Cue-induced cigarette craving and mixed emotions: A role for positive affect in the craving process

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HIGHLIGHTS

► Simultaneous positive and negative affect reported in response to cues
► Cigarette cues associated with higher mixed emotion than other cue types
► Pleasant cues elicit higher craving than neutral or unpleasant cues
► Mixed emotions to cigarette cues predict self-reported craving
► Results suggest a role for positive affect in the cue-reactivity craving process

ABSTRACT

Craving is an important component of nicotine addiction, and extant research has demonstrated a clear link between cue-induced craving and negative affect, with mixed results in the positive affect domain. The current study was designed to test the idea that cue-reactive craving might be associated with a mixed emotional process, or the simultaneous experience of positive and negative affect. Participants were 86 non-deprived regular smokers and tobacco chippers who provided simultaneous ratings of positive and negative affect during cue exposure to pleasant, unpleasant, neutral and cigarette cues. Results indicated that self-reported craving was elevated in response to cigarette cues compared to other valenced cue types and craving was higher to pleasant cues than either neutral or unpleasant cues. Mixed emotional responses were higher to cigarette cues than other cue types. In addition, mixed emotional responses to cigarette cues predicted craving even after controlling for smoker type, difficulties regulating negative emotion, baseline craving level and mixed emotional responses to neutral cues. In addition, our findings suggest that positive affect processes may indeed play a role in craving among non-deprived smokers.

1. Introduction

Craving for cigarettes, whether induced by withdrawal or in response to cues, has been clearly linked to affective processes (Tiffany, 2009). In the realm of cue-reactivity, a robust relationship has been demonstrated between negative affect and craving (Brandon, Wetter, & Baker, 1996; Carter & Tiffany, 2001; Drobes & Tiffany, 1997; Maude-Griffin & Tiffany, 1996; Taylor, Harris, Singleton, Moolchan, & Heishman, 2000). Despite these findings, the precise nature of the relationship between craving and affect remains uncertain. Further examination of the affective processes associated with cue response may prove important, particularly if affective responses contribute to self-reported craving and/or behavioral outcomes.

1.1. Craving and negative affect

The relationship between cue-reactive craving and negative affect is clearly established in the literature. A host of evidence suggests that negative affect manipulations, even without the addition of smoking cues, prompt increased craving levels (Maude-Griffin & Tiffany, 1996; Taylor et al., 2000). Negative affect predicts craving when measured prospectively (Brandon et al., 1996; Drobes & Tiffany, 1997), and negative states show robust correlations with craving (Carter & Tiffany, 2001; Lee et al., 2007; Singleton, Anderson, & Heishman, 2000).
1.2. Craving and positive affect

At first blush, it appears that positive affect typically either has no correlation to smoking urge (e.g., Drobes & Tiffany, 1997; Kassel et al., 2007), or is associated with decreased urge (Bailey, Goedeker, & Tiffany, 2010; Maude-Griffin & Tiffany, 1996; Taylor et al., 2000; Tiffany, 2009).

Theoretically, however, positive affect has been linked to urge. A recent model of impulsivity suggested that certain individuals are likely to act rashly (e.g. succumb to urges) when in a positive mood (Cyders & Smith, 2008; Cyders et al., 2007). In addition, Baker and colleagues (Baker, Morse, & Sherman, 1987) proposed a craving model with two separate urge pathways such that a positive-urge network may be activated by appetitive stimuli, particularly for non-deprived smokers. As an example, in a study comparing deprived and continuing smokers on craving and affect ratings over a 24-hour period, Zinser and colleagues (Zinser, Baker, Sherman, & Cannon, 1992) found a significant positive relationship between positive affect and craving for continuing smokers, whereas deprived smokers expressed concordant negative affect and craving (however, see Brandon et al., 1996 for contradictory findings).

Several of the studies that found a negative relationship between positive affect and craving have investigated the effect of positive mood, typically induced in a laboratory setting, on subsequent cue-reactive craving (Maude-Griffin & Tiffany, 1996; Taylor et al., 2000). Whether mood state influences reaction to cues is a different, albeit related, question than whether self-reported craving increases in response to valenced cues or if changes in affect follow from presentation of cigarette cues. Self-reported craving in response to valenced cues has received limited empirical attention in the realm of cue-reactivity, as the typical cue-reactivity study compares craving responses to cigarette cues with craving responses to neutral cues (Carter & Tiffany, 1999). However, recent work comparing craving responses to a full set of valenced cues (e.g., including both pleasant and unpleasant cue stimuli) found heightened craving in response to positive cues when compared to negative and neutral cues (Muñoz et al., 2010; Robinson et al., 2011). Moreover, in the realm of psychophysiology, startle eyeblink responses (where heightened responses are indicative of negative affect) are dampened to both cigarette and pleasant cues (Cui, Robinson, Versace, Lam, & Minnix, 2012; Dempsey, Cohen, Hobson, & Randall, 2007). Overall, these studies suggest that smoking cues are appetitive.

