 1995), which would make it difficult to detect significant relationships between craving and outcome. However, results from this review suggest that this was not the case; studies in which data were available indicate that the average prequit score on the craving measure was at approximately the midpoint (i.e., 47.5%) of the total possible score.

The quality and level of postquit craving may also have an impact on its predictive relationship with treatment outcome. Craving measured postquit may capture the experience of nicotine withdrawal, and thus may be stronger in magnitude and/or qualitatively different than prequit levels of craving. The idea that stronger craving is more likely to be associated with drug seeking and consumption has been posited in at least one theory of addiction (Baker, Morse, & Sherman, 1987), and craving reflecting nicotine withdrawal may be more tightly coupled to relapse. Studies examining the trajectory of craving after the initiation of a quit attempt indicate that both frequency and intensity of craving typically spike (i.e., increases from prequit levels) during the first few days of a quit attempt followed by a subsequent decline (Doherty, Kinnunen, Militello, & Garvey, 1995; Shiffman, 2008; Shiffman & Jarvik, 1976; Van Zundert et al., 2009). This profile mirrors the pattern of craving ratings reported in this review, with the magnitude of craving increasing over the first 48 hr postquit.

Beyond potential differences in craving magnitude, substantial intraindividual variability in levels and patterns of postquit craving has been demonstrated (Kavanagh et al., 2005; McCarthy et al., 2006; Piasecki et al., 2000). Thus, there may be a greater opportunity for the craving–relapse association to be detected after the quit attempt due to increased variability of scores on craving measurements over the postquit period.

Methodological considerations may also account for why postquit craving was more consistently related to outcomes than prequit craving. Because the stability of the relationship between craving and outcome is likely affected by the passage of time, postquit measures may have a stronger relationship with outcome than prequit measures of craving as they were collected more closely in time to outcome data. Notably, among studies that reported both pre- and postquit craving, there was no instance of a significant relationship between prequit craving and cessation status when postquit craving was not found to be associated significantly with outcome. A second methodological consideration is the sample size used across different types of studies. While the median sample size of studies measuring postquit craving was 214, those that measured prequit craving reported a median sample size of 107.

### The Relationship Between Cue-Specific Craving and Treatment Outcome

Craving measured within cue-reactivity studies evinced a weak association with treatment outcome. Three of the eight cue-reactivity studies did, however, report significant relationships

between craving in response to smoking-related cues and subsequent smoking status. This finding is in contrast to claims that no study has presented results in support of any significant association between cue-specific craving and treatment outcome (e.g., Perkins, 2009), and suggests that cue-specific craving has the potential to predict drug use behavior. It may be that cue-specific craving is not tightly coupled to treatment outcome; alternatively, the mixed results may be explained by differences across studies in how cue reactivity was defined and the way in which craving was measured.

Cue-specific craving is generally conceptualized as craving experienced after the presentation of a drug-related cue minus some control for general levels of craving (either baseline levels or response after the presentation of a neutral cue; Sayette, Griffin, & Sayers, 2010). Despite this, four of the studies in this review that purported to measure cue-reactivity related postcue craving to treatment outcome without accounting for general craving or craving reported after a neutral cue (see Table 1). Further, although the most sensitive measure of cue-specific craving may be the difference in craving between a smoking and a neutral cue (Carter & Tiffany, 1999), only one study (Powell, Dawkins, West, Powell, & Pickering, 2010) used methods consistent with this definition. Before firm conclusions can be drawn regarding the relationship between cue-induced craving and treatment outcome, further research that employs a measurement model consistent with how cue reactivity is currently conceptualized is necessary.

The measurement of cue reactivity extends beyond the methodological question of how to quantify cue-specific craving. As craving has been shown to change over time and settings, an important consideration when relating craving to outcomes is whether a state or trait measure is desired (Tiffany & Wray, 2012). Each of the cue-reactivity studies included in this review related a state measure of craving (i.e., a measurement taken at one point in time) to subsequent treatment outcome. However, if the question of interest is whether drug users who are generally more reactive to cues are more likely to have difficulty quitting, it seems as though a more stable (trait) measurement would be appropriate. Trait measures of cue-specific craving may require estimates aggregated across multiple cue-reactivity assessment sessions and settings.

A third methodological consideration that may account for the weak relationship between craving measured within cue-reactivity studies and outcome involves the craving assessment. Significant associations between cue-induced craving and treatment outcome were restricted to studies that measured craving on or after the day participants attempted abstinence, which suggests the predictive validity of cue-induced craving may be strongest at times most proximal to the quit attempt. This pattern of results is consistent with the findings that general levels of postquit craving were more closely associated with outcome than prequit craving.

### Assessment of the Relationship Between Craving and Treatment Outcome

Several design issues may have impeded the detection of a craving-relapse relationship in the reviewed research. When we considered average correlations across all studies by assigning 0.0 to unreported nonsignificant associations, the average coefficient was .10; a sample size of 779 would be required to detect a significant effect size of this magnitude. Even in the

best case scenario, the average significant correlation reported between craving and treatment outcome was .19, which would require a sample size of 212 to detect a significant association at this level. None of the cue-reactivity studies included in this review (which reported an average sample size of 87) and fewer than half of studies in this review overall included a sample size of at least 212.

