The Role of Craving in Substance Use Disorders: Theoretical and Methodological Issues

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Abstract

Craving is a central feature of addiction. Its recent inclusion as a diagnostic criterion for substance use disorders in the fifth edition of the *Diagnostic and Statistical Manual of Mental Disorder*s appears at a time when craving research is at an all-time high. Craving is thought to predict relapse and may deter individuals from even trying to quit. Researchers have developed experimental craving-induction paradigms to identify factors contributing to craving and to test interventions to alleviate craving. This review offers a critique of laboratory craving studies, with particular emphasis on cigarette craving. It raises questions concerning several conceptual and methodological assumptions underlying this research, identifies processes that may explain why cravings are linked to drug use and relapse, addresses contextual factors that may influence various experiences of craving, and considers recent interventions targeting craving. The relation between craving and both emotion and coping is discussed, as well as the level of insight that individuals have about their own future cravings.

Contents

1. INTRODUCTION

A man who gives way to pleasure will be swept away by craving and his thoughts will make him suffer, like waves.

—Dhammapada v. 339

He begins to die that quits his desires.

—George Herbert, English poet, 1640

Craving represents one of the most enduring yet vexing constructs in the field of addiction research. This should not be surprising; many of our greatest poets, philosophers, playwrights, and religious theorists have struggled to make sense of the concepts of craving and desire, sometimes arguing for their vitality while at other times (e.g., in the aforementioned Buddhist verse) contending that they are a source of suffering. One need not read far into Genesis to find Adam and Eve struggling with temptation. Indeed, although craving currently is scrutinized and debated by addiction researchers, it is notable that often this debate has occurred in an intellectual vacuum, with little regard for how these issues have been addressed elsewhere.

Within the scientific community, craving has long been a focus of study (e.g., Lindesmith 1938). Jellinek (1960) proposed that craving underlies the loss of control at the heart of addictive behavior. During the height of behaviorism, interest in craving waned as researchers began to question its importance (e.g., Mello 1975); however, as the cognitive revolution penetrated the addiction research field (Wilson 1987), interest in craving resurfaced (Sayette et al. 2000). This interest continues into the present. Indeed, thousands of studies have been published on craving in the past decade (Tiffany & Wray 2012).

Addiction theorists have struggled to define and conceptualize craving. With few exceptions (e.g., Tiffany 1990), craving is thought to reflect a drug acquisitive state motivating drug use. Several definitional and conceptual issues remain unresolved (for elaboration, see Sayette et al. 2000). First, investigators have questioned the association between craving and desire, and relatedly,

whether craving should be described dimensionally along a continuum of desire or instead be restricted to extreme desire or yearning (Abrams 2000, Kozlowski & Wilkinson 1987, Sayette et al. 2000). Stated simply, is a mild craving an oxymoron (West & Brown 2013)? Although viewing craving as an intense desire is consistent with lay and dictionary definitions, as well as those offered by leading addiction scientists (e.g., George & Koob 2013, Volkow et al. 2010), researchers typically assess craving as if it can be any level of desire, and they use the terms craving and desire interchangeably. Wrestling with the relation between desire and craving is not new to addiction researchers, and elsewhere distinctions have been drawn between these concepts. Within the teachings of Buddhism, for example, craving (*tanhā*) and desire are inequivalent; certain altruistic desires are aspirational, whereas cravings for sensory pleasures underlie suffering (Rahula 1974). Pascal, the seventeenth-century mathematician, distinguished desire from "force," with the former driving voluntary, and the latter involuntary, actions. In Section 6, intensity is revisited, but for the moment it is notable that this fundamental issue remains up for debate.

Second, craving researchers differ regarding the content or scope of their definition. Although most definitions emphasize desire, others target intention to use a drug. Still others suggest that cravings refer to a desire to experience effects of the drug (see Marlatt 1985). Tiffany & Drobes (1991) suggest craving should encompass anticipation of a drug's reinforcing effects, intention to engage in drug use, and desire for the drug. Views of craving that extend beyond desire have been criticized, however, for including processes that are correlated with, but conceptually distinct from, craving (Kozlowski et al. 1996).

Third, there remains debate regarding the time frame of a craving experience. Some who measure craving assume it to be fairly stable (e.g., rating across a day or week), whereas others view it as a momentary state (Sayette et al. 2000). Craving shifts over the course of the day, and ratings obtained at different times have different meanings and predictive power (Shiffman et al. 1996). Although appealing, assessing craving over an extended time interval may not offer accurate responses (Tiffany & Wray 2012).

Fourth, although many investigators assume craving requires conscious recognition of the desire for drug use (Baker et al. 2006, Tiffany & Wray 2012), others suggest it can exist outside of conscious awareness (Berridge & Robinson 1995). [For discussion of experientially conscious versus meta-conscious craving, see Sayette et al. (2010b).] If one can crave without awareness, then nonverbal measures should feature at least as prominently as self-report measures in assessment. Research examining animal models of drug seeking also becomes relevant to understanding craving and its relation to loss of control and relapse in humans (Li 2000). The challenge, though, is to identify when "unconscious" cravings precipitate use and when use occurs in the absence of any craving.

2. UTILITY OF CRAVING AS A CONSTRUCT

Some researchers have distinguished between craving as a clinical phenomenon described by patients and craving as a process that interacts with other phenomena to affect drug use (Drummond 2000). At its core, though, craving is a hypothetical construct. The history of experimental psychology demonstrates that unobservable constructs are often needed to explain data and advance research. Breakthroughs in areas such as memory and attitudes have emerged from the use of latent constructs. It is critical, however, that such constructs be carefully defined and tied to observable variables within a theoretical framework (Cronbach & Meehl 1955). If a construct does not improve explanation and prediction of behavior, then it would be better to abandon it in favor of parsimony. As noted by Abrams (2000), ". . .if it [craving] has unique explanatory power, then the concept would sharpen the distinction between diagnostic categories, improve prognostic indicators of the severity of addiction and enhance our theories as well as the development of more

effective tailored treatment and prevention" (p. S237). A continuing challenge for craving proponents is to provide data that cannot be well explained without use of this hypothetical construct and that systematically test the validity of the concept.

Ecological momentary assessments: use of electronic diaries to assess behavior in real time (or near-real time) and in real-world settings

Drug craving: a drug-acquisitive emotional state motivating drug use. Because use is multiply determined, craving is neither necessary nor sufficient for use to occur

Criticism of Craving

A major source of criticism derives from invoking craving as the cause of relapse. As argued by Mello (1975), defining craving by the very behavior (loss of control) that it seeks to explain is tautological. More recently, critics claim that when craving and drug use are viewed distinctly, the link between craving and cessation is weak (see Wray et al. 2013). Perkins (2009) has challenged researchers to "justify why studies of cue-induced craving contribute to our understanding of dependence" (p. 1610). From this perspective, further work is needed before craving can satisfy the criteria noted above for evaluating a hypothetical construct.

Defense of Craving

Despite criticisms of craving, existing research offers a credible defense of its utility. Many studies do find cravings to predict clinical outcomes (see Monti & Ray 2012, Sayette & Tiffany 2013). Further, when craving fails to predict drug use and relapse, methodological limitations and interpretative concerns are often implicated (Sayette & Tiffany 2013). These concerns involve reliable assessment of both craving and clinical outcomes. For instance, sometimes craving is assessed many months before drug use is assessed (see Gass et al. 2014). A recent review of studies employing ecological momentary assessments to capture craving in close temporal proximity to drug use revealed robust support for an association between craving and substance use (Serre et al. 2015).

More recent research in and outside the laboratory provides support for the clinical significance of craving. Baker and colleagues (2006) observed that cravings and negative affect are the most motivationally relevant withdrawal symptoms. Their studies reveal that measures such as rise time of craving, duration of high levels of craving, and average levels of craving consistently predict smoking relapse. In their review, Tiffany & Wray (2012) tout the clinical and diagnostic utility of craving. Moreover, concern about craving can deter even trying to quit (Orleans et al. 1991). Support for the value of craving reached a milestone when it was included as a criterion for diagnosis of substance use disorder in the latest edition of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-5; Am. Psychiatr. Assoc. 2013). Despite some dissent (e.g., Moss 2011), a number of analyses supported its inclusion (see Tiffany & Wray 2012). Craving also features in nearly all theories of addiction. [It is beyond the scope of this article, however, to outline the dozens of conditioning, expectancy, affective, cognitive, economic, and homeostatic addiction models and their relation to craving (see Baker et al. 1987, 2004; Loewenstein 1999; Niaura et al. 1988; Piper 2015; Sayette 1999; Tiffany 1990, 2010).] Nevertheless, even defenders of craving recognize the need to improve conceptualization and assessment and to develop a more nuanced understanding of the link between craving and use (Sayette et al. 2000, Tiffany & Wray 2012).

