Harnessing the power of disgust: a randomized trial to reduce high-calorie food appeal through implicit priming

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ABSTRACT

Background: In our increasingly obesogenic environment, in which high-calorie convenience foods are readily available, food choices can drastically affect weight and overall health. Learned food preferences, which are developed through repeated pairings with positively and negatively valenced stimuli, can contribute to obesity susceptibility if positive attitudes toward high-calorie foods are developed. Thus, the modification of automatic associations with food may be a viable strategy to promote healthier eating behaviors.

Objective: In this study, we investigated the ability of an implicit priming (IP) intervention to alter responses to visual food cues by using an evaluative conditioning approach. The main objective was to implicitly (i.e., below conscious perception) associate disgust with high-calorie foods with the aim of reducing liking of these foods.

Design: Participants were randomly assigned to active or control IP. In active IP (n = 22), high-calorie food images were implicitly primed with negatively valenced images, and low-calorie food images were implicitly primed with positively valenced images. In control IP (n = 20), all food images were primed with neutral images of fixation crosses. Food images were rated on the desire to eat immediately before and after IP.

Results: A significant main effect of calorie (high compared with low; P < 0.001) and a significant calorie-by-group (active compared with control) interaction (P = 0.025) were observed. Post hoc tests identified a significantly greater high-calorie rating decline after active IP than after control IP (P = 0.036). Furthermore, there was significantly greater change in high-calorie ratings than in low-calorie ratings in the active group (P = 0.001). Active IP effects extended to high-calorie foods not specifically included in the intervention, which suggested an effect generalization. Moreover, a greater change in high-calorie ratings than in low-calorie ratings persisted 3–5 d after active IP (P < 0.007), which suggested lasting effects.

Conclusion: This study provides initial evidence that IP can be used to alter high-calorie food preferences, which could promote healthier eating habits. This trial was registered at clinicaltrials.gov as NCT02347527.

Keywords: disgust, food preferences, implicit priming, nutrition, obesity

INTRODUCTION

In our increasingly obesogenic environment, with readily available high-calorie foods, food choices can drastically affect weight and overall health (1). In addition to factors such as cost, availability, and social context, food preferences play a critical role in eating choices. These preferences are thought to be learned responses, which are developed via conditioning through repeated pairings with positively and negatively valenced stimuli (2–4).

Food choices often rely on automatic decision-making processes without lengthy consideration of nutritional value, calories, or health impact (5). For example, most grocery store decisions are made in a matter of seconds, with an estimated 40% of all money spent consisting of impulsive rather than planned purchases (6). Underlying learned food preferences are an important driver of these automatic processes by influencing food choices outside conscious awareness. The interaction between our automatic learned preferences and the myriad of contextual food cues we experience on a daily basis, such as television advertising and product placement (7, 8), grocery store displays (6), product packaging (9), and menu presentation (10), can strongly influence typical food intake behaviors.

Because of this influence, the modification of automatic associations may be a worthwhile strategy to promote healthier eating behaviors. A potential method to accomplish this goal is via a conditioning approach in which food images are repeatedly paired with primes of negative or positive valence. A small number of studies investigated the use of explicit priming (i.e., presenting primes of which participants are aware) to influence food choices.

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For example, differences in snack selection were observed after explicitly pairing food images with words and pictures of positive or negative valence (11) or with images of potential health consequences of unhealthy eating (e.g., obesity, heart disease) (12). Explicitly pairing food images with obese body images was associated with reduced liking of those foods in one study (13) and with less-positive automatic associations with those foods in another study, although overt behavioral effects were not observed (14).

