Appetite 54 (2010) 579–582

Contents lists available at ScienceDirect

Appetite

journal homepage: www.elsevier.com/locate/appet

Short communication

All I saw was the cake. Hunger effects on attentional capture by visual food cues

Richard M. Piech *, Michael T. Pastorino, David H. Zald

Department of Psychology, Vanderbilt University, PMB 407817, Nashville, TN 37240, USA

ARTICLE INFO

Article history:
Received 6 August 2009
Received in revised form 5 November 2009
Accepted 5 November 2009

Keywords:
Food
Hunger
Motivation
Cognition
Attentional blink

ABSTRACT

While effects of hunger on motivation and food reward value are well-established, far less is known about the effects of hunger on cognitive processes. Here, we deployed the emotional blink of attention paradigm to investigate the impact of visual food cues on attentional capture under conditions of hunger and satiety. Participants were asked to detect targets which appeared in a rapid visual stream after different types of task irrelevant distractors. We observed that food stimuli acquired increased power to capture attention and prevent target detection when participants were hungry. This occurred despite monetary incentives to perform well. Our findings suggest an attentional mechanism through which hunger heightens perception of food cues. As an objective behavioral marker of the attentional sensitivity to food cues, the emotional attentional blink paradigm may provide a useful technique for studying individual differences, and state manipulations in the sensitivity to food cues.

Published by Elsevier Ltd.

Introduction

Food consumption in humans is a highly complex behavior. It is influenced by a multitude of factors, each of which may act on multiple levels (Berthoud, 2007). Hunger provides a powerful motivational force, which may not only involve physiological and affective properties, but may modulate aspects of cognition. While evidence of motivational modulations of the cognitive operations has grown in recent years, the cognitive effects specific to being hungry have received relatively little attention. Previous studies showed that hunger can increase selective attention to food-related words when enough time is provided (Mogg, Bradley, Hyare, & Lee, 1998), improve the memory advantage for food items (Morris & Dolan, 2001), and restrict attentional shifting (Piech, Hampshire, Owen, & Parkinson, 2009).

In some cases, emotionally arousing stimuli can capture attention to such an extent as to eliminate awareness of stimuli that appear immediately after the arousing stimulus. In the current study, we tested if hunger selectively biases attention to food, creating attentional capture. We utilized the emotional blink of attention (EBA) paradigm (Most, Chun, Widders, & Zald, 2005), which indexes the ability of stimuli to capture attention. In this task, a person attempts to detect a previously defined target in a stream of rapidly displayed images. Images depicting certain salient objects can prevent target detection if presented shortly before the target itself. Crucially, such distractors can prevent awareness of subsequent stimuli even if the distractors are completely irrelevant to the task at hand and when there is strong incentive to ignore them. This EBA effect has been observed for threatening, gory, and sexual distractor images (Most et al., 2005; Most, Smith, Cooter, Levy, & Zald, 2007), as well as for natively neutral images conditioned to be associated with negative events (Smith, Most, Newsome, & Zald, 2006). However, to date, it has not been tested whether EBA performance is modulated by the state of the participant.

We hypothesized that food cues – images of food – would become more powerful distractors when participants completing an EBA task were hungry, than when they were sated. Were that so, it would show that hunger can bias perception to involuntarily attend to food cues, even to the extent of disrupting otherwise motivated attention to other tasks. In a foraging environment, such a mechanism would seem both plausible and adaptive, as it would enhance acquisition of food in a physiological state of need. In a modern affluent society, it may lead to disruption of goal-directed behavior and drive attention to food regardless of other goals, such as maintaining a diet.

Method

Thirty undergraduate students (20 women) participated in the study for credit in a psychology course. Participants were additionally compensated as described below. Participants were informed when signing up for the study that they should not participate if they had diabetes, hypoglycemia, or any condition which requires regular eating patterns. All participants had normal or corrected-to-normal vision. Each person gave informed written consent prior to participating. The study was approved by the Vanderbilt University Institutional Review Board.

All stimuli were color images, 9.5 cm wide and 7.5 cm tall, viewed from 50 cm distance. The participants' task was to detect a rotated

* Corresponding author.
E-mail address: r.piech@vanderbilt.edu (R.M. Piech).

