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State Craving, Food Availability, and Reactivity to Preferred Snack Foods

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Abstract

The startle response has been shown to be useful in studying reactivity to food cues. Following 6h of food deprivation and exposure to neutral and food cues, we examined the role of state craving combined with both a short and long delay of consumption on affect and startle reflex. Participants completed the PANAS, consumed a controlled early morning meal, and experienced 6h of food deprivation. They then reported back to the laboratory, completed a second baseline PANAS, and had their baseline eyeblink EMG startle responses to 100 dB(A) startle probe assessed. Prior to and following the presentation of cues, startle probes were presented and responses were recorded. The PANAS and state craving were also assessed after each cue. Food cues provoked higher levels of state craving than neutral cues and startle responses failed to habituate as quickly to food cues as they did to neutral cues. In addition, cue exposure created the highest NA among high state cravers in the long delay of consumption group. Startle responses differed from NA in that with long delay startle was high irrespective of state craving scores; in the short delay of consumption condition, startle increased linearly with state craving. These results illustrate that state craving and expectations of food availability are important variables in understanding food-related cue reactivity.

Keywords

Food Craving; Startle; Fasting; Negative Affect; Food Availability

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Due to the risk and health consequences of obesity, overeating has been recognized as a significant health threat both in Europe and in the United States (Abelson & Kennedy, 2004). Because food has effects on the brain that are similar to addictive behaviors such as smoking and drug abuse (Pelchat, Johnson, Chan, Valdez, & Ragland, 2004), recidivism in the treatment of obesity is common and results of weight lost in behavioral interventions are characterized by substantial within treatment variability (Wadden & Osei, 2002). Indeed, it is known that dopamine increases with the consumption of food (Berridge, 1996) and, over time, this increase becomes conditioned to the anticipation of food consumption (Phillips, Atkinson, Blackburn, & Blaha, 1993). The objective of the current research is to begin to understand how individual differences in state craving for preferred foods and food deprivation influence affect and a physiological marker of appetitive versus aversive states, the startle response. The defensive startle reflex is potentiated by unpleasant and frustrating experience (Bradley, Cuthbert, & Lang, 1990; Cook, III, Hawk, Jr., Davis, & Stevenson, 1991) and it is well recognized that affect is a core component of desire for substances such as food. Specifically, the elaborated intrusion theory of desire (Kavanagh, Andrade, & May, 2005) "...holds that emotive imagery and associated sensations are especially important in craving because somatosensory links contribute a particular piquancy and motivational power to the experience" (p. 446). The fact that startle is an automatic and pre-attentive marker of affect suggests that it may be a useful additional index of desire, craving, and frustration. Startle may also be a more useful measure than either cardiovascular reactivity or skin conductance, both of which are good metrics of arousal, since startle can serve as a signal for both the direction of affect as well as arousal.

In attempting to understand the etiology of overeating, there has been increased interest in the concept of food craving (Gibson & Desmond, 1999; Gendall, Joyce, Sullivan, & Bulik, 1998; Rogers & Smit, 2000; White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). Although individual differences in food craving are not entirely dependent upon differential levels of satiety (Cornell, Rodin, & Weingarten, 1989), it is well recognized that the reinforcing value of food increases with food deprivation (Epstein, Truesdale, Wojcik, Paluch, & Raynor, 2003). This is an important relationship given the central role that caloric restriction plays in weight loss. Hawk and colleagues recently examined startle response during exposure to slides of preferred food cues following 12-hours of food deprivation (Hawk, Baschnagel, Ashare, & Epstein, 2004). They reported an inhibition of the startle reflex, but only among high and not low state cravers. This pattern suggests that participants were experiencing positive hedonic tone due to anticipated consumption, as would be expected given that participants were allowed to consume food during the course of the experiment.