The way in which craving was assessed may have also prevented detection of a consistent association between urge and treatment outcome. Fewer than half of the analyses (39%; see Tables 1–4) used a multi-item assessment to measure craving. Further, none of the cue-reactivity studies used a craving assessment with more than a single item. Single-item assessment of craving is less reliable than multi-item measurement (Tiffany & Wray, 2012), and the inconsistent association between craving and relapse has previously been attributed to psychometric limitations in craving assessment (Ooteman, Koeter, Versheul, Schippers, & van den Brink, 2006; Sayette et al., 2000).

Finally, the way in which cessation success was measured may have made the detection of significant relationships between craving and outcome difficult. Most analyses were based on dichotomous outcome measures (i.e., abstinent or not abstinent) at each follow-up timepoint. Only 49 of the 203 analyses (24%) used a continuous measure of treatment outcome. Continuous data allow for more powerful statistical analysis, which may be critical in explicating the relationships between predictor variables (including craving) and treatment outcome (Steketee & Chambless, 1992).

### Theoretical Implications of the Relationships Between Craving and Smoking Cessation Outcome

The patterns of relationships between craving and treatment outcome discussed in this review have important theoretical implications. Many theories of addiction make explicit predictions about the role of craving in drug-seeking and drug-taking behavior. One view of the craving-relapse relationship holds that craving is a necessary condition of relapse. For example, Robinson and Berridge's (1993, 2003) incentive-sensitization model posits that "addicts develop an obsessive craving for drugs, a craving that is so irresistible that it almost inevitably leads to drug seeking and drug taking" (Robinson & Berridge, 1993, p. 248). The model also suggests that conditioned stimuli (i.e., drug cues) elicit craving and thus should promote relapse.

Other theories suggest that craving may occur before a drug use episode, but that it does not necessarily need to be present. Tiffany's (1990) cognitive processing model hypothesizes that separate processes underlie craving and drug use behavior. While craving is viewed as being regulated by nonautomatic, controlled processes, drug use behavior in the experienced user is thought to be driven by automatic processes. As such, this model predicts that drug use can occur in the absence of desire or urge for the drug, which is consistent with the findings of the current review (i.e., a great deal of variance in factors that may precipitate drug use may be explained by factors other than craving).

Finally, Kavanagh et al.'s (2005) elaborated intrusion theory of desire also holds that a modest relationship should exist between craving and drug use. This theory predicts when and under which conditions craving and relapse are most likely to be associated. For example, according to the theory, the extent to which craving and relapse are associated is moderated by a

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number of factors, including attention diversion, the presence of other powerful incentives, mood, and self-efficacy.

The conclusions presented in this review can guide the refinement and evaluation of these and other models of addictive behavior. Results suggest that general craving was inconsistently related to smoking relapse, and even in cases where significant results were found, the magnitude of the association was small. As such, data from the smoking literature do not support models that view craving and relapse as inseparable. Further, the next generation of addiction theories should be able to make reliable predictions about when and under which conditions craving and relapse are likely to be associated.

### Clinical Implications of the Relationships Between Craving and Smoking Cessation Outcome

In clinical trials, the reduction of craving is often identified as an aim of the intervention with the assumption that craving reduction will reduce risk of relapse. For example, psychosocial interventions often include techniques on how to manage, reduce, or avoid drug craving (Anton 1999; Drummond et al. 2000), and pharmacological interventions across all drugs of abuse are often hypothesized to be effective through a reduction in craving (Lowman et al., 2000). However, most of the studies in this review that included a formal treatment component did not report analyses to address the question of whether or not treatment affected craving. In addition, the idea that craving is the mechanism through which treatment influences outcome is often assumed but rarely tested.

Results of this review suggest that a craving–outcome link cannot be assumed; thus if this relationship is of interest, it should be examined statistically. We identified more than 100 treatment studies that measured both craving and treatment outcome but did not report analyses linking the two variables, indicating that many studies collect data that can answer many basic question regarding associations between these variables. Further, only 3 of the 62 studies included in this review (Ferguson et al., 2006; McCarthy et al., 2008; Piper et al., 2008) tested the hypothesis that craving was the mechanism through which treatment had an effect on outcome (i.e., via mediation analyses). Each of these studies found evidence of at least partial mediation (i.e., nicotine replacement therapy or bupropion reduced craving, which led to positive effects on treatment outcome); however, McCarthy et al. (2008) reported that randomly sampled craving mediated this relationship, while craving assessed at a single (evening) timepoint did not.

The studies reviewed here also speak to the prognostic utility of craving for cigarettes. The current state of the literature suggests that the ability of craving to predict outcome may be limited. This pattern is not unlike some candidate variables (e.g., the ability of nicotine dependence as assessed by the FTND to predict relapse has not been consistent across studies, Baker et al., 2007). However, the magnitude of the craving–outcome association may not be as strong as is seen with other variables (e.g., self-efficacy has demonstrated a small to moderately sized relationship with outcome, Gwaltney, Metrik, Kahler, & Shiffman, 2009).