Other recent work has examined changes in affect following the presentation of cigarette cues, with mixed results. One study found that generalized positive affect decreased and negative affect increased in response to cigarette cue exposure (Doran et al., 2008). Another study found that smoking cues are associated with higher excitement (a specific positive feeling), when compared to non-smoking cues (Conklin et al., 2010). A third recent study examining self-reported mood in response to valenced and cigarette cues found that positive mood was higher to cigarette and positive cues compared to neutral and unpleasant cues (Robinson et al., 2011). In sum, although there is burgeoning evidence that smoking cues are appetitive, and theoretical frameworks proposing a link between positive affect and craving, the remaining empirical research on the relation between positive affect and craving is mixed. Considering that a synonym often used for craving is “desire,” which has a positive connotation, the mixed evidence is an apparent conundrum. Research focused on positive affect and craving may benefit from considering alternative approaches and methodologies to determine if, when, and for whom positive affect relates to craving.

1.3. Comparing positive and negative affect

An additional piece of the puzzle is that positive and negative affect are rarely compared to one another. For example, in a study comparing affective responses to cues, positive affect was lower in response to an imagery exposure with urge content compared to an imagery script with neutral content (Drobes & Tiffany, 1997). However, ratings of positive affect across the entire study were considerably higher than ratings of negative affect, a point not raised by the authors, as they focused on comparisons of smoking to neutral cues rather than comparisons of negative and positive affect.

Examining changes in emotional response to cues is important, but comparison of levels of negative and positive affect may provide different—and potentially equally important—information. For example, Sayette and Hufford (1995) found that participants manifested more positively valenced facial expressions than negative during initial cue exposure, and that more positive urge characteristics were self-generated during cigarette cue exposure compared to neutral cues, a relationship not found for negative urge characteristics (Sayette & Hufford, 1997). This study suggests that comparison of negative and positive affect might highlight the role of positive affect in cue-reactivity which is often obscured in other study designs. Moreover, a comparison of emotional responses may elucidate the relative contributions of positive and negative affect, both together and separately, on craving responses.

1.4. Mixed emotions

Highlighting the role of positive affect in cue-reactivity is only important if positive affect influences craving and/or behavior. Considering the robust relationship between craving and negative affect, it may be that “pure” positive affect has little role in the craving process. However, there may be benefit in modeling simultaneous positive and negative affect, dubbed “mixed emotions” (Larsen & McGraw, 2011; Larsen, McGraw, & Cacioppo, 2001; Larsen, McGraw, Mellers, & Cacioppo, 2004; Larsen & Stastny, 2011). In basic emotion research, Larsen and colleagues have demonstrated that many people experience heightened positive and negative affect when confronted with a film that is both funny and tragic; when experiencing the celebration and fear associated with graduating from college; or when reacting to disappointing wins and relieving losses (Larsen, Norris, McGraw, Hawley, & Cacioppo, 2009; Larsen et al., 2001; Larsen et al., 2004).

The concept of mixed emotions calls into question the assumption that positive and negative affect must be mutually exclusive, an assumption that is common in basic emotion research (e.g., Russell, 2003) as well as implicitly endorsed in many of the cue-reactivity studies reviewed above. If negative affect and positive affect are opposites, and mutually exclusive, when negative affect goes up, positive affect must, by definition, go down. However, if positive and negative affect are independent and modeled simultaneously, we can establish if cues elicit relatively pure emotional responses or if cue-reactivity may be associated with a mixed emotional response.

The idea that craving might involve both positive and negative affect processes is certainly not new (Baker et al., 1987; Breiner, Stritzke, & Lang, 1999; Kavanagh, Andrade, & May, 2005). However, to our knowledge, the association between craving and mixed emotion has not been explicitly tested. Nonetheless, several studies have yielded findings consistent with a mixed emotional perspective. Taylor et al. (2000) created a variety of imagery scripts that differed in valence and smoking urge, and examined how the scripts influenced positive affect, negative affect and craving. For positively valenced scripts, the inclusion of urge-related material decreased positive affect and increased negative affect compared to the no-urge scripts. However, for negatively valenced scripts, the inclusion of urge-related material resulted in lower negative affect and heightened positive affect compared to no-urge negative scripts. Thus, the addition of the urge component attenuated the effect of negative stimuli on self-reported...
affect. These results are consistent with a mixed emotional experience; the urge component elicited some positivity to the negative scripts, and some negativity to the positive scripts.

One recent study investigating ambivalence about smoking explicitly examined mixed emotional facial expressions during a cue reactivity paradigm. Among regular smokers who were 7 hours deprived, Griffin and Sayette (2008) measured positive and negative facial expressions while smokers were exposed to smoking and neutral cues. They found that 24% of participants exhibited both positive and negative facial expressions in response to smoking cues, where no mixed expressions (termed ‘ambivalent’ by the authors) were evident in response to neutral cues. Moreover, participants who displayed mixed expressions also evidenced elevated withdrawal symptoms and a greater interest in quitting compared to participants who did not display a mixed emotional response.

It is important to test the relationship between craving and mixed emotions for several reasons. A mixed emotional experience is qualitatively different, and appears to be theoretically less common than either a “pure” negative experience or a “pure” positive experience (Larsen, Hemenover, Norris, & Cacioppo, 2003). In other words, there is inherent conflict in a mixed emotional experience that may result in experiential discomfort. If craving elicits a mixed emotional experience, and subsequent cigarette smoking resolves the mixed feeling, simultaneous positive and negative reinforcement processes may be at work. Moreover, considering mixed emotional responses allows a role for positive affect in the craving process, which is theoretically suggested and may be obscured by considering positive and negative separately.

