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BRIEF REPORT

Emotional stimuli exert parallel effects on attention and memory

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Because emotional and neutral stimuli typically differ on non-emotional dimensions, it has been difficult to determine conclusively which factors underlie the ability of emotional stimuli to enhance immediate long-term memory. Here we induced arousal by varying participants' goals, a method that removes many potential confounds between emotional and non-emotional items. Hungry and sated participants encoded food and clothing images under divided attention conditions. Sated participants attended to and recalled food and clothing images equivalently. Hungry participants performed worse on the concurrent tone-discrimination task when they viewed food relative to clothing images, suggesting enhanced attention to food images, and they recalled more food than clothing images. A follow-up regression analysis of the factors predicting memory for individual pictures revealed that food images had parallel effects on attention and memory in hungry participants, so that enhanced attention to food images did not predict their enhanced memory. We suggest that immediate long-term memory for food is enhanced in the hungry state because hunger leads to more distinctive processing of food images rendering them more accessible during retrieval.

Keywords: Emotion; Arousal; Memory; Free recall; Hunger; Attention.

Enhanced memory for emotional stimuli has been demonstrated in a wide range of studies (LaBar & Cabeza, 2006). To manipulate the emotional content of to-be-remembered items researchers normally vary the stimuli, comparing neutral stimuli to stimuli that induce emotional arousal. Many varieties of stimuli have been used, including stories, real-life scenes and film clips, and negative and taboo words. Common to them all is the difficulty of equating neutral and emotional stimuli on non-emotional characteristics. Because differences between emotional and neutral stimuli

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may influence memory, it had been difficult to determine exactly what accounts for enhanced immediate long-term memory for emotional material (Talmi & McGarry, 2012). Here we overcome the problem of inherent stimulus differences by keeping the stimuli constant but varying their emotional significance to the participant.

Goal relevance is the hallmark of what makes a stimulus emotionally arousing (Lazarus, 1991). Hunger is a motivational state associated not only with increased food consumption but also liking, approach, and increased reinforcing value of food-related stimuli (Grill, Berridge, Sprague, & Epstein, 2009; Lavy & Vandenhout, 1993; Saelens, Epstein, Bickel, & Vuchinich, 2009; Seibt, Hafner, & Deutsch, 2007), indicating that these stimuli are goal relevant. Goal relevance is considered a primary activator of the amygdala (Sander, Grafman, & Zalla, 2003), a region associated with emotional arousal (Labar & Cabeza, 2006). Indeed, the amygdala is preferentially activated when hungry, as opposed to sated, participants view food images (Labar et al., 2001). Labar et al.'s paradigm, therefore, is ideal for investigating emotional memory, because it allows the experimenter to keep the stimuli constant while varying their emotional value for participants. Using this paradigm, Morris and Dolan (2001) found that hungry, but not sated, participants exhibited enhanced memory for food images, an effect associated with amygdala activation at encoding. Their findings replicated those of studies using inherently emotional stimuli, and thus supported the claim that emotion enhances memory directly, without mediation by cognitive factors such as attention (Labar & Cabeza, 2006).

This conclusion, however, may be premature as varying goal states also alters the attention paid to emotionally arousing stimuli (Schimmack, 2005), and it may be attention at encoding, rather than emotion per se, that enhances memory (Hamann, 2001; Talmi & McGarry, 2012; Talmi, Schimmack, Paterson, & Moscovitch, 2007). Crucially, studies manipulating goal state found that hungry participants attended food stimuli preferentially (Channon & Hayward, 1990; Mogg, Bradley, Hyare, & Lee, 1998; Piech, Pastorino, & Zald, 2010; Placanica, Faunce, & Soames Job, 2002; Stockburger, Schmalzle, Flaisch, Bublatzky, & Schupp, 2009). Thus, hungry participants in Morris and Dolan's (2001) study may have remembered food images better because they paid more attention to them. Our experiment tests this hypothesis.

We adapted Morris and Dolan's (2001) procedure, requesting participants to encode the stimuli under divided-attention conditions, namely, while simultaneously maximising their performance on a tone-classification task (Talmi et al., 2007). Greater attention to pictured stimuli was reflected by reduced performance on the tone classification task (Kahneman, 1973). We predicted that hungry participants would remember food images better and attend to them more than control images and that the difference between memory and attention to food and non-food images would be attenuated in sated participants, replicating previous work. Our novel prediction was that the memory advantage for food stimuli in hungry participants would depend on the amount of attention allocated to these stimuli.