Why Focus on Cigarette Craving?

Although this article aims to address craving across substances, it primarily focuses on cigarette craving. Much research on drug craving targets smoking, and there are several reasons why smoking presents an ideal domain. First is the relative ease and safety with which this research can be conducted. Unlike studies of heroin or cocaine, for example, one need not conduct cigarette-craving studies in hospital or correctional facilities. Smokers are relatively easy to recruit, often boosting statistical power relative to testing other drugs. Second, nicotine withdrawal states can be induced

via robust deprivation manipulations with healthy participants, often eliciting the most powerful urges in laboratory studies (see Wertz & Sayette 2001a). Third is the presumption that smokers have fewer complicating psychiatric and social concerns in comparison with individuals with more severe drug addictions. Fourth, smoking remains a particularly important and intense addiction to examine. The public health implications of nicotine dependence dwarf those of all other drugs (US Dep. Health Hum. Serv. 2004), and nicotine is highly addictive relative to other drugs. Accordingly, the study of cigarette craving is especially valuable for understanding craving more generally.

In vivo smoking cue exposure: participants hold, light, and/or look at an actual cigarette as opposed to viewing a picture or a video of a cigarette

Tonic craving: withdrawal-based craving thought to be independent of craving triggered by drug-related cues

Phasic cravings: episodic bursts of craving often stimulated by exposure to drug-related cues

Supplemental Material

3. CRAVING INDUCTION

A variety of laboratory procedures are used to induce cravings. Many studies instruct participants to refrain from drug use prior to entering the lab. Requiring daily smokers to abstain, for example, reliably enhances craving (Sayette et al. 2001). Manipulations that affect mood (e.g., induce stress) are also popular for eliciting cravings (Tiffany 2010). The most common induction exposes participants to stimuli associated with their drug use. These may be in vivo smoking cue exposures such as holding a lit cigarette, or they may be images or videos of people using the drug (see **Supplemental Video**; follow the **Supplemental Material link** in the online version of this article or at **http://www.annualreviews.org**). Requesting participants to imagine drug scenarios also has been used. In some instances, one drug, such as alcohol, can trigger craving for a second drug, such as nicotine (see Sayette & Creswell 2016). Conklin and colleagues (2013) have found that people can serve as potent drug cues. They also have argued for tailoring cues to an individual and have distinguished between distal cues, which may create a high-risk context, and proximal cues, which may serve as the last straw to a lapse. Recently, virtual reality methods have elicited craving using a complex and personally relevant constellation of cues (see Hone-Blanchet et al. 2014). Nevertheless, though cue-exposure approaches reliably enhance drug craving (Carter & Tiffany 1999), key assumptions regarding craving inductions await further scrutiny.

Perhaps the most fundamental assumption, especially regarding cigarette craving, is the distinction between tonic or withdrawal-based craving and phasic or episodic bursts of craving often provoked by exposure to a drug cue. Although leading investigators acknowledge that research has yet to establish that clinical features of these two forms of craving are qualitatively distinct (Shiffman 2000, Tiffany & Wray 2012), this assumption is nearly universally held. Cues can trigger relapse months after withdrawal symptoms have disappeared, and as Shiffman (2000) notes, these two forms of craving likely follow different causal paths. In most studies—using animals and humans—the distinction is noted without explanation. This distinction has gained particular traction when evaluating cessation medications. For instance, researchers conclude that certain interventions attenuate just tonic craving (Ferguson & Shiffman 2009), whereas others reduce both tonic and phasic cravings (Brandon et al. 2011).

In reaction to this apparent consensus, Sayette & Tiffany (2013) argued that "sometimes it is unfeasible—and in some instances conceptually misguided—to disentangle abstinence-based and cued components of cigarette cravings" (p. 1019). Methodologically, it is challenging to independently assess tonic and phasic cravings. When nicotine-deprived smokers enter a laboratory rich in smoking cues, a cue as mild as completing a baseline urge questionnaire may provoke craving. Consequently, elevated precue urge ratings may limit sensitivity to detect further increases related to smoking cue reactivity: "At least among abstinent dependent smokers, cue-elicited urge indexed as the difference between the cued and 'uncued' condition likely underestimates the effect of smoking cue-exposure on urges" (Sayette & Tiffany 2013, p. 1020). Such concern may lead to curious findings, such as greater cue reactivity in nonabstinent conditions compared to abstinent conditions (see Sayette et al. 2000).

Peak-provoked craving (PPC): induction of robust craving states stemming from both abstinence and environmental triggers

Abstinence self-efficacy: confidence in one's ability to abstain from drug use

To address high tonic (precue) cravings among abstinent smokers, sometimes participants are instructed to smoke just before the study. This often leads to low tonic levels followed by statistically significant increases in phasic craving during smoking cue exposure. In this case, however, the absolute levels of craving generated may be clinically unremarkable (Sayette & Tiffany 2013). Practically, the need to distinguish between tonic and phasic craving outside the laboratory often may be less compelling than imagined, as many relapses occur during the first few days, when both withdrawal and drug cues are involved. Conceptually, the two sources of craving may not be independent. Both types appear to share common neural substrates (Oliver et al. 2013). Moreover, perceptions of environmental cues vary based on internal states, such as withdrawal (Piper 2015, Wertz & Sayette 2001b). For instance, smokers may be more likely to notice a cigarette butt on the sidewalk when they have not smoked for a few hours than just after smoking. Animal data also indicate that the impact of cues is heightened during periods of drug abstinence (Oliver et al. 2013).

In light of the challenges related to disaggregating abstinence-based and cued craving, Sayette & Tiffany (2013) suggested an alternative peak-provoked craving (PPC) approach to studying cigarette craving that is complementary to traditional cue reactivity. The PPC design uses nicotine-deprived smokers and—in contrast to cue reactivity—focuses on urges during smoking cue exposure without subtracting out urge ratings during control (neutral) cue or baseline assessments. Rather than trying to disentangle the two forms of craving, PPC aims to induce robust craving states that stem from both abstinence and environmental triggers. In contrast to milder craving states produced with nicotine deprivation or a smoking cue alone, PPC assumes that we can obtain valuable information about addiction by testing a smoker in a peak-craving state. Consistent with this "critical mass" perspective are findings from both field and laboratory studies (see Sayette & Tiffany 2013). For instance, after a quit attempt, if prelapse urges fell below maximum values, they were uncorrelated with ratings of abstinence self-efficacy (i.e., confidence in ability to abstain from drug use). But during maximal urges, self-efficacy plummeted, suggesting that extremely high urges may be "a categorically different experience for the smoker than urge at any other level" (Gwaltney et al. 2005, p. 659). Analogous to this PPC approach is research testing diabetes heritability. Twin studies initially found surprisingly weak concordance rates for the disease. When study participants were exposed to an extreme glucose infusion (glucose tolerance test), however, concordance rates rose dramatically (Gottesman & Shields 1972), suggesting that extreme conditions were necessary to observe vulnerability. As summarized in Section 5, peak-craving states are associated with a range of clinically significant outcomes (Sayette & Creswell 2016). Importantly, PPC seems useful when drug (e.g., nicotine) withdrawal elevates baseline urge ratings, whereas traditional drug cue reactivity may be preferred when testing drugs for which abstinence alone may not lead to heightened baseline cravings.

Although PPC focuses on craving derived from both abstinence and in vivo smoking cues, recently Baker, Piper, and their colleagues have suggested that the source of craving affects the experience (see, e.g., Piper 2015).

> In essence, an urge is not an urge, and urges that are associatively elicited (e.g., from habit driven dorsal striatal influence), that arise from disrupted self-administration rituals (i.e., "behavioral withdrawal/craving"), that arise from interoceptive cues of decreasing drug levels, that arise from external stressors (and associated interoceptive cues), and that arise from activation of ventral striatal structures/systems (e.g., incentive effects)—all these are different phenomena and it may be important to understand the causal influences on the imprecise, subjective urge label. (T. Baker, personal communication, Sept. 15, 2014)

This intriguing proposal invites further investigation of the response systems used to assess craving and the boundary conditions under which a PPC model applies. It also is compatible with research described in Section 6 describing the impact of contextual factors on craving. Furthermore, consistent with a key element of PPC, Piper (2015) recommends examining cue reactivity during deprivation in order to better understand the relation between withdrawal and addiction and notes that coping with craving, irrespective of its source, exhausts self-regulatory processes and may precipitate relapse.