1.5. The current study

The current study was designed to extend cue-reactivity research in several ways. First, in addition to providing smoking and neutral cues, as is common in cue-reactivity studies (e.g., Bailey et al., 2010; Doran et al., 2008; Sayette & Hufford, 1995), pleasant and unpleasant affective cues were also included in order to better facilitate understanding of the craving-emotion relationship. Specifically, pleasant and unpleasant cues were included as additional comparison points to neutral cues to replicate recent findings that positive cues prompt heightened craving compared to negative and neutral cues (Muñoz et al., 2010; Robinson et al., 2011).

Second, we investigated the relationship between mixed emotion and craving using a measure of emotion developed from an emotion model that posits negative and positive affect as partially independent systems (Evaluative Space Model; Cacioppo & Berntson, 1994, Cacioppo & Berntson, 1999). We predicted that compared to the other valenced cue types, mixed emotions would be heightened in response to cigarette cues. We also predicted that mixed emotions would predict self-reported craving above and beyond mixed emotional responses to neutral cues.

Third, to attend to critiques that cue-reactivity research often neglects behavioral outcomes (Perkins, 2009; Rosenberg, 2009; Sayette et al., 2000), we hypothesized that craving in response to cigarette cues would predict risk-taking behavior. Moreover, we investigated these relationships in a sample of both regular smokers and tobacco chippers, guided by the assumption that the relationship between emotion and smoking might differ for smokers with different dependence and smoking frequency rates.

2. Methods

2.1. Participants

Participants were recruited via online advertisements (Craigslist) in a large Midwestern city. Respondents over age 18 (N=1600) were screened to determine eligibility. Inclusion criteria were: smoking at the same rate for two years, not currently trying to quit, no more than three quit attempts in the past two years with none in the last six months, no self-identified cardiovascular disease, not pregnant, and no regular use of other tobacco products. Eligible participants were invited to the laboratory if they were either (a) a regular smoker, defined as smoking on average at least 16 cigarettes daily, or (b) a tobacco chipper, smoking on average between 1 and 5 cigarettes a day at least 4 days per week. These criteria are similar to other studies that compared regular smokers and chippers (e.g. Shiffman, Paty, Kassel, Gnyr, & Zettler-Segal, 1994). A total of 303 applicants qualified for an invitation to the laboratory study (158 regular smokers, 145 tobacco chippers), and 100 qualified participants responded to the invitation, scheduled a session and completed the study.

2.2. Procedure

As this study aimed to understand regular craving throughout the day rather than model the effects of deprivation on craving, participants were allowed to smoke normally up to the start of the session. After completing informed consent, participants provided an expired-air carbon monoxide (CO; Vitalograph, Lexington, KY) reading to verify smoker status. Participants then completed self-report questionnaires and were trained on how to use the Continuous Evaluative Space Grid (CESG). During training, participants were instructed in how to describe mixed emotions if they were experienced as well as how to describe non-mixed emotions if/when they were experienced. The goal was to give participants enough instruction to use the measure but not so much that strong demand effects were created. After verbal instruction, participants rated several sample slides with the experimenter remaining in the room to handle any questions. Following training but before the cue-reactivity segment, participants engaged in an initial assessment of risk behavior.

The cue-reactivity procedure involved viewing 48 slides, 12 of each emotional valence (pleasant, unpleasant, neutral) and 12 depicting cigarette cues (Carter et al., 2006). The emotionally valenced slides were taken from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1995), where pleasant and unpleasant slides were matched on normed ratings of arousal (Using the IAPS numbering system, the positive slides were: 1463, 2057, 4668, 4677, 4693, 7330, 7350, 7470, 7499, 8030, 8492, and 8501. Negative slides: 1050, 1304, 3150, 3266, 3350, 6250, 6550, 9414, 9571, 9584, 9810, 9940. Neutral slides: 2190, 2240, 2397, 2620, 5731, 7004, 7010, 7026, 7100, 7175, 7185, and 7491). The cigarette slides were developed by Carter and colleagues (Carter et al., 2006), who found the slides to elicit high levels of craving in both deprived and non-deprived smokers. The slides were displayed in blocks, with 8 slides to a block (2 of each category). The slides within each block were presented in randomized order, and the blocks themselves were randomized. This procedure assured that no category would be displayed more than twice in a row.

Each slide was preceded by a 10 second re-orienting white screen. The slides were presented for 15 seconds each on one half of the screen, with the CESG presented on the other half. Participants used the mouse to move around the CESG continuously (as much or as little as they felt) during the slide presentation. Immediately following each slide, the participant was asked to complete a single visual analogue craving rating. Following the entire cue reactivity paradigm, participants completed another craving measure (QSU), and then a second craving rating. Following the entire cue reactivity paradigm, participants completed another craving measure (QSU), and then a second craving rating. The slides within each block were presented in randomized order, and the blocks themselves were randomized. This procedure assured that no category would be displayed more than twice in a row.

