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Image Memory for Hyperpalatable Foods in University Aged Females

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Abstract

Hyperpalatable foods are high in sugar and/or fat and highly processed. These foods increase dopamine in the brain similar to other rewards, such as drugs of abuse, producing pleasure and an enhanced drive to consume them. Undergraduate students ($n = 44$) completed an explicit memory task where they were asked if they recalled various types of food (high sugar, high fat, sugar+fat, fruits, vegetables and breads) and non-food images. Questionnaires evaluating eating patterns were also completed. It was hypothesized that hyperpalatable foods would be recalled better and faster than less-palatable foods or non-food images. The study found that hyperpalatable foods, especially high sugar and high fat foods, were recalled significantly faster than less palatable foods. Results also revealed significantly fewer false alarms for high sugar, high fat, and sugar+fat foods. Thus, hyperpalatable foods appear to create stronger memories, which may contribute to stronger motivation and consumption drives.

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Choosing what to eat is a process that involves many different factors including factors that an individual may be unaware of such as previous associations or memory for foods. Research has shown that when remembering food, humans' memory is stronger for foods that are liked (Laureati et al., 2008). It has been hypothesized that stronger memories for foods that are very well liked may contribute to the irresistibility of some foods and drive compulsive patterns of eating of these foods. The term "hyperpalatable" describes foods that are very pleasurable (Tenk & Felfeli, 2015), such as foods that are processed to include high quantities of sugar, fat, sodium and/or other food additives (Schulte, Avena, Gearhardt, 2015). These foods cause a heightened drive to consume them (Gearhardt, Davis, Kuschner, & Brownell, 2011). Hyperpalatable foods include cakes, ice cream, soda pop, potato chips and fast food, among many others. These foods exert similar brain responses as drugs of abuse, increasing opioid and dopamine activity in the brain's mesocorticolimbic pathways (Gearhardt et al., 2011). This translates into increased motivation for these foods that is triggered by food and food-related cues (Gearhardt et al., 2011). Should memory for hyperpalatable foods and their associated cues be stronger this would result in an even greater activation of these dopamine-driven motivational circuits and an enhanced potential to trigger compulsive consumption (Gearhardt et al., 2011). Understanding which foods may create stronger memories, and subsequently trigger stronger drives to eat will contribute importantly to understanding compulsive eating and potential causes of binge eating disorders and obesity.

Evolutionarily, humans have sought out foods that are high in calories for survival (Gerber, Williams, & Gray, 1999**)**. This predisposition has driven humans to consume high sugar and high fat foods. In today's world, high sugar and/or high fat hyperpalatable foods are increasingly available and this may contribute in part to observations of compulsive eating in recent years. Compulsive eating is described as an individual’s loss of control over eating (Pedram et al., 2013). The loss of control can be explained by the addictive potential of hyperpalatable foods. When an individual eats hyperpalatable food, they experience an increase of dopamine in the reward and motivational circuitry of the brain (Schulte, et al., 2015), similar to drugs of abuse (Gearhardt et al., 2011). Elevations of dopamine mediate both the pleasurable experience of the food itself as well as the motivation to consume the food (Berridge, Robinson, & Aldridge, 2009). The spike in dopamine is not seen in response to all foods, but specifically to highly processed foods high in sugar and/or fat (Gearhardt, Grilo, DiLeone, Brownell, & Potenza, 2011). Processed foods are typically made to increase sugar and fat in order to make the food taste better, while unprocessed foods do not include high levels of both sugar and fat (Schulte et al., 2015). Unprocessed foods such as vegetables, fruits, nuts and breads do not exhibit this increase in dopamine (Schulte et al., 2015). Furthermore, it has been shown that among varying levels of hyperpalatable foods, adolescent rats preferred foods with high sugar and fat over foods high in only sugar or fat (Tenk & Felfeli, 2015). Humans have exhibited similar responses to high sugar+fat foods (Schulte et al., 2015; Drewnowski, & Greenwood, 1983). In particular, Drewnowski and Greenwood (1983) found that high fat foods were rated higher in hedonic pleasure when paired with sugar than alone. Individuals have also indicated that sugar+fat foods are associated with more addictive-like eating than foods with high sugar, high fat or less-palatable foods (Schulte et al., 2015). The increase in dopamine from ingesting hyperpalatable food amplifies motivation for the food and leads an individual to seek out this substance more frequently than non-palatable foods, meaning that hyperpalatable foods create a compulsion to consume them (Gearhardt et al., 2011). Importantly, these increases in dopaminergic activity do not occur without an environmental trigger that begins the motivational cascade and prompts an individual to seek the food.