Study 1 of an earlier paper by Drobles and colleagues (2001) examined how the duration of food deprivation—0, 6h, or 24h—influenced startle responses in the presence of pictures of food. While they point out that food deprivation can increase the appetitive value of food cues as seen by Hawk et al., resulting in an inhibition of the startle reflex, food cues could facilitate startle if there is not an explicit opportunity for consumption, since this creates a state of frustration (Amsel, 1958). In the Drobles et al. study, participants were not allowed to consume food until the entire experimental protocol had been completed. They found that either 6h or 24h of food deprivation increased startle magnitude as compared to the no deprivation condition. In addition, in study 2, they found that the presentation of food cues in food deprived participants and binge eaters led to increases in startle magnitude as compared to participants who had not been food deprived or scored high on a restraint scale, however, this effect was only observed among those who scored high on a measure of state craving.

The concept of availability and craving has been a focal point of study in the smoking and drug addiction literature for a number of years (Carter & Tiffany, 2001) with a meta-analysis of over 40 cue-reactivity studies with cigarette smokers, alcoholics, and cocaine addicts supporting the position that addicts have significant cue-specific reactions to drug related stimuli (Carter

& Tiffany, 1999). Using a novel study design, Carter and Tiffany (Carter & Tiffany, 2001) found that smokers had stronger negative affect during the presentation of smoking cues, but only on trials when access to the stimuli was not permitted. In other words, the cues were appetitive when smoking was allowed upon exposure to the cues, but were aversive when participants had to wait until the experiment had ended—a short delay between exposure and availability of a cigarette. This finding parallels the differential effects observed with food cues by Hawk et al. (2004) and Drobles et al. (2001) as discussed previously. Carter and Tiffany also concluded that negative affect, not positive affect, is most clearly related to craving, and that there is little evidence for concordance between self-report and physiological measures of craving.

In the current study, we were interested in examining how the independent and combined effects of food availability and state craving would influence both affect and the startle response when participants were exposed to either neutral or food cues. Availability was manipulated as either a short (after an experimental session that lasted ~30 min had been completed) or long (the expectation of an additional 6h fast) delay for consumption. Expectations of availability are conceptually important in caloric restriction particularly when cravings may occur in conjunction with preferred food cues. For example, in their elaborated intrusion theory of desire, Kavanagh and May (2005) argue that desire or craving is initiated as an automatic process involving intrusive thoughts about an appetitive target that are subsequently subjected to cognitive elaboration. The hypotheses investigated here were that negative affect and startle responses would be higher in the long than short delay food availability condition when participants were exposed to food as opposed to neutral cues. We also expected state craving to be directly related to negative affect and startle responses following exposure to the food cues. Because expectations of availability—a form of cognitive elaboration (Kavanagh et al., 2005)—likely fuel the aversive nature of food cues under conditions of deprivation, we hypothesized that the most negative affect and highest startle reflex would occur in response to food cues among high state craving participants in the long delay availability condition.

Methods

Participants

Participants for this study were recruited from freshman and sophomore classes at Wake Forest University ($n = 46$) and were paid \$25 as compensation for the time commitment. There were an equal number of men and women in the study and all participants were neither actively dieting nor self-reported an eating disorder. The mean (SD) age and BMI were 19.02 (1.03) and 24.39 (3.31), respectively. The research protocol for this study was approved by the university review board for human research in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Materials and Measures

Eyeblink EMG—Eyeblink EMG responses were measured from the orbicularis oculi muscle with In Vivo Metric surface recording electrodes (Ag/AgCl, 11mm outer diameter, 4mm inner diameter contact surface) placed below the left eye. EMG activity of this muscle was amplified with a Biopac EMG amplifier and sampled (1000Hz) by a Biopac MP150 workstation which stored four versions of the EMG input: raw unfiltered EMG, filtered EMG in a passband of 28–500Hz, a rectification of the filtered EMG signal, and a rectified and smoothed (five sample boxcar filter) derivation of the filtered signal. The data reported in this paper are based on the smoothed EMG signal (Franklin, Moretti, & Blumenthal, 2007), with raw blink magnitudes in microvolts and proportional blink magnitudes in ratios (mean for the cue condition divided by the baseline mean).