Another assumption common to cue-reactivity studies is that they should include multiple drug and control cue-exposure trials. Such an approach assumes that humans can return to a neutral baseline state following each trial, allowing each trial to offer an independent manipulation of craving. Unfortunately, exposure to a drug cue can create a craving that carries over into the subsequent trial. Such carryover effects are observed across a range of substances and measures, including cognitive tasks (e.g., smoking and other drug Stroop tasks, working memory), self-reported urge, and neurobiological measures (see Wilson et al. 2007). If the assumption of trial independence is flawed in multitrial tasks, then carryover effects may impede observation of drug cue effects.

Cue-reactivity studies: investigations that focus on the difference between craving responses found during drug cue exposure and those during an abstinence-based baseline or control cue exposure

Carryover effect: a level of reactivity to an experimental trial that persists during exposure to the subsequent trial(s)

Determining the order that drug and control cues are presented is critical to the design of cue-exposure investigations. It is widely assumed that cue-exposure studies should counterbalance the order in which drug and control cues are presented (see Carter & Tiffany 1999). Most smoking cue studies counterbalance cue order without bothering to justify this design (see Sayette et al. 2010a). Presumably, a fixed order (e.g., neutral cue preceding cigarette cue) would create a confound, such that drug cue effects cannot be disentangled from order of cue presentation. Thus, extraneous factors (e.g., fatigue, habituation, time since last consumption) are inadvertently introduced. Accordingly, if exposure to one cue affects responding to the next, then counterbalancing may be needed to control for this order effect.

At first glance, the decision to counterbalance seems straightforward. Often ignored, though, is the assumption underlying counterbalancing procedures that initial cue presentations do not produce carryover effects differentially across the various manipulations. Counterbalancing is problematic if carryover effects interact with the different experimental treatments or orders of treatments (Campbell & Stanley 1963). Yet in some fairly common cue-exposure procedures, it is unclear that each order of cue presentation is similarly vulnerable to carryover effects (Sayette et al. 2010a), and differential carryover effects may be problematic. Indeed, many prominent methodologists have concluded that differential carryover effects across conditions preclude use of a counterbalanced design. For instance, Winer (1971) cautions: "A strong word of warning is required in connection with order (or sequence) effects. If such effects exist, randomizing or counterbalancing does not remove them; rather such procedures completely entangle the latter [order effects] with treatment effects" (p. 517). A recent review revealed that the vast majority of smoking cue-exposure studies did not report any tests of order effects, and those that did suggest order effects are nontrivial (Sayette et al. 2010a). Some null findings in the literature may be attributable to the loss in power associated with order interactions (Sayette et al. 2010a).

There is no perfect approach to cue exposure, and research would be useful to evaluate a variety of methods. Because of concerns about adequate counterbalancing, my colleagues and I often gravitate toward single cue-exposure manipulations using either a between-subject design (drug cue versus neutral cue) or a within-subject fixed order design in which neutral cues precede drug cues (see Sayette et al. 2010a). In sum, keen interest in developing laboratory paradigms to manipulate cravings arguably has led to premature acceptance of presumed best-practices experimental methods (e.g., multiple cue trials, counterbalanced orders, within-subject designs). Although in some cases these approaches may be optimal, a craving may linger from one trial into the next,

and researchers need to better consider this concern and adopt craving-induction methods that are best for particular research aims.

Meta-consciousness: the capacity to intermittently take stock of the current contents of thought

4. CRAVING ASSESSMENT

Because there is no single accepted measure of craving, the challenge is to select optimal measures for a specific clinical or research application. It is beyond the scope of this article to comprehensively address various assessment approaches (see Sayette et al. 2000). Here, I briefly consider some of the primary assessments. Nearly all conceptualizations of craving assume that it can be assessed at least partially through self-report measures of subjective experience. Yet self-reports of craving do not provide a direct readout of one's craving state and are influenced by factors that also shape verbal behavior: "Craving researchers need to be sensitive to memory biases, misattributions, response styles and other sorts of craving-irrelevant influences that can affect craving ratings" (Sayette et al. 2000, pp. S191–S192).

There is debate regarding the use of single-item versus multi-item craving scales in laboratory studies. Adding items enhances reliability, though above a few items, the increased reliability generally appears to be negligible (Sayette et al. 2000, Tiffany & Wray 2012). Multi-item scales also enable coverage of a broad span of craving severity (Tiffany & Wray 2012). Some have criticized single-item craving scales for lacking sensitivity, but reviews suggest that single-item scales consistently support the diagnostic utility of craving (Tiffany & Wray 2012). Indeed, Heckman et al.'s (2013) meta-analysis of cigarette craving revealed that "although not significant, studies that utilized single-item craving indices showed larger cue-provoked cravings than those with multi-item measures" (p. 2071). Moreover, single-item scales are advantageous in situations calling for repeated and rapid reporting of craving throughout an experimental paradigm where measurement reactivity can be problematic (Sayette et al. 2000). Repeated assessment can be useful for understanding not just intensity but also duration and peak levels of craving (Sayette et al. 2005). Nevertheless, it is hard to argue with Tiffany & Wray's (2012) call for research on the psychometric performance of craving items, especially when the items are being used for diagnostic purposes.

In nearly all laboratory studies, participants are probed to report their current craving state, which necessarily draws craving into meta-consciousness (Sayette et al. 2010b). Research on mind wandering suggests a complementary (self-caught) approach to assessing self-reported urge, in which participants indicate when they realize they are craving; this approach deserves further investigation (Sayette et al. 2010b). Nevertheless, despite concerns that relate to validity, reliability, specificity, sensitivity, and reactivity, self-report often provides crucial information about craving and will continue to play a major role in assessment. [For a comprehensive discussion of self-reported craving measurement, see Sayette et al. (2000).]

Nonverbal measures include drug self-administration, reinforcement proxies, cognitive processing tasks, expressive behavior, peripheral psychophysiological responding, and neurobiological responding. In contrast to self-report, many nonverbal measures may be less sensitive to conscious control and response bias, and in some instances (e.g., unobtrusively recorded facial expression) may be less subject to reactivity concerns. Interpretation of these responses depends on one's theory of craving. If self-reports of craving are viewed as the gold standard for measurement, then these nonverbal responses are simply related to (self-reported) craving or, as in the case of cognitive processing, an effect of craving. Consequently, these measures would be less central to the assessment of craving. In contrast, if craving is thought to be a construct that is only imperfectly indexed by a host of self-report and nonverbal measures, then nonverbal measures play a more critical role in its assessment (see Sayette et al. 2000). In this case, though, selected measures should be consistent with a particular theory of craving (Baker et al. 1987, Tiffany 1990) and not simply responses that are correlated with reports of craving.

Recently, some investigators have argued that researchers underappreciate the role of behavioral measures of cue-elicited craving (Perkins 2009). Reliance on drug use behaviors is favored by those who oppose use of craving (e.g., Mello 1975) and those testing animal models. From this perspective, we infer motivation to consume a substance by behaviors such as whether (or how quickly) respondents use it when permitted, how hard they work to obtain it, or the amount of money they need to continue abstaining. Research has productively linked this last approach to behavioral economics theories highlighting temporal relations between craving and use (e.g., MacKillop et al. 2010). Nevertheless, forces other than craving can affect use. For instance, one can experience a strong craving, but if the drug is unavailable or too expensive, or if one is determined to quit, then consumption may not ensue. [Indeed, as noted by Baker et al. (1987), craving may be a more psychologically relevant aspect of addiction than is drug use behavior.] Conversely, one might use a drug or relapse in the absence of craving, and research is needed to identify conditions under which cravings predict consumption (Sayette et al. 2000). One final comment regarding the use of drug use behaviors to assess cue reactivity is warranted. Usually ignored in the cue-reactivity literature when discussing measures of drug use behavior is that the behavioral measure itself is often a powerful drug cue. For instance, if the number of puffs of one's cigarette is the behavioral measure, then participants will necessarily be smoking the cigarette in order to collect the relevant information, which of course is the ultimate smoking cue. This is a problem for many studies that bid to compare cue reactivity between a drug-cue group (e.g., individuals viewing smoking images) and a neutral-cue group (e.g., those viewing nondrug images). When both groups subsequently are permitted to smoke their preferred brand of cigarette (to collect the behavioral cue-reactivity data), it is clear that at the very moment that the behavioral measure is obtained, the neutral-cue group is no longer neutral and instead is being exposed to a potent, multisensory smoking cue (i.e., actually smoking a cigarette involves exposure to visual, olfactory, tactile, and airway sensation cues associated with smoking). Accordingly, the measure of smoking behavior can transform the neutral-cue condition into a smoking-cue condition at the precise moment of cue-reactivity assessment.