The strongest trigger, or cue, for food-related dopamine activity is visual cues (Van der Laan, Ridder, Charbonnier, Viergever, & Smeets, 2014). The typical street in North America is inundated with advertising of hyperpalatable foods that are easily accessible. Restaurant chain signs are an example of visual cues for foods that prompt a response in the brain (Van der Laan, Ridder, Viergever, & Smeets, 2011). Van Gucht, Vansteenwegen, Van den Bergh and Beckers (2008) found that seeing chocolate creates a craving for it based on the memories the image produces. This finding demonstrates the importance of memory formation in visual cues prompting motivation to consume food. It was hypothesized that the pleasurable experience of the food is remembered and the memories for these rewards are more easily accessed in the future when exposed to previously predictive visual cues. In addition, it was found that seeing predictive cues elicits approach behaviours (Van Gucht et al., 2008). Thus, predictive cues, such as these visual images, cause anticipatory dopaminergic responses in the brain, which activate the drive to consume the food (Van Gucht et al., 2008). These responses are similar to the behaviour seen in individuals with substance abuse disorders (Tolliver et al., 2010). In recent research, food has been likened to addictive drugs many times, identifying comparable factors such as the potential for cravings, possible withdrawal effects and the compulsion to continue use of the substance despite the possible negative repercussions (Gearhardt et al., 2011). Indeed, hyperpalatable foods share many characteristics with addictive drugs and are processed as a reward by our brains (Gearhardt et al., 2011).

Similar to the drive to consume food, memory for rewards is often triggered visually, and simply seeing the reward, or something related to a reward, will trigger a similar activation in the brain as the reward itself (Wittmann et al., 2005). In a study by Wittmann et al. (2005), it was found that seeing a reward-related image was remembered better than a neutral image, which coincided with an increase in dopaminergic activity in the brain. It has also been demonstrated that if an individual is motivated by an anticipatory reward, he or she will form a stronger memory (Adcock, Thangavel, Whitfield-Gabrieli, Knutson, & Gabrieli, 2006). Knutson and Adcock (2005) described how remembering the emotion and the feeling the image brings to mind is not done with effort, or even with conscious knowledge. It is these unconscious feelings and emotions generated by the image that elicits the response. Studies have shown that emotional images are remembered significantly better than images that are neutral (Versace, Bradley, & Lang, 2010). This demonstrates the importance of dopamine for the formation of the memories, as well as its importance for the retrieval of the memories, especially in cases of reward (Morrison & Dolan, 2001). Therefore, it can be determined that humans remember reward stimuli more than neutral stimuli due to the role of dopamine in the brain (Morrison & Dolan, 2001). Hyperpalatable foods produce a similar increase in dopamine activity in the brain as reward stimuli (Schulte et al., 2015). It follows that if dopamine increases the strength of memory formation, then memory for hyperpalatable food should also be stronger than for neutral stimuli.