0195-6663/$ – see front matter. Published by Elsevier Ltd.
doi:10.1016/j.appet.2009.11.003

image among a set of landscape images. The landscape images consisted of 252 photographs of natural landscapes or pictures of buildings. A subset (168) of these images were rotated by 90°, clockwise or counterclockwise and served as the target images (they remained 9.5 cm wide and 7.5 cm tall). Distractor images consisted of images of food, images of romantic scenes, and neutral images, with 56 images coming from each of the distractor categories.

Neutral distractor stimuli were drawn from the International Affective Picture System (IAPS) database (Lang, Bradley, & Cuthbert, 2001), they were selected to have neutral valence and low arousal ratings, and consisted of everyday objects and people. IAPS-images of food and of romantic scenes were supplemented with images from the internet. Food images depicted a variety of dishes and courses, including salads, main courses, and desserts. Romantic scenes depicted clothed couples (a man and a woman) holding hands, laughing, dining, walking, or a combination of the above. The three distractor categories were matched on average image luminosity.

Participants completed the EBA task (Fig. 1A) during two sessions. For one of the sessions ('hungry'), they were instructed to refrain from eating, but continue drinking as usual, for 6 hours prior to the experiment. For the other ('sated') session they were to eat as usual. Sated and hungry sessions were counterbalanced across the participants. To verify that the procedures modulated hunger, participants indicated their hunger level during both sessions, using a Likert scale of 0 (not hungry at all) to 7 (extremely hungry).

The EBA task consisted of rapid presentations of images with embedded distractors and targets (see Fig. 1a). Each trial contained 17 image presentations of 100 ms. The participant's task was to identify the target among them – a rotated landscape. Participants

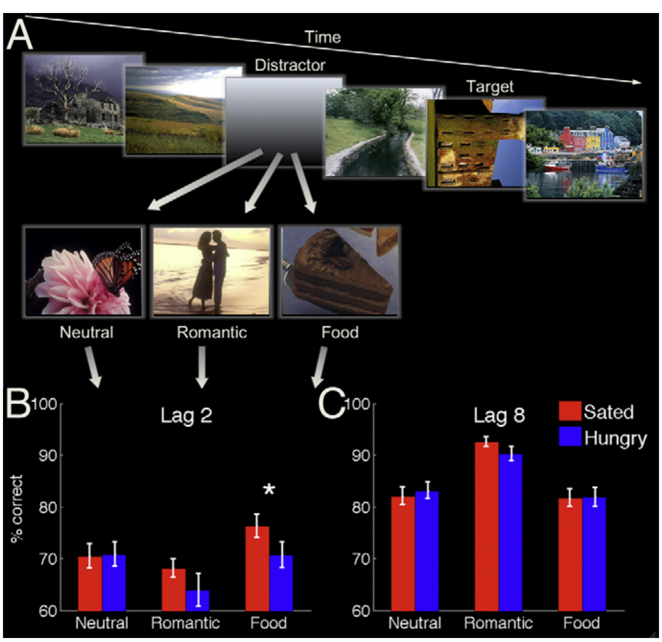

Fig. 1. Design and results of the emotional blink of attention task. Panel A: Representation of a single task trial. Seventeen (only six shown) images are presented for 100 ms each. The distractor belongs to one of three image categories: neutral pictures, romantic scenes, or food pictures. The target is a rotated landscape and appears two (or eight) presentations after the distractor (referred to as Lag 2 and Lag 8). At the end of the trial, participants indicate if they saw the target, and which way it was rotated. Panel B: Accuracy in the task for Lag 2, grouped for neutral, romantic, and food distractors. Lower accuracy indicated greater attentional blink. The asterisk indicates significant performance decrease after food distractors during the hungry condition ($p = .016$ (one-tailed)). No significant decrease was observed for the other distractor categories ($ps > .2$). Panel C: Accuracy in the task for Lag 8 did not differ due to hunger level. Overall performance at Lag 8 was better after romantic distractors than after either of the other categories. Error bars indicate one standard error of the mean.

were told that the target items would always be landscapes, and that images of other objects may also appear, but should be ignored. Participants responded pressing right or left arrow keys to indicate target rotation (right: clockwise). To minimize the number of correct responses due to chance alone, participants first had to indicate whether they saw a target or not, and only trials in which the participant indicated seeing the target and accurately identified its rotation were counted as correct. A quarter of the trials – the catch trials – did not actually have a target.

Crucially, every trial included a distractor, belonging to one of the three categories described above: neutral, romantic, or food. The distractors preceded targets such that targets occurred either two (lag 2) or eight (lag 8) presentations after the target. In past studies, it has been shown that EBA effects are strong at lag 2, but performance usually recovers by lag 8. The comparison of accurate target detection performance at lag 2 for the three distractor categories during the hungry and sated sessions is the primary contrast of interest.