A secondary purpose of our study was to examine the possible moderating role of dietary restraint (Polivy, Herman, Howard, & Hersen, 1988) on memory for food pictures in both the hungry and sated conditions. Because participants with high restraint scores are chronic dieters and/or show undue concern with their weight (Heatherton, Herman, Polivy, King, & McGree, 1988) they may be considered to be in a consistently deprived state. Therefore, we predicted that the food deprivation manipulation would have a weaker effect on memory and attention in restrained than in unrestrained eaters.

METHOD

Participants

Forty-nine University of Manchester undergraduates completed the study for course credit. All participants gave informed consent. The study was approved by the university's research ethics committee. Data from three sated participants whose mean hunger rating on a 7-point scale was above three and one hungry participant whose rating was below four were excluded. Data from two other participants were lost. The final sample included 43 participants (40 females, $M_{age} = 19.34$ years, $SD = 0.91$).

Materials

Pictures. Thirty-two pictures of food and 32 pictures of clothing were taken from google.com image search. The pictures were sorted into four groups, creating 16 mixed lists. Sixteen additional pictures, the first and last two in each list, were used as buffers and excluded from the analysis. The pictures were presented centrally on a white background.

Tone discrimination. The stimuli for this task were 250, 750, and 2,250 Hz 100-ms pure tones. The 750-Hz tone served as the target tone.

Restraint Scale. The 10-item Restraint Scale (Polivy et al., 1988) is a self-report instrument for identifying chronic dieters. Items on this scale reflect concern for dieting and weight fluctuations. We used a median split to classify participants as restrained or unrestrained.

Distractor task. This task, used to prevent rehearsal, involved choosing the larger resulting value from a set of two presented equations by pressing corresponding left and right arrow keys.

E-prime software was used for presentation and data collection.

Procedure

Participants were asked to refrain from consuming anything other than water in the 12 hours preceding the experiment. Upon arrival participants assigned to the sated condition were given their choice of a shop-bought sandwich (a variety of fillings of about 400 caloric value were available) and a glass of water. They were asked to consume as much of their sandwich as they could and were given 10 minutes to do so. Participants assigned to the Hungry condition were not given the sandwich. Everyone then rated their current hunger level on a 7-point scale ranging from 1 (*Not at all hungry*) to 7 (*Extremely hungry*).

Participants then practised all tasks. First, they were asked to classify tones to target/distractors as quickly and accurately as possible by pressing one of two keys. The tone discrimination practice used 18 tones, presented every two seconds. Participants whose accuracy fell below 80% repeated the practice. Participants were then asked to perform the same task while viewing five practice pictures, and informed that their memory for the pictures would be tested. Pictures were presented for two seconds every six seconds. One tone was paired with picture onset, one with picture offset, and one presented during the inter-trial interval; the stimulus-onset asynchrony (SOA) between pictures and tones was thus 0, 2 and 4 s. Participants were instructed to treat the tone-discrimination task as primary and maximise performance on that task. Participants then engaged for one minute in the distractor task. They were then given three minutes to recall the pictures that they had seen in any order by describing them in writing in a recall booklet. The experimenter ensured that participants understood the task, and explained that the experiment included six sets of the tasks they had just completed: picture presentation with tones, arithmetic task, and recall.

Upon completion of these tasks participants rated their hunger level again using the same scale. Participants assigned to the Hungry condition were then given 10 minutes to eat a shop-bought sandwich of their choice. Everyone then completed the Restraint Scale.

RESULTS

In these analyses we used a significance threshold of $p < .05$ and corrected for violations of sphericity using Greenhouse–Geisser. Error bars in all figures represent within-subject 95% confidence intervals (Cousineau, 2005).

Restraint scale. The median score across all participants with completed questionnaires was 13.5. Five participants did not answer all questions on the Restraint Scale. Using the median score as a reference, four of these participants could be classified confidently to one of the groups. The fifth was assigned to the unrestrained group but the results do not change if this participant was assigned to the high-restraint group. The final sample included 10 unrestrained-hungry, 12 restrained-hungry, 12 unrestrained-sated and 9 restrained-sated participants.