Given the wide availability of hyperpalatable foods, it is important for future research to examine memory for food rewards. In recent years research has investigated the role of novelty food in food selection (Morin-Audebrand et al., 2012) and the role of liking in memory for food (Laureati et al., 2008). A study investigating age differences in memory for food, Laureati et al. (2008) found that liking a food was the strongest predictor that it would be remembered. The study used an incidental memory task that required participants to ingest a meal and 24 hours later the participants were asked whether or not they had eaten the food the previous day; the participants did not know there would be a memory task. The study investigated unintentional, or unconscious memory, rather than explicit memory, which studies conscious memory. In previous research into memory for food, most experiments have included ingesting the food to elicit memories; however, with the knowledge that visual cues can produce the same response as eating the food: craving, dopaminergic activity and drive to consume (Van Gucht, et al., 2008), further research should be done to investigate the strength of memories for food from visual cues. The *food-pics* database (Blechert, Meule, Busch, & Ohla, 2014), consisting of a wide variety of standardized food images, facilitates additional research utilizing visual food cues including the investigation of explicit memory strength of hyperpalatable food images, investigations that are currently lacking.

In the current study, memory for hyperpalatable food images was investigated using the *food-pics* database (Blechert et al., 2014). Participants were tested on their ability to recognize different types of hyperpalatable foods (high sugar, high fat, and sugar+fat), less palatable foods and non-food images. The current study tested the explicit memory of food images by using similar methods to Versace et al. (2010), presenting the participants with a series of images during a study phase, followed by a test phase consisting of more images that probed if the participant had already seen the image or not. Memory for the images, as well as response time for each answer was recorded. Individual ratings of palatability and desirability were also collected using a scale developed for this study to analyze personal perceptions of reward. It was hypothesized that participants would remember hyperpalatable food images the best, remembering more hyperpalatable food images than non-food images or less palatable food images. It was also hypothesized that among hyperpalatable foods, foods high in both sugar and fat would be remembered better than hyperpalatable foods high in sugar or high in fat. It was also predicted that the hyperpalatable foods would be recalled faster than the non-food images or the less palatable food images, specifically, the sugar+fat foods would be remembered faster than other hyperpalatable food images as well as the non-food images or less palatable food images. Information on participants' eating behaviour was collected using standardized questionnaires including the Yale Food Addiction Scale (YFAS; Gearhardt, Corbin, & Bronwell, 2009) and the Dutch Eating Behaviour Questionnaire (DEBQ; Strien, Frijters, Bergers, & Defares, 1986).

Methods

Participants

Participants in this study were female undergraduate students recruited from the Brescia University Undergraduate Research Pool of Psychology 1000 students (n = 44, M = 19.5 years old). Due to the food nature of the images used in the study any participant that rated their hunger above a five out of 10 at the start of the experiment were excluded from all analyses, thus the final sample size was, n = 35. All participants were given three credits for their participation.

Materials

All questionnaires in this study were hard copies. Participants answered a Demographics Questionnaire that was created for the purpose of this study including questions about their age, sex, school program, their current hunger rating, allergies, and eating style (i.e., omnivore, vegetarian, or vegan) (Appendix A). The participants then participated in a memory task that used SuperLab 5 (Cedrus, 2015) technology that presented images selected from the *food-pics* standardized image database (Blechert et al., 2014). The stimuli for the memory task were presented on a MacBook Pro 13 inch screen. The images presented were of one of seven categories: fruits, vegetables, breads, high fat foods, high sugar foods, sugar+fat foods and common non-food items.

The participants were then asked to complete the YFAS (Gearhardt et al., 2009) to obtain information about their eating habits over the last year. The YFAS consists of 27 questions answered on a five point Likert scale where zero, is never, one, is once a month, two, is two to four times a month, three, is two to three times a week, and four, is four or more times or daily. The questions probe for the seven symptoms of substance dependence as per the Diagnostic and Statistical Manual IV-TR: ingestion of substance more than intended, inability to stop ingestion, disruption of life, usage of substance despite negative consequences, tolerance, and withdrawal (Gearhardt et al., 2009). There were also two questions added to address clinical distress/impairment. The questionnaire generated three separate scores. 1) Continuous symptom count, in which the total number of criteria met are calculated out of seven. 2) Dichotomous scoring assigns a diagnosis of food addiction or not, requiring three out of seven symptoms plus clinical distress/ impairment. 3) Severity of symptoms calculated as the total score sum of questionnaire answers out of 76.