The task consisted of six blocks of 32 trials, totaling 192 trials, with participants taking short breaks between blocks. Distractors were positioned as the 4th, 6th, or 8th image within the stream, followed by targets two or eight positions later. Distractor categories and positions were counterbalanced. Participants completed 16 practice trials.

To ensure that performance impairment associated with attentional capture by the distractors was involuntary, participants received a strong incentive to detect targets correctly. They knew they would be compensated additionally if they did well, with 10 USD for an overall performance of 80%, 20 USD for 90% or more in each session. Additionally, the best participant from each group of 20 received 50 USD. Thus, ignoring the distractors and detecting the targets was rewarded with up to 90 USD.

After the second experimental session, participants rated all distractor images for pleasantness (valence) and arousal using a labeled magnitude scale (Lishner, Cooter, & Zald, 2008). The images were presented for 100ms each.

Results

Self-report hunger measure

Prior to commencing the EBA task, participants indicated their hunger level on a 0 (not hungry at all) to 7 (extremely hungry) Likert scale. Out of 30 participants, five did not indicate greater hunger during the hungry session than during the sated session, and were excluded from further analyses. Two additional participants were excluded due to accuracy of more than 2 standard deviations below the mean for the respective condition. This resulted in 23 (7 men) participants with usable data. These subjects reported a mean hunger level of 5.4 (SD 1.4) during the hungry and of 2.4 (1.2) during the sated session ($t(22) = 10.9$, $p < .0005$), thus showing a strong manipulation effect.

Emotional blink of attention task

As the dependant variable, we calculated the percentage of correct trials in each condition. The experimental design resulted in a 4-factor mixed effects analysis of variance (ANOVA). It included three repeated-measures factors: Lag (2 or 8), State (Sated or Hungry), and Category (Neutral, Romantic, or Food), and one between-subjects factor, Sequence (of sessions: Hungry first or Sated first). (Sequence was included as a between-subjects factor, as we observed practice effects across sessions, i.e. participants performed better during the second session, independent of the effects of hunger. The accuracy was at 75.5% (SD: 7.3) during the first, and at 80.2% (SD: 6.7) during the second session. An ANOVA revealed the main effect of session number as significant: $F(1,22) = 15.3$, $p = .001$.)

The overall ANOVA revealed a main effect of Lag: accuracy was as expected higher at Lag 8 than at Lag 2 ($F(1,21) = 130.1$, $p < .0005$). This confirmed that our distractors were successful at creating an attentional blink at Lag 2. Planned comparisons showed that this was the case for all distractor categories (all *t*s > 4.5, all *p*s < .0005). We therefore focused the analysis on performance at Lag 2, with which our main hypotheses were concerned.

Lag 2 analysis

The ANOVA addressing performance only at Lag 2 consisted of two repeated-measures factors: Category (Food, Neutral, Romantic) and State (Hungry, Sated), and one between-subjects factor, Sequence (Fig. 1). This ANOVA revealed main effects for Category ($F(2,21) = 11.4$, $p = .001$) and State ($F(1,21) = 8.3$, $p = .009$; see Fig. 1B). The main effects reflected a lower performance after romantic distractors and an overall lower performance during the hungry session. Planned comparisons showed romantic distractors produced worse performance than either neutral or food distractors ($t(22) = 4.5$, $p < .0005$; $t(22) = 3.9$, $p = .001$, respectively). The ANOVA also revealed an interaction between Category and State ($F(2,21) = 3.8$, $p = .030$). To understand this interaction, we compared the performance after each distractor category during the Sated and Hungry sessions using paired-samples *T*-tests. These showed that only the food distractors led to significantly worse performance during the hungry session ($t(22) = 2.3$, $p = .016$ (one-tailed)). For the other distractor categories, no significant impairment after fasting was observed ($t(22) = .1$, $p = .874$ (neutral); $t(22) = 1.3$, $p = .212$ (romantic). The results confirmed the main hypothesis of the study: food pictures create an attentional blink that is enhanced after fasting.

