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Cue-Reactivity in the Natural Environment of Cigarette Smokers:

The Impact of Photographic and In Vivo Smoking

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Abstract

The cue reactivity paradigm has been used extensively in laboratory settings to study cue-specific craving responses to drug-related cues. However, this procedure has been used in only one study to assess craving in the drug user's natural environment (Warthen & Tiffany, 2009). The present study combined cue-reactivity with ecological momentary assessment (CREMA) to evaluate smokers' cue reactions in natural environments as a further validation and extension of this procedure. A total of 66 daily cigarette smokers carried a personal digital assistant (PDA) and had the opportunity to respond to 32 cue reactivity sessions across eight days. Cues were presented through in vivo and photographic modes. During in vivo sessions, participants handled and looked at a cigarette or neutral object, while during photographic sessions, participants looked at a smoking related or neutral photograph on the PDA. Craving and mood were assessed before and after cue presentations. Cues were also presented in the laboratory both before (Lab I) and after (Lab II) the eight-day CREMA procedure. Participants completed over 90% of cue-reactivity sessions delivered with the CREMA procedure. Analyses revealed robust cue-reactivity in the natural environment and laboratory across both modes of presentation. Photographic cues elicited significantly stronger cue-reactivity effects than in vivo cues across all sessions. The CREMA procedure has been shown to elicit robust cue-reactivity effects across multiple modes of cue presentation. Results support the use of the CREMA procedure for examining cue-specific craving in the natural environment of smokers.

Keywords

Craving; Cue-Reactivity; Ecological Momentary Assessment; Tobacco; Cigarettes

Modern addiction theories typically identify craving as a major contributor to ongoing drug use (Drummond; 2001; Skinner & Aubin, 2010; Tiffany, 1990). Craving is also clinically relevant - smokers often cite strong craving as an obstacle to smoking cessation, and craving is a risk factor for relapse among smokers attempting to quit (Killen & Fortmann, 1997). Traditional laboratory-based assessments of craving have used the cue reactivity paradigm, which evaluates craving responses to presentations of drug-related stimuli (Drummond, Tiffany, Glautier & Remmington, 1995). Drug cues consistently increase craving across all major substance-use disorders (Carter & Tiffany, 1999); however, all of this research has

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been conducted in the laboratory - the generalizability of these findings to the natural environment of drug users has not been evaluated systematically.

The examination of cue-reactivity in the daily lives of drug users is possible through the use of ecological momentary assessment, which allows participants to report information in real time and in their natural environment (Stone & Shiffman, 1994). This procedure holds great potential for the evaluation of a wide range of factors involved in substance-use disorders, including cue-induced craving (Rosenberg, 2009). To date, EMA has been used in only one study to investigate cue reactivity in real-world environments. Warthen & Tiffany (2009) presented photographs and imagery scripts to 43 cigarette smokers on personal digital assistants (PDAs) over an eight-day period. Presentations of smoking cues increased craving relative to neutral cues across both modes of presentation, and cue-specific craving effects were stronger for photographic cues than for imagery scripts. These findings provide support for continued examination of cue reactivity in real-world conditions.

From a learning perspective, craving evocative cues should be effective to the extent that they match the encoded stimulus configurations responsible for the production of cue-specific craving processes (e.g., Baker, Morse, & Sherman, 1987; Tiffany, 1990). In vivo cue manipulations, in which participants or an experimenter hold, light, and/or look at a cigarette or view a lit cigarette in an ashtray, generate robust craving effects (e.g., Drobes & Tiffany, 1997; Rickard-Figueroa & Zeichner, 1985). Given that cigarettes have been paired with nicotine administration multiple times over the course of a smoker's history, in vivo cues should provide particularly effective stimuli for the production of cue-specific craving. In vivo presentations involve the multisensory experience of touching, smelling, and viewing a highly salient stimulus (i.e., a cigarette), which should maximize the chances of matching the encoded stimuli that generate cue-specific craving. In combination, these factors are likely to produce robust cue-reactivity effects with in vivo presentations of smoking stimuli.

Photographic cues have also been used to evoke craving, with smoking related photographs consistently producing higher levels of craving than photographs with neutral content (Carter et al., 2006; Conklin, Robin, Perkins, Salkeld & McClernon, 2008). Although in vivo and photographic cues have not been compared directly, in vivo cues have been tested against other modes of cue delivery (e.g., imagery scripts). The research is mixed on the effect of modality, with some studies concluding that in vivo cues produce stronger effects than alternative cues (e.g., Niaura et al., 1998) and others finding that in vivo and other types of cues are equally effective at elevating craving (e.g., Drobes & Tiffany, 1997; Erblich & Bovbjerg, 2004; Tiffany, Cox, & Elash, 2000).

