Changing the visualization of food to reduce food cue reactivity: An event-related potential study

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ABSTRACT

Visual food cues automatically capture our attention. Moreover, food cue exposure is associated with an increased desire to eat (craving) and food consumption. We attempted to reduce the attentional bias to images depicting a specific food (M&Ms), craving, and consumption through mental imagery in a sample of 98 females (mean age = 23.82 years). The participants either listened to a guided imagery script that described the crushing of M&Ms to reduce the appetitive value of the chocolates, or they envisioned the sorting of M&Ms, or marbles (as control conditions). Afterward, participants were presented with images of M&Ms (not crushed) and marbles while their electroencephalogram, craving ratings, and M&M consumption were measured. The visualization of crushing M&Ms was associated with increased early (P200) and late positivity (P300, early LPP) to M&M pictures, which indicate automatic (P200/P300) and deliberate attention (LPP). M&M sorting increased craving but did not influence M&M consumption. Our findings show that imaginary M&M crushing cannot reduce attention to M&M images and even has the opposite of the intended effect.

1. Introduction

Visual food cues (e.g., food advertisements, cooking shows on TV, food displays in supermarkets) automatically capture attention and evoke the desire to eat (Boswell & Kober, 2016). In line with this observation, eye-tracking studies have shown that individuals tend to direct more initial attention (first fixations) to food vs. non-food and look longer at images depicting food compared to non-edible items (Pothoff, Jurinec, & Schienle, 2019).

Studies with electroencephalography (EEG) have demonstrated that food images (compared with non-food images) elicit enhanced amplitudes of early as well as late event-related potentials (ERPs), such as the P200, P300, and the late positive potential (LPP) (Blechert, Gotsche, Herbert, & Wilhelm, 2014; Nijs, Muris, Euser, & Franken, 2010; Schwan, Giraldo, Spiegl, & Schienle, 2017). The mentioned ERP components reflect the amount of attention captured by a (food) stimulus (Olofsson, Nordin, Sequeira, & Polich, 2008). The P200, a positive deflection in the EEG that can be detected around 200 ms post-stimulus onset, is an indicator of early attention and stimulus-context discrimination (Freunberger, Klimesch, Doppelmayr, & Höller, 2007). The P300 (≈ 300 ms) and the LPP (400–600 ms) reflect the motivational relevance of a stimulus and its emotional content (Olofsson et al., 2008). The P300 has been linked with automatic attention allocation, whereas the subsequent LPP reflects more sustained and deliberate attentional processes (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Hajcak, MacNamara, & Olvet, 2010; Schupp et al., 2000). The LPP can be differentiated into an early (400–600 ms) and a late component (> 600 ms). Whereas the early component accompanies affective encoding and reflects the arousal induced by a stimulus (similar to the P300), the late component is implicated in prolonged effortful processing (Cuthbert et al., 2000; Foti, Hajcak, & Dien, 2009; Schupp et al., 2000, 2004).

The prioritized processing of food cues (evident in increased amplitudes of the P300 and the LPP) is particularly noticeable for high-calorie relative to low-calorie foods (Meule, Kübler, & Blechert, 2013) and in states of food deprivation (Nijs et al., 2010; Stockburger, Schmälzle, Flaisch, Bublatzky, & Schupp, 2009). Moreover, P300/LPP amplitudes to food images have been positively correlated with self-reports of craving and food intake (Biehl, Keil, Naumann, & Svaldi, 2020; Nijs et al., 2010; Svaldi et al., 2015).