Psychophysiological measures such as heart rate have been used to index craving but have come under criticism. These responses also serve functions independent of drug use motivation, and it is sometimes uncertain whether increases or decreases should be linked to craving (Niaura et al. 1988, Tiffany 1990). Some researchers have employed measures such as startle response that are linked to craving theories (e.g., Zinser et al. 1999). Facial coding systems also may prove useful for detecting expressions associated with craving (e.g., Sayette et al. 2003b).

Studies using brain-imaging measures to index craving responses have also proliferated. Recent studies have highlighted the value of neurobiological craving research to improve treatment and to target who is at heightened risk of relapse (Wiers & Heinz 2015). Although multiple neural regions and networks are implicated in the experience and regulation of craving (see Wilson & Sayette 2015), the bulk of neurobiological addiction research targeting reward processing has focused on the mesolimbic dopamine pathway (Lopez et al. 2015). Dopamine signaling appears to be a critical neurobiological substrate underlying drug cue learning and motivational responses to drugs (Berridge & Robinson 1995). For instance, considerable evidence indicates that phasic dopamine release in the ventral striatum motivates goal-directed behavior (Wiers & Heinz 2015). Clearly, this measurement domain holds promise (see Section 10). Nevertheless, similar to many nonverbal measures, by themselves imaging data merely indicate changes in electrophysiological or hemodynamic brain activity and should be interpreted in the context of study manipulations and measures (Wilson & Sayette 2015).

Two novel implicit approaches to assessment have been examined recently. Participants squeezed a handheld dynamometer as forcefully and for as long as they wished to indicate their

hunger levels. Dynamometer recordings of hunger during exposure to freshly popped popcorn predicted amount consumed better than did self-reported hunger (K.G. Creswell, M.A. Sayette, J.W. Schooler, A.G.C. Wright, & L.E. Pacilio, manuscript under review). Another implicit craving measure showing promise examined the time required to complete an urge rating (Germeroth et al. 2015). Additional research would be helpful to determine the utility of these measures.

Nonautomatic processing: a type of cognitive processing that is generally thought to require effort, intentionality, or control and to be modifiable, relatively slow, and subject to conscious awareness

Self-regulation: any effort by human beings to alter their own responses

Finally, investigators have used cognitive performance tasks such as secondary response time probes, design-tracing tasks, drug Stroop tasks, dot-probes tasks, word-stem completion tasks, and eye-tracking studies to implicitly measure craving (for reviews, see Field et al. 2009, Tiffany 1990, Waters & Sayette 2006). Much of this work stems from assumptions that craving leads to a redistribution of nonautomatic (limited-capacity) cognitive processing resources (Tiffany 1990). Research with smokers indicates that performance on this type of measure (e.g., smoking-Stroop) can predict time to relapse (Waters et al. 2003). Such indirect measures may limit response bias found in self-reported craving questionnaires and may improve understanding of why cravings alter perceptions and decisions associated with drug use (Sayette & Creswell 2016). [For broader discussion of implicit measures, see Stacy & Wiers (2010).]

Across response modalities, concerns over laboratory approaches to craving assessment highlight the value of continuing to develop and refine ecological momentary assessments, which capture naturally occurring craving experiences (Shiffman et al. 1996). Recent efforts to combine the rigor and power of laboratory-based cue-exposure methods with ecological momentary assessment (Wray et al. 2015) and with other emerging (mobile) technologies (Kirchner et al. 2013) are promising.

In summary, despite limitations, self-report measures can detect craving and undoubtedly will continue to be widely used in research and clinical settings. Nevertheless, like other hypothetical constructs, understanding of craving will be enhanced through development of a multimodal battery of measures across diverse response domains.

5. WHY IS CRAVING RELATED TO SELF-REGULATION FAILURE?

Despite concerns regarding manipulating and measuring craving in the laboratory, much has been learned from experimental research. As noted in Section 2, consensus has emerged that craving is a clinically meaningful construct. Indeed, methodological concerns raised in the prior two sections likely have led to underestimating the effects of craving. Although considerable research documents the clinical relevance of craving, little attention focuses on why craving is clinically significant. What happens when one is craving that may lead to use or to relapse? Three general cognitive processing changes may offer insights into the power of cravings to affect self-regulation failure: attentional and monitoring processes, informational (reasoning) processes, and temporal cognition (for elaboration, see Sayette & Creswell 2016). Most research focuses on attentional processes. The notion that deprivation (e.g., starvation) can affect cognitive and attentional processes has a long history (Keys et al. 1950). Studies indicate that craving demands nonautomatic cognitive processes (Tiffany 1990). Moreover, the impact of these shifts in processing is exacerbated because craving also interferes with the ability to notice these changes (Sayette et al. 2010b). As noted in Section 4, craving can shift nonautomatic cognitive processing resources toward drug-related cues. Determining the content of these cognitions remains a critical matter yet has received little focus.

Research using a PPC approach—by generating robust cravings through both nicotine deprivation and smoking cue exposure—has examined the way in which craving may influence how one generates and evaluates smoking-related information. A peak-craving condition is compared to a low-craving control condition in which smokers smoke just before or at the beginning of the experiment and are exposed to a neutral cue. In the peak-craving condition, smokers generated a

list of smoking characteristics that was positively biased, relative to when they were not craving (Sayette & Hufford 1997). Craving also may be associated with evaluation of smoking-related information. In two studies, smokers in a peak-craving condition tended to judge positive smoking consequences to be more probable, relative to negative ones, than did low-craving smokers (Sayette et al. 2001, 2005). As Marlatt (1985) suggested, craving may bolster drug use outcome expectancies, such that positive outcomes appear more likely than negative ones. Furthermore, the value of non-drug-related stimuli (e.g., money) is diminished during craving (see Piper 2015, Wilson et al. 2014). Future research might examine changes in contextual information related to decision making [e.g., a smoker who is craving and about to relapse might view the likelihood of dying from a non-smoking-related cause (car accident) to be elevated, such that enjoying life by smoking momentarily may appear rational].

Understanding the impact of craving on temporal cognition may yield clues for understanding why craving may precipitate relapse. Time appears to pass more slowly when individuals are craving than when they are not craving (Klein et al. 2003, Sayette et al. 2005). In addition, when smokers are in a peak-craving state and asked to predict the trajectory of their craving over the next 40 minutes, they tend to overestimate its intensity and duration (Sayette et al. 2005). In other words, they feel that without smoking, their already high craving will unremittingly worsen. In fact, even unrequited cravings tend to dissipate naturally (Marlatt 1985, Niaura et al. 1999). The act of self-regulation appears to change subjective experience of time, such that time feels more extended than it really is, and this state leads to subsequent failures in self-regulation (Vohs & Schmeichel 2003).

In summary, craving-related changes in cognitive processing may facilitate drug use and relapse (see also Baker et al. 2004). Craving drug users may be more likely to notice substance cues in their environment and in turn may consider the act of consuming to be more attractive, whereas cues associated with nondrug activities become less attractive than they would in a neutral state. Moreover, altered time perception may impede the ability to exercise self-regulation. These processes are unlikely to be an exhaustive set of potential mechanisms underlying the presumed association between craving and drug use. Whether these changes are manifestations of craving or merely effects of craving depends on one's conceptualization (Sayette et al. 2000). Regardless, these changes highlight a research approach that moves beyond establishing a link between craving and drug use to identify processes that make craving a clinically meaningful construct. They also suggest that measuring one's attitudes about drug use may require careful consideration of the assessment context. A clinician who learns, for example, that a smoker holds a negative view of smoking and is motivated to quit may be surprised to hear of a subsequent relapse days later. Had assessment occurred while craving, the information might have revealed the smoker to be ambivalent about quitting. After all, it takes only a single moment of weakness during a high-risk situation for a committed quitter to reconsider and smoke (Sayette & Creswell 2016). Finally, these craving-related changes may or may not be disordered. Privileging of certain stimuli and information has adaptive value; thus, the challenge is to understand how such basic processes can become hijacked into the service of a hazardous behavior.