Manipulation check. The difference between the mean hunger rating of Hungry (5.54, $SD = 0.57$) and Sated (1.48, $SD = 0.62$) participants was significant, $t(41) = 22.28$, $p < .001$.

Concurrent task latency. Figure 1 shows that hungry participants as well as restrained participants responded more slowly to food than to clothing images, but picture type did not influence latency in sated or unrestrained participants. The median latency of correct responses to the three tones paired with each picture was computed for each participant and the mean of the three medians was entered into a mixed analysis of variance (ANOVA) with the between-subject factor Satiety (sated, hungry) and the within-subject factors Image (clothing, food) and Restraint (restrained, unrestrained). The two-way interactions between Image and Satiety, $F(1, 39) = 4.21$, $p < .05$, and Image and Restraint, $F(1, 39) = 6.94$, $p < .05$, were significant, subsuming a main effect of picture type, $F(1, 39) = 5.66$, $p < .05$. No other effects were significant. Post hoc Bonferroni-corrected *t*-tests confirmed that hungry participants were slower to respond to food than to clothing images, $t(21) = 3.05$, $p < .01$, but this difference was not significant for sated participants, $t < 1$. Restrained participants, $t(20) = 4.59$, $p < .001$, but not unrestrained participants, $t < 1$, were slower to respond to food than clothing images. Neither between-subject tests was significant.

Memory. Free recall was scored separately by the two experimenters; their scores correlated

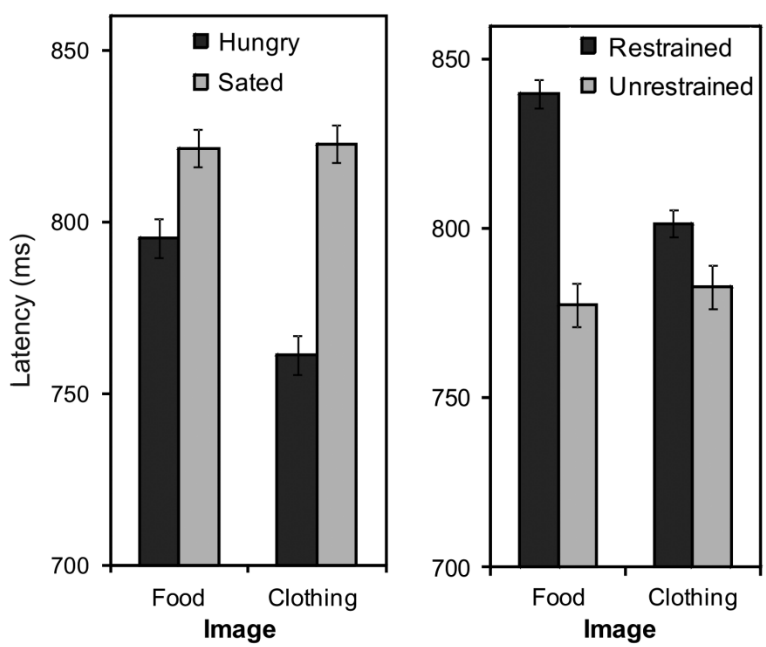

Figure 1. *Latency of concurrent task performance (ms) as a function of satiety, image and restraint. Error bars represent within-subject 95% confidence interval.*

highly, $r = .99$, $p < .001$. We analysed free recall data with the within-subject factor Image and the between-subject factors Satiety and Restraint. Figure 2 shows that hungry participants recalled more food than clothing pictures, resulting in a significant Satiety by Image interaction, $F(1, 39) = 8.64$, $p < .01$, subsuming a marginally significant effect of Image, $F(1, 39) = 3.58$, $p = .07$. No other effects were significant. Post hoc Bonferroni-corrected t-tests confirmed that hungry participants remembered more food than clothing pictures, $t(21) = 3.26$, $p < .01$, but this comparison was not significant for sated participants, $t < 1$. Object memory was better in sated than hungry participants, $t(41) = 2.66$, $p = .011$.