The large number of studies that did find support for a significant association between craving and treatment outcome indicates that, at least under certain conditions, this relationship is present. The potential for craving as a prognostic indicator of subsequent status may rest on our ability to determine

the most appropriate way to assess this relationship (Tiffany et al., 2009; Tiffany & Wray, 2012). Some candidate moderators that emerged in this review include the timing of the craving assessment, the number of items used, and the proximity of the craving–relapse measurements. Future research examining these and other moderators of the relationship between craving and treatment outcome is recommended to elucidate the conditions under which craving might be used as a prognostic indicator of treatment success. A final consideration that may be critical in evaluating the relationship between craving and relapse is that craving that occurs as part of a high-risk situation may be a much stronger predictor of whether or not someone smokes under those circumstances than craving assessed more distally to that episode. There are very few studies that evaluate the immediate consequences of craving prospectively, so the literature may underestimate the impact of craving on the probability of relapse.

### Limitations and Future Directions

Several limitations of the current study should be noted. First are those that are inherent in conducting a literature review, including the possibility that not all published articles that include the information of interest were located. Although this scenario is plausible, the conclusions drawn in this review are based on a large number of analyses extracted from the treatment literature, and it is unlikely that a few missing studies would radically change these results. Publication bias in the form of studies that find null effects going unpublished may have skewed the findings (i.e., the file drawer problem). However, given the large number of articles that did report a lack of association between craving and treatment outcome, it appears that numerous articles of this type have been published. An additional consideration is that this project was restricted to cigarette smokers seeking cessation treatment. Therefore, the generalization of the findings to craving–relapse relationships in situations of self-initiated cessation or across other drugs of abuse should be approached cautiously. This review did not examine many of the candidate moderators between craving and outcome, such as the potential impact of abstinence on craving ratings or the type of treatment administered.

Important limitations in the research to date relating craving and treatment outcome may be hindering the detection of this association. While the current state of the literature suggests a weak and inconsistent relationship between craving and treatment outcome, many of the studies reporting these findings may not have been designed adequately to detect this relationship. Future studies reporting analyses linking these variables must recruit a sufficient sample size and should assess craving at various timepoints around the quit attempt using multi-item assessment measures. Further, treatment outcome should be assessed at timepoints both proximal and distal to the quit attempt, and continuous measures of outcome should be used when possible. Future research might use meta-analytic techniques to examine subsets of the studies included in this review to focus on only those studies that used equivalent outcome measures and data analytic strategies (e.g., only including studies that used ORs or HRs).

The overall results suggest that, while desire to smoke and cessation status were related significantly in approximately half of the reported analyses, craving was not tightly and reliably coupled with treatment outcome. Future research would

benefit from the exploration of the moderators discussed in this review to determine the conditions under which craving may offer predictive utility. Theories of addiction that address craving must take the mixed relationship between craving and relapse into account and should be able to predict when and under what conditions significant associations should be observed. Finally, when discussing associations between craving and treatment outcome, researchers should be careful to accurately portray the strength of the relationship.

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## DECLARATION OF INTERESTS

None declared.

## REFERENCES

References marked with \* indicate studies included in this review

- \*Abrams, D. B., Monti, P. M., Carey, K. B., Pinto, R. P., & Jacobus, S. I. (1988). Reactivity to smoking cues and relapse: Two studies of discriminant validity. *Behavioural Research and Therapy*, *26*, 225–233. doi:10.1016/0005-7967(88)90003-4
- \*al'Absi, M., Hatsukami, D., & Davis, G. L. (2005). Attenuated androcorticotropic responses to psychological stress are associated with early smoking relapse. *Psychopharmacology*, *181*, 107–117. doi:10.1007/s00213-005-2225-3
- \*al'Absi, M., Hatsukami, D., Davis, G. L., & Wittmers, L. E. (2004). Prospective examination of effects of smoking abstinence on cortisol and withdrawal symptoms as predictors of early smoking relapse. *Drug and Alcohol Dependence*, *73*, 267–278. doi:10.1016/j.drugalcdep.2003.10.014
- \*Allen, A. M., Allen, S. S., Lunos, S., & Pomerleau, C. S. (2010). Severity of withdrawal symptomatology in follicular versus luteal quitters: The combined effects of menstrual phase and withdrawal on smoking cessation outcome. *Addictive Behaviors*, *35*, 549–552. doi:10.1016/j.addbeh.2010.01.003
- \*Allen, A. M., Allen, S. S., Widenmier, J., & al'Absi, M. (2009). Patterns of cortisol and craving by menstrual phase in women attempting to quit smoking. *Addictive Behaviors*, *34*, 632–635. doi:10.1016/j.addbeh.2009.03.024
- \*Allen, S. S., Bade, T., Center, B., Finstad, D., & Hatsukami, D. (2008a). Menstrual phase effects on smoking relapse. *Addiction*, *103*, 809–821. doi:10.1111/j.1360-0443.2008.02146.x
- \*Allen, S. S., Bade, T., Hatsukami, D., & Center, B. (2008b). Craving, withdrawal, and smoking urges on days immediately prior to smoking relapse. *Nicotine & Tobacco Research*, *10*, 35–45. doi:10.1080/14622200701705076
- Anton, R. F. (1999). What is craving? Models and implications for treatment. *Alcohol Research & Health*, *23*, 165–173. Retrieved from <http://pubs.niaaa.nih.gov>
- \*Bagot, K. S., Heishman, S. J., & Moolchan, E. T. (2007). Tobacco craving predicts lapse to smoking among adolescent smokers in cessation treatment. *Nicotine & Tobacco Research*, *9*, 647–652. doi:10.1080/14622200701365178
- \*Bailey, S. R., Hammer, S. A., Bryson, S. W., Schatzberg, A. F., & Killen, J. D. (2010). Using treatment process data to predict maintained smoking abstinence. *American Journal of*