In light of the novelty of the cue-presentation procedures conducted by Warthen and Tiffany (2009), the present study sought to replicate those results with a larger sample and with smokers recruited from a different geographical locale. In addition, this study extended those findings by examining in vivo cues as a mode of stimulus presentation and comparing the reactions generated by those cues with reactions produced by photographic cues. We predicted that the presentation of smoking-related cues in the participants' natural environment would produce robust cue-specific craving effects (similar to the effects found in laboratory-based cue-reactivity studies). Further, we anticipated that in vivo presentations of smoking cues would produce stronger cue-specific craving than photographic presentations of smoking cues.

Methods

Participants

Participants (n=68; 27 male, 41 female) were daily smokers recruited through local newspaper advertisements and flyers in Buffalo, NY. Eligible participants were 18+ years of age, smoked at least 15 cigarettes per day, had been smoking for at least one year, were not attempting to quit or restrict their smoking, and had an expired carbon monoxide (CO) level of 10 ppm or greater. Participants received compensation for each completed CREMA session.

Materials

Expired CO was collected with a Vitalograph Monitor. Personal Digital Assistants (PDA's; Palm Tungsten E2) were programmed with a modified version of the Purdue Momentary Assessment Tool (PMAT; Weiss, Beal, Lucy, & MacDermid, 2004).[1] Self-report measures completed by participants at the beginning of the Lab I session included the Nicotine Addiction Taxon Scale (NATS; Goedeker & Tiffany, 2008) and a Smoking History Form.

Laboratory Procedures

Laboratory sessions (Lab I and Lab II)—Participants attended two laboratory-based sessions with an eight-day interval separating the two sessions. At Lab 1, which was approximately one hour in length, participants were consented and expired CO was collected. Participants completed a battery of self-report measures while smoking one of their own cigarettes. Participants were then trained on how to operate the PDA[2] and completed eight cue-reactivity trials using this device. Two trials of each stimulus type and mode of presentation were administered at each laboratory visit (i.e., two smoking photographs, two neutral photographs, two in vivo smoking cues, and two in vivo neutral cues). Five cue orders were utilized, with cue types counterbalanced and randomized across participants. Each photographic cue appeared only once across the study.

Before and after cue presentations, participants completed assessments comprised of a randomized presentation of the Craving Questionnaire (a four-item assessment of craving; Carter & Tiffany, 2001), one positive mood item, and one negative mood item. After cue presentations, participants were also asked how carefully they looked at the photograph/object, their level of distraction, and whether or not they held an object/cigarette (for in vivo trials only).

During photographic trials, participants were instructed to look carefully at a photograph presented on the PDA screen for 10 seconds. Smoking photos (N = 20) depicted smoking stimuli (e.g., lit cigarettes, ashtrays, cigarette packs, and people smoking). Neutral photos (N = 20) depicted non-smoking objects (e.g., pencils, scissors, tools). During in vivo smoking trials, participants were asked to take out a cigarette, hold it, and look at it until an alarm sounded (10 seconds later). Participants then put the cigarette out of sight. During in vivo neutral trials, participants were asked to hold and look at a neutral object, which were described as objects that were not smoking related (e.g., keys, cell phones, and wallets). Participants were instructed to view this object until an alarm sounded (10 seconds later), and then to put it out of sight.

[1]PMAT software modifications that were made to run CREMA sessions are available through Stephen Tiffany's lab at the University at Buffalo, The State University of New York.
[2]A detailed, structured protocol was used for PDA training, which is available from the researchers upon request.

At the end of Lab I, participants were given a PDA to take home and were scheduled to return on the tenth day after their initial appointment. At Lab II, which was approximately thirty minutes in length, CO levels were collected, participants smoked one of their own cigarettes, and cue-reactivity trials were administered on the PDA.