Startle Stimuli—Startle stimuli were 100dB(A) broadband noises (20Hz – 20KHz), with a 50ms duration and a rise/fall time of <1ms, presented to the participants through Bose Triport headphones. Stimulus intensities were calibrated with steady-state signals presented through the headphones and measured with a Quest sound level meter with a fitted earpiece. The startle stimuli were presented to participants using SuperLab software integrated with the Biopac MP150 workstation. Within each assessment block, stimuli were presented to the participant every 10–20 seconds (15 sec average ITI).

Positive and Negative Affect Schedule (PANAS)—To measure state changes in affect, we used the short form of the PANAS, which consists of 10-items, 5 that measure positive affect and 5 that measure negative affect (Mackinnon et al., 1999). In a large probability sample ($n = 2651$), the measure was found to have acceptable factor structure with all factor loadings on both subscales in excess of 0.50. In the current study, the Cronbach's alpha was 0.78 for positive affect and 0.87 for negative affect.

Food Craving Inventory (FCI)—The FCI was used to measure food cravings (White, Whisenhunt, Williamson, Greenway, & Netemeyer, 2002). The FCI was originally designed as a trait measure and consists of 28 items. Although there are 4 subscales—high fats, sweets, carbohydrates/starches, and fast-food fats—these are highly correlated, producing one higher order factor called food craving. Both the total score and the subscale scores have good internal consistency reliability (>0.75) and test-retest reliability coefficients (>0.86). White and colleagues (2002) have provided evidence for both the concurrent and discriminant validity of the measure. Recently, this research group has also developed a state food craving inventory. This measure consists of 15 items that target craving for a specific food using a 5-point Likert format (scored 1–5) from “strongly disagree” to “strongly agree” with the mid-point being anchored by the label “neutral”. A complete copy of the scale is available from the authors upon request. The 15-items are averaged for a total score. In the current study, we found that the 15-items loaded on a single factor in which all loadings were in excess of 0.50. The Cronbach's alpha internal consistency reliability was excellent, 0.90.

Procedures

The experimental protocol required 2 visits to the laboratory and a 6h period of food deprivation between visits. The first laboratory visit took place between the hours of 8:00–10:00am and lasted approximately 20 minutes. Participants were instructed not to eat breakfast prior to reporting to this morning visit. Once participants completed an informed consent and it was verified via self-report that participants had not consumed any food, they completed a trait related measure of food craving and the short form of the PANAS. Subsequently, participants consumed a liquid meal produced by GNC that contained 290 calories. Half of the participants consumed a protein meal—MEGA MRP EXTREME—the other half consumed a carbohydrate meal—CYTOCARB II. We included this manipulation to gather pilot data for future research on how the type of nutrients consumed might influence responses to food cues after a period of food deprivation. Once the breakfast meal had been completed, participants were shown 12 different snack foods that are popular among college students and were asked to identify their *most frequently craved snack*. The purpose of this latter step was to enable us to identify desired snack foods for each person so that these could then be used in the afternoon startle experiment. Before being dismissed, participants were instructed not to eat any food between the time that they left the morning session and their scheduled afternoon session, which occurred 6–7 hours later. They were instructed to drink plenty of water during this interval of time.

Upon reporting to the laboratory for the afternoon session, participants were queried to be certain that they had not eaten since the morning meal. Not a single participant indicated that he or she had failed to follow this aspect of the protocol. Subsequently, participants were asked

to sit in a chair in an electrically-shielded experimental room. Participants were then administered the PANAS for a second time and two eyeblink EMG electrodes were attached to the face below the left eye, with a ground electrode attached on the left temple area. Participants were then informed that they would be wearing headphones at various points during the experiment and that a technician would be responsible for putting these on and removing them in order to prevent disruption of the electrodes. They were told that the entire procedure would take no more than 30 minutes. At this point, participants were introduced to the first phase of the startle response testing protocol. The description first underscored the importance of sitting quietly during all measurements. They were told that as they sat in the chair they would hear brief, loud bursts of noise separated by periods of no noise. Participants were reminded that the volume of the noise was not harmful and that they would be left alone in the experimental room while being monitored by a closed-circuit TV. There were 4 bursts of noise provided as a habituation phase (these trials are not included in any data analysis, being used only to habituate the startle response), followed by 6 noise bursts that were used as the baseline startle assessment.