- Health Behavior*, *34*, 801–810. Retrieved from <http://www.ncbi.nlm.nih.gov/pubmed>
- Baker, T. B., Morse, E., & Sherman, J. E. (1987). The motivation to use drugs: A psychobiological analysis of urges. In P. C. Rivers (Ed.), *The Nebraska symposium on motivation: Alcohol and addictive behavior* (pp. 257–323). Lincoln, NE: University of Nebraska Press.
- Baker, T. B., Piper, M. E., McCarthy, D. E., Bolt, D. M., Smith, S. S., Kim, S. Y., & Toll, B. A. (2007). Time to first cigarette in the morning as an index of ability to quit smoking: Implications for nicotine dependence. *Nicotine & Tobacco Research*, *9*(Suppl. 4), S555–S570. doi:10.1080/14622200701673480
- \*Berkman, E. T., Dickenson, J., Falk, E. B., & Lieberman, M. D. (2011). Using SMS text messaging to assess moderators of smoking reduction: Validating a new tool for ecological measurement of health behaviors. *Health Psychology*, *30*, 186–194. doi:10.1037/a0022201
- \*Businelle, M. S., Kendzor, D. E., Reitzel, L. R., Costello, T. J., Cofta-Woerpel, L., Li, Y., ... Wetter, D. W. (2010). Mechanisms linking socioeconomic status to smoking cessation: A structural equation modeling approach. *Health Psychology*, *29*, 262–273. doi:10.1037/a0019285
- Carter, B. L., & Tiffany, S. T. (1999). Meta-analysis of cue-reactivity in addiction research. *Addiction*, *94*, 327–340. doi:10.1046/j.1360-0443.1999.9433273.x
- \*Castro, Y., Kendzor, D., Businelle, M., Mazas, C., Cofta-Woerpel, L., Cinciripini, P., & Wetter, D. (2011). Structural and predictive equivalency of the Wisconsin Smoking Withdrawal Scale across three racial/ethnic groups. *Nicotine & Tobacco Research*, *13*, 548–555. doi:10.1093/ntr/ntr039
- \*Cofta-Woerpel, L., McClure, J. B., Li, Y., Urbauer, D., Cinciripini, P. M., & Wetter, D. W. (2011). Early cessation success or failure among women attempting to quit smoking: Trajectories and volatility of urge and negative mood during the first postcessation week. *Journal of Abnormal Psychology*, *120*, 596–606. doi:10.1037/a0023755
- Cohen, J. (1992). A power primer. *Psychological Bulletin*, *112*, 155–159. doi:10.1037/0033-2909.112.1.155
- \*Cooney, N. L., Litt, M. D., Cooney, J. D., Pilkey, D. T., Steinberg, H. R., & Oncken, C. A. (2007). Alcohol and tobacco cessation in alcohol dependent smokers: Analysis of real time reports. *Psychology of Addictive Behaviors*, *21*, 277–286. doi:10.1037/0893-164X.21.3.277
- Deeks, J. J., Higgins, J. P. T., & Altman, D. G. (2008). Chapter 9: Analysing data and undertaking meta-analyses. In J. P. T. Higgins and S. Green (Eds.), *Cochrane handbook for systematic reviews of interventions. Version 5.0.1 [updated September 2008]* (pp. 9.1–9.43). Chichester, UK: The Cochrane Collaboration, John Wiley & Sons Ltd.
- \*Doherty, K., Kinnunen, T., Militello, F. S., & Garvey, A. J. (1995). Urges to smoke during the first month of abstinence: Relationship to relapse and predictors. *Psychopharmacology*, *119*, 171–178. doi:10.1007/BF02246158
- \*Doran, N., Spring, B., McChargue, D., Pergadia, M., & Richmond, M. (2004). Impulsivity and smoking relapse. *Nicotine & Tobacco Research*, *6*, 641–647. doi:10.1080/14622200410001727939
- \*Dorner, T., Tröstl, A., Womastek, I., & Groman, E. (2011). Predictors of short-term success in smoking cessation in relation to attendance at a smoking cessation program. *Nicotine & Tobacco Research*, *13*, 1068–1075. doi:10.1093/ntr/ntr179
- Drummond, D. C. (2001). Theories of drug craving, ancient and modern. *Addiction*, *96*, 33–46. doi:10.1046/j.1360-0443.2001.961333.x
- Drummond, D. C., Litten, R. Z., Lowman, C., & Hunt, W. A. (2000). Craving research: Future directions. *Addiction*, *95*(Suppl. 2), 247–255. doi:10.1046/j.1360-0443.95.8s2.13.x