The ANOVA at Lag 2 also showed interactions of the experimental Sequence with the State factor ($F(1,21) = 31.2$, $p < .0005$) and with the State–Category interaction $F(2,21) = 5.0$, $p = .011$. The first interaction reflects performance being overall somewhat better during session two (consistent with a practice effect), but the presence and extent of this improvement depends upon the sequence of conditions, since half the subjects performed the sated condition first, and the other half performed the hungry session first. The second interaction reflects that the degree of improvement from session one to two was greatest for romantic distractors, regardless of state, whereas the presence and extent of improvement for food distractors from the first to second session was dependent upon the sequence of conditions. These interactions validate the inclusion of sequence as a factor in the statistical model and were not further investigated.

Lag 8 analysis

An ANOVA addressing performance at Lag 8 resembled the one for Lag 2. It revealed a main effect of Category ($F(2,21) = 34.7$, $p < .0005$), but planned comparisons showed better performance after romantic distractors, compared to both neutral and food distractors (both *p*s < .0005), which were at an equivalent level. Thus, romantic distractors showed a different pattern of effects for Lag 2 and Lag 8. While they were the most distracting category at Lag 2 (see analysis above), leading to impaired performance in the task, at Lag 8, performance in romantic distractor trials was elevated compared to the other categories. This was confirmed by an interaction of Lag and Category in the overall 4-factor ANOVA described above ($F(2,21) = 38.1$, $p < .0005$).

No effects of State or interaction of Category with State were observed in the ANOVA of Lag 8 (see Fig. 1C). Like for Lag 2, the Lag 8 ANOVA showed an interaction between experimental Sequence and State ($F(1,21) = 5.7$, $p = .026$), reflecting improved performance during the second session.

We also explored participants' scores on the dietary restraint scale (Herman, Polivy, Pliner, Threlkeld, & Munic, 1978). The mean score for our sample was 12.9 (SD = 4.9), indicating on average medium restraint (Coelho, Polivy, Herman, & Pliner, 2008). The Pearson correlation between the restraint scores and the performance impairment in the hungry condition after food distractors at Lag 2 was not statistically significant ($r = -.29$, $p = .182$), suggesting that the relationship between dietary restraint and hunger induced changes in attentional capture is at best modest.

Distractor valence and arousal

Participants' valence rating scores for neutral, romantic, and food distractors were: 0.1 (SD 10.7), 26.1 (14.3), 34.0 (22.6), respectively. An ANOVA showed a significant effect of Category ($F(1,22) = 29.6$, $p < .0005$), and planned comparisons indicated that both romantic and food distractors received higher valence scores than neutral ones (*p*s < .0005), but were not different from one another ($p = .153$).

Arousal scores showed a similar pattern. The scores for neutral, romantic, and food distractors were: 16.4 (SD 12.1), 32.7 (18.0), 40.8 (27.2), respectively, with a significant effect of Category ($F(1,22) = 13.0$, $p = .001$). Both romantic and food distractors received higher arousal scores than neutral ones (*p*s < .0005), but were not different from one another ($p = .186$).

Half of the participants rated the stimuli while hungry, and half while sated. Only food stimuli were rated differently based on State: they were rated as more arousing and more positive by the hungry group. *Valence* ratings showed an interaction effect with State ($F(2,42) = 9.0$, $p = .001$). Independent *T*-tests showed a higher food cue valence rating for the hungry group ($t(21) = 4.2$, $p < .0005$), but not for neutral or romantic distractors (*p*s > .4). Similarly, *arousal* ratings showed an interaction with State ($F(2,42) = 11.9$, $p = .001$). Independent *T*-tests showed a higher food cue arousal rating for the hungry group ($t(21) = 3.8$, $p = .001$), but not for neutral or romantic distractors (*p*s > .7). In summary, neutral distractors were less positive and less arousing than either of the affective distractor categories. There was no significant difference between the food and romantic distractors on either scale, although numerically food distractors were rated higher on both scales.

Discussion

Hunger influences food intake through mechanisms beyond the mere desire to eat. Here, we have demonstrated a cognitive effect of hunger, namely the increased capture of attention by food cues. This process appears involuntary, in that it occurs even when participants are rewarded for tasks that require them to ignore the foods. The modulation of attentional capture by hunger may prove particularly problematic for individuals who are dieting, as the hungrier they get, the more likely food stimuli are to capture their attention and interrupt goal-directed behavior. This relationship resembles that of drug addiction: biasing cognitive processing toward reinforcers (Garavan & Hester, 2007).