Each slide was preceded by a 10 second re-orienting white screen. The slides were presented for 15 seconds each on one half of the screen, with the CESG presented on the other half. Participants used the mouse to move around the CESG continuously (as much or as little as they felt) during the slide presentation. Immediately following each slide, the participant was asked to complete a single visual analogue craving rating. Following the entire cue reactivity paradigm, participants completed another craving measure (QSU), and then a second trial of the BART risk task. Finally, participants were given the opportunity to smoke in the lab. The entire experimental session was approximately 90 minutes in duration.

2.3. Measures

2.3.1. Smoking measures

Smoking dependence was assessed using the total score from the Nicotine Dependence Syndrome Scale (NDSS; Shiffman, Waters, &
2.3.2. Computerized Evaluative Space Grid

Mixed emotions were evaluated using the Computerized Evaluative Space Grid (CESG; Larsen et al., 2009), a single-item measure of simultaneous positivity and negativity developed from the Evaluative Space Model of emotion (Cacioppo & Berntson, 1994). The measure was displayed graphically in a 9 × 9 matrix, with current level of positivity (0 to 8) on the X-axis and current level of negativity (0 to 8) on the Y-axis. The current study utilized the Continuous Evaluative Space Grid (CESG), a computerized version of the grid whereby the participant moved a computer mouse around the screen continuously and the program recorded the mouse position of both positivity and negativity every half second. The CESG was always presented to the right of the slide on a 20 inch widescreen LCD monitor. Due to the nature of the instrument, namely that single item ratings are made over time, psychometric properties (e.g., alpha) are not calculable, though the measure has been used in several other studies (Larsen & McGraw, 2011; van Reekum et al., 2011; Wardle & de Wit, 2012).

2.3.3. Balloon Analogue Risk Task

The Balloon Analogue Risk Task (BART; Lejuez et al., 2002) is a computerized, behavioral measure of risk taking where participants inflate virtual balloons for monetary awards and lose money when the virtual balloons “explode.” For the current study, the amount earned per trial was utilized as an outcome measure (Lejuez et al., 2002). The BART was administered near the beginning of the study to assess baseline impulsive responses uncoupled with smoking availability, and again after the cue-reactivity portion. Immediately prior to the second administration of the BART, participants were told they would be allowed to smoke following completion of the task. Thus, change scores from first to second administration were used as an indication of smoking value: if participants earned less money, they would be able to smoke more quickly. There is precedent for assessing change scores in the BART; Cyders (2008) used the BART toward assessing propensity to rash action (i.e., an increased in the number of exploded balloons) in response to a positive affect induction.

2.4. Analytic plan

We first examined descriptive statistics and used independent samples t-tests to evaluate differences between regular smokers and chippers on all study measures, as well as gender differences. Visual analogue craving scores were collected after each slide, and an average craving score per slide condition was then calculated for each individual. A 4 (within-subject slide condition: pleasant, unpleasant, neutral, and cigarette) × 2 (regular smoker, chipper) mixed design ANOVA was conducted on the visual analogue craving scores to replicate the typical finding that craving responses were higher to cigarette slides in comparison to neutral slides (Carter & Tiffany, 1999), and to evaluate the craving response to pleasant (appetitive) and unpleasant (aversive) stimuli.

Positive and negativity responses to the slide conditions (pleasant, unpleasant, neutral, and cigarette) were evaluated using separate within-subject ANOVAs, where average positivity and negativity responses to each slide were calculated, then a mean response for each slide condition. Of note, although smoker type (regular smoker versus chipper) was initially analyzed as a potential moderator variable, no main effects or interactions related to smoking group emerged and thus only the main effects of slide condition on emotional response are reported here.

In addition to assessing separate positive and negativity scores for the slides, mixed emotional responses were calculated using the MIN index (Larsen & McGraw, 2011; Schimmack, 2001). Specifically, the average minimum value of each participant’s positivity and negativity ratings were calculated for each slide, and then for each of the four slide conditions (MIN[Positivity, Negativity]). As MIN uses the minimum value for either positivity or negativity, it will be zero if no mixed emotion is present (e.g., if only positivity or negativity are reported). This is a conservative test of mixed emotions, as it represents only the minimum value at which both positivity and negativity are activated.

A hierarchical regression was conducted to assess if mixed emotional responses to cigarette slides predict craving to cigarette slides. Hierarchical regression was used to control for several salient variables. Specifically, nicotine dependence was entered in Step 1, followed by baseline craving measured by the Questionnaire of Smoking Urges and visual analogue craving to neutral slides in Step 2. Both baseline craving and craving to neutral slides were included to ensure that the mixed emotions were predictive of craving specifically to cigarette slides, not merely heightened craving due to abstinence or reactive craving to a slide viewing paradigm. In Step 3 mixed emotional responses to neutral slides and cigarette slides entered the model.

Finally, another hierarchical regression was conducted to predict change in BART earnings from the initial trial to the second trial, when participants were told that they would be able to smoke after completing the second BART. Nicotine dependence and initial BART earnings were entered in Step 1, and visual analogue craving to neutral and cigarette slides were entered in Step 2. Thus, this regression tested if craving to slides is predictive of change in BART scores.