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- Durcan, M. J., Deener, G., White, J., Johnston, J. A., Gonzales, D., Niaura, R., ... Sachs, D. P. L. (2002). The effect of bupropion sustained-release on cigarette craving after smoking cessation. *Clinical Therapeutics*, *24*, 540–551. doi:10.1016/S0149-2918(02)85130-X
- Ferguson, S. G., & Shiffman, S. (2009). The relevance and treatment of cue-induced cravings in tobacco dependence. *Journal of Substance Abuse Treatment*, *36*, 235–243. doi:10.1016/j.jsat.2008.06.005
- \*Ferguson, S. G., Shiffman, S., & Gwaltney, C. J. (2006). Does reducing withdrawal severity mediate nicotine patch efficacy? A randomized clinical trial. *Journal of Consulting and Clinical Psychology*, *74*, 1153–1161. doi:10.1037/0022-006X.74.6.1153
- Gwaltney, C. H., Metrik, J., Kahler, C. W., & Shiffman, S. (2009). Self-efficacy and smoking cessation: A meta-analysis. *Psychology of Addictive Behaviors*, *23*, 56–66. doi:10.1037/a0013529
- Heatherington, T. F., Kozlowski, L. T., Frecker, R. C., & Fagerström, K. O. (1991). The Fagerström Test for Nicotine Dependence: A revision of the Fagerström Tolerance Questionnaire. *British Journal of Addiction*, *86*, 1119–1127. doi:10.1111/j.1360-0443.1991.tb01879.x
- \*Holt, L. J., Litt, M. D., & Cooney, N. L. (2011). Prospective analysis of early lapse to drinking and smoking among individuals in concurrent alcohol and tobacco. doi:10.1037/a0026039
- \*Hughes, J. R. (1992). Tobacco withdrawal in self-quitters. *Journal of Consulting and Clinical Psychology*, *60*, 689–697. doi:10.1037/0022-006X.60.5.689
- Hughes, J. R. (2010). Craving among long-abstinent smokers: An internet survey. *Nicotine & Tobacco Research*, *12*, 459–462. doi:10.1093/ntr/ntq009
- \*Javitz, H., Swan, G., & Lerman, C. (2011). The dynamics of the urge-to-smoke following smoking cessation via pharmacotherapy. *Addiction*, *106*, 1835–1845. doi:10.1111/j.1360-0443.2011.03495.x
- \*Juliano, L. M., Houtsmuller, E. J., & Stitzer, M. L. (2006). A preliminary investigation of rapid smoking as a lapse-responsive treatment for tobacco dependence. *Experimental and Clinical Psychopharmacology*, *14*, 429–438. doi:10.1037/1064-1297.14.4.429
- Kassel, J. D., & Shiffman, S. (1992). What can hunger teach us about drug craving? A comparative analysis of the two constructs. *Advances in Behaviour Research and Therapy*, *14*, 141–167. doi:10.1016/0146-6402(92)90006-A
- \*Kaufmann, V., Jepson, C., Rukstalis, M., Perkins, K., Audrain-McGovern, J., & Lerman, C. (2004). Subjective effects of an initial dose of nicotine nasal spray predicts treatment outcome. *Psychopharmacology*, *172*, 271–276. doi:10.1007/s00213-003-1659-8
- Kavanagh, D. J., Andrade, J., & May, J. (2005). Imaginary relish and exquisite torture: The elaborated intrusion theory of desire. *Psychological Review*, *112*, 446–467.
- \*Killen, J. D., & Fortmann, S. P. (1994). Role of nicotine dependence in smoking relapse: Results from a prospective study using population-based recruitment methodology. *International Journal of Behavioral Medicine*, *1*, 320–334. doi:10.1037/0022-006X.60.5.797
- \*Killen, J. D., & Fortmann, S. P. (1997). Craving is associated with smoking relapse: Findings from three prospective studies. *Experimental & Clinical Psychopharmacology*, *5*, 137–142. doi:10.1037/1064-1297.5.2.137
- \*Killen, J. D., Fortmann, S. P., Davis, L., Strausberg, L., & Varady, A. (1999). Do heavy smokers benefit from higher dose nicotine patch therapy? *Experimental and Clinical Psychopharmacology*, *7*, 226–233. doi:10.1037/1064-1297.7.3.226