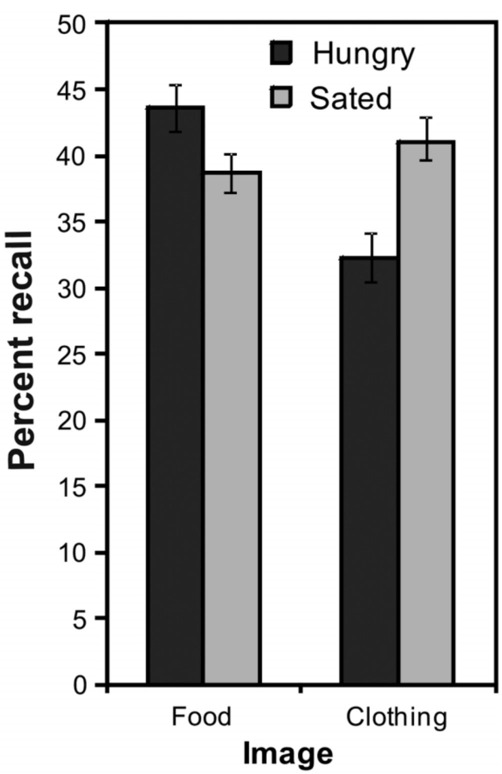

Figure 2. *Memory (percent recalled) as a function of satiety and image. Error bars represent within-subject 95% confidence interval.*

Concurrent task accuracy. The same analysis on the accuracy data revealed that the response to food images was less accurate than was the response to clothing images, $F(1, 39) = 4.31$, $p < .05$. The interaction between Satiety and Restraint was surprisingly also significant, $F(1, 39) = 4.37$, $p < .05$, due to lower accuracy in hungry unrestrained participants and sated restrained participants. None of the post hoc tests following up on this interaction, nor any other effects, were significant.

Regression analysis. To investigate whether enhanced attention to food images in hungry participants accounted for their enhanced memory for these images we examined whether attention and recall correlated, and used multiple regression to check whether attention significantly predicted memory results beyond the effect of image type alone. We analysed the hungry and the sated conditions separately. Both analyses were conducted across images (including both food and clothing images) rather than across participants, following Talmi et al. (2007). Attention to each image was computed by calculating latency and accuracy scores in the tone discrimination task across participants when they viewed that specific image. For latency, this was a mean across three median latency scores, reflecting correct responses to the three tones paired with each picture; for accuracy this was a mean across three accuracy scores for the same three tones. Memory for each image was likewise computed as the mean free recall of that image across participants.

Memory significantly correlated with latency in hungry participants, $r = .29$, $p < .05$, but not in sated participants, $r = -.14$, $p > .28$ (Figure 3). Notably, while the correlation between attention to pictures in hungry participants and free recall was positive, reflecting better memory when tone classification was delayed, namely, when more attention was allocated to the picture, the direction of the correlation was opposite in sated participants (Figure 3). This result suggests that the non-significant correlation between attention and memory in this group was not due to low power.