3. Results

3.1. Participant characteristics

One hundred qualified participants completed the laboratory study. However, ten individuals who refused to smoke as part of the experiment as well as four others who had substantial missing data were excluded from further analyses, resulting in a final sample of 86 participants: 41 tobacco chippers (19 women, 22 men) and 45 regular smokers (21 females, 24 males). The ethnic breakdown was 66.3% Caucasian, 12.8% African American, 10.5% Latino/a, 4.7% Asian American, and an additional 5.8% that responded ‘other’ or opted to not provide ethnicity information. Consistent with previous literature suggesting a higher percentage of minorities are chippers (e.g., Coggin, Murrell, Carchman, & Heidbreder, 2009), 17.8% of the regular smoker group identified as non-Caucasian, whereas 46.3% of the chipper group identified as non-Caucasian. The mean age of the sample was 30.84 (SD = 9.60). There were no differences in the ages of the regular smokers (M = 32.23; SD = 10.71) and chippers (M = 29.34; SD = 8.10), t(83) = 1.39, ns. However, the women (M = 34.26, SD = 10.80) were slightly older than the men (M = 27.93; SD = 7.40), t(83) = 3.19, p < .01.

1 Due to gender differences in affective vulnerability (e.g., Hankin & Abramson, 2001), gender was evaluated as a moderator of all outcomes. Results indicated that women demonstrated less craving to neutral slides (M = 30.71) than men (M = 49.05) and women had stronger negativity responses to negative slides (M = 5.41) than men (M = 4.54). Despite these differences, no significant gender differences emerged on key variables (mixed emotional responses, craving to cigarette slides, or BART scores) nor was gender a significant moderator of the relationship between mixed emotions and craving or change in risk, and are thus not mentioned further to simplify presentation of the results.
Table 1
Descriptive statistics and comparison of regular smokers and tobacco chippers.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regular smokers</th>
<th>Chips</th>
<th>t or χ²</th>
</tr>
</thead>
<tbody>
<tr>
<td>% with past quit attempt</td>
<td>77.78% (n = 35)</td>
<td>63% (n = 63)</td>
<td>χ² = 2.15</td>
</tr>
<tr>
<td>Cigarettes/day</td>
<td>19.21 (4.55)</td>
<td>4.19 (1.58)</td>
<td>t(77) = 18.86***</td>
</tr>
<tr>
<td>Interest in quitting</td>
<td>4.31 (2.89)</td>
<td>4.34 (2.67)</td>
<td>t(84) = .05</td>
</tr>
<tr>
<td>NDSS total</td>
<td>57 (88)</td>
<td>.81 (89)</td>
<td>t(84) = 7.25***</td>
</tr>
<tr>
<td>Baseline QSU</td>
<td>34.11 (12.44)</td>
<td>34.76 (12.54)</td>
<td>t(84) = .24</td>
</tr>
<tr>
<td>Post cue-reactivity QSU</td>
<td>49.00 (13.07)</td>
<td>43.95 (15.60)</td>
<td>t(84) = 1.63</td>
</tr>
<tr>
<td>Baseline CD</td>
<td>20.93 (9.97)</td>
<td>8.41 (8.98)</td>
<td>t(84) = 6.10***</td>
</tr>
<tr>
<td>Recency of smoking (minutes)</td>
<td>19.58 (22.10)</td>
<td>116.84 (184.51)</td>
<td>t(80) = 3.51***</td>
</tr>
</tbody>
</table>

***p<.001, **p<.01.

3.2. Descriptive statistics

Descriptive characteristics of the sample are displayed in Table 1. Regular smokers differed from tobacco chippers on number of cigarettes smoked per day, dependence (NDSS), recency of smoking, and baseline expired air carbon monoxide. No differences between regular smokers and chippers were found on interest in quitting, past quit attempts, craving, or difficulties with emotion regulation. Of note, no gender differences were found on any of these individual difference variables (all ps > .05).

3.3. Craving in response to valenced slides

Overall, regular smokers exhibited higher craving than chippers, F(1, 84) = 3.98, p < .05, η²p = .05, though we found no interaction between smoker type and slide condition, F(3, 252) = 1.32, ns, η²p = .01. Craving level significantly differed by slide type, F(3, 252) = 35.52, p < .001, η²p = .30. Bonferroni post-hoc tests revealed that craving to cigarette slides was higher than any of the other slide types. In addition, craving was higher to pleasant slides than to either unpleasant slides or neutral slides, the latter two of which did not differ from one another. Means and standard deviations can be found in Table 2.

3.4. Emotional responses to slides

Positivity ratings differed by slide type, F(3, 252) = 294.16, p < .001, η²p = .78, where positivity ratings were higher to pleasant slides than cigarette slides, but cigarette slides were associated with higher positivity than neutral slides, which in turn were more positive than unpleasant slides. Means and standard deviations can be found in Table 2. Negativity ratings also differed by slide type, F(3, 252) = 400.95, p < .001, η²p = .83, where negativity ratings were higher to unpleasant than to cigarette slides, which were rated as more negative than pleasant or neutral slides.