After the baseline block was completed, the participants were randomly assigned to a specific cue order (neutral or food first), and to a level of the delay of consumption manipulation (short or long delay). Randomization was accomplished by blocking on sex to distribute any effect due to sex equally across all treatment conditions. The technician then entered the experimental room and prepared participants for exposure to the two experimental blocks: the presentation of a food cue (their preferred snacks) and the neutral cue (a roll of black electrical tape) in counterbalanced order (food first for some participants and the tape first for others). Prior to the presentation of the cues, half of the participants were told that they would be allowed to consume the snack after all testing had been completed (*the short delay manipulation*), whereas the other half were instructed that the experiment would not officially end for another 6 hours and that they would have to refrain from eating until this time has passed and they had completed a final questionnaire (*the long delay manipulation*). In reality, all participants were allowed to eat immediately following the afternoon experimental session. Food and tape cues were presented to participants on a plate that was concealed by an opaque cover until the time of cue presentation. When the cue was presented, the cover was removed and participants were instructed to simply look at it for 15 seconds; they were then asked to pick it up, smell it, and examine it for another 30 seconds.

Once the delay of consumption instructions and cue handling had been completed, participants were asked to place the object (food or tape) on the plate in front of them and to maintain visual contact with the object during the assessment block. As with baseline assessments, each cue condition was followed by 6 bursts of loud noise as startle responses were recorded. Following both cue conditions, participants completed the PANAS and a state measure of food craving. The technician then removed the EMG electrodes and the participant was allowed to eat the snack food if they so desired. They were then debriefed and allowed to leave.

Statistical Analyses

In any within-subject study design, the problem of order effects and differential order effects cannot be assumed to be absent simply due to randomization. Thus, we conducted the appropriate analyses as described by Keppel (1991) to examine these effects. In addition, we initially conducted analyses to determine whether the type of food consumed in the morning meal had any influence on either affect or startle responses. Preliminary analyses revealed that neither the type of morning meal consumed nor trait craving scores were relevant to the hypotheses under investigation, so these variables were eliminated from subsequent consideration.

The final set of analyses was conducted within the repeated measures and univariate general linear model programs for SPSS 17.0. For each significant effect, we computed partial η^2 as an index of effect size. Although the details related to the structure of each analysis are provided in the results section to facilitate readability, state craving was maintained as a continuous variable throughout and the interaction for state craving by the delay of consumption manipulation (coded as either 0 or 1) was represented as a vector created by multiplying the state craving scores by the delay condition. As described by Aiken and West (1991), this is the preferred approach to studying such interactions because it increases statistical power and prevents biasing that can occur with artificial dichotomization of independent variables.

Startle data were quantified for response magnitude (Blumenthal et al., 2005). This outcome was the average of the difference between peak and onset voltage of the smoothed EMG, measured in microvolts, within a window of 20–150 ms after stimulus onset, for all trials on which a response could have been detected (those trials not contaminated by artifact), with trials on which no response was seen assigned a magnitude of zero.

Results

The two delay of consumption groups (short or long delay) had nearly identical mean (SD) BMI scores, 24.72 (3.52) vs. 24.02 (3.09), and BMI did not have a significant relationship with state craving. In addition, mean (SD) state craving scores were nearly identical for men and women: 3.43(0.63) vs. 3.56(0.56), respectively.