The DEBQ (Strien, et al., 1986) was given to gather information about the participant’s restrictive, emotional, and external eating patterns. The DEBQ consists of 33 questions, answered on a five point Likert scale, where one is never and five is very often.

The DEBQ has 10 questions for the restrictive eating behaviour and the external eating behaviour sections, and 13 questions for the emotional eating behaviour section. The questionnaire scores the three parts separately by adding the numerical values of each question in the section (i.e., if a participant responded with five for every question in the external eating section the score would be 50), it is possible to then divide the raw scores by the total number of questions per section for the normative scores.

Participants were also asked to rate the 30 target food images from the study phase, using the Image Questionnaire (Appendix B) created for this study. Here participants rated the desirability and the palatability of the food to them personally, and were asked to assign a calorie count for each food. Students indicated their desirability and palatability by marking a ten-centimeter length line where one end was “not at all” and the other was “extremely”. Thus, by measuring the location of the mark on the line, a score of a food item's palatability and desirability out of 10 was produced. .

The height of each participant was measured using a tape measure affixed to a wall and participant weight was measured using a weigh scale (Conair Consumer Products, Thinner 200C).

Procedure

Participants that agreed to participate were asked to meet the researcher in the lobby of Ursuline Hall where the researcher escorted them to the Psychology Undergraduate Research Laboratory at Brescia.

After providing written informed consent the participants were first asked to answer the Demographics questionnaire. The researcher then explained the study phase of the memory test. The study phase included the presentation of 30 non-food images, as well as 30 food images consisting of five images of each of the following categories: fruits, vegetables, breads, high fat foods, high sugar foods and sugar+fat foods. Images were randomly presented once. The target images were shown for five seconds each, with a three second inter-stimulus interval (ISI). During the ISI there was a prompt on the screen for the participants to answer whether or not the image was familiar or novel. The participants were instructed to press “Y” for yes, the image is familiar, or “N” for no, the image is not familiar. Participants were asked to respond in order to achieve sustained attention to the task (Konkle, Brady, Alvarez & Oliva, 2010). The answers as well as the speed in which the participants answered were recorded.

Once the study phase of the memory task was completed the YFAS and the DEBQ were administered. The participants had 30 minutes to complete the questionnaires before they began the test phase of the memory task.

The test phase consisted of presenting 120 images: 60 non-food images, and 60 food images consisting of 10 images each of the following categories: fruits, vegetables, breads, high sugar foods, high fat foods, and sugar+fat foods. The 60 food images included the 30 study phase images previously shown to the participants; these images are the target images of the study. The 30 additional food images are the distractor images. The images were shown for five seconds with a three second ISI. While the images were on the screen participants were asked to indicate if they had seen the image previously or not. If they believed they previously saw the image they were to press the “Y” key and if they believed they did not see the image they were to press the “N” key. The answers and speed in which participants answered was recorded. Reaction time was recorded in milliseconds, and the answers were recorded and then coded as correct or error using the SuperLab 5 (Cedrus,

2015) software.

When the memory task was finished the participants were given the Image Questionnaire (Appendix B) for each food image of the study phase (30 images). Once finished the researcher weighed and measured the height of the participants to calculate the participants Body Mass Index (BMI).

Statistical Analysis

This study analyzed components of the data using Pearson Bivariate Correlations, Oneway analysis of variance (ANOVA), *t* tests, Repeated Measures ANOVA, and Chi Square. Some participants were missing data due to missed responses during the memory task and thus were excluded on a per analysis basis. Greenhouse-Geisser correction factor was used where appropriate for ANOVA analysis and the level of significance for all analyses was set at $\alpha = .05$.

Results

Only YFAS, DEBQ, BMI data together with the accuracy and speed of responses during the test phase of the memory task are analyzed and presented here.

Yale Food Addiction Scale (YFAS) and Body Mass Index (BMI)

Since only one participant met the criteria for food addiction, no further analysis was possible using the diagnostic data of the YFAS. Four participants were missing measures of BMI due to initial calibration issues with the scale, so were excluded from all analyses using BMI.