Importantly, mixed emotions (MIN ratings) also differed by slide type, F(3, 252) = 34.23, p < .001, η²p = .29. Cigarette slides had higher mixed emotional ratings than the pleasant slides, which were higher than the unpleasant slides. Mixed emotional ratings to neutral slides were marginally higher than unpleasant slides and marginally lower than unpleasant slides.

3.5. Mixed emotions and craving

The overall regression model accounted for a significant amount of variance in visual analogue craving to cigarette slides, R² = .68, F(5, 80) = 334.47, p < .001. Step 1 accounted for 16.2% of the overall variability in post-cue-reactivity craving. Higher dependence was associated with higher craving, B = 9.14, p < .001. Step 2, with the addition of baseline craving scores and craving in response to neutral slides, accounted for an additional 50% of the variability in craving to cigarette cues, Fchange(1,82) = 60.32, p < .001. As would be expected, higher baseline craving scores (B = .44, p < .01) and higher craving to neutral slides (B = .62, p < .001) were both predictive of higher craving to cigarette slides. Finally, Step 3 accounted for an additional 2.2% of the variance, Fchange(2, 80) = 2.77, p = .07. Mixed emotional responses to neutral slides were not predictive of craving, B = -.24.8, ns, whereas mixed emotional responses to cigarette slides were predictive of craving, B = 5.57, p < .05.

3.6. Predicting BART change

The regression model accounted for 48.5% of variability in amount earned on the second BART trial, F(4, 81) = 19.08, p < .001. Step 1, with dependence scores, was not predictive of BART earnings, F(1, 84) = .72, ns. Step 2 revealed that initial BART earnings were predictive of subsequent BART earnings, Fchange(1, 83), 66.31, p < .001. Step 3 accounted for an additional 3.6% of variance in BART earnings Fchange(2, 81), 2.86, p = .06. Visual analogue craving to cigarette slides was predictive of BART earnings (B = -.2, p < .05) after controlling for craving to neutral slides (B = .01, ns). The direction of the effect was negative, indicating that higher craving to cigarette slides was associated with smaller increases in BART winnings at the second trial.

4. Discussion

The central goals of the study were to (a) investigate emotion and craving response to a full set of valenced cues (pleasant/appetitive, unpleasant/aversive, neutral and cigarette), (b) model the relationship between simultaneous positive and negative affect or mixed emotional responses and craving for cigarettes, and (c) examine the effects of self-reported craving on subsequent behavior.

Table 2
Visual analogue craving and emotional responses by slide type.

<table>
<thead>
<tr>
<th></th>
<th>Positive slides</th>
<th>Negative slides</th>
<th>Neutral slides</th>
<th>Cigarette slides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual analogue craving</td>
<td>48.55±(24.70)</td>
<td>42.45±(27.21)</td>
<td>40.52±(25.84)</td>
<td>57.37±(25.41)</td>
</tr>
<tr>
<td>Positivity</td>
<td>4.93±(1.24)</td>
<td>.77±(.80)</td>
<td>2.44±(1.09)</td>
<td>3.78±(1.48)</td>
</tr>
<tr>
<td>Negativity</td>
<td>.93±(.76)</td>
<td>4.95±(1.43)</td>
<td>.90±(.85)</td>
<td>1.44±(1.19)</td>
</tr>
<tr>
<td>Mixed emotion</td>
<td>.72±(.62)</td>
<td>.44±(.38)</td>
<td>.56±(.61)</td>
<td>1.03±(.80)</td>
</tr>
</tbody>
</table>

Within each row, different superscripts represent statistically significant differences at p<.05.
As expected, craving responses were stronger to cigarette cues than to neutral cues, replicating many past findings (Carter & Tiffany, 1999; Conklin & Tiffany, 2001; Litvin & Brandon, 2010; Robinson et al., 2011; Sayette & Hufford, 1997; Shadel, Niaura, & Abrams, 2004; Warthen & Tiffany, 2009). However, because the current study included pleasant and unpleasant cues in addition to cigarette and neutral cues, this design afforded more detailed analysis of craving responses. In particular, we were interested in the craving responses to positive cues, and we replicated recent work demonstrating higher craving to pleasant cues when compared to negative or neutral cues (Muñoz et al., 2010; Robinson et al., 2011).

These results are consistent with a motivational intensity model of the affect-cognition relationship (Gable & Harmon-Jones, 2010), which suggests that positive affect high in approach motivation narrows attention. Pleasant IAPS slides of the type used in the current study, as well as in other cue-reactivity studies utilizing slide cues (Muñoz et al., 2010; Robinson et al., 2011), are typically matched on arousal with unpleasant IAPS slides, and are thus slides depicting high-octane sports scenes (e.g. sky diving, ski jumping), tantalizing food, and erotic pictures. It may be that increased attention to high-motivational targets such as those used in the current study increased attention to motivational processes and thus induced a heightened craving response. Future work may wish to compare craving responses to low-approach intensity stimuli to determine if positive affect differing in motivational intensity exerts different effects on self-reported craving.