Ecological Measures and Procedure

CREMA sessions—Participants carried a PDA over eight consecutive days and were instructed to keep the PDA with them at all times. The PDA was used to present CREMA sessions, which were approximately three minutes in length. Auditory alarms prompted participants to complete four randomly scheduled cue-reactivity sessions throughout the course of the day. Alarms were distributed over a 12-hour period, divided into four, 3-hour blocks. Each session consisted of the presentation of two successive cue trials of the same type and mode. Participants had the opportunity to complete 32 CREMA sessions (16 smoking sessions and 16 neutral sessions) and a total of 64 cue trials (32 smoking trials and 32 neutral trials).

At the start of a session, participants were asked to finish their cigarette if they were currently smoking, then answered the Craving Questionnaire, mood items, and questions about situational and contextual variables. Next, a photograph or instructions to look at a cigarette or neutral object were presented on the PDA screen. Two consecutive trials of the same cue type were administered within each CREMA session (1st and 2nd position). An alarm sounded at the end of each cue trial. Participants then responded to the Craving Questionnaire and mood items and were asked how carefully they looked at the photograph/object, their level of distraction during each trial, and, on in vivo trials, whether or not they held an object/cigarette.

Data reduction

In vivo trials where participants indicated that they did not hold a cigarette or object during both trials within a session were eliminated from analyses. Within-subjects ANOVAs were conducted for the CREMA Week data to analyze the effect of stimulus type, mode of presentation, and trial position (1st and 2nd) on craving ratings and for the laboratory data to analyze the effect of stimulus type, mode of presentation, and session on craving ratings.

Results

Participant Characteristics

Of the 68 participants enrolled in the study, 66 returned to the second laboratory visit. Participants reported smoking an average of 20 cigarettes per day (*SD* = 7.0), had a 28-year smoking history (*SD* = 13.6), and averaged 42 years of age (*SD* = 13.1). CO levels averaged 31.7 ppm (*SD*=18.9) at the Lab I visit and 30.3 ppm (*SD*=12.3) at the Lab II visit (difference was not significant). All but one participant met NATS criteria for nicotine dependence.

CREMA Data

During the CREMA interval, participants responded to an average of 29.2 alarms (range of 20 to 32). Data collected during CREMA sessions indicated that participants reported holding a cigarette during 98% of sessions and holding an object during 99.8% of sessions.

Craving—During CREMA sessions, smoking cues elicited significantly higher craving ratings than neutral cues, F (1,65) = 89.41, p<.0001, partial η^2 = .58 (see Figure 1 & Table 1). This cue-specific effect differed as a function of presentation mode as indicated by a

significant stimulus type by mode interaction, F (1,65) = 4.43, p<.05, partial η^2 = .06. Further analyses revealed that cue-specific craving was greater for photographic cues (F [1, 65] = 72.46, p<.0001, partial η^2 = .53) than in vivo cues (F [1, 65] = 37.90, p<.0001, η^2 = .37). Smoking cues presented in the 2nd trial position elicited significantly higher craving ratings than smoking cues presented in the 1st position, F (1,65) = 5.66, p<.05, partial η^2 = .08.

Mood, focus, and distraction—During CREMA, positive mood did not differ as a function of cue type, mode of presentation, or trial position (see Table 1). However, negative mood ratings were significantly higher after smoking cues than after neutral cues, F (1, 65) = 4.30, p<.05, partial η^2 = .06. Focus ratings were significantly higher during photographic trials than in vivo trials, F (1, 65) = 4.39, p<.05, partial η^2 = .06. Distraction ratings were significantly higher during in vivo trials than photographic trials, F (1, 65) = 5.14, p<.05, partial η^2 = .07.

Analyses Involving Baseline Ratings—Presentations of smoking cues significantly increased craving relative to baseline ratings, F (1,65) = 26.18, p<.0001, partial η^2 = .29, while neutral cues significantly decreased craving ratings relative to baseline, F (1,65) = 56.80, p<.0001, partial η^2 = .47.

Laboratory Data

Craving—During the laboratory sessions, smoking stimuli elicited significantly higher craving than neutral stimuli, F (1, 64) = 71.65, p<.0001, partial η^2 = .53 (see Table 2). There was also a significant cue type by mode of presentation interaction during laboratory sessions, F (1,64) = 11.59, p<.01, partial η^2 = .15. Cue-specific craving was more pronounced for photo cues (F [1,64] = 66.56, p<.0001, partial η^2 = .50) than for in vivo cues (F [1,64] = 43.64, p<.0001, partial η^2 = .39).