Craving (the desire to eat) and attentional biases towards food cues are a part of a broader appetitive response pattern to stimuli that signal the availability of food – food cue reactivity (FCR), which is one of the

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most important predictors of overeating and weight gain (Boswell & Koerber, 2016). FCR is a response pattern experienced by everyone; exposure to food cues is related to an increase in FCR in both normal weight and overweight participants (Ferriday & Brunstrom, 2011). However, studies show that FCR is more pronounced in unsuccessful dieters, obese people, and also certain clinical groups, such as patients with binge eating disorders (Tetley, Brunstrom, & Griffiths, 2009; van den Akker, Stewert, Antoniou, Palmberg, & Jansen, 2014). For the western world, where we are constantly surrounded by food cues, finding easy-to-apply strategies for FCR regulation is of the utmost importance.

Since craving is an affective state (Giuliani & Berkman, 2015) it can be changed through emotion regulation strategies. Several EEG studies have attempted to reduce the attentional bias to food cues and the associated propensity to eat by using cognitive self-control strategies such as reappraisal – some with more success (Svaldi et al., 2015) than others (Sarlo, Ubel, Leutgeb, & Schiene, 2013). Besides showing mixed results in the literature, reappraisal involves explicit cognitive processes that are effortful and challenging – even more so for individuals with a tendency to overeat (Ouwehand et al., 2010). However, studies show that FCR is more pronounced in unsuccessful dieters, obese people, and also certain clinical groups, such as patients with binge eating disorders (Tetley, Brunstrom, & Griffiths, 2009; van den Akker, Stewert, Antoniou, Palmberg, & Jansen, 2014). For the western world, where we are constantly surrounded by food cues, finding easy-to-apply strategies for FCR regulation is of the utmost importance.

Alternative implicit regulation strategies for reducing food cue reactivity could therefore be beneficial. Implicit regulation strategies are defined as a change in one’s emotions or behavior without engaging in deliberate control (Mocaiber et al., 2010). Previously, a study by Mor-ewedge, Huh, and Vogserau (2010) used an implicit imagery-based technique. The participants envisioned the repeated consumption of M&Ms (eating a total of 30 M&Ms; one at a time), which reduced the actual consumption of the chocolates. The authors argued that this was due to habituation. The repeated exposure to a specific stimulus decreases the physiological and behavioral responses to it (Epstein, Temple, Roemmich, & Bouton, 2009). Because perception and mental imagery overlap in the activation of neural structures (Kosslyn, Ganis, & Thompson, 2001), the repeated mental exposure to a stimulus could lead to habituation, causing decreased responses to the food cue. However, an investigation by Zorjan, Schwab, and Schiene (2020) was not able to replicate the finding by Morewedge et al. (2010). The results of this EEG study showed that imaginary eating did not change responses (reactivity) to M&M images. More specifically, it did neither reduce self-reported craving for M&Ms, the visual attention devoted to M&M images (as indexed by late ERPs), nor M&M consumption.

Another possibility of changing responses to a food cue refers to changing its visual properties. In many cases, the first sensory contact with a food item is through visual processing, as reflected in the popular saying “you eat with your eyes first”. The sight of food can facilitate the desire to eat a specific food (Hill, Magson, & Blundell, 1984; Marcelino, Adam, Couronne, Köster, & Siefriedmann, 2001) and activates neural pathways associated with reward (Beaver et al., 2006).

In the present study, we examined whether the visualization of changing the appearance of food could provide an effective strategy for reducing food cue reactivity. Participants listened to a guided imagery script that described the repeated crushing of M&M chocolates with a hammer. This strategy aimed to reduce the appetizing appearance of food by turning food into non-food or less desired food. Several studies have shown that the perceived palatability of a given food determines what and how much individuals consume (Delwiche, 2012) and that food presented nicely enhances food liking (Zellner, Los, Zearfoss, & Remolina, 2014). Based on these studies, repeatedly imagining a food being crushed or destroyed could be expected to result in reduced perceived palatability and liking, leading to reduced consumption (Delwiche, 2012). Previous studies have demonstrated that less appealing visual properties can reduce the appetitive value of a specific food. For example, Wu, Sample, and Haws (2021) presented participants with a cake presented in either a “messy” (i.e., smashed) or “neat” (i.e., nicely cut) manner. They concluded that the visual degradation of a food’s presentation decreases tastiness perception (Wu et al., 2021). Strategies that reduce the perceived palatability of a certain food cue, therefore, have the potential of changing craving, consumption, and also neurophysiological processing of visual food cues – a hypothesis yet to be tested.