A potentially more powerful conditioning approach may be the use of implicit priming (IP) (15), which, to our knowledge, has not yet been studied in the context of food preferences. In IP, subjects do not consciously perceive priming stimuli and, thus, are unaware of specific pairings. Distinct from top-down cognitive constructs in explicit priming (e.g., increasing awareness of unhealthy eating consequences), the goal of the IP intervention is to elicit a more visceral, automatic response. To examine the potential ability of IP to alter food preferences, the current study primed food images with implicitly presented images of either negative valence, which were chosen to elicit disgust (paired with high-calorie foods), or positive valence (paired with low-calorie foods). We hypothesized that this bottom-up sensory-level conditioning approach would effectively activate feelings of disgust while viewing high-calorie food images and result in reduced preference. If successful, this approach could reduce automatic preferences for high-calorie foods, thereby promoting healthier eating habits.

METHODS

Participant characteristics and recruitment

To assess the effects of IP on food attitudes, 42 healthy adults completed the study (Figure 1) with 22 subjects randomly assigned to the active group, and 20 subjects randomly assigned to the control group. Baseline participant characteristics are described in Table 1. Participants were recruited via a flyer advertisement in Aurora, Colorado, between May 2013 and March 2014. All study activities were completed at the University of Colorado Anschutz Medical Campus, Aurora, Colorado. Groups did not significantly differ in age or BMI. Exclusion criteria included active dieting or self-identification as being a vegetarian or vegan or having other wide-ranging food restrictions. Study participation was initiated 1–2 h postprandially (mean ± SEM: 15.93 kcal/100 g) and low-calorie (mean ± SEM: 73.63 ± 8.65 kcal/100 g) image groups were matched for palatability as described previously (17). The desire to eat was defined as “the degree to which a person wants to eat that food at that moment” and rated by using a VAS from 0 to 100 (anchored by “not at all” on the left and “very much” on the right). Of 45 high-calorie images included in the pre-intervention food-ratings task, 30 images were specifically included in the subsequent IP task (primed images; phase 2), and the remaining 15 images were not included in the IP task (novel images). Similarly, 30 of 45 low-calorie–food images in the food-ratings task were specifically included in the IP task (primed images; phase 2), and 15 images were not included in the IP task (novel images). Novel images were not primed at any point during the experiment. These images were included to investigate if IP task effects were specific to the images used in the priming task (primed images) or if effects generalized to images that were not specifically primed (novel images). The order of food-image presentation was randomized for each participant during the food-ratings task by using the ImageRate program.

Phase 1: pre-intervention food ratings

A total of 90 food images (45 high-calorie and 45 low-calorie images) were assessed for the desire to eat by using a visual analog scale (VAS) with the ImageRate program (17). High-calorie (mean ± SEM: 303.65 ± 15.93 kcal/100 g) and low-calorie (mean ± SEM: 73.63 ± 8.65 kcal/100 g) image groups were matched for palatability as described previously (17). The desire to eat was defined as “the degree to which a person wants to eat that food at that moment” and rated by using a VAS from 0 to 100 (anchored by “not at all” on the left and “very much” on the right). Of 45 high-calorie images included in the pre-intervention food-ratings task, 30 images were specifically included in the subsequent IP task (primed images; phase 2), and the remaining 15 images were not included in the IP task (novel images). Similarly, 30 of 45 low-calorie–food images in the food-ratings task were specifically included in the IP task (primed images; phase 2), and 15 images were not included in the IP task (novel images). Novel images were not primed at any point during the experiment. These images were included to investigate if IP task effects were specific to the images used in the priming task (primed images) or if effects generalized to images that were not specifically primed (novel images). The order of food-image presentation was randomized for each participant during the food-ratings task by using the ImageRate program.

Phase 2: IP task

During the IP task, participants also viewed food images that consisted of 80 high-calorie images and 80 low-calorie images. Of these images, as previously noted, 30 high-calorie images and 30 low-calorie images were primed images included in the phase 1 food-ratings task. The ~20-ms duration of priming image presentation was chosen to be below conscious perception. High-speed video photography (Casio High Speed Exilim EX-ZR20