- \*Killen, J. D., Fortmann, S. P., Kraemer, H. C., Varady, A., & Newman, B. (1992). Who will relapse? Symptoms of nicotine dependence predict long-term relapse after smoking cessation. *Journal of Consulting and Clinical Psychology*, *60*, 797–801. doi:10.1037/0022-006X.60.5.797
- \*Killen, J. D., Fortmann, S. P., Murphy, G. M., Hayward, C., Arredondo, C., Crompton, D., ... Schatzberg, A. F. (2006). Extended treatment with bupropion SR for cigarette smoking cessation. *Journal of Consulting and Clinical Psychology*, *74*, 286–294. doi:10.1037/0022-006X.74.2.286
- \*Lerman, C., Shields, P. G., Wileyto, E. P., Audrain, J., Pinto, A., Hawk, L., ... Epstein, L. (2002). Pharmacogenetic investigation of smoking cessation treatment. *Pharmacogenetics*, *12*, 627–634. doi:10.1097/00008571-200211000-00007
- Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. Thousand Oaks, CA: Sage. ISBN:0-7619-2168-0
- Lowman, C., Hunt, W. A., Litten, R. Z., & Drummond, D. C. (2000). Research perspectives on alcohol craving: An overview. *Addiction*, *95*, 45–54. doi:10.1046/j.1360-0443.95.8s2.14.x
- Marlatt, G. A. (1985). Relapse prevention. Theoretical rationale and overview of the model. In G. A. Marlatt & J. R. Gordon (Eds.), *Relapse prevention* (pp. 250–280). New York, NY: Guilford Press.
- Mash, D. C., Kovera, C., Pablo, J., Tyndale, R. F., Ervin, F. D., Williams, I. C., ... Mayor, M. (2000). Ibogaine: Complex pharmacokinetics, concerns for safety, and preliminary efficacy measures. *Annals of the New York Academy of Sciences*, *914*, 394–401. doi:10.1111/j.1749-6632.2000.tb05213.x
- \*McCarthy, D. E., Piasecki, T. M., Fiore, M. C., & Baker, T. B. (2006). Life before and after quitting smoking: An electronic diary study. *Journal of Abnormal Psychology*, *115*, 454–466. doi:10.1037/0021-843X.115.3.454
- \*McCarthy, D. E., Piasecki, T. M., Lawrence, D. L., Jorenby, D. E., Shiffman, S., & Baker, T. B. (2008). Psychological mediators of bupropion sustained-release treatment for smoking cessation. *Addiction*, *103*, 1521–1533. doi:10.1111/j.1360-0443.2008.02275.x
- Mezinskas, J. P., Honos-Webb, L., Kropp, F., & Somoza, E. (2001). The measurement of craving. *Journal of Addictive Diseases*, *20*, 67–81. doi:10.1300/J069v20n03\_07
- \*Niaura, R., Abrams, D., Demuth, B., Pinto, R., & Monti, P. (1989a). Responses to smoking-related stimuli and early relapse to smoking. *Addictive Behaviors*, *14*, 419–428. doi:10.1016/0306-4603(89)90029-4
- Niaura, R., Abrams, D. B., Monti, P. M., & Pedraza, M. (1989b). Reactivity to high risk situations and smoking cessation outcome. *Journal of Substance Abuse*, *1*, 393–405.
- \*Niaura, R., Shadel, W. G., Britt, D. M., & Abrams, D. B. (2002). Responses to social stress, urge to smoke, and smoking cessation. *Addictive Behaviors*, *27*, 241–250. doi:10.1016/S0306-4603(00)00180-5
- \*Norregaard, J., Tonnesen, P., & Petersen, L. (1993). Predictors and reasons for relapse in smoking cessation with nicotine and placebo patches. *Preventive Medicine*, *22*, 261–271. doi:10.1006/pmed.1993.1021
- O'Malley, S. S., Croop, R. S., Wroblewski, J. M., Labriola, D. F., & Volpicelli, J. R. (1995). Naltrexone in the treatment of alcohol dependence: A combined analysis of two trials. *Psychiatric Annals*, *25*, 681–688.
- Ooteman, W., Koeter, M. W. J., Vserheul, R., Schippers, G. M., & van den Brink, W. (2006). Measuring craving: An attempt to connect subjective craving with cue reactivity. *Alcoholism: Clinical and Experimental Research*, *30*, 57–69. doi:10.1016/j.euroneuro.2007.02.012
- Orleans, C. T., Rimer, B. K., Cristinzio, S., Keintz, M. K., & Fleisher, L. (1991). A national survey of older smokers: Treatment needs for a growing population. *Health Psychology*, *10*, 343–351. doi:10.1037/0278-6133.10.5.343