In the present study, participants were randomly assigned to one of three guided imagery conditions while their EEG was recorded. In the Crashing condition, participants were asked to crush 30 colorful M&M chocolates one at a time. This imagery condition was compared with two control conditions to determine that the effect is not due to exposure to M&Ms (i.e., Sorting of 30 M&Ms according to color) and that the effect is food-specific (i.e., Sorting of 30 marbles according to color). The imagery task was followed by a passive viewing task with pictures of M&Ms and marbles (used as control stimuli due to the physical similarities to M&Ms).

We chose an imagery-based strategy because previous research has shown that visual imagery recruits similar neural structures as actual visual perception (Sues et al., 2015). Additionally, imagery strategies can be easily applied in practical (clinical) contexts. We decided against including aversive stimuli in the imagery script (i.e., imagine a moldy piece of food) to limit the unpleasantness of the strategy. Studies in the past have paired aversive stimuli (e.g., bitter taste from wormwood tea) with food picture viewing (Schwab et al., 2017). This strategy reduced food cue reactivity but was perceived as highly aversive by the participants. Thus, a clinical application of this approach seems questionable.

Based on the mentioned studies, we expected that the imaginary crushing of M&Ms would reduce reported craving, consumption, and ERP positivity (P200/P300/LPP amplitudes) to the M&M images relative to the other two conditions (M&M sorting and Marble sorting).

2. Method

2.1. Participants

A total of 98 healthy women with a mean age of 23.82 years (SD = 4.06) and a self-reported body mass index (BMI) of M = 22.64 (SD = 3.40) were recruited via campus announcements. All women had a university (39.8 %) or high school diploma (60.2 %). Exclusion criteria (assessed via self-report) were neurological or current mental disorders (e.g., eating disorders).

Prior to the experiment, participants were randomly assigned to one of three imagery groups: M&M Sorting (n = 32), M&M Crushing (n = 34) and Marble Sorting (n = 32). At the beginning of the experiment all participants rated their hunger level on a scale from 1 (not at all) to 9 (very much). The mean hunger level was M = 3.93 (SD = 2.29). Hunger levels did not differ between the groups (F(2, 95) = 1.74, p = .18). Furthermore, participants in the three groups were comparable in age (F (2, 95) = .56, p = .57), level of education (X²(2) = 3.86, p = .15), BMI (F (2, 94) = .47, p = .63), and reported liking of M&M chocolates (F(2, 95) = 1.75, p = .18). Additionally, groups were comparable in their propensity for eating disorders (assessed by the Eating Disorder Examination Questionnaire - EDE-Q; Hilbert, Tuschen-Caffier, Karwautz, Niederhofer, & Mansch, 2007); F(2, 94) = .46, p = .63.. The means for the total scores were as follows – M&M Sorting: M = 1.22, SD = 1.03; M&M Crushing: M = 1.00, SD = .72; Marble Sorting: M = 1.10, SD = .98).

2.2. Experimental stimuli and design

2.2.1. Guided imagery scripts

Participants were seated alone in the lab while listening to a 10-minute audio recording presented via loudspeakers. The recording either described the imaginary crushing of M&Ms with a hammer, imaginary sorting of M&Ms by color, or imaginary sorting of marbles by color. In
each imagery instruction, participants were asked to close their eyes and visualize a table with a bowl that was filled with either M&Ms or marbles. In the M&M Crushing condition, participants were repeatedly asked to imagine reaching into the bowl, take an M&M of a certain color and then crush it with a hammer. In the M&M Sorting condition, participants were asked to imagine reaching into the bowl, take an M&M of a certain color, and then place it in another small bowl according to the color. In the Marble Sorting condition, participants were asked to imagine reaching into the bowl, taking a marble of a certain color, and placing it into another small bowl according to the color. The three scripts described different actions (i.e., crushing or sorting M&Ms or sorting marbles) but were comparable in all other aspects (e.g., introduction/ending of the imagery instruction, word count, motor components of the imagined hand movements; repetitions (30) of each action). Excerpts from the guided imagery scripts are available in the Supplementary Materials.