Visual attention processes are frequently considered to be driven by two principal kinds of mechanisms, bottom-up (stimulus driven) and top-down (endogenous control) (Connor, Egeth, & Yantis, 2004). Bottom-up mechanisms of attentional capture are thought to be automatic and due to salient properties of a given stimulus, for example bright colors or movement. Top-down control mechanisms are endogenous to the individual performing a task. In the attention literature, top-down effects are typically exercised deliberately and result from awareness and knowledge about the current task demands. The ability of certain high arousal stimuli to capture attention even when they are irrelevant to the task has the hallmark characteristics of a bottom-up mechanism.

Yet, the demonstrated influence of hunger on capture by food stimuli also bears top-down characteristics. The effect of hunger cannot be viewed as purely stimulus driven given that the stimuli remained unchanged for the two sessions. Rather, what alters the distractors' potential to disrupt task performance is a parameter which is crucially internal to the participants, namely their motivational state. As such, the effect can be argued to be a form of top-down control.

The described hunger effect departs from standard top-down mechanisms in a critical respect. It is unlikely to reflect a conscious intentional process of cognitive control, since there was no advantage gained from paying more attention to the food stimuli, and indeed directing attention to these irrelevant stimuli actually impairs performance. Given the monetary incentive to perform well, participants are on the contrary likely to exert top-down effort to counter attentional capture by food cues. Thus, to the extent that hunger provides a top-down bias, it is likely involuntary in nature, which stands in sharp contrast to the deliberate and conscious effects that typically characterize top-down control of visual attention. Existing reports of motivational effects on visual attention typically show a performance gain when participants expect higher rewards from doing well on an attentional task (Engelmann, Damaraju, Padmala, & Pessoa, 2009). However, it is important to distinguish between paradigms in which the motivationally relevant stimuli are targets vs. distractors, as the role of the stimuli in the task is critical in determining whether they will have positive or negative effects on task performance.

The present study was conducted as a proof of concept for the potential utility of the EBA paradigm for research on eating behavior. We tested the effects in an undergraduate student population without specific weight requirements. Because of this and the small sample size, it would be wrong to consider the size of the hunger effect as normative in nature. Future testing of clinical populations (and well-screened healthy controls) will be crucial for determining the clinical relevance of our finding.

The current paradigm may be of particular utility for testing models of overeating that emphasize individual differences in sensitivity to external food cues (Schachter & Rodin, 1974). Our study did not measure such sensitivity, and future investigations of this relationship will be valuable. We did, however, include a measure of dietary restraint, which notably did not show a significant relationship of hunger induced changes in attentional capture by food. But, sensitivity to external food cues may reflect a distinct process from what is measured by dietary restraint. The described mechanism of attentional capture has the potential to influence eating habits, reflecting the extent to which food stimuli draw an individual's attention even when the person attempts to ignore them. Differential levels of this tendency may predict the risk of obesity or the success at maintaining a diet, akin to the concept of external food sensitivity (Passamonti et al., 2009). Interestingly, Brignell, Griffiths, Bradley, & Mogg (2009) recently reported an association between reaction times in a food-related dot probe paradigm and high external eating, such that the high external eaters showed greater allocation of attention to food words. Obese individuals show a similar pattern, with greater orienting to food cues in general, and greater time looking at food cues than normal weight individuals in situations in which they are not hungry (Castellanos et al., 2009).

Attentional blink effects akin to the ones reported here have been shown for a variety of motivationally significant stimuli, including gore, erotic scenes, and negatively conditioned stimuli (Most et al., 2005; Most et al., 2007; Smith et al., 2006). These stimulus classes share a high level of perceived arousal. Such observations lead to the conclusion that the arousal value of stimuli drives their potential to capture attention and create an attentional blink (Anderson, 2005; Vuilleumier, Armony, Driver, & Dolan, 2001). Our data appear congruent with this conclusion. Participants' ratings of arousal for food images were increased in the hungry sessions, reflecting the increased attentional blink caused by food stimuli. Consistent with an arousal interpretation, ratings of arousal for the nonfood stimuli in this study did not change, and EBA performance for such stimuli did not demonstrate a statistically significant effect of the hunger manipulation. However, as is often the case in studies with emotional stimuli, the valence profile of our food conditions mirrored the one for arousal, with participants also rating the food as more pleasant when hungry. Thus, while consistent with an arousal explanation of the attentional blink, the study does not specifically distinguish between arousal and valence.