- \*Payne, T. J., Smith, P. O., Adams, S. G., & Diefenbach, L. (2006). Pretreatment cue reactivity predicts end-of-treatment smoking. *Addictive Behaviors, 31*, 702–710. doi:10.1016/j.addbeh.2005.05.053
- Perkins, K. (2009). Does smoking cue-induced craving tell us anything important about nicotine dependence? *Addiction, 104*, 1610–1616. doi:10.1111/j.1360-0443.2009.02550.x
- Perkins, K. (2012). Subjective reactivity to smoking cues as a predictor of quitting success. *Nicotine & Tobacco Research, 14*, 383–387. doi:10.1093/ntr/ntr229
- \*Persico, A. M. (1992). Predictors of smoking cessation in a sample of Italian smokers. *The International Journal of the Addictions, 27*, 683–695. doi:10.3109/10826089209068760
- \*Piasecki, T. M., Niaura, R., Shadel, W. G., Abrams, D., Goldstein, M., Fiore, M. C., & Baker, T. B. (2000). Smoking withdrawal dynamics in unaided quitters. *Journal of Abnormal Psychology, 109*, 74–86. doi:10.1037/0021-843X.109.1.74
- \*Piper, M. E., Federman, E. B., McCarthy, D. E., Bolt, D. M., Smith, S. S., Fiore, M., & Baker, T. B. (2008). Using mediation models to explore the nature of tobacco motivation and tobacco treatment effects. *Journal of Abnormal Psychology, 117*, 94–105. doi:10.1037/0021-843X.117.1.94
- \*Piper, M. E., Schlam, T. R., Cook, J. W., Sheffer, M. A., Smith, S. S., Loh, W., ... Baker, T. B. (2011). Tobacco withdrawal components and their relations with cessation success. *Psychopharmacology, 216*, 569–578. doi:10.1007/s00213-011-2250-3
- \*Pomerleau, O. F., Pomerleau, C. S., Mehringer, A. M., Snedecor, S. M., Ninowski, R., & Sen, A. (2005). Nicotine dependence, depression, and gender: Characterizing phenotypes based on withdrawal discomfort, response to smoking, and ability to abstain. *Nicotine & Tobacco Research, 7*, 91–102. doi:10.1080/14622200412331328466
- Powell, J. (1995). Conditioned responses to drug-related stimuli: Is context crucial? *Addiction, 90*, 1089–1095. doi:10.1046/j.1360-0443.1995.90810897.x
- Powell, J., Dawkins, L., West, R., Powell, J., & Pickering, A. (2010). Relapse to smoking during unaided cessation: Clinical, cognitive, and motivational predictors. *Psychopharmacology, 212*, 537–549. doi:10.1007/s00213-010-1975-8
- \*Powell, J., Dawkins, L., West, R., Powell, J., & Pickering, A. (2011). Erratum to: Relapse to smoking during unaided cessation: Clinical, cognitive and motivational predictors. *Psychopharmacology, 215*, 607. doi:10.1007/s00213-011-2300-x
- \*Raw, M., & Russell, M. A. H. (1980). Rapid smoking, cue exposure and support in the modification of smoking. *Behaviour Research & Therapy, 18*, 363–372. doi:10.1016/0005-7967(80)90001-7
- Robinson, T. E., & Berridge, K. C. (1993). The neural basis of drug craving: An incentive-sensitization theory of addiction. *Brain Research Reviews, 18*, 247–291. doi:10.1016/0165-0173(93)90013-P
- Robinson, T. E., & Berridge, K. C. (2003). Addiction. *Annual Review of Psychology, 54*, 25–53. doi:10.1146/annurev.psych.54.101601.145237
- \*Robinson, J. D., Lam, C. Y., Carter, B. L., Minnix, J. A., Cui, Y., Versace, F., ... Cinciripini, P. M. (2011). A multimodal approach to assessing the impact of nicotine dependence, nicotine abstinence, and craving on negative affect in smokers. *Experimental and Clinical Psychopharmacology, 19*, 40–52. doi:10.1037/a0022114
- Rohsenow, D. J., & Monti, P. M. (1999). Does urge to drink predict drinking after treatment? *Alcohol Research and Health, 23*, 225–232. Retrieved from <http://pubs.niaaa.nih.gov>
- Sayette, M. A., Griffin, K. M., & Sayers, W. M. (2010). Counterbalancing in smoking research: A critical analysis. *Nicotine & Tobacco Research, 12*, 1068–1079. doi:10.1093/ntr/ntq159
- Sayette, M. A., Shiffman, S., Tiffany, S. T., Niaura, R. S., Martin, C. S., & Shadel, W. G. (2000). The measurement of drug craving. *Addiction, 95*(Suppl. 2), S189–S210. doi:10.1046/j.1360-0443.95.8s2.8.x
- \*Schnoll, R. A., Martinez, E., Tatum, K. L., Glass, M., Bernath, A., Ferris, D., & Reynolds, P. (2011). Increased self-efficacy to quit and perceived control over withdrawal symptoms predict smoking cessation following nicotine dependence treatment. *Addictive Behaviors, 36*, 144–147. doi:10.1016/j.addbeh.2010.08.024
- Schuh, K. J., & Stitzer, M. L. (1995). Desire to smoke during spaced smoking intervals. *Psychopharmacology, 120*, 289–295. doi:10.1007/BF02311176
- \*Segan, C., & Borland, R. (2011). Does extended telephone callback counselling prevent smoking relapse? *Health Education Research, 26*, 336–347. doi:10.1093/her/cyr009
- \*Shadel, W. G., Martino, S. C., Setodji, C., Cervone, D., Witkiewitz, K., Beckjord, E., & ... Shih, R. (2011). Lapse-induced surges in craving influence relapse in adult smokers: An experimental investigation. *Health Psychology, 30*, 588–596. doi:10.1037/a0023445
- \*Shadel, W. G., Niaura, R., Abrams, D. B., Goldstein, M. G., Rohsenow, D. J., Sirota, A. D., Monti, P. M. (1998). Scripted imagery manipulations and smoking cue reactivity in a clinical sample of self-quitters. *Experimental and Clinical Psychopharmacology, 6*, 179–186. doi:10.1037/1064-1297.6.2.179
- \*Shiffman, S. (2008). Effect of nicotine lozenges on affective smoking withdrawal symptoms: Secondary analysis of a randomized, double-blind, placebo-controlled clinical trial. *Clinical Therapeutics, 30*, 1461–1475. doi:10.1016/j.clinthera.2008.07.019
- Shiffman, S., Ferguson, S. G., Gwaltney, C. J., Balabanis, M. H., & Shadel, W. G. (2006). Reduction of abstinence-induced withdrawal and craving using high-dose nicotine replacement therapy. *Psychopharmacology, 184*, 637–644. doi:10.1007/s00213-005-0184-3
- Shiffman, S., & Jarvik, M. E. (1976). Smoking withdrawal symptoms in two weeks of abstinence. *Psychopharmacology, 50*, 35–39. doi:10.1007/BF00634151
- \*Shiffman, S., Perz, W. G., Gnys, M., Kassel, J. D., & Hickcox, M. (1997). A day at a time: Predicting smoking lapse from daily urge. *Journal of Abnormal Psychology, 106*, 104–116. doi:10.1037/0021-843X.106.1.104
- Siegel, S. (1989). Pharmacological conditioning and drug effects. In A. J. Goudie & M. W. Emmett-Oglesby (Eds.), *Psychoactive drugs: Tolerance and sensitization* (pp. 115–180). Totowa, NJ: Humana Press.
- Steketee, G., & Chambless, D. L. (1992). Methodological issues in prediction of treatment outcome. *Clinical Psychology Review, 12*, 387–400. doi:10.1016/0272-7358(92)90123-P
- \*Strong, D. R., Leventhal, A. M., Evatt, D. P., Haber, S., Greenberg, B. D., Abrams, D., & Niaura, R. (2011). Positive reactions to tobacco predict relapse after cessation. *Journal of Abnormal Psychology, 120*, 999–1005. doi:10.1037/a0023666
- \*Swan, G. E., Ward, M. M., & Jack, L. M. (1996). Abstinence effects as predictors of 28-day relapse in smokers. *Addictive Behaviors, 21*, 481–490. doi:10.1016/0306-4603(95)00070-4
- Tiffany, S. T. (1990). A cognitive model of drug urge and drug-use behavior: Role of automatic and nonautomatic processes. *Psychological Review, 97*, 147–168. doi:10.1037/0033-295X.97.2.147