2.2.2. Images
Participants viewed a total of 60 different pictures from two categories: M&Ms (30 pictures) and marbles (30 pictures). The two image categories (M&Ms, marbles) were matched according to contrast and complexity. Visual properties of the pictures were analyzed using R (R Core Team, 2020). The pictures were shown in a randomized order for 3000 ms each and were preceded by a fixation cross (500–1000 ms). During the picture presentation, participants were asked five times to rate their current M&M craving using a 9-point Likert scale ranging from 1 (low) to 9 (high). The average of the five ratings was used to analyze the effects of the three imagery conditions on craving.

2.3. Procedure
Participants first provided written informed consent and completed an online screening questionnaire to check for inclusion and exclusion criteria. Those women who were eligible to participate were invited to the EEG laboratory. The participants were instructed to refrain from eating for at least three hours before attending the laboratory session. After arriving to the lab, EEG electrodes were placed. The participants were instructed and completed a test trial. Subsequently, they listened to the audible recording (~ 10 min), which was followed by the picture presentation (~ 10 min). At the end of the experiment, participants were presented with a filler questionnaire - the German version of the Difficulties in Emotion Regulation Scale (DERS; Kaufman et al., 2016) and a questionnaire on the Marble Sorting condition, participants were asked five times to rate their current M&M craving using a 9-point Likert scale ranging from 1 (low) to 9 (high). The average of the five ratings was used to analyze the effects of the three imagery conditions on craving.

2.4. Electrophysiological recording and data analyses
Data were recorded with an actiCHamp system (actiCHamp, Brain Products GmbH, Gilching, Germany) using 63 active actiCAP snap electrodes (according to the 10–10 system at Fp1, Fz, F3, F7, F9, FC5, FC1, C3, T7, TP9, CP5, CP1, Pz, P3, P7, O1, Oz, O2, P4, P8, TP10, CP6, CP2, Cz, C4, T8, FT10, FC6, FC2, F4, F8, Fp2, Af7, Af3, Afz, F1, F5, FT7, FC3, C1, C5, TP7, CP3, P1, P5, P7, PO3, POz, PO4, PO8, P6, P2, CP2, CP4, TP8, C6, C2, FC4, FT8, F6, AF8, AF4, F2) with BrainVision Recorder (version 1.21). The reference electrode was placed on position FCz, the ground electrode on position FPz. An electrolyte gel was applied to each electrode to keep electrode impedances below 20 kΩ. EEG was recorded with a sampling rate of 2500 Hz and a passband of 0.016–1000 Hz. For raw data analysis, BrainVision Analyzer (version 2.0.4) was used. The sampling rate was changed to 250 Hz. The data were referenced to linked mastoid electrodes (i.e., TP9, TP10). Artifacts due to eye movements were corrected via the implemented ICA ocular correction software. Further artifact episodes were excluded after visual inspection. Six participants were excluded from the analysis due to artifacts (i.e., <70 % of artifact-free segments). Therefore, the ERP analyses were conducted with a sample of 92 participants (M&M Crushing group: n = 32, M&M Sorting group: n = 29; Marble Sorting group: n = 31). The excluded participants did not differ from the rest of the sample in mean age, hunger level, BMI, reported liking of M&Ms, propensity for eating disorders, or level of education (all ps > .38). The mean number of artifact-free trials (M = 92%, SD = 6.8 %) did not differ between groups (F(2, 89) = 2.14, p = .12). Data were segmented in 3200 ms intervals (200 ms pre-stimulus onset, 3000 ms post-stimulus onset) and corrected to the 200 ms pre-stimulus baseline. A 30 Hz low pass filter was applied. Data were averaged for all groups and conditions separately.