Analysis of State Craving and Affect Data

Initial analyses were conducted to examine the state craving and affect data for the two cue conditions by the delay of consumption manipulation. In a cue type (tape vs. food) by delay of consumption (short vs. long) repeated measures general linear model for state craving, the only significant effect was for cue type, $F(1,44) = 12.51$, $p < .01$, partial $\eta^2 = 0.22$. As shown in Table 1, the food cue produced higher state craving responses than did the neutral cue. As expected state craving scores for the two cues were highly related to one another, $r = .80$, $p < .01$. In addition, it is interesting to note that state craving scores were directed related to both early morning negative affect (NA), $r = .32$, $p < .05$, and baseline NA $r = .40$, $p < .01$.

Table 2 provides the raw data for the PANAS scores. Analyses of these data occurred in 2 steps. First, time of assessment (morning, baseline, neutral cue, and food cue) by delay of consumption (short vs. long) repeated measures general linear models were conducted to examine whether NA and positive affect (PA) changed across the course of the study and whether these effects were influenced by the delay manipulation. Inspection of the data in Table 2 suggests that NA increased from early morning to baseline and again from baseline to cue exposure. There were trends for NA to be higher in the long delay than short delay condition and no obvious patterns for positive affect (PA). In repeated measures analyses for NA and PA with time of assessment and delay as terms in the models, the only statistically significant effect was a main effect for NA— $F(2,132) = 3.90$, $p < .05$, partial $\eta^2 = 0.22$ —illustrating that morning NA (mean $\pm$ SE = 6.33 ± 0.24) was lower ($p < .05$) than NA at baseline (6.90 ± 0.31), and following either the neutral cue (7.32 ± 0.39), or the food cue (7.43 ± 0.39).

The second step was the primary analysis for NA. In this general linear model, the data for cue type was combined since there was no evidence that NA differed as a function of exposure to either the tape or food cue. Terms in the model included a main effect for delay of consumption, a main effect for state craving (combining data from both cues), the interaction of delay by state craving, and the use of baseline as a covariate. The model produced a statistically significant interaction term for delay by state craving, $F(1,41) = 10.79$, $p < .01$, partial $\eta^2 = 0.21$. To assist with interpretation of this effect, we conducted a 3-way split on the state craving

scores and plotted the interaction effect for state craving by delay (see Figure 1). The highest NA occurred among participants who scored high on state craving and were exposed to a long delay of consumption. Simple effect correlational analyses between state craving and NA within the short and long delay conditions confirmed the interpretation of this effect; that is, there was no relationship (or a zero slope) between state craving and NA in the short delay condition ($r = -.11$, $p > .05$), yet a significant direct relationship between state craving and NA in the long delay condition ($r = .66$, $p > .01$).

Startle Magnitude

The baseline startle data, collected before the delay manipulation and exposure to the experimental cues, varied somewhat between the four groups of participants (see Table 3). These differences were not statistically significant (p for cue order = .554, for delay of consumption $p = .097$, and for the cue order by delay of consumption interaction $p = .150$) and could not have been due to either cue order or delay of consumption, since group assignment was completed and baseline startle data were measured before either variable was introduced. However, these random between group differences at baseline may have obscured our ability to evaluate the hypotheses of interest. Thus, to decrease the impact of this inter-participant variability on our analyses, startle magnitude was analyzed as a ratio of post-cue responses divided by pre-cue baseline values.

The first analysis was a repeated measures general linear model examining the effects of cue order, cue type, and delay of consumption on startle magnitude. A significant main effect for delay of consumption was found, $F(1,42) = 5.534$, $p < .025$, partial $\eta^2 = 0.17$, with larger proportional startle values for long than short delay (mean $\pm$ SE ratios of 1.04 ± 0.06 and $.83 \pm 0.06$, respectively). In addition, there was a significant interaction for cue type by cue order, $F(1,42) = 4.91$, $p < .05$, partial $\eta^2 = 0.10$ (see Figure 2). Simple effect testing within each cue order revealed that startle magnitude was higher for the food cue than for the neutral cue when the neutral cue was presented first ($p < .05$), however, when food was presented in the 2nd position, the startle response for the neutral and food cues were essentially identical ($p = .33$). In essence, the presence of food in the 2nd position blunted the habituation effect that was observed when the neutral cue appeared 2nd (see Schicatano and Blumenthal (1994) for a similar finding with caffeine).