6. IS CRAVING A UNITARY CONSTRUCT?

Craving often has been described as a unitary construct that predicts clinical outcomes. Yet the former assumption can be challenged in light of available evidence. States of mild desire often created in craving experiments may produce qualitatively distinct experiences from the more intense desire often associated with the term. For instance, some cigarette craving studies begin by having participants smoke, thereby creating satiety. A review of neuroimaging studies of cigarette

cue-elicited craving revealed distinct patterns of neural activation when participants were nicotine deprived (experiencing strong craving) compared to when participants were nondeprived (experiencing a milder state of desire) (Wilson & Sayette 2015). Although there may be value in studying less intense desire (see Abrams 2000, Shiffman 2013), such research should specify mild desire rather than craving as its focus.

Relatedly, the context in which craving occurs may influence the experience and measurement of craving (e.g., Piper 2015). Some theorists posit that social context may affect the association between craving and drug use (Drummond et al. 1995, Gass et al. 2014, Kavanagh et al. 2005, Sayette & Creswell 2016). Abrams (2000) proposes factors such as sociocultural norms, role modeling, and contextual factors such as religious ceremonies. Research seldom has investigated, however, the impact of such factors on the experience of craving. Drug use is often a social activity and though rarely conceived of in this fashion, there may be merit to viewing craving as a social construct. [Indeed, the earliest medieval usages of craving noted in the *Oxford English Dictionary* describe a social exchange (one person making a claim or accusation upon another[1]), a usage that extends through the writings of Shakespeare (e.g., in *Twelfth Night*, ". . .I shall crave of you your leave. . .").] Modeling research reveals that drinking behavior is influenced by one's social environment (see Quigley & Collins 1999), and other people associated with past use can serve as drug cues even in the absence of traditional drug stimuli (Conklin et al. 2013). It is reasonable to wonder if social context affects not just strength but also emotional tone of craving (Abrams 2000, Sayette & Creswell 2016). For instance, does one's craving experienced in the company of a spouse differ if the spouse is disgusted by the habit or if the spouse instead admires the partner's courage to even try to quit? Research to determine the clinical significance of these potentially different types of cravings is indicated.

Perhaps the most studied contextual factor is perceived drug use opportunity. Perceived drug use opportunity (Wertz & Sayette 2001a) is preferred to drug availability because sometimes a drug may be physically available, but perceived opportunity to use it may be limited [e.g., due to a religious prohibition against smoking on the Sabbath (Schachter et al. 1977)]. With some exceptions (Baker et al. 1987, Juliano & Brandon 1998), perceived drug use opportunity was traditionally thought to have minimal effect on craving (e.g., Carter & Tiffany 1999).

Several factors can affect perceived drug use opportunity, including motivation for treatment, availability of the drug, and even one's meta-cognitions about experiencing craving. To the likely surprise of many clinicians and researchers, a review of drug cue-exposure studies revealed that patients entering studies as part of drug treatment reported far less craving during cue exposure than did continuing users (Wertz & Sayette 2001a). This is notable, as treatment seekers often are heavier users than continuing participants. Similarly, a review of brain-imaging studies revealed different patterns of neural activation among treatment-seeking participants and active users (Wilson et al. 2004).

Carter & Tiffany's (2001) cue-availability paradigm revealed that drug availability was associated with elevated craving, a finding reinforced in a review of cue-exposure studies manipulating drug use opportunity (Wertz & Sayette 2001a). In addition, smokers expecting to smoke soon were more distracted by smoking cues than were those not anticipating to smoke (Wertz & Sayette 2001b). Individuals experiencing positive anticipatory states may access drug-related memories of positive sensory experiences (Kavanagh et al. 2005). Further, studies coding affect-related facial expression during cue exposure reveal that when continuing users expect to smoke imminently, they evince predominantly positive expressions, whereas negative expressions predominate when use is delayed (Sayette et al. 2003b). Together with animal data (see Weiss et al. 2000), these studies

[1]I thank Richard Mallen, PhD, for his insightful suggestions regarding craving and language.

suggest that some of the perceived reward generally associated with drug use may actually precede consumption and that craving itself may be rewarding, particularly to those who anticipate using the drug very soon (Sayette & Creswell 2016, Zinser et al. 1999). For instance, craving smokers told they could smoke soon preferred viewing smoking images (relative to alcohol images) more so than did smokers told they could not smoke (Dimoff & Sayette 2015). That is, viewing smoking images seemed to become relatively more pleasant when smoking soon was anticipated. In some cases, participants may be motivated to delay actual use in order to prolong the pleasure associated with positive cravings. Loewenstein (1987) describes savoring as "positive utility derived from anticipation of future consumption" (p. 667). Children who hoard their Halloween candy, for example, may prefer savoring their candy to actually consuming it.

Savoring: pleasure derived from anticipation of future drug consumption

Quitting drugs necessarily eliminates these regularly experienced positive craving states, and their loss may help explain the increase in negative affect following cessation (Baker et al. 2004, 2006). Not only does quitting require giving up drug ingestion and the behavioral and sensory experiences of the self-administration ritual (e.g., the feel and sensations of smoking or drinking), but it also eliminates the regularly scheduled moments of anticipatory pleasure accompanying positive craving states. These moments (e.g., the final hour of the work day before hitting the pub) may require just as much clinical attention as do the hours that were linked to actual drug use.

Another contextual factor involves one's meta-emotions about experiencing craving. In some instances, a craving may signal threat or weakness [e.g., if one plans to quit, a strong craving during assessment may be upsetting (Unrod et al. 2014)]. In other cases, a continuing user may savor the craving, knowing that s/he momentarily will satisfy it by using the drug. In vulnerable moments, a craving may be enhanced in order to justify an imminent relapse. In each case, how individuals feel about their craving offers a critical contextual layer influencing their experience [e.g., tolerance of an unpleasant craving state (McRobbie & West 2013)]. Consequently, a self-reported urge rating during cue exposure may partly reflect one's comfort with experiencing or reporting a craving (Sayette & Parrott 1999).

Baumeister and colleagues (1994) propose that drug users sometimes may acquiesce in their own self-regulation failures. Consistent with this premise, users may indulge their cravings, albeit without awareness they are doing so (Sayette & Creswell 2016). That is, the degree to which a cue stimulates the senses and becomes alluring depends on one's mindset at that moment. Determination to remain abstinent can exert an overarching influence on these immediate circumstances. This concept appears in the Indian religious text, *The Bhagavad Gita*: To control his craving, Arjuna first must endeavor to withdraw his senses from the desired object. By determining in advance that under no circumstances will we eat between meals, for example, we can detach our mind from our senses and remain abstinent (Satchidananda 1988). [See also self-control by precommitment (Ariely & Wertenbroch 2002).] In contrast, when determination is lacking from the outset, we may permit our senses to run wild, ramping up our cravings to unmanageable levels. More research is needed to uncover these meta-influences on craving.

Individual differences add yet another contextual factor to understanding craving. Although person-level factors have been linked to the development of withdrawal and addiction more broadly (e.g., Piper 2015, Sher 1991), there has been comparatively little focus on craving. Nonetheless, a scattering of factors have moderated laboratory-induced craving, including trait impulsivity (e.g., Doran et al. 2007), genetics [e.g., variation in the dopamine receptor D4 (*DRD4*) polymorphism in some but not all studies (see Creswell et al. 2012, Monti & Ray 2012)], and level of dependence (Donny et al. 2008). Variation in experience of negative affective withdrawal symptoms also appears to affect craving (Baker et al. 2006), and trait levels of anhedonia may relate to craving (Leventhal et al. 2009). Researchers have wondered if gender moderates cue-elicited craving, though neither laboratory nor field studies have consistently observed gender differences (Sayette et al. 2001,

Wray et al. 2015, Zinser et al. 1999). In summary, there is wide individual variability in the experience of cravings. This variability has been linked to differences in personality, genetics, dependence level, anhedonia, and affective responding. These sources of variance are important for understanding craving in the individual and for understanding risk processes (Sher & Wood 2005). Further research on individual differences that affect craving, including psychiatric comorbidity (Drummond 2000), is a priority. Research also is needed regarding how craving may change across the life span. In the next section, associations between craving and emotion provide another set of contextual factors that influence craving.