Based on previous research (Foti et al., 2009; Meule et al., 2013; Schwab, Zorjan, & Schienle, 2021) and visual inspection of grand average waveforms (see Fig. 3), we extracted ERPs for the P200 (time window 180–250 ms after picture onset), P300 (time window 300–400 ms after picture onset), early LPP (time window 400–600 ms after picture onset) and late LPP time window (600–3000 ms after picture onset). Mean amplitudes were aggregated across a centro-parietal cluster (Cpz, CP1, CP3, CP5, CP2, CP4, CP6, Pz, P1, P3, P5, P7, P2, P4, P6, P8), which is in line with literature showing that the P300 and LPP are maximal at centro-parietal sites (Foti & Hajcak, 2008; Hajcak, Dunning, & Foti, 2007; Keil et al., 2002). Additionally, mean amplitudes were aggregated across a frontal cluster (Fx, F1, F3, F5, F2, F4, F6, Afz, Af3, Af7, F4, AF8; exploratory approach). Analyses for the late LPP time window and the frontal cluster revealed no statistically significant interaction effects between Group and Picture Category and are therefore not reported.

2.4.1. Statistical analyses
One-way ANOVAs were conducted to compare the craving ratings (calculated as the mean of five craving ratings during picture presentation) and consumption of M&Ms (in grams) between the groups. To examine imagery effects on the ERPs, we conducted repeated measures ANOVAs with the within-subjects factor Picture Category (two levels: M&Ms, marbles) and the between-subjects factor Group (three levels: M&M Sorting, M&M Crushing, Marble Sorting), for different time windows (P200, P300, early/late LPP). Significant effects were followed-up with multiple comparisons, using the Holm-Bonferroni correction to adjust for multiple testing. Corrected p values are reported.

3. Results
3.1. Behavioral and self-report data
3.1.1. Self-reported craving
The groups differed significantly in their reported craving for the M&M images (F(2, 95) = 7.28, p < .01; see Fig. 1). Follow-up pairwise comparisons showed that the M&M Sorting group reported more intense craving (M = 7.21, SD = 1.32) compared to the M&M Crushing group (M = 5.65, SD = 2.16; p = .004) and the Marble Sorting group (M = 5.56, SD = 2.21; p = .003). The M&M Crushing group and the Marble Sorting group did not differ from each other (p = .84).

3.1.2. Consumption
The participants ate an average of 14.35 g (SD = 18.72) M&Ms after the experiment. The groups did not differ from each other, F(2, 94) = .87, p = .42 (M&M Sorting: M = 17.72, SD = 23.22; M&M Crushing: M = 13.73, SD = 12.50; Marble Sorting: M = 11.63, SD = 19.09). Out of the 97 participants, 29 did not consume any M&Ms. The proportion of participants who did not consume any M&Ms was the lowest in the M&M Crushing group (n = 7; 24.10 %), followed by the M&M Sorting group (n = 10; 24.50 %) and the Marble Sorting group (n = 12; 41.40 %). However, group differences were not statistically significant, χ²(2) = 2.10, p = .35.
3.2.1. P200 (180–250 ms)

The main effect of Picture Category was statistically significant, F(1, 89) = 6.06, p = .016, η² = .06. The mean amplitudes were higher for M&M pictures (M = 1.25, SE = .30) than for marble pictures (M = 0.85, SE = .31). The main effect of Group was not significant, F(2, 89) = 2.39, p = .10. Importantly, the interaction between Picture Category and Group was statistically significant, F(2, 89) = 4.51, p = .014, η² = .09. Follow-up pairwise comparisons showed that the three groups did not differ in the amplitudes for the marble pictures (all ps > .61). They did, however, differ in the amplitudes in response to the M&M pictures (see Figs. 2 and 3). More specifically, the Crushing group showed higher amplitudes for M&M pictures (M = 2.48, SE = .51) compared to the M&M Sorting group (M = .53, SE = .54, p = .03) and the Marble Sorting group (M = .75, SE = .52, p = .04).