In a final analysis, state craving and the interaction of state craving by delay were included as additional effects. In addition to the previously discussed findings, this model yielded a statistically significant state craving by delay interaction term, $F(1,40) = 4.42$, $p < .05$, partial $\eta^2 = 0.10$. To elucidate the meaning of this interaction, Figure 3 provides the startle magnitude data partitioned by delay and a 3-way split on state craving scores. These data illustrate that startle magnitude increased with state craving scores within the short delay condition, yet were unrelated to state craving in the long delay condition; that is, startle responses were elevated in the long delay condition irrespective of the level of state craving. Simple effect correlational analyses between state craving and startle magnitude within the short and long delay conditions confirmed the interpretation of this effect; that is, there was a significant relationship between startle magnitude and state craving within the short delay condition ($r = .61$, $p < .01$), yet no relationship (or a zero slope) between state craving and startle magnitude within the long delay condition ($r = -.06$, $p > .05$).

Discussion

Surveys conducted in the United States, Canada, and Great Britain suggest that food cravings are highly prevalent in adults of all ages (Pelchat, 1997; Weingarten & Elston, 1991). Food cravings are particularly relevant to weight loss because they contribute to excessive overeating (Hetherington & Macdiarmid, 1995), disproportionate snacking behavior (Basdevant, Craplet,

& Guy-Grand, 1993), poor adherence to caloric restrictions (Gendall & Joyce, 2001; Delahanty, Meigs, Hayden, Williamson, & Nathan, 2002), increased frequency of eating fast foods (Siwik & Senf, 2006), and binge eating (Waters, Hill, & Waller, 2001). There is also a growing literature suggesting that chronic dieters, or restrained eaters—a high proportion of participants in controlled clinical trials of weight loss—are prone to food cravings that lead to increased food intake (Cepeda-Benito, Fernandez, & Moreno, 2003; Fedoroff, Polivy, & Herman, 1997; Hill, Weaver, & Blundell, 1991; Polivy, Coleman, & Herman, 2005).

To our knowledge, the current investigation is the first to evaluate how the length of delay in food availability following exposure to food cues in conjunction with state craving influence affect and startle. Availability was manipulated as the expectation of either a short or long delay before the opportunity for food consumption. We hypothesized that negative affect (NA) and startle responses would be higher in the long than short delay of consumption condition when participants were exposed to food as opposed to neutral cues. Whereas we also expected a similar pattern in the data for state craving, we hypothesized that these effects would be qualified by 3-way interaction terms in which the most negative affect and highest startle reflex would occur in response to food cues among high state craving participants that were randomized to the long delay consumption condition.

The study results offered partial support for the hypothesized effects and raise a number of interesting questions. First, although the magnitude of the difference in state craving between the tape and food cue conditions was rather small, it was statistically significant and confirmed the fact that the food cue provoked a higher state craving response than did the tape (neutral) cue. This same food cue reactivity effect was observed by Hawk and colleagues (2004). Second, it is interesting to note that state craving scores were related to baseline NA whether it was assessed early in the morning or following 6h of fasting. Thus, state craving was found to be directed related to NA. Although the direction of causation is unclear, these data are consistent with the position espoused by Carter and Tiffany (2001) that NA is conceptually related to the experience of cravings. Additionally, affective processes, particularly NA, predict self-regulatory failure in the realm of eating behavior (Ganley, 1989; Macht, 2008; Tuomisto, Tuomisto, Hetherington, & Lappalainen, 1998). Interestingly, in study 2 of an experiment by Drobles and colleagues (2001), binge eaters that were able to eat up until the time of testing had a startle response to food cues under a short delay of consumption condition that was equivalent to non-binge eaters within the same cue context that had been exposed to 16h of food deprivation! Hence, future research on the topic of obesity treatment should consider modeling the structural relationships between negative affect, state craving, and proscribed behaviors that are essential to therapeutic efforts at weight loss.