Mood, focus, and distraction—There was a significant effect of cue type on negative mood ratings with higher post-cue negative mood ratings after smoking related cues, F (1,64) = 10.22, p<.01, partial η^2 = .14. No significant effects were found during the laboratory sessions for positive mood, focus or distraction ratings (see Table 2).

Discussion

Smoking-related cues presented in the natural environment of smokers elicited robust craving effects, and these effects were evident across two modes of stimulus presentation. These cue-specific effects were also present in the laboratory-based sessions. A systematic comparison of the magnitude of effects between CREMA and laboratory sessions would require the use of strictly comparable exposure parameters across both settings, as cue presentation differed across these distinct settings. During laboratory sessions, eight smoking and neutral trials were presented in a counterbalanced fashion within a single study visit, whereas sessions in the natural environment involved two trials of the same type and mode of presentation over the span of eight days. Despite these differences, the magnitude of the cue-reactivity effects in the natural environment was at least as great as the effects generated in the laboratory, and the robust cue-reactivity effects found in the natural environment of smokers paralleled findings typically obtained in laboratory settings. The results also replicated data obtained by the only other study to date using CREMA to study cue-reactivity in the natural environment (Warthen & Tiffany, 2009); the currrent study involved a larger sample size and utilized participants recruited from a different geographical location (Buffalo, NY vs. Salt Lake City, UT). In addition, these results extend

previous findings by demonstrating the feasibility and effectiveness of using in vivo cues as a mode of stimulus presentation.

Beyond these generalized cue effects across CREMA and laboratory sessions, smoking photos consistently generated stronger cue-specific craving than in vivo smoking cues. Our examination of the differences in cue-specific craving as a function of presentation mode suggests that two factors contributed to the advantage of photographic cues over in vivo cues; photographic smoking cues enhanced craving and neutral photographic cues suppressed craving relative to the respective in vivo conditions. Several factors may explain the larger effect for photographs. The novelty of the photographs may have contributed to the relatively stronger cue-specific craving effects with these cues, as a different photo was presented during each trial of the laboratory and CREMA sessions. In contrast, holding an object (either smoking or neutral) was not a particularly novel act for the participants in this study and may not have the same impact as the photographic cues. Therefore, photos have exerted more control over craving (i.e., photos were more likely to trigger craving in the presence of smoking photographs or to suppress craving in the presence of neutral photographs). The content of the smoking photographs may also have contributed to the stronger effects for these cues. That is, lit cigarettes were depicted in the majority of smoking photographs while in vivo smoking cues always involved viewing an unlit cigarette. Previous research has demonstrated that smoking cues more proximal to nicotine administration have elicited stronger cue-reactivity effects than more distal cues (Conklin, Robin, Perkins, Salkeld, & McClernon, 2008). In addition, Warthen and Tiffany (2009) also found that neutral photographs suppressed craving more than their second cue type, neutral imagery scripts. These findings across studies suggest that neutral photographs, which tend to generate low levels of craving, offer excellent control stimuli for studies of cue reactivity.

During CREMA, craving ratings collected after smoking cues in the 2nd trial position were higher than craving ratings collected after smoking cues in the 1st trial position. This finding, also reported by Warthen and Tiffany (2009), may represent a carry-over effect of cue-specific craving within sessions. In traditional cue-reactivity designs, where neutral and smoking cues are presented in close succession, carry-over craving effects may dilute estimates of cue-specific craving to the extent that craving generated by a smoking cue trial intrudes into subsequent neutral trials (Sayette, Griffin, & Sayers, in press). In contrast, during CREMA, smoking and neutral cues were presented in sessions separated by several hours. With this design, carry-over effects across sessions would be diminished, whereas carry-over effects within smoking trial sessions would tend to enhance overall estimates of cue-specific craving.

Another pattern of effects observed in this research may also have implications for the design of cue-reactivity studies. Across all sessions and both modes of cue presentation, neutral cues significantly decreased craving relative to baseline (see Warthen & Tiffany, 2009, for similar findings). This suggests that cue-reactivity designs that compare neutral and smoking related cues may generate stronger effects than designs that use baseline ratings for the control condition (c.f., Sayette et al., in press).