Abbreviations used: IAT, implicit association test; IP, implicit priming; VAS, visual analog scale.
digital camera; Casio) was used to confirm priming image presentation timing. During the IP task, which was presented with E-Prime 2.0 software (Psychology Software Tools), all food images were preceded by a 500-ms fixation cross followed by ~20 ms of IP image presentation (LCD-monitor refresh rate of 75 Hz; image presentation duration was nominally 13.3 ms plus a rise and fall time of 5–7 ms on the LCD monitor, which led to a visible duration between 18 and 20 ms as assessed by using the high-speed camera) (Figure 2). Subjects were informed of the presence of the priming images, but were not made aware of the image content or group assignment. In the active group, high-calorie food images were primed with negatively valenced images, and low-calorie food images were primed with positively valenced images. All priming images were selected from the International Affective Picture System database (18). Although the images shown in Figure 2 are an approximation of images used in the task, the Center for the Study of Emotion and Attention at the University of Florida, from which the International Affective Picture System images were obtained, requested that the images not be made publicly available, and thus, visual examples have not been included in this manuscript. However, interested researchers can request the images from the Center for Study of Emotion and Attention (http://csea.phhp.ufl.edu/media.html). Negative primes were chosen to elicit disgust (e.g., contamination and mutilation) with an emotion rating between 1.5 and 3.99 (excluding the most negative 5%). Some examples of negative prime images used were of a cockroach on a slice of pizza, vomit in an unclean lavatory, a burn wound on skin, and a broken bone. Positive primes were chosen as those rated >6, examples of which included images of a group of kittens, a smiling baby, a butterfly on a flower, and a couple smiling happily. In the control group, priming images were not presented before food images. However, to ensure blinding to group assignment, an image of 3 fixation crosses was presented for the same duration (~20 ms) before each food image in the control condition. In both groups, participants received a brief flash before food images, but were not able to discern the image content. A debriefing questionnaire after the IP task confirmed that participants were unable to identify the

![Study flow diagram. IP, implicit priming.](image)

**TABLE 1**
Participant baseline characteristics for active and control groups

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Active (n = 22)</th>
<th>Control (n = 20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>30.7 ± 1.3[^2]</td>
<td>35.1 ± 2.7</td>
</tr>
<tr>
<td>BMI, kg/m[^2]</td>
<td>22.5 ± 0.6</td>
<td>24.2 ± 0.9</td>
</tr>
<tr>
<td>Sex, M, %</td>
<td>36.4</td>
<td>40.0</td>
</tr>
<tr>
<td>Race-ethnicity, %</td>
<td></td>
<td></td>
</tr>
<tr>
<td>African American/Black</td>
<td>0.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Asian</td>
<td>9.1</td>
<td>5.0</td>
</tr>
<tr>
<td>Caucasian</td>
<td>77.3</td>
<td>70.0</td>
</tr>
<tr>
<td>Hispanic</td>
<td>13.6</td>
<td>20.0</td>
</tr>
<tr>
<td>Food ratings across category[^1]</td>
<td>54.8 ± 2.3</td>
<td>50.2 ± 3.3</td>
</tr>
<tr>
<td>High-calorie food ratings[^1,3]</td>
<td>51.8 ± 2.8</td>
<td>48.6 ± 4.9</td>
</tr>
<tr>
<td>Low-calorie food ratings[^1,3]</td>
<td>57.8 ± 2.9</td>
<td>51.8 ± 2.4</td>
</tr>
</tbody>
</table>

[^1]: No significant group differences observed, \( P > 0.05 \) (independent samples \( t \) tests).

[^2]: Mean ± SEM (all such values).

[^3]: No significant differences observed between baseline high- and low-calorie food ratings, \( P > 0.05 \) (paired samples \( t \) tests).
FIGURE 2  Design of the implicit priming intervention in which a fixation cross on a black screen was shown for 500 ms and followed by an implicit prime presented for ~20 ms. Following the implicit prime image, a food image was presented for 4 s. In the active condition, the implicit prime was either a positively valenced image paired with a subsequent low-calorie food image or a negatively valenced image paired with a subsequent high-calorie food image (as shown in figure). In the control condition, the implicit prime paired with both low- and high-calorie food images was a neutral image of 3 fixation crosses. Images shown are representative of those used in the study, although not actually from the International Affective Picture System database as per the International Affective Picture System use agreement. Images shown were modified from public domain images that are freely available under Creative Commons deed CC0.