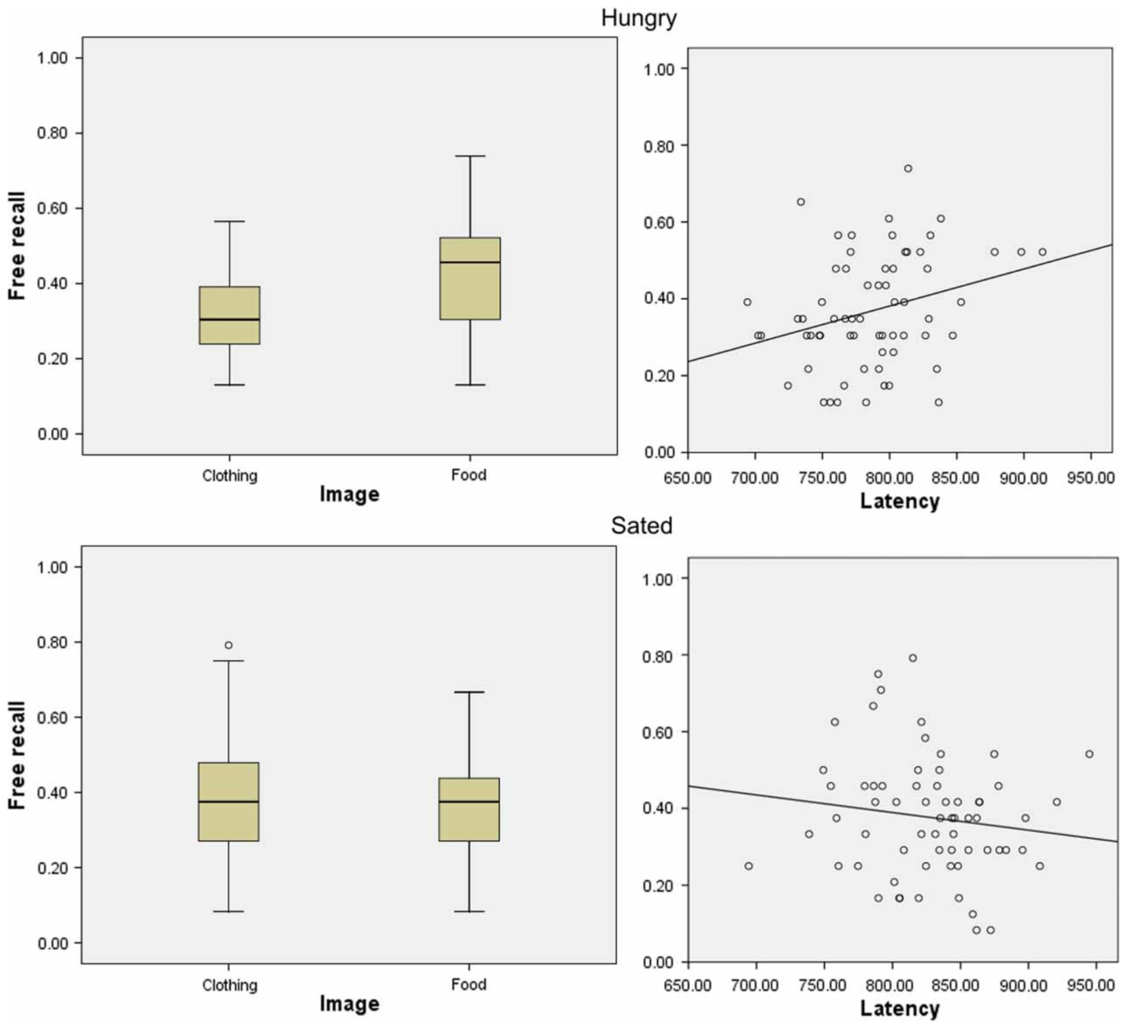

Figure 3. *The relationship, across images, between free recall and its predictors: image type (left) and response latency (right). The left panels depict the inter-quartile range with outliers represented as a circle. The right panels depict observed (circles) and estimated linear fit (line). Top panels depict data from hungry participants, and bottom panels depict data from sated participants.*

Next, we checked whether free recall in hungry participants was significantly predicted by increased attention to food images, or whether the effects of food on attention and memory were independent. A stepwise multiple regression with image type (dummy coded), image latency and image accuracy as predictors and free recall as a dependent variable was significant, $F(1, 63) = 8.79$, $p < .01$, however, only image type, not attention, significantly predicted memory, $t = 2.96$, $p < .01$.

Mediation analysis. Multiple regression suffers from limited power to detect mediation effects. The Sobel test is a more direct and more powerful method (Preacher & Hayes, 2004). Here we used the bootstrapped ratio, which is comparable to the Sobel test but specialised for use with relatively small sample sizes. The bootstrapped ratio is a non-parametric test of the hypothesis that the indirect effect is significant. This approach is preferable because it does not assume that indirect effects are distributed normally and symmetrically, an assumption which is often violated, especially in small samples (Preacher & Hayes, 2004). The bootstrapped ratio makes no assumption about the shape of the distribution of this effect and instead uses the sampling distribution to derive a confidence interval. Here we used 2,000 bootstraps and a 95% confidence interval. The bootstrapped results (mean 0.02, with a confidence interval between -0.2 and 0.7) indicated that the effect of image was not mediated by attention. The direct effect of image on memory remained significant after taking attention into account ($b = 0.08$, $p < .05$).

DISCUSSION

This experiment replicated previous findings (Morris & Dolan, 2001) that memory for food images was enhanced relative to memory for non-food images in participants who fasted, and therefore were likely to experience the food images as goal relevant and emotionally arousing. Because both hungry and sated participants encoded identical images we can be certain that this effect did not stem from common confounds between emotionally arousing and neutral items. Using a divided-attention paradigm we also replicated previous findings that hungry participants attend to food images preferentially (Channon & Hayward, 1990; Mogg et al., 1998; Piech et al., 2010; Placanica et al., 2002; Stockburger et al., 2009).