7. CRAVING AND EMOTION

Nearly all addiction models recognize that both craving and negative emotion constitute central features of withdrawal and of substance use disorders more generally (Piasecki et al. 2000, Piper 2015). Indeed, the negative affect associated with withdrawal can be profound. As Baker et al. (2006) observe, ". . .addicted individuals commonly report that giving up a drug seems like losing a dear friend or experiencing a death of a family member" (p. 233). Yet one of the thorniest issues facing researchers is to understand how the concepts of craving and emotion interact (Oliver et al. 2013). A recent review indicates that negative affect precipitates craving (Heckman et al. 2013). It also has been noted that under certain conditions, craving may correlate with positive affect (Baker et al. 1987). A full understanding of the link between craving and emotion is complicated because craving itself is often thought to be fundamentally affective (Baker et al. 1987, Sayette et al. 2003a).

Baker et al. (1987) posit two craving networks (a positive- and a negative-affect urge network) in which information pertaining to drug use is coded. This dual-affect model remains one of the most provocative, yet understudied, models of craving. It articulates a testable theory of craving that can account for both positive- and negative-affect-related urges and provides a framework for understanding the relations between various response systems used to assess craving. Although support has been mixed, few studies have been designed to adequately test the model (for elaboration, see Sayette 1999), and further research is warranted. [See also Stacy & Wiers (2010) and Goldman (1999) for other memory-network accounts of addiction.]

One consequence of viewing cravings as affects, and in accord with Lang's (1984) bioinformation approach to emotion, is that under extreme conditions, diverse responses associated with a positive-affect or negative-affect urge network (involving self-report, behavior, and physiology) may produce coherent response patterns. Although some conclude there is only weak correspondence across self-report and other response domains purporting to assess craving (Tiffany 1990), others find that, consistent with Lang's approach, craving responses converge when motivation to use is strongest (Field et al. 2009, Sayette et al. 2003a).

Thus, cravings may represent a particular type of affective state (Baker et al. 1987). This conceptual overlap between craving and emotion may seem at odds with the notion that an emotional state causes craving. Nevertheless, as Baker et al. (2006) conclude, "There exist both biological and theoretical reasons to distinguish urges from the emotional components of withdrawal" (p. 233). The present view is that various affective states can precipitate cravings, which themselves are a type of affect that varies according to context. When one anticipates using the drug immediately, for example, craving may be pleasurable as one savors the moment, whereas when not expecting to use, craving may be suffused with frustration (Sayette et al. 2003b). Moreover, the particular affective response of a craving may change over the course of the experience (Kavanagh et al. 2005).

This craving-as-emotion framework accommodates the possibility that sometimes craving can be experienced as affectively ambivalent. Breiner et al. (1999) found that quitting smokers

Figure 1

A study participant displaying ambivalent facial expression.

simultaneously endorsed strong inclinations to smoke and to avoid doing so when presented with smoking-related pictures. More recently, continuing smokers who displayed ambivalent facial expressions (concurrent display of expressions related to both positive and negative affect) while holding a lit cigarette reported higher levels of smoking ambivalence than did those who did not display ambivalent facial expressions (Griffin & Sayette 2008) (see **Figure 1**).

In addition, if craving is an emotional experience, then research on emotion suppression also should apply to craving (Kavanagh et al. 2005, Palfai et al. 1997). As noted by Shiffman et al. (2013), cues intended to provoke craving may elicit efforts to suppress craving. Consistent with studies showing an emotional rebound following suppression (e.g., Wegner & Gold 1995), participants evincing suppression-related facial expressions during cue exposure subsequently valued smoking more than did those not displaying these expressions (Sayers & Sayette 2013).

Finally, considerable research has examined the reciprocal relation between emotion and cognition (Bandura 1986, Bower 1981). Aristotle recognized this association when he claimed that reason and passion must work together and that controlling one's own urges was more challenging than conquering an enemy (Shields 2015). Aristotle was neither the first nor last philosopher to recognize the relation between these two concepts, a point that is reemerging thanks in part to neuroimaging craving research linking limbic and prefrontal brain regions (e.g., Wilson et al. 2012). If emotions can influence cognitive processes such as memory, attention, problem solving, and time perception, then conceiving of craving as an affective state raises fertile research questions related to how craving might also influence these processes (Sayette & Creswell 2016), a point considered in Section 5.

8. CRAVING AND COPING

Relapse is often associated with poor use of cognitive and behavioral coping skills (Brandon et al. 1990, Shiffman 1982). Indeed, drug use remains an effective (albeit short-term) coping response

to withdrawal-based negative affect, and abstinent users may remain vulnerable to drug cues until learning a replacement coping response to consumption (Baker et al. 2006).

Despite continuing research and clinical interest regarding the relations among craving, coping, and drug use, challenging conceptual issues remain. The standard assumption is that lapses occur when powerful cravings overwhelm existing coping skills (see Niaura 2000). Although more complex variations of this craving/coping relation exist, both variables are thought to be distinct [e.g., levels of craving and coping can vary within a factorial design (see Abrams 2000)]. Once one experiences a craving, presumably s/he draws upon coping skills to manage it. Unsuccessful coping may precipitate a lapse, whereas successful coping often leads to a temptation episode (Shiffman et al. 1996). This linear approach has received surprisingly little empirical scrutiny, however, and much of the existing research has relied on self-report measures that struggle to capture parallel processing or experiences that are not entirely accessible to introspection. For instance, one may be asked shortly after lapsing to record the level of craving and the degree of coping just prior to the lapse, information that could be influenced by the knowledge that one, in fact, lapsed. Alternative approaches are worth considering. Abrams (2000) speculates that cravings may simply be "a posthoc explanation of the individual's behavior as a result of largely unconscious processes." (p. S239). In instances when persons acquiesce to their cravings, poor coping may not cause lapses but rather may reflect an intended lapse (see Sayette 2006). That is, once individuals decide, perhaps unconsciously, to indulge their craving, they may fail to employ coping skills they have learned. Consider that 71% of treated smokers who mastered a set of coping skills and quit smoking only to subsequently relapse reported (after their initial lapse) using none of these skills (Brandon et al. 1990). Accordingly, coping sometimes may be a reflection of craving, such that modest cravings provide opportunities for coping responses to be employed, whereas strong cravings, or at least cravings accompanied by an intention to use, may preclude coping. As the eighteenth-century poet William Blake wrote in *The Marriage of Heaven and Hell*, "Those who restrain desire do so because theirs is weak enough to be restrained." Still another alternative is that inchoate intentions to use (caused by, for example, an argument earlier in the day) subtly influence in parallel both craving and the accessing or use of coping resources. That is, a distal cue may set the stage for a subsequent lapse that simultaneously features high craving and weak coping, with craving and coping reciprocally influencing each other (see **Figure 2**).

These alternative approaches to craving and coping share features with Lazarus & Folkman's (1984) conception of stress and coping. Their three-stage appraisal model proposes that stress reflects a primary appraisal of loss, threat, or harm, coupled with a secondary appraisal of coping resources available to counter the stressor. A third reappraisal stage, which takes into account both primary and secondary appraisals, ultimately determines the level of stress response. Importantly,

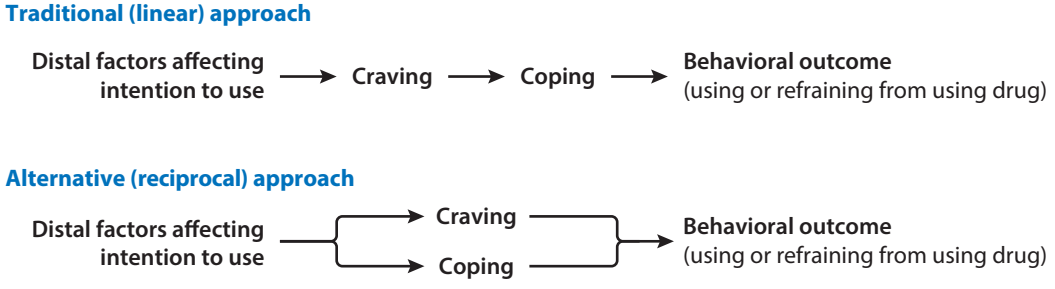

Figure 2

Alternative approaches to craving and coping.

these three appraisal processes blend together seamlessly. In the context of craving, this framework suggests that in an instant, a craving appraisal can emerge that is a function of (*a*) a primary appraisal of a desire to use, (*b*) a secondary appraisal regarding whether or not one will acquiesce (i.e., cope by using the drug) or attempt to resist the urge, and (*c*) a craving reappraisal that may reveal a high craving along with weak efforts to cope (if one were to acquiesce) or less intense desires accompanied by strong attempts to cope (if one aimed to remain abstinent). Importantly, this approach does not require that these appraisal processes be subject to conscious awareness. Research using both explicit and implicit methods is needed to investigate the distinctiveness of concepts such as intention to use, craving, and coping and their interrelations (Sayette 2006).