Phase 3: postintervention food ratings

Ratings of the same 90 food images (45 high-calorie and 45 low-calorie images) included in pre-intervention food ratings were repeated immediately after completion of the IP task. Food images in the postintervention rating task were presented in a different random order than were those in the pre-intervention rating task to reduce recall effects. As before, all food images were rated on a desire to eat by using a VAS (0–100) with the ImageRate program.

Phase 4: repeat assessment

Participants in the active group were asked to return 3–5 d later to repeat food-image ratings in the ImageRate program to assess lasting effects. All but 2 participants returned to complete this measure (n = 20; Figure 1). Participants arrived 1–2 h postprandially to match hunger levels of the first study day (mean ± SEM hours since eating: 1.49 ± 0.14; no significant difference from the time since eating on study day 1). As with phases 1 and 3, participants rated the same 90 food images (45 high-calorie and 45 low-calorie images) for the desire to eat by using a VAS (0–100) with the ImageRate program.

Data analyses

Effects of IP were assessed by using a repeated-measures ANOVA with SPSS v.22 software (IBM Corp.). Before analyses, data normality was confirmed by using the Shapiro-Wilk test. Change scores (postintervention minus pre-intervention) were used for all analyses with calorie (high compared with low) as a within-subjects factor and group (active compared with control) as a between-subjects factor (α level of 0.05). Post hoc t tests were used to assess differences in high-calorie and low-calorie change between active and control groups. In addition to considering high-calorie and low-calorie image groups as a whole, effects specific to primed images and novel images were assessed separately to determine the generalizability of IP effects. This effect generalizability was evaluated by using a repeated-measures ANOVA on change scores (postintervention minus pre-intervention) with calorie (high compared with low) and type (primed compared with novel) as within-subjects factors and group (active compared with control) as a between-subjects factor (α level of 0.05). To investigate lasting effects in the active group, a repeated-measures ANOVA was used to assess differences in changes from baseline with calorie (high compared with low) and time of measurement (acute effect immediately postintervention compared with repeat assessment 3–5 d later) as within-subjects factors (α level of 0.05).

RESULTS

There were no significant baseline group differences (active compared with control) in overall food ratings (across high-calorie foods and low-calorie foods), high-calorie food ratings, or low-calorie food ratings (P > 0.05). In addition, ratings of high-calorie foods did not significantly differ from ratings of low-calorie foods at baseline (Table 1).

A main effect of calorie on change score (postintervention minus pre-intervention) was observed, with a greater change associated with high-calorie ratings than with low-calorie ratings across group ($F_{1,40} = 15.99, P < 0.001$) (Figure 3). Furthermore, a significant group (active compared with control) × calorie (high compared with low) interaction was observed, $F_{1,40} = 5.42, P = 0.025$. Post hoc tests showed that active
IP (mean ± SEM change: $-6.82 ± 1.30$; 95% CI: $-9.45, -4.19$) was associated with a significantly greater decline in high-calorie food ratings than for control IP (mean ± SEM change: $-2.71 ± 1.37$; 95% CI: $-5.47, 0.04$) ($t_{[40]} = 2.18, P = 0.036$). The change in low-calorie food ratings did not significantly differ between the active group (mean ± SEM change: $-0.75 ± 0.92$; 95% CI: $-1.12, 2.62$) and the control group (mean ± SEM change: $-0.71 ± 0.97$; 95% CI: $-2.67, 1.24$). Within the active group, the change in high-calorie ratings was significantly greater than the change in low-calorie ratings ($t_{[21]} = 3.87, P = 0.001$), but there were no significant differences between high-calorie and low-calorie changes in the control group.