Under the conditions of this study, cue-specifc craving was somewhat more robust with the CREMA procedure than with the laboratory-based assessment. However, as we have noted, the methodology employed during the CREMA procedure differed in critical respects from that used during laboratory sessions, and these methodological differences may have advantaged the generation and detection of cue-specific craving with CREMA. As discussed previously, potential craving carry-over may have enhanced estimates of cue-specific craving during CREMA sessions. Further, the CREMA procedure may have generated more reliable estimates of cue-specific craving than produced during the laboratory sessions, as

the CREMA averages were based on 32 smoking and 32 neutral trials as opposed to four smoking and four neutral trials during laboratory sessions. Finally, cigarette availability may have affected the outcome of the cue trials, as previous research has shown that cue-reactivity is enhanced when cigarettes are immediately available (Tiffany, 2009; Wertz & Sayette, 2001). In the present study, participants reported that cigarettes were at least somewhat available on more than 95% of the CREMA sessions. In contrast, cigarettes were unavailable during laboratory-based trials. In light of these considerations, further research is warranted before any general claims can be advanced regarding the relative impact of cue-reactivity manipulations conducted in natural settings as opposed to laboratory environments.

Several limitations of the current study should be noted. First, the use of assessment procedures in the natural environment provides less experiemental control than is possible in the laboratory. Although participants were asked to report whether they actually held neutral objects or cigarettes during in vivo sessions, we were unable to observe whether or not this occurred. In addition, the generalizability of these results may have some limitations, for example the demands of the CREMA procedure could restrict who is willing or able to participate, and this project focused exclusively on daily smokers.

Overall, the results strongly support the feasibility and utility of the CREMA procedure for examining cue-specific craving in the natural environments of smokers. The procedure elicits robust cue-specific craving effects across a wide range of stimulus modes and diverse situations outside of the laboratory, with exceptional compliance rates for cue-reactivity trials. While the focus of this study was restricted to comparing aggregated ratings across different cue types and modes of presentation, this data set is rich with information to address more nuanced questions about cue-reactivity in the natural environment of smokers. More sophisticated data analytic techniques can be implemented in future research to explore how variables such as mood, location, availability of cigarettes, acceptability of smoking, or time of day may influence responsiveness to cues. The continued use of ecological momentary assessment in substance abuse research has considerable potential for helping researchers understand the nature of craving and other cue-reactivity variables in real-world settings.

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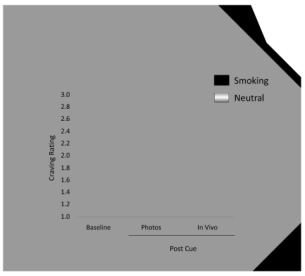

Figure 1.
CREMA craving ratings collected before (baseline) and after (post cue) the cue presentation (rating scale 1–5). The post-cue ratings are shown as a function of cue type (smoking and neutral) and mode of cue presentation (photographic and in vivo).

Table 1

Means and (standard deviations) of post cue ratings during CREMA Week

	CREMA WEEK	
	Smoking	**Neutral**
Craving rating		
Photo	2.79 (1.34)	2.17 (1.23)
In Vivo	2.76 (1.32)	2.35 (1.19)
Positive mood rating		
Photo	2.91 (0.62)	2.98 (0.62)
In Vivo	2.95 (0.60)	2.96 (0.58)
Negative mood rating		
Photo	1.86 (0.89)	1.76 (0.77)
In Vivo	1.88 (0.80)	1.84 (0.87)
Distraction rating		
Photo	1.54 (0.65)	1.50 (0.54)
In Vivo	1.60 (0.66)	1.60 (0.57)
Focus rating		
Photo	4.72 (0.47)	4.71 (0.49)
In Vivo	4.64 (0.50)	4.62 (0.50)

Table 2

Means and (standard deviations) of post cue ratings during laboratory sessions

	LABORATORY*	
	Smoking	**Neutral**
Craving ratings		
Photo	2.45 (1.03)	1.75 (0.74)
In Vivo	2.30 (0.93)	1.86 (0.78)
Positive mood ratings		
Photo	2.83 (0.73)	2.95 (0.69)
In Vivo	2.86 (0.75)	2.87 (0.76)
Negative mood ratings		
Photo	1.69(0.85)	1.57 (0.70)
In Vivo	1.70 (0.80)	1.63 (0.76)
Distraction ratings		
Photo	1.27 (0.52)	1.26 (0.52)
In Vivo	1.33 (0.54)	1.33 (0.52)
Focus ratings		
Photo	4.80 (0.43)	4.77 (0.46)
In Vivo	4.61 (0.66)	4.71 (0.51)

* averaged across Lab I and Lab II sessions