We also found, as predicted, that cigarette cues were associated with a higher degree of mixed emotional responses compared to neutral and other valenced cue types. Moreover, mixed emotional responses to cigarette cues were associated with increased craving, even after controlling for other salient factors such as nicotine dependence and baseline craving, as well as craving and mixed emotional responses to neutral cues. Inclusion of the covariates provides evidence that the mixed emotional responses were predictive of craving responses to cigarette cues in particular, not merely increases in craving throughout the study. As this was the first explicit test of cue-induced craving and mixed emotions, it would be premature to make definitive conclusions about the role of mixed emotions in the craving process, particularly as this study did not manipulate deprivation or availability of cigarettes, other factors known to influence cue-reactivity (e.g., Bailey et al., 2010; Sayette, Martin, Wertz, Shiffman, & Perrott, 2001; Wertz & Sayette, 2001). That said, the results suggest that modeling the co-occurrence of conflicting feelings may provide additional avenues of study in the realm of cue-reactivity.

Conceptually, mixed emotions are consistent with the construct of ambivalence (Miller & Rollnick, 2002). Ambivalence is a state of internal conflict, often associated with discomfort, where individuals are motivated to resolve the ambivalence to resolve the conflict. Mixed emotions, which might be classified as emotional ambivalence, also frequently result in felt discomfort (Hong & Lee, 2010; Larsen et al., 2003; Williams & Aker, 2002). In fact, it is exactly this discomfort with ambivalent or mixed states that may partially explain the often-found relationship between cue-induced craving and negative affect. Essentially, the ambivalent discomfort may fuel self-report of negative affect in response to cigarette cues. Whether those who experience greater mixed emotions during cue-reactivity have heightened negative affect after cue-reactivity remains to be tested in future studies.

Finally, we evaluated the effect of cue-reactivity on risk behavior and found that self-reported craving to cigarette cues predicted changes in risk functioning. The BART task is typically conceptualized as a measure of risk such that higher earnings represent riskier behavior. In the current study, we used the BART twice, where the first administration was an initial risk assessment and the second was introduced to the participant with the promise that he or she could smoke immediately after completing the task. In this way, the BART was intended to represent the value of smoking, as desire for a cigarette might prompt quick and careless task behavior, just as a boss telling an employee to finish one last thing before a smoke break might inadvertently prompt sloppy work. Inclusion of the first trial at a previous step in the regression meant that any subsequent predictors were essentially predicting change in BART performance, or the increases in earnings on the second trial relative to the first. We found that craving to cigarette cues predicted less increase at the second BART trial, suggesting that those who had higher craving reactivity to smoking slides were less able to improve upon their initial performance.

It is also worth noting that although the regular smokers and chippers in the current study differed on salient smoking variables (dependence, quantity and frequency of smoking, expired CO, etc.), the two groups of smokers in this study demonstrated only mild differences in craving for cigarettes, and no differences in emotional responsivity to smoking cues. The assumption that these groups might differ stems from models of dependence development such as the opponent process model (Koob & Le Moal, 2008), which would suggest that lighter and less dependent smokers are not as sensitive to negative reinforcement and thus may have increased positive responses to cues. Yet in this study, no differences between the two groups emerged. One possible explanation is that all participants in this study were required to have smoked in the same pattern for over two years, and the chippers were predominantly daily smokers. Recent research has begun to examine differences between light daily smokers and non-daily, intermittent smokers (e.g. Berg, Buchanan, & Ahluwalia, 2011; Cooper et al., 2010), and it may be that the habitual pattern of smoking matters more than the number of cigarettes consumed per day when it comes to emotional responses to cues. Alternatively, it may be that differences between groups would appear under conditions of smoking deprivation, which is likely to affect regular smokers more than tobacco chippers.

### 4.1. Strengths and limitations

The present study has multiple strengths. First, the study utilized a community sample of non-deprived smokers, with the intention of answering questions about how smokers might respond to cues in everyday life. Although the results were non-significant, the study also examined both regular daily smokers and lighter “tobacco chipper” smokers to examine potential differences in emotional response. Importantly, the study is the first to explicitly examine mixed emotional responses to cues using a theoretically derived measure of emotion that has demonstrated utility in other studies of mixed emotion (Larsen et al., 2001; Larsen et al., 2009). The study also included pleasant and unpleasant cues in addition to neutral and smoking cues to provide a broader range of emotional stimuli—after all, individuals encounter valenced stimuli in everyday life beyond smoking and neutral cues. The study also included a behavioral outcome measure, significant in light of recent critique of cue-reactivity studies (Perkins, 2009), which highlighted the dearth of evidence connecting cue-induced craving to subsequent smoking behavior.

The current study is limited in the use of a sole self-report scale to measure emotion, which assumes that participants are aware of their own emotional states. Future studies may wish to examine craving and mixed emotions using multiple self-report scales and/or objective measures, including coding of emotional facial expressions (Griffin & Sayette, 2008), psychophysiology (Bailey et al., 2010; Heishman, Lee, Taylor, & Singleton, 2010; Rehme et al., 2009), and/or brain functioning (Zhang et al., 2011). Moreover, future research is needed to examine intensity levels of mixed emotions to evaluate any differences between mixed emotional states that are highly simultaneous (e.g. both positivity and negativity equally elevated and strong; Oceja & Carrera, 2009) versus mixed states where one valence is potentiated in comparison to the other. In addition, the current study used static
cues in a systematic laboratory setting, which may not generalize to real-life craving. In the real world, cues may be static (e.g., a magazine photo of a cigarette ad) or they may be dynamic and complex (e.g., a colleague smoking a cigarette while telling a dramatic, suspenseful story). Future studies may wish to incorporate assessment of mixed emotions in a dynamic framework, such as in a daily diary or ecological momentary assessment framework.