The data suggest that the active IP response generalized to other high-calorie foods not specifically included in the priming paradigm. In the food-rating task, additional subsets of high-calorie and low-calorie images were included that were not featured in the priming task. Postintervention changes in response to these novel images were similar to those observed for primed images (images included in both the rating task and the priming task). When parsing images into primed and novel, a main effect of calorie (high compared with low) was still observed ($F_{[1,40]} = 12.13, P = 0.001$), as was a significant calorie × group (active compared with control) interaction ($F_{[1,40]} = 6.25, P = 0.017$) (Figure 4). There was no significant effect of type (primed compared with novel) or any significant interactions between type and calories or between type and group. Within the active group, post hoc tests showed significant differences between primed high-calorie changes in ratings (mean ± SEM change: $-6.92 ± 1.41$; 95% CI: $-9.77, -4.08$) and low-calorie changes in ratings (mean ± SEM change: $0.80 ± 1.12$; 95% CI: $-1.46, 3.06$) ($t_{[21]} = 4.07, P = 0.001$). There was also a similar difference between novel high-calorie rating changes (mean ± SEM change: $-6.59 ± 1.56$; 95% CI: $-9.74, -3.44$) and low-calorie rating changes (mean ± SEM change: $0.65 ± 1.09$; 95% CI: $-1.56, 2.86$) ($t_{[40]} = 2.92, P = 0.008$). There were no significant differences observed between changes in primed compared with novel ratings for either high-calorie or low-calorie foods. Within the control group, there were no differences between primed high-calorie rating changes (mean ± SEM change: $-3.43 ± 1.48$; 95% CI: $-6.42, -0.45$) and low-calorie rating changes (mean ± SEM change: $-0.97 ± 1.17$; 95% CI: $-3.35, 1.40$) or between novel high-calorie rating changes (mean ± SEM change: $-2.34 ± 1.64$; 95% CI: $-5.65, 0.96$) and low-calorie rating changes (mean ± SEM change: $-2.35 ± 1.15$; 95% CI: $-4.67, -0.02$).

In the active group, 20 participants repeated the food-rating task 3–5 d after the IP intervention to assess lasting intervention effects. A significant main effect of calorie was observed ($F_{[1,19]} = 16.32, P = 0.001$). Post hoc tests found a significant difference between high- and low-calorie changes from baseline both immediately after the intervention (acute effect; $t_{[21]} = 3.88, P = 0.001$) and 3–5 d postintervention (3–5 d retest; $t_{[19]} = 3.03, P = 0.007$) (Figure 5). Effects of measurement timing (acute compared with retest) on the change in ratings were not significant ($F_{[1,19]} = 3.57, P = 0.074$), and there was no significant interaction between calories (high compared with low) and measurement timing ($F_{[1,19]} = 1.57, P = 0.225$).

**DISCUSSION**

An IP approach to reduce the preference for high-calorie foods resulted in reduced ratings of high-calorie food images. The same reduction was not observed in the control group, which suggested that the result was specifically related to the IP intervention and not simply to effects of habituation or focusing on the health value of foods during the intervention. As anticipated, focusing on whether each food was healthy or not healthy during the priming task, similar to top-down cognitive approaches for diet improvement, did not significantly affect high-calorie ratings in and of itself. However, the bottom-up sensory conditioning approach of the IP intervention, which focused on implicitly pairing disgust feelings with high-calorie food images, resulted in a reduction of these ratings. This outcome suggests that pairing feelings of disgust with foods that are not compatible with a healthy diet could reduce the likelihood of choosing these foods.
Another potential reason could be that learned food aversions may be formed more rapidly than are learned food preferences (20). Another potential study limitation was that the control group did not complete the food-ratings task again. To assess lasting effects of the intervention, subjects in the active group returned to complete the food-ratings task again 3–5 d after the intervention (3–5 Day Retest; n = 20). A significant main effect of calorie was observed (P = 0.001), but effects of measurement timing (acute compared with retest) were not significant (P = 0.074), and there was no significant interaction between calories (high compared with low) and measurement timing (P = 0.225). *Significant difference between high-calorie acute change compared with low-calorie acute change, P = 0.001 (post hoc paired samples t test); **significant difference between high-calorie retest change compared with low-calorie retest change, **P = 0.007 (post hoc paired samples t test).