Cold-to-hot empathy gap: underestimation while in an emotionally neutral "cold" state of the impact on future behavior of being in an emotionally charged "hot" state

9. INSIGHT INTO CRAVINGS: COLD-TO-HOT EMPATHY GAP

Related to coping is Bandura's (1986) concept of self-efficacy, which has been applied to addictive behaviors. Individuals with greater abstinence self-efficacy should be more likely to maintain abstinence (Marlatt 1985, Niaura et al. 1988). Yet pretreatment abstinence self-efficacy judgments do not always predict relapse (see Sayette & Creswell 2016). One reason may be that initial efficacy judgments usually are made in a neutral state, whereas temptation periods that one must overcome to remain abstinent are typically affectively charged and accompanied by craving.

People in an emotionally neutral cold state often underestimate the impact of being in an emotionally charged hot state on their own future behavior, which is referred to by Loewenstein (1999) as the cold-to-hot empathy gap. Consistent with this view, a disproportionate number of individuals inaccurately report maximum self-efficacy scores across behaviors (see Forsyth & Carey 1998). According to the cold-to-hot empathy gap, potential quitters, who are typically affectively neutral during assessment, should overstate their level of abstinence self-efficacy relative to their eventual outcome. Were initial self-efficacy assessments recorded while craving, which more closely reflects high-risk situations, they might prove more accurate than they usually are for predicting quitting. To test the link between abstinence self-efficacy and craving, smokers entering treatment repeatedly reported their smoking urge and abstinence self-efficacy using ecological momentary assessment (Gwaltney et al. 2005). As noted in Section 3, abstinence self-efficacy ratings were inflated during moments of submaximal craving relative to peak-craving states.

Laboratory studies also support the existence of this empathy gap. Smokers in a cold low-craving state, but not those in a hot high-craving state, underpredicted the value of smoking during a subsequent high-craving session (Sayette et al. 2008). This lack of insight is also found for other motivations [e.g., sex, shopping, curiosity (see Loewenstein 1999)]. Individuals may not appreciate the powerful effects of craving when they currently are not craving. Underestimating risk may lead a quitting smoker, for example, to erroneously believe that s/he can handle attending a party where there will be smoking. This poor insight about the power of future craving, coupled with various cognitive processing changes that occur during craving (reviewed in Section 5), further undermines self-regulation efforts (see also Baker et al. 2006). Moreover, if longtime smokers who have ample experience with craving still underpredict its force, one can envision how adolescents may decide to try smoking, assuming it will be easy to later quit (Sayette et al. 2008).

10. HOW TO INTEGRATE NEUROBIOLOGICAL AND BEHAVIORAL INVESTIGATIONS OF CRAVING

A rapidly growing domain of craving research relies on neuroimaging. Functional brain-imaging methods permit noninvasive assessment of signals associated with neural activity under conditions designed to elicit craving. The field has progressed beyond mapping brain responses to

drug-related cues and increasingly considers more nuanced questions about craving. This work presents both challenges and opportunities (Sayette & Wilson 2015). On one hand, many studies arguably have been too quick to apply behavioral cue-exposure methods without accounting for the unique environment of the scanner. In addition (as noted in Section 7), several studies seeking to evaluate craving instead have examined mild states of desire (Wilson & Sayette 2015). On the other hand, identifying neural patterns associated with basic cognitive and emotional experiences may lead to important scientific advances and inform a new generation of behavioral research. Imaging research is not necessarily subject to the language constraints of self-report assessments, which permit craving responses to be examined without thrusting craving into meta-consciousness through use of a self-report craving instrument that prompts the very phenomenon it seeks to assess (Sayette et al. 2010b). Imaging cue-reactivity research points to key neural differences between deprived and nondeprived smokers and suggests that drug cue exposure can generate neural responses that carry over into subsequent neutral cue trials (Sayette & Wilson 2015).

Conversely, behavioral research can efficiently set the stage for more time-consuming imaging studies. As one example, behavioral research (reviewed in Section 6) suggested that perceived drug use opportunity can affect craving. During cue exposure, treatment-motivated users reported weaker cravings than did continuing users. This behavioral research helped to organize a contradictory neuroimaging literature (see Wilson et al. 2004) and led to empirical studies identifying distinct neural patterns associated with these different contexts (e.g., Wilson et al. 2012). Future research integrating brain imaging with other nonverbal measures (e.g., facial coding) may lead to further advances in understanding craving.

11. INTERVENTIONS

New addiction treatments are needed, including interventions focusing on craving (Ferguson & Shiffman 2009, Unrod et al. 2014). Craving may directly drive drug use and relapse. Insofar as craving is distressing, it warrants intervention regardless of its effects on use (Tiffany & Wray 2012). Moreover, testing new craving interventions in the lab is less expensive than, and may prove to be a useful precursor to, clinical trials (Abrams 2000). Pharmacological, neurobiological, and behavioral craving interventions have been evaluated. Medication development is a priority at many addiction research institutions, though not all medications directly address craving. With respect to smoking, pharmacotherapies reduce relapse in part by attenuating craving (Baker et al. 2006). Interventions include nicotine replacement products, as well as medications such as bupropion and varenicline (Brandon et al. 2011). The best-known pharmacological intervention for alcohol craving is naltrexone, which is thought to extinguish the association between alcohol cues and reinforcement (the feeling of a "high") in the form of opiate receptor activation (Wiers & Heinz 2015). Methadone and buprenorphine both have been found to alleviate opioid cravings. (For elaboration on pharmacotherapies, see Natl. Inst. Drug Abuse 2012.) With respect to neurobiological interventions, brain stimulation approaches have drawn attention recently as a method for reducing cravings and curbing addiction (see Hader & Zangen 2015).

Behavioral interventions include approaches in which craving is first provoked via cue exposure, and then the user may wait until the urge begins to naturally abate or may implement coping skills to combat the urge. Although initial efforts with alcohol were promising (Monti et al. 1993), interventions for other drugs have been less successful. Conklin & Tiffany (2002) address how clinical efforts might benefit from a closer reading of preclinical research examining basic principles of learning and extinction (see also Unrod et al. 2014). Interventions also emphasize cognitive and affective strategies. Palfai (2006) describes approaches to enhance the automaticity of self-control processes during high-risk moments. It may be useful to learn to relate automatically the

occurrence of a high-risk situation with a healthy outcome, coined an implementation intention (Gollwitzer 1999) (e.g., "If I am around a person using this drug, then I will leave the area").

Efforts have been made to reduce craving and relapse by relieving negative affective states related to withdrawal. Baker et al. (2006) suggest pairing drug replacement with the self-administration ritual to "quell withdrawal distress and promote successful cessation of drug use" (p. 236). Heckman et al. (2013) propose intervention strategies to attenuate negative affect or weaken the association between negative affect and craving or drug seeking. More recently, apps have been developed that access real-time help with cravings.

In addition, novel efforts have been made to curb cravings that require additional research to support their efficacy. Mindfulness practices, which direct attention to momentary experiences together with acceptance of those experiences, show promise by enhancing the capacity to monitor and cope with craving-related distress (Bowen et al. 2014). Rose and colleagues tested the impact of inhaling various substances designed to simulate the pleasurable sensory experience of smoking on craving relief (airway sensory replacement). Independent of nicotine, these sensations relieve craving and facilitate smoking abstinence (see Rose 2006). Nevertheless, the long-term success of this replacement method remains unknown, and "no satisfactory approach has yet been developed" (Rose 2006, p. 281).

In contrast to airway sensory replacement, preliminary research has focused on olfactory cues to distract a smoker away from smoking, perhaps by evoking non-smoking-related emotional memories. The premise that odors are better suited than other sensory cues to reduce affectively charged cravings receives support from multiple sources. Cravings are emotional "visceral" experiences (Loewenstein 1999), and emotions are better manipulated through olfaction than other sensory systems (Herz 2012). Indeed, the importance of olfaction in stimulating smoking has not gone unnoticed by the tobacco industry. As one Philip Morris scientist predicted, "The continued financial success of our business will rely to an ever increasing degree upon our understanding of the chemical senses and application of this information in the design of new products" (cited in Megerdichian et al. 2007, p. 1125). This approach was supported in a study testing olfactory cues on craving relief in smokers (Sayette & Parrott 1999). After experiencing a peak craving via smoking cue exposure, abstinent smokers sniffed one of three preselected odors (among those they had ranked most pleasant, least pleasant, or neutral) and immediately rated their urge. Exposure to the pleasant or unpleasant odor (similarly) reduced the urge to smoke relative to the control odor. The drop in urge among those assigned to sniff an emotionally provocative odor doubled that found for the control odor (Sayette & Parrott 1999). A follow-up study to extend these findings is in progress. Finally, olfaction is not the only sense being targeted to distract one from a craving. Andrade and colleagues (2012) developed a visuospatial task (modeling clay into shapes) and found that visual imagery reduced chocolate cravings.