Research on the importance of social, cognitive and environmental factors for human eating behavior have recently led some to favor these factors over the 'traditional' hunger when trying to explain healthy eating patterns, as well as obesity or eating disorders (Herman & Polivy, 2005). Our experiment shows that hunger can very well influence these non-homeostatic factors, and that the influence is likely to be exercised despite a person's deliberate attempts to the contrary.

References

Anderson, A. (2005). Affective influences on the attentional dynamics supporting awareness. *Journal of Experimental Psychology-General, 134*(2), 258–280.

Berthoud, H. (2007). Interactions between the 'cognitive' and 'metabolic' brain in the control of food intake. *Physiology & Behavior, 91*(5), 486–498.

Brignell, C., Griffiths, T., Bradley, B., & Mogg, K. (2009). Attentional and approach biases for pictorial food cues. Influence of external eating. *Appetite, 52*(2), 299–306.

Castellanos, E., Charboneau, E., Dietrich, M., Park, S., Bradley, B., Mogg, K., et al. (2009). Obese adults have visual attention bias for food cue images: Evidence for altered reward system function. *International Journal of Obesity,* 1476–5497.

Coelho, J., Polivy, J., Herman, C., & Pliner, P. (2008). Effects of food-cue exposure on dieting-related goals: A limitation to counteractive-control theory. *Appetite, 51*(2), 347–349.

Connor, C., Egeth, H., & Yantis, S. (2004). Visual attention: bottom-up versus top-down. *Current Biology, 14*(19), 850–852.

Engelmann, J., Damaraju, E., Padmala, S., & Pessoa, L. (2009). Combined effects of attention and motivation on visual task performance: Transient and sustained motivational effects. *Frontiers in Human Neuroscience 3.*

Garavan, H., & Hester, R. (2007). The role of cognitive control in cocaine dependence. *Neuropsychology Review, 17*(3), 337–345.

Herman, C., & Polivy, J. (2005). Normative influences on food intake. *Physiology & behavior, 86*(5), 762–772.

Herman, C., Polivy, J., Pliner, P., Threlkeld, J., & Munic, D. (1978). Distractibility in dieters and nondieters: An alternative view of "externality". *Journal of Personality and Social Psychology, 36*(5), 536.

Lang, P., Bradley, M., & Cuthbert, B. (2001). *International affective picture system (IAPS): Instruction manual and affective ratings*. The Center for Research in Psychophysiology, University of Florida.

Lishner, D., Cooter, A., & Zald, D. (2008). Addressing measurement limitations in affective rating scales: Development of an empirical valence scale. *Cognition & Emotion, 22*(1), 12.

Mogg, K., Bradley, B. P., Hyare, H., & Lee, S. (1998). Selective attention to food-related stimuli in hunger: Are attentional biases specific to emotional and psychopathological states, or are they also found in normal drive states? *Behaviour Research and Therapy, 36*(2), 227–237.

Morris, J. S., & Dolan, R. J. (2001). Involvement of human amygdala and orbitofrontal cortex in hunger-enhanced memory for food stimuli. *Journal of Neuroscience, 21*(14), 5304.

Most, S., Chun, M., Widders, D., & Zald, D. (2005). Attentional rubbernecking: Cognitive control and personality in emotion-induced blindness. *Psychonomic Bulletin and Review, 12*(4), 654.

Most, S., Smith, S., Cooter, A., Levy, B., & Zald, D. (2007). The naked truth: Positive, arousing distractors impair rapid target perception. *Cognition & Emotion, 21*(5), 964–981.

Passamonti, L., Rowe, J., Schwarzbauer, C., Ewbank, M., von dem Hagen, E., & Calder, A. (2009). Personality predicts the brain's response to viewing appetizing foods: The neural basis of a risk factor for overeating. *Journal of Neuroscience, 29*(1), 43.

Piech, R., Hampshire, A., Owen, A., & Parkinson, J. (2009). Modulation of cognitive flexibility by hunger and desire. *Cognition & Emotion, 23*(3), 528–540.

Schachter, S., & Rodin, J. (1974). *Obese humans and rats*. Washnigton, DC: Erlbaum/ Halstead.

Smith, S., Most, S., Newsome, L., & Zald, D. (2006). An emotion-induced attentional blink elicited by aversively conditioned stimuli. *Emotion, 6*(3), 523–527.

Vuilleumier, P., Armony, J., Driver, J., & Dolan, R. (2001). Effects of attention and emotion on face processing in the human brain an event-related fMRI study. *Neuron, 30*(3), 829–841.