With respect to the primary hypotheses under investigation, we did not find that NA differed across the tape and food cue conditions as a function of either delay of consumption or state craving responses to the cues. However, we did observe that, irrespective of cue type, the highest NA was reported among individuals that expected a long delay before food consumption and were high in state craving. This response is consistent with the conceptual argument posed by Drobles et al. (2001) and early work by Amsel (1958). That is, frustrative nonreward, and thus the highest level of NA, was reported by individuals high in state craving exposed to cues under the expectation of an extended delay for food consumption. Cue reactivity (due to exposure to a particular environmental stimulus) is heightened by both unconscious (craving) and conscious (expectation of delay in consumption) factors. Also, in line with Kavanagh and colleagues (2005), the expectation of an extended delay before consumption constitutes a form of conscious cognitive elaboration of an aversive state automatically triggered by food related cues. Based on work by Jansen (1998), future research should consider the potential role of individual differences in food constraint and how this

construct may play a role in determining levels of state craving during exposure to food cues while varying time to consumption—availability.

The results for startle magnitude were more complex. Specifically, a 2-way interaction of cue order by cue type supported the presence of cue reactivity in startle that was observed by Drobos et al. (2001), in that the food cue provoked a larger startle response than the tape (neutral) cue when food was presented first, yet the startle responses to the two cues did not differ from one another when the neutral cue appeared first. The former effect may have been due to habituation of startle from the first (food) to the second (tape) trial block. However, the fact that habituation to the food cue was blunted when food was presented in the 2nd position is consistent with previous research in which a stimulant drug, caffeine, delayed the habituation of startle (Schicatanio & Blumenthal, 1994). In addition, when we added state craving and an interaction term for state craving by delay of consumption to the model, the interaction term proved to be statistically significant. These data illustrated that startle responses in the long delay condition were consistently high irrespective of participants' level of state craving, whereas in the short delay condition startle responses increased linearly with state craving; in fact, participants in the short delay condition that were high in state craving did not differ from high state cravers in the long delay condition. These data reinforce the role that state craving, in conjunction with expectations concerning the delay of consumption, have on startle magnitude (Drobos et al., 2001); yet suggest that the relationship between state craving and startle is moderated by the extent of expectations related to delay of consumption. Note that the pattern for startle responses observed in the state craving by delay of consumption interaction term differed somewhat from the previously discussed data on NA. Although startle is an objective index of threat, these findings reinforce the position the self-reported NA is not isomorphic with the physiological marker of affect that is provided by startle magnitude (Carter & Tiffany, 1999; Carter & Tiffany, 2001).

Initially, we had expected to observe more pronounced effects due to cue type: the tape or food cue. As noted above, although there were expected differences in state craving between the two cue conditions, cue type had no effect on NA, and a small yet interesting effect on startle magnitude. In retrospect, we believe that both cues were mildly frustrating. While we initially intended for the black tape to be a neutral cue, to optimize experimental control, the tape was presented on a covered dish identical to that used for the food cue. In retrospect, we believe that the mere presence of a covered dish resulted in food related thoughts, an effect that is certainly consistent with Jansen's (1998) learning model of cue reactivity. Of interest is the fact that in the study by Hawk and colleagues (2004), startle magnitude for the same neutral cue used in the current study was comparable to the response observed for an aversive stimulus; that is, smoke cues presented to a non-smoker. Thus, we believe that Hawk and colleagues created the same frustrating event that we did in presenting a roll of black tape on a covered plate.