## Craving and smoking cessation outcome

- Tiffany, S. T., Warthen, M. W., & Goedecker, K. C. (2009). The functional significance of craving in nicotine dependence. In R. Bevins & T. Caggiula (Eds.), *Nebraska symposium on motivation: The motivational impact of nicotine and its role in tobacco use* (pp. 171–197). Lincoln, NE: University of Nebraska Press. doi:10.1007/978-0-387-78748-0\_10
- Tiffany, S. T., & Wray, J. M. (2009). The continuing conundrum of craving. *Addiction*, *104*, 1618–1619. doi:10.1111/j.1360-0443.2009.02588.x
- Tiffany, S. T., & Wray, J. M. (2012). The clinical significance of drug craving. *Annals of the New York Academy of Sciences*, *1248*, 1–17. doi:10.1111/j.1749-6632.2011.06298.x
- \*Tonnesen, P., Tonstad, S., Hjalmarson, A., Leborgy, F., Spiegel, P. I. V., Hider, A., ... Townsend, J. (2003). A multicentre, randomized, double-blind, placebo-controlled, 1-year study of bupropion SR for smoking cessation. *Journal of Internal Medicine*, *254*, 184–192. doi:10.1046/j.1365-2796.2003.01185.x
- \*Van Gucht, D., Beckers, T., Van den Berg, O., & Vansteenwegen, D. (2010). Does exposure to habitual smoking contexts before smoking cessation reduce relapse? Results from a pilot study. *Behaviour Change*, *27*, 19–28. doi:10.1375/bech.27.1.19
- \*Van Zundert, R. M., Boogerd E. A., Vermulst A. A., & Engels R. C. (2009). Nicotine withdrawal symptoms following a quit attempt: An ecological momentary assessment study among adolescents. *Nicotine & Tobacco Research*, *11*, 722–729. doi:10.1093/ntr/ntp055
- \*Van Zundert, R. M., Ferguson, S. G., Shiffman, S., & Engels, R. (2011). Dynamic effects of craving and negative affect on adolescent smoking relapse. *Health Psychology*, *31*, 226–234. doi:10.1037/a0025204
- \*Waters, A. J., Shiffman, S., Sayette, M. A., Paty, J. A., Gwaltney, C. J., & Balabanis, M. H. (2003). Attentional bias predicts outcome in smoking cessation. *Health Psychology*, *22*, 378–387. doi:10.1037/0278-6133.22.4.378
- \*Waters, A. J., Shiffman, S., Sayette, M. A., Paty, J. A., Gwaltney, C. J., & Balabanis, M. H. (2004). Cue-provoked craving and nicotine replacement therapy in smoking cessation. *Journal of Clinical and Consulting Psychology*, *72*, 1136–1143. doi:10.1037/0022-006X.72.6.1136
- \*West, R. J., Hajek, P., & Belcher, M. (1989). Severity of withdrawal symptoms as a predictor of outcome of an attempt to quit smoking. *Psychological Medicine*, *19*, 981–985. doi:10.1017/S0033291700005705
- \*Westman, E. C., Behm, F. M., Simel, D. L., & Rose, J. E. (1997). Smoking behavior on the first day of a quit attempt predicts long-term abstinence. *Archives of Internal Medicine*, *157*, 335–340. doi:10.1001/archinte.157.3.335
- Witkiewitz, K., & Marlatt, G. A. (2004). Relapse prevention for alcohol and drug problems: That was zen, this is tao. *American Psychologist*, *59*, 224–235. doi:10.1037/0003-066X.59.4.224
- \*Zelman, D. C., Brandon, T. H., Jorenby, D. E., & Baker, T. B. (1992). Measures of affect and nicotine dependence predict differential response to smoking cessation treatments. *Journal of Consulting and Clinical Psychology*, *60*, 943–952. doi:10.1037/0022-006X.60.6.943
- \*Zhou, X., Nonnemaker, J., Sherrill, B., Gilsenan, A. W., Coste, F., & West, R. (2009). Attempts to quit smoking and relapse: Factors associated with success or failure from the ATTEMPTS cohort study. *Addictive Behaviors*, *34*, 365–373. doi:10.1016/j.addbeh.2008.11.013