Another key variable for intervention effectiveness would be that the stimuli paired with low-calorie foods were not as salient as those paired with high-calorie foods. The high-calorie foods were paired with images specifically chosen to elicit feelings of disgust. Disgust is a salient emotion that is well known to be effective in conditioning food aversion (20–22). Compared with other methods of aversive conditioning, disgust-elicited food aversion was shown to be stronger and longer lasting (3, 22). The identification of images that would elicit a similarly strong positive effect is more challenging. Although the images paired with low-calorie foods in this study were chosen as those rated as having positive affective associations (18), such as fluffy bunnies and happy babies, it is likely that they were simply not salient enough to alter food preferences. For optimal intervention success, it would be ideal to simultaneously increase the preference for low-calorie foods in addition to reducing the preference for high-calorie foods. Because of this, future studies could investigate the use of positive images that may be more salient.

It could be debated whether implicit or explicit priming is a more effective evaluative conditioning approach. Previous studies assessed effects of explicitly priming foods by pairing them with various body or health images (12–14), or with words and pictures of negative or positive valence (11), but results have been mixed. Behavioral effects of priming could be affected by subject knowledge of the desired response (e.g., choosing fruit) on the basis of the pairings presented in the intervention (23). An individual’s awareness of the pairing contingency may also affect learning effects (15). Studies have shown that subjects with explicit memories of being primed associated less positive feelings with the primed item than did those who were unaware of the priming (24). For example, when testing product-placement effectiveness during a television show (an attempt to increase positive affect associated with the product), Law and Braun (7) observed that items were less-frequently chosen during a shopping test if participants explicitly remembered the priming event (i.e., remembered seeing the item during the show) than if the item was viewed during the show, but not explicitly recalled. As such, we suggest that an IP approach may produce stronger effects than would explicit priming.

A potential limitation of this study was that measures of unconscious food attitudes, such as those that could be measured by an implicit association test (IAT) (25), were not included. This design choice was made for 2 reasons. First, studies showed that the simple administration of an IAT may affect attitudes through associative learning throughout the task (26). As such, to ensure that observed effects were related to the IP intervention and not to administration of the IAT, we opted not to include this measure. Second, Ayres et al. (27) determined that explicit measures of food palatability, similar to the food ratings used as the primary outcome measure in the current study, are predictive of food choices, and the inclusion of implicit measures of attitudes did not increase the predictive validity beyond that provided by explicit palatability measures. Ayres et al. (27) proposed that the assessment of intervention effects with explicit palatability measures is more desirable than the assessment of change in implicit attitudes because the prediction of food consumption appears to be dominated by explicit palatability measures (27).

Another potential study limitation was that the control group did not complete 3–5-d retest measures because the hypothesized comparison of interest only concerned the active group. However, the inclusion of this aspect in future studies would allow
for a more thorough examination of the persistence of experimental effects.

In conclusion, this study provides initial evidence that an IP approach can be used to alter automatic high-calorie food preferences by associating food images with disgust feelings. Food preferences are largely learned through conditioning, with daily choices influenced by an abundance of contextual food cues so entrenched in daily life that the influence of these cues on individual behavior goes largely unnoticed. The IP approach described in this article could be a successful tactic to combat the onslaught of food cues that promote unhealthy eating by conditioning automatic food preferences in a way that promotes better choices in the absence of focused cognitive effort. As such, the strategy studied in this article may represent a useful and, to our knowledge, novel tool to alter food-intake behaviors and improve health.

The authors’ responsibilities were as follows—KTL and JRT: designed and conducted the research; KTL: analyzed data, wrote the manuscript, and had primary responsibility for the final content of the manuscript; M-AC, DCR, BL, and JRT: critically reviewed the manuscript; and all authors: provided essential research materials and read and approved the final manuscript. None of the authors reported a conflict of interest related to the study.

REFERENCES