Future research might also consider embellishing food cue manipulations to ensure that it is a focus point of attention for participants. For example, Coelho and co-investigators (Coelho, Jansen, Roefs, & Nederkoorn, 2009) recently reported that participants who attended more to food cues also reported more hunger, whereas Siep et al. (2009) have evidence that attentional focus enhances the BOLD response to food cues during an fMRI scan. At the same time, we would be remiss not to reiterate that, as observed in our own data, a common finding in cue reactivity research is a lack of congruence between self-report and physiological responses (Carter & Tiffany, 1999; Carter & Tiffany, 2001).

It is important to note several limitations of this study. First, the study population included college students that had a mean BMI in the normal range. Thus, these data have limited generalizability. Second, the protocol involved a single exposure to the tape and food cues.

The use of multiple trials may have helped to enhance differences between the two cues and improved statistical power. Third, due to sample size, tests of some interaction effects were constrained. Fourth, the study did not include a measure of food restraint. In general, it would be useful to have data that might help to explain the variability in state craving.

In conclusion, in the current study food cues provoked higher levels of state craving than neutral cues and startle responses failed to habituate as quickly to food cues as they did to neutral cues. In addition, exposure to food and food-related cues following food deprivation created the highest self-reported NA among high state craving individuals that expected a long delay prior to food consumption. However, startle responses exhibited a different pattern in that with the long delay manipulation startle was high irrespective of state craving scores, whereas the startle responses of participants in short delay of consumption increased linearly with state craving to a point where there was no difference in startle between those high in state craving in either short or long delay of consumption. Overall these data suggest that state craving and expectations regarding the availability of food are important in understanding food and food-related cue reactivity. Future research should examine the potential role that these variables may play within the context of self-regulatory failure as people attempt to lose weight via dietary restriction.

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Figure 1.
The interaction of the fasting manipulation and state craving on negative affect

Figure 2.
The interaction of cue type and cue order

Figure 3.
The interaction of state craving with the delay manipulation on startle magnitude

Table 1Means $\pm$ SE for State Craving by Cue Condition and Delay of Consumption

Cue Type	Delay Manipulation		Row Means
	Short	Long	
Neutral	3.32 $\pm$ 0.12	3.29 $\pm$ 0.11	3.30 $\pm$ 0.08
Food	3.50 $\pm$ 0.13	3.49 $\pm$ 0.12	3.49 $\pm$ 0.08
Column Means	3.40 $\pm$ 0.12	3.39 $\pm$ 0.11	

Table 2Raw Means $\pm$ SE for Affect by Delay of Consumption

	PANAS Scores			
	Negative Affect		Positive Affect	
	Short Delay	Long Delay	Short Delay	Long Delay
Early Morning	6.61 $\pm$ 0.36	6.04 $\pm$ 0.34	10.29 $\pm$ 0.79	10.44 $\pm$ 0.49
Baseline	6.76 $\pm$ 0.46	7.04 $\pm$ 0.43	10.95 $\pm$ 0.77	11.00 $\pm$ 0.71
Neutral Cue	7.05 $\pm$ 0.57	7.60 $\pm$ 0.53	9.62 $\pm$ 0.79	9.72 $\pm$ 0.73
Food Cue	6.90 $\pm$ 0.58	7.96 $\pm$ 0.53	11.42 $\pm$ 0.82	10.52 $\pm$ 0.76

Table 3Means $\pm$ SE for Startle Data by Delay of Consumption

Assessment	Short Delay	Long Delay
Baseline (microvolts)	2.51 $\pm$ 0.57	3.65 $\pm$ 0.52
Neutral Cue (microvolts)	2.06 $\pm$ 0.58	3.49 $\pm$ 0.53
Food Cue (microvolts)	2.07 $\pm$ 0.52	3.49 $\pm$ 0.58
Neutral Cue (ratio scale)	0.83 $\pm$ 0.07	0.96 $\pm$ 0.07
Food Cue (ratio scale)	0.82 $\pm$ 0.08	1.10 $\pm$ 0.08