Although hungry participants paid more attention to food images than to object images and recalled food images better than object images, effects that were absent in sated participants, they did not pay *more* attention to food images than did sated participants. In fact, they paid slightly, although not significantly, less attention to both food and object pictures. The fact that they remembered food images numerically better than did control participants supports the hypothesis that enhanced attention to food under conditions of hunger was not responsible for enhanced memory for food in that condition. The regression analysis confirmed these results: Although attention to food images correlated with free recall of these images only image type, not attention, predicted free recall, suggesting that superior memory for emotional stimuli is not driven by extra attention devoted to them.

This intriguing pattern replicates our previous findings from a study that used an identical paradigm but where the stimuli consisted of negatively valenced, emotionally arousing scenes and neutral scenes (Talmi et al., 2007). In that study arousal ratings, not attention, accounted for enhanced memory for the emotional pictures. A direct link between arousal ratings and memory, above and beyond partial mediation via attention, had recently been obtained in another laboratory (Pottage & Schaefer, 2012). The difference between our findings and those of Pottage and Schaefer is that they observed both a direct and an attention-mediated effect of emotion on memory. The discrepancy could be due to the fact that only Talmi et al.'s stimuli were controlled for semantic relatedness. In our experience it is difficult to bring the organisation of a neutral set up to the level of organisation of the emotional set, suggesting that neutral stimuli in Pottage and Schaefer's study were less well organised than the emotional ones. Given evidence that divided attention influences memory for related-neutral stimuli more than for random-neutral stimuli (Talmi & McGarry, 2012), it is possible that mediation via attention in Pottage and Schaefer reflected the memory consequences of enhanced attention to relatedness cues in their emotional stimulus set.

Clearly, the dummy-coded variable "image type" in the present study and arousal ratings in Talmi et al. (2007) indexes not only the emotional arousal participants experience when they view a stimulus, but also the degree to which those emotions encourage distinctive processing of the stimulus. Participants naturally encode the differences between salient stimuli and their context, and this "processing for differences" (Hunt & Worthen, 2006) renders the salient stimuli more distinctive in memory. We suggest that when this occurs the subtle effect of attention on encoding of goal-relevant stimuli (negative scenes, food images in hungry participants) may be "drowned" by the greater distinctiveness of the goal-relevant category during retrieval. In other words, when participants are engaged in freely recalling the gist of pictures they saw, the tag of emotional arousal associated with food images and negative scenes may allow those images to compete successfully for retrieval. By contrast, when the test relies on memory for detailed aspects of the pictures, as in a recognition memory tests with highly similar lures, performance would benefit from enhanced attention and a mediation effect could be obtained.

Indeed, when we manipulated arousal, distinctiveness, and attention in the same experiment (Talmi & McGarry, 2012, Experiment 1), we found that only distinctiveness, not arousal, explained the superior memory for negative scenes embedded between neutral scenes—a finding that supports our hypothesis that distinctiveness accounts for enhanced memory for food in hunger. The same methodology could be employed to follow up the current study, by comparing a condition in which food and clothing pictures are presented separately in blocked lists or together in mixed lists. We predict that when "relative" or "primary" (Hunt & Worthen, 2006) distinctiveness is the same for food and non-food items, namely when food items do not stand out in their local context, enhanced memory for food in hunger would be eliminated even if food images were attended better.

The between-subject effects in this study were intriguing, especially the unexpected finding that the manipulation of hunger decreased memory for objects more robustly than it increased memory for food. It is difficult to interpret this result because other comparisons between hungry and sated participants were statistically non-significant, suggesting insufficient power to detect between-subject differences, possibly due to the modest sample size used. Additionally, we must acknowledge that the main finding in this paper is a non-significant effect of mediation, an effect which is also vulnerable to an insufficient power interpretation. Going against this interpretation is the robust direct link between image type, on the one hand, and memory and attention, on the other, and the numerically greater memory for food in hungry than sated participants, combined with their reduced attention to food.

Dietary restraint did not have a significant influence on memory for food, but it changed the way participants attended images. Similarly to the hungry participants, who allocated more attention to food than the sated participants, restrained participants, who may be considered to always be in a food-deprived state (Heatherton et al., 1988), allocated more attention to food than unrestrained participants.

In conclusion, our findings show that although goal-relevant stimuli attract attention and are remembered better, the extra attention does not account for the enhanced memory. Our previous work suggests that distinctive processing holds the clue to this latter effect.

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