Subsequently, we calculated a difference score between the two picture categories (i.e., M&Ms – marbles) and compared the groups. The results showed that in the M&M Crushing group the difference score was significantly higher (M_difference = 1.10, SE = .33) compared to the Marble Sorting group (M_difference = .01, SE = .27, p = .02) and the M&M Sorting group (M_difference = .11, SE = .23, p = .03).

3.2.2. P300 (300–400 ms)

The main effect of Picture Category was significant, F(1, 89) = 23.83, p < .01, η² = .21, indicating that the mean amplitude for the M&M pictures was higher (M = 1.94, SE = .30) compared to the marble pictures (M = .99, SE = .31). The main effect of Group was not statistically significant, F(2, 89) = 2.21, p = .12. There was a significant interaction between Picture Category and Group, F(2, 89) = 3.76, p = .027, η² = .08. Post-hoc pairwise comparisons indicated that the groups did not differ in amplitudes in response to the marble pictures (all ps > .55; see Figs. 2 and 3). In response to the M&M pictures, the Crushing group showed significantly higher amplitudes (M = 3.05, SE = .51) relative to the Marble Sorting group (M = 1.09, SE = .52, p = .02). Other comparisons (i.e., the Crushing vs. M&M Sorting and M&M vs. Marble Sorting) were not statistically significant (all ps > .13).

We then calculated the difference score (M&M – marble) for each of the groups. The comparison showed that the score was significantly higher in the M&M Crushing condition (M_difference = 1.48, SE = .37) compared to the Marble Sorting condition (M_difference = .23, SE = .33, p = .03), but not compared to the M&M Sorting condition (M_difference = 1.14, SE = .29, p = .48). The difference between M&M Sorting and Marble Sorting group was not statistically significant (p = .12).

3.2.3. Early LPP (400–600 ms)

The significant main effect of Picture Category (F(1, 89) = 81.34, p < .01, η² = .48) indicated that the amplitudes were higher for the M&M pictures (M = 2.08, SE = .26) compared to the marble pictures (M = .39, SE = .29). The main effect of group was not significant, F(2, 89) = 1.32, p = .27. The interaction between Picture Category and Group was statistically significant, F(2, 89) = 4.73, p = .01, η² = .10. Follow-up pairwise comparisons indicated that the groups did not differ in mean amplitudes in response to the marble pictures (all ps > .99). They did, however, differ in mean amplitudes in response to the M&M pictures (see Figs. 2 and 3). More specifically, the M&M Crushing group showed significantly higher amplitudes for the M&M pictures (M = 2.83, SE = .45) relative to the Marble Sorting group (M = 1.22, SE = .45, p = .04), but not to the M&M Sorting group (M = 2.18, SE = .47, p = .29). The M&M Sorting and the Marble Sorting group did not differ in mean amplitudes for the M&M pictures (p = .32).

Again, we computed the difference score (M&M – marble) and compared the groups. The comparisons of the difference score showed that the Marble Sorting group (M_difference = .88, SE = .33) had a statistically lower difference in the amplitudes between M&M and marble images compared to the M&M Crushing group (M_difference = 2.07, SE = .35, p = .03) and the M&M Sorting group (M_difference = 2.12, SE = .28, p = .02). The groups M&M Crushing and M&M Sorting did not differ from each other (p > .93).