As was the first explicit examination of craving and its association with mixed emotions, we chose to study cue-reactivity in non-deprived smokers. As such, we did not manipulate factors of deprivation/abstinence or availability of cigarettes, two factors known to influence craving (e.g., Bailey et al., 2010; Sayette et al., 2001; Wertz & Sayette, 2001). The craving processes in deprivation versus non-deprivation contexts are likely quite different, such that it may be only in a non-deprived context that craving is reliably related to increases in positive affect (e.g., Dunbar, Scharf, Kirchner, & Shiffman, 2010). Notably, our participants began the study shortly after smoking and in a fairly low craving state. Throughout the hour and a half time frame of the study, the regular smokers may have started to experience withdrawal symptoms, perhaps disproportionally to the chippers, and future studies may wish to measure withdrawal throughout the course of laboratory studies to ensure withdrawal symptoms do not influence the results. However, despite this possibility, smokers must frequently restrain from smoking for several hours during a typical work day or a long commute. Thus, the withdrawal experienced here is qualitatively different than a deprivation manipulation where participants are asked to refrain from smoking for many hours prior to the start of a study and can still be considered an examination of non-deprived smokers. Both deprivation and availability are important future contexts in which to study the craving-mixed emotion relationship. That said, most smokers do not intentionally deprive themselves or make cigarettes unavailable for use, suggesting that inclusion of non-deprived smokers is a strength of the study despite limiting generalizability.

4.2. Clinical implications

Definitive statements about clinical implications of these findings are premature, as this is an initial examination of mixed emotions in a craving context, and the sample used here is qualitatively different than a treatment-seeking sample of smokers (e.g., intentional, self-imposed deprivation versus the non-deprived sample used in the current study). Even so, some tentative implications can be identified and may guide future efforts to explicitly address clinically-relevant outcomes. First, it must be established how mixed emotions and craving are connected for individuals at differing stages of change (Prochaska & DiClemente, 1983). If heightened mixed emotions and heightened positive responses to cues are only prominent at the pre-contemplation stage, laboratory-based training methods could be used to coach individuals to attend to the negative aspects of cues, potentially facilitating movement towards a change attempt in a manner consistent with motivational interviewing (Miller & Rollnick, 2002). Alternatively, if mixed emotions are tied to craving at the preparation or action stages, efforts might focus on accepting the ambiguity of mixed feelings or producing other strategies for effective resolution of conflicting feelings.

The current study also found that craving to cigarette cues predicted a shift in risk behavior. The elaborated intrusion model of desire predicts that through elaboration, cues will consume more mental energy and be associated increases in negative affect over time (Kavanagh et al., 2005). The elaborated intrusion model is compatible with ego-depletion, the theory that that attempts at self-control weaken the self-control system, making subsequent failures of self-regulation more likely (Baumeister & Heatherton, 1996). The results found here are also consistent with ego-depletion theory, such that increased craving and affect may require self-control energy, thus facilitating later disinhibition. Future work may wish to extend the current study in a manner consistent with other ego-depletion research (e.g., Martijn et al., 2007) to explore strategies that can restore self-control energy to craving smokers.

4.3. Conclusions

Mixed emotions appear to be a real phenomenon that people experience (Griffin & Sayette, 2008; Hong & Lee, 2010; Larsen et al., 2001; Larsen et al., 2009; Rafaeli, Rogers, & Revelle, 2007; Williams & Aaker, 2002), and it is reasonable to empirically evaluate the idea that smoking cues could generate both positive thoughts and feelings (e.g., “A cigarette would taste really good right now.”) and negative thoughts and feelings (e.g., “I wish I weren’t reliant on cigarettes”). In fact, we found that smoking cues induced a higher degree of mixed emotion than other valenced cue types, underscoring the need to examine the relationship between positive and negative affect in a cue-reactivity context rather than simply treating each variable as separate, unrelated phenomena.

Moreover, despite theoretical frameworks that predict some role for positive affect or approach behavior in the craving process (Baker et al., 1987, Breiner et al., 1999; Kavanagh et al., 2005), empirical examination of positive affect in a craving context has received limited attention compared to the negative affect-craving relationship. There may be good reason for this neglect, in the way of file-drawer studies, and ultimately positive affect may exert a negligible influence on the craving process. However, further study is necessary before that conclusion can be reached, and the results of the current study provide a counterpoint, suggesting that positive cues can elicit a heightened craving response. Research that examines the contexts in which positive affect and/or mixed emotions elicit craving may help us better illustrate for whom and in what contexts craving and associated changes in affect prompt smokers to continue smoking.

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Contributors

Jennifer Veilleux designed the study with assistance from Jon Kassel. Megan Conrad provided data management and oversight of data collection. Jennifer Veilleux wrote the manuscript with editing done by Jon Kassel and Megan Conrad.

Conflict of interest statement

The authors have no conflicts of interests to declare.

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