In summary, there is interest in developing and refining pharmacological and behavioral interventions targeting drug craving. One implication is the need to create clinical settings that incorporate high craving states into their assessments and interventions (Sayette & Creswell 2016).

12. CONCLUSIONS

Craving is central to addiction. Despite continuing conceptual and methodological debates, craving remains a useful construct to both researchers and clinicians. In clinical settings, self-reports of craving can be assessed easily and reliably. There also is support for its inclusion as a criterion for diagnosis of substance-use disorder and as a clinical outcome in treatment research. Nevertheless, although there is a consensus that craving is a clinically meaningful concept, theory-driven, multimethod, interdisciplinary research still is needed to better understand this complex

experience (Abrams 2000, Sayette et al. 2000). Shiffman's (2000) assertion that "we have to understand craving better" (p. S175) remains accurate.

Research highlights the importance of craving intensity, and additional investigations are needed to determine if distinctions between mild and powerful desires to use represent two points on a craving continuum or qualitatively distinct experiences. Relatedly, further scrutiny is needed of basic methodological assumptions underlying drug-cue-reactivity research. With regard to cigarettes, for example, when withdrawn smokers are tested, merely completing a baseline craving measure while immersed in a laboratory replete with smoking stimuli may serve as a smoking cue, making it difficult to capture with a self-report instrument a true baseline craving value.

In contrast to most traditional perspectives, cravings are not uniformly unpleasant. Although frustration is common when someone is resisting or is otherwise prevented from using, in circumstances in which one perceives an opportunity to use the substance imminently, the experience can be quite pleasant. Clinically, these positive states may be interesting to study, as the affective responses to their loss upon quitting (in addition to termination of actual drug use) may constitute a relapse risk. It also is becoming clear that a host of contextual factors likely influence craving. Understanding these moderating factors may help refine understanding of the link between craving and use. For instance, seeking abstinence, seeking to avoid abstinence imposed by environmental limitations, or interacting with others who are using appears to alter the affective experience of craving, the degree that attentional resources are directed toward drug use, the underlying patterns of neural activation, and the magnitude of self-reported urge. Although coping resources are thought to respond to cravings, alternative models that view both craving and coping responses as operating in parallel (with both affected by a possibly unconscious intention to acquiesce or resist) may yield new approaches for intervention and assessment. In addition, meta-emotional processes associated with craving may prove to be a useful research direction.

As the clinical utility of craving becomes recognized, the need to conduct research on mechanisms underlying its association to consumption is paramount. This article outlines some explanations for why craving may promote relapse, including changes in attentional processes, monitoring of internal states, processing of drug- and non-drug-related information, and temporal cognition. This list likely represents only some of the processes underlying the craving–drug use relation, and additional tightly controlled experimental research is indicated. Laboratory scientists must continue, however, to scrutinize conventional methods for conducting craving research, including use of within-subjects designs incorporating multiple trials of drug and neutral cues. Although in theory such approaches provide optimal conditions for investigating craving, concerns regarding the independence of trials often are ignored. Relatedly, methodological concerns also limit the ability to fully evaluate the utility of distinguishing between tonic and phasic cravings, and further research on this topic is needed given the near-universal acceptance of this putative distinction. PPC approaches can complement traditional cue-reactivity methods in studies that have particular difficulty teasing apart withdrawal-based and cued effects. In summary, studies to develop novel theories and clinical interventions require valid paradigms for manipulating and assessing craving. Although standard methods for inducing craving have yielded key insights and likely will continue to do so, improved methodological rigor is needed to better understand their limitations. In addition, the development and testing of alternative craving-induction methods should be encouraged.

It is likely that self-reported urge measures will remain the most popular method to assess craving. Although these traditional approaches necessarily draw craving into meta-conscious experience, alternative (self-caught) approaches to assessing self-reported urge may provide a useful complement. In addition, efforts to develop and refine reliable nonverbal approaches to craving assessment remain a research priority. As neuroimaging craving research abounds, it will be

important to integrate it with the latest behavioral findings. Already there exist reciprocally informative data from each domain.

With countless opportunities to crave, it is easy to imagine that users become adept at appreciating the power of future cravings, which may explain why many assessment instruments are administered while users are in a neutral (noncraving) state. Yet research on the cold-to-hot empathy gap suggests that users systematically underpredict the power of future cravings, and they may do so at their peril. This lack of insight may contribute to relapse risk and deserves additional focus by researchers and clinicians.

In summary, craving is one of the most studied topics in addiction. Its recent inclusion in DSM-5 reinforces its status as a clinically meaningful construct. Yet we continue to struggle as a field to understand this complex experience or set of experiences. Too often our scientific approach to craving has been narrow; we do not adequately appreciate the intellectual contributions to its understanding provided by writers, scholars, and philosophers through the centuries. This rich source of ideas cannot be comprehensively considered here, but select illustrations suggest that we may need to think differently about our scientific discourse on craving, and they highlight factors that invite further investigation including volition, context, the link between craving and behavior, internal experiences that set the stage for either an overwhelming or a manageable craving, and the occasional association between craving and vitality and well-being.

Such openness to new ideas is crucial, as in many respects we are at a crossroads. There is momentum to apply our current craving methodologies to exciting and expensive projects designed to develop new clinical assessments, interventions, and groundbreaking neurobiological models of addiction. And yet we sometimes find ourselves relying on inadequately tested conceptual and methodological assumptions about craving. Craving researchers should take a half step back and scrutinize these basic assumptions. Admittedly, such foundational craving research may feel unsatisfying when there is a pressing demand for craving manipulations and assessments, which despite some limitations are still advancing knowledge. In order to optimally progress as a field, however, we must embrace this tension and push forward on both basic and applied fronts. Such efforts promise to improve understanding of the link between craving and substance use and will help to refine clinical interventions.

SUMMARY POINTS

1. The inclusion of craving as a criterion for substance use disorder in DSM-5 reinforces its diagnostic and clinical utility as a construct at the core of addiction.
2. Laboratory research has begun to establish a link between craving and drug use and to identify mechanisms underlying this association.
3. Multiple contextual factors affect the diversity of craving experiences.
4. Despite the powerful effects associated with craving, when in neutral states individuals tend to underpredict the effects of future cravings.
5. Standard laboratory methods for manipulating and measuring craving have yielded key insights, yet they often have failed to receive the necessary empirical scrutiny.
6. Peak-provoked craving offers a viable approach to organizing many prior studies of cigarette craving and may prove useful for studying other drugs that produce rapid withdrawal states.

7. Although self-report measures can detect craving and will continue to be widely used in research and clinical settings, understanding of craving will be enhanced through development of a multimodal battery of measures across diverse response domains.
8. Research examining individual variation in craving responding represents an emerging area of investigation that promises to advance knowledge of craving and to identify persons at risk for developing substance use disorders.

FUTURE ISSUES

1. There is need for a renewed commitment to methods research aimed at refining existing, and developing alternative, approaches to the manipulation and assessment of craving.
2. More studies of craving-related responses are needed to determine why craving may increase relapse risk and to examine how these craving-related responses may change across the life span.
3. The development of nonverbal and implicit measures of craving and the integration of brain imaging and behavioral craving responses, including facial coding, may lead to advances in understanding craving and coping and their relation to drug use and relapse.
4. Studies on craving should continue to apply laboratory methods and emerging mobile technologies to develop multimodal approaches to ecological momentary assessment.
5. Further research is needed to fully evaluate the utility of distinguishing between tonic and phasic cravings for different substances.
6. Additional research focused on the diverse manifestations of craving, including cravings linked to positive affect, would have both conceptual and clinical implications.
7. Studies evaluating the possible differences between mild and robust states of desire are needed.
8. Meta-emotional processes associated with craving (i.e., how one feels about a current craving) may prove to be a useful research direction.
9. There is a need to develop novel psychological approaches to craving reduction that apply research in areas such as sensation, perception, memory, emotion, motivation, and social processes.
10. There is further need to create clinical settings (actual or virtual) that incorporate craving states into their assessments and interventions.

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