3.3. Exploratory correlation analyses

The centro-parietal P200, P300 and LPP amplitudes did not correlate with craving and M&M consumption. The reported M&M craving correlated positively with M&M consumption (r = .44, p < .01). These correlations were similar in the three groups (M&M Crushing: r = .41, p = .02; M&M Sorting: r = .39, p = .03; Marble Sorting: r = .55, p < .01).

3.4. Exploratory P200 habituation effect analysis

Based on the suggestion of a reviewer, we conducted an exploratory analysis of the possible P200 habituation effect. More specifically, we exported individual M&Ms trials’ amplitudes and then compared the mean amplitude of the first 50% of the segments with the mean amplitude of the last 50% of the segments (due to prior exclusion of segments with many artifacts, the exact number of segments differed for each participant) using a paired-samples t-test. Data were averaged across a centro-parietal cluster. The results showed that in the M&M Crushing group the mean amplitude in response to M&M pictures was significantly higher in the first 50% of segments (M = 1.21, SE = .30), relative to the last 50% of segments (M = .43, SE = .31), t(31) = 2.20, p = .04, indicating a habituation of the P200 component.

4. Discussion

The present study investigated an imagery-based strategy to reduce attention to a specific food cue (M&Ms), reported craving, and consumption. We asked participants to picture the crushing of M&Ms, which aimed at reducing early and late positivity (P200, P300, LPP) when viewing M&M pictures. The chosen approach, however, had the opposite of the intended effect. The visualization of crushing M&Ms increased P200 components compared to the other two imagery groups (sorting of M&Ms, sorting of marbles) and increased late positivity (P300, LPP) compared to marble sorting.

Our results suggest that the imaginary crushing of the M&Ms increased early automatic processing of the M&M images, as indicated by the increased P200 amplitudes. Early and mid-latency ERPs, such as the P200, index early attention orientation during affective picture...
viewing (Olofsson et al., 2008). In the context of food cue processing, food pictures can be viewed as natural ‘target stimuli’ that automatically capture our attention. Indeed, previous studies repeatedly found that the P200 is enhanced when comparing responses to food cues vs. non-food cues (Hume, Howells, Rauch, Kroff, & Lambert, 2015; Nijs et al., 2010). The P200 is also related to context updating and accompanies stimulus pre-classification before P300-related processes (Crowley & Colrain, 2004; Lenartowicz, Escobedo-Quiroz, & Cohen, 2010). The P200 has been suggested to be a part of a cognitive matching system that compares sensory inputs with stored memories (Freunberger et al., 2007). One possible explanation of the results could be that the Crushing group perceived the M&M pictures displaying unbroken chocolates as deviations from their expectations. This group imagined that the M&Ms were crushed with a hammer and smashed into pieces. However, during the subsequent picture viewing, the participants were exposed to whole M&Ms, which might have induced a positive surprise that in turn increased stimulus salience. This interpretation is also corroborated by the additional exploratory analyses of the P200 effect. More specifically, for the M&M Crushing group, the P200 amplitudes were significantly higher in the first 50% of the trials, relative to the last 50% of the trials.

In line with this interpretation, the Crushing group also showed increased long-latency ERPs (>300 ms; P300 and early LPP) that reflect maintained attention (i.e., the difficulty to disengage attention from food stimuli). These findings are in line with emotion research, showing that both ERP components are modulated by the motivational significance of a stimulus (Olofsson et al., 2008; Schupp et al., 2007). Moreover, we also found enhanced early LPP amplitudes in the M&M Sorting group. Therefore, our data suggest that the repeated imagined handling of a specific food (i.e., crushing and sorting) enhances motivated attention for that specific food relative to control (non-food) stimuli.

The P200/P300/early LPP amplitudes did not correlate with self-reported craving or consumption. This is in line with some studies (Meule et al., 2013) but not with others (Biehl et al., 2020; Nijs, Franken, & Muris, 2008; Svaldi et al., 2015). More specifically, a study by Meule et al. (2013) found that craving correlated with the LPP only when participants focused on the long-term effects of food consumption but
not when they focused on the immediate effects. Neural responses to visual food cues seem to depend upon the attentional focus (i.e., whether an individual focuses on the hedonic aspects, or the negative consequences of consumption) rather than food palatability alone (Franssen, Jansen, van den Hurk, Roebroeck, & Roefs, 2020). More specifically, during a passive viewing design an individual can either focus on the delicious taste of the food or – on the other hand – they could focus on the number of calories in the food. In previous studies, this was referred to as the ‘double-sided nature of high-caloric food perception’. The attentional focus (health vs hedonic focus) could differ between participants or possibly also within a participant over time. Lately, researchers have emphasized that the assumption of hedonic value always taking precedence is unwarranted (Roefs, Franssen, & Jansen, 2018). Future studies should, therefore, consider the attentional focus when assessing neural concomitants of food cue processing. Self-reported craving did, however, correlate positively with consumption, which is in line with studies that emphasize craving as one of the most important predictors of food consumption (Bowell & Kober, 2016).

In the present study, the M&M Sorting group reported more cravings than the two other groups (M&M Crushing, Marble Sorting). This finding is in line with the Morewedge et al. (2010) study, which also observed increased craving and M&M consumption when participants imagined the repeated sorting of M&Ms. The authors concluded that the repetitive priming sensitized participants to this specific food. In the present study, we did not find any group differences in consumption, which could be attributed to the fact that participants were not required to eat, which differs from the typical procedures that assess eating in the laboratory (Morewedge et al., 2010; Robinson et al., 2017). Looking at the craving ratings, we could conclude that the strategy was somewhat effective since the reported craving did not increase, as it did when individuals were simply imagining sorting the food. Based on food cue reactivity theory, exposure to food triggers is expected to increase craving and consumption (Nederkoorn & Jansen, 2002). Imagery-based destruction of the food therefore somewhat inhibited the self-reported craving – possibly through reductions in perceived palatability of food. Future studies should examine this finding (and the related mechanisms) in more detail. Nevertheless, based on ERP data, M&M Crushing increase (motivated) attention towards the food cue and overall did not contribute to less craving (relative to Marble Sorting) or consumption.

The results of the current study must be interpreted with the following limitations in mind: participants were young, healthy females; therefore, the results cannot be generalized to other groups. It is possible that the imagery strategy was not effective because of the studied sample. Future studies should test individuals who struggle with cravings in everyday life (e.g., overweight and/or obese individuals or individuals with binge-eating disorder). Another option would be to have healthy participants undergo fasting before testing to increase cravings. As mentioned before, our assessment of food intake differed somewhat from the standard bogus taste test procedure (Robinson et al., 2017), resulting in a subsample of participants who did not eat at all (29.9%). With a bogus taste test procedure, individuals who do not eat are less frequent (Morewedge et al., 2010). We did not specifically assess how easy it was for the participants to follow the imagery instructions and whether they experienced vivid mental images. These assessments should be included in future studies. Additionally, future studies could incorporate a craving assessment immediately before the guided imagery scripts and include other types of food to examine the generalizability of our findings. Other imagery-based interventions for reducing food consumption found that the results were not food-specific (Morewedge et al., 2010), suggesting that the results would also hold for other types of food.

In sum, we found that the imaginary destruction of a food’s appearance did not reduce visual food cue reactivity. Our data thus demonstrate that successful craving reduction is difficult to achieve and that strategies that incorporate repeated exposure to food stimuli as the means for craving/consumption reduction can even have – according to the ERP data – the opposite of the intended effect.

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Declaration of Competing Interest

The authors report no declarations of interest.

Fig. 3. Headmaps for the time window 400–600 ms for the three groups (electrodes included in the centro-parietal cluster marked) (a). Grand averages for the centro-parietal cluster for M&M and marble pictures for the three groups (b).
Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: https://10.1016/j.biopsycho.2021.10.8173.

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