Potential associations between YFAS symptom count (M = 1.89, SD = 1.21) and YFAS symptom severity (M = 19.54, SD = 6.64) scores and Body Mass Index (BMI) were examined using the Pearson Bivariate Correlation. These correlations are shown in Table 1.

The correlation between symptom count and BMI, as well as the correlation between symptom severity and BMI, were found to be non-significant.

The effect of weight classification (e.g. underweight, normal weight, overweight, and obese) on YFAS symptom count and YFAS symptom severity was also examined using a Oneway ANOVA with a between subjects factor of Weight Class (4 levels: underweight, normal weight, overweight, and obese). The ANOVA did not reveal a significant effect of Weight Class on either symptom count $F(3, 30) = 1.79$, $p = .18$, or symptom severity, $F(3, 30) = 1.48$, $p = .24$.

Dutch Eating Behavior Questionnaire (DEBQ) and Body Mass Index (BMI)

Potential associations between the DEBQ measures of restrained ($M = 25.31$, $SD = 8.68$), emotional ($M = 30.54$, $SD = 8.41$), and external ($M = 32.29$, $SD = 4.79$) and BMI were examined using Pearson Bivariate Correlations (Table 1).

These analyses revealed a significant positive relationship between restrained eating and BMI, such that as BMI increased so did restrained eating scores. However, correlations between emotional eating and BMI, and external eating and BMI, were found to be non-significant.

The effect of weight classification on restrained, emotional, and external eating behaviour scores from the DEBQ was also examined using a Oneway ANOVA with a between subjects factor of Weight Class (4 levels: underweight, normal weight, overweight, and obese). There was a significant effect of Weight Class on restrained eating, $F(3, 30) =$

Table 1

Correlations between Body Mass Index (BMI) and scores on the Yale Food Addiction Scale (YFAS) and the Dutch Eating Behaviour Questionnaire (DEBQ) measures

Measure	*r* (*n* = 31)	*p*- Value
BMI- YFAS Symptom Count	-.11	.55
BMI- YFAS Symptom Severity	-.01	.95
BMI- DEBQ Restrained Eating	.36	.05*
BMI- DEBQ Emotional Eating	.17	.36
BMI- DEBQ External Eating	.00	1.00

Note. Correlational analysis revealed a positive significant relationship between BMI and restrained eating behaviour scores on the DEBQ *$p = .05$.

3.25, $p = .04$. Least Significant Difference (LSD) post hoc tests revealed that normal weight and overweight individuals showed more restrained eating than underweight individuals (*p*'s < .05). Weight Class did not significantly affect emotional, $F(3, 30) = .89$, $p = .46$, or external, $F(3, 30) = .18$, $p = .91$, eating behaviour scores.

Yale Food Addiction Scale (YFAS) and Dutch Eating Behavior Questionnaire (DEBQ)

Potential associations between YFAS symptom count and symptom severity and DEBQ measures of restrained, emotional and external eating were also examined using Pearson Bivariate correlations. These relationships are shown in Figure 1 (Symptom severity) and Figure 2 (symptom count). Symptom severity was found to be significantly and positively correlated with emotional eating score $r(33) = .51$, $p = .002$, such that as emotional eating increased so did symptom severity. Symptom severity and external eating was also found to be significantly and positively correlated, $r(33) = .33$, $p = .05$. The analyses did not reveal any other significant correlation between symptom severity and restrained eating, $r(33) = .03$, $p = .87$. Analyses also did not show any significant correlations between symptom count and restrained eating, $r(33) = -.08$, $p = .66$, symptom count and emotional eating, $r(33) = .22$, $p = .20$, or symptom count and external eating, $r(33) = .12$, $p = .48$.

Reaction Time

Reaction times for target images were analyzed separately from reaction times for distractor images. Participants were excluded on a per analysis basis if they were missing one or more responses to relevant images.

<u>Target Images</u>

Mean reaction times for food ($M = 1381.61$, $SD = 271.15$) and non-food ($M = 1385.03$, $SD = 319.70$) images were compared using a paired samples *t* test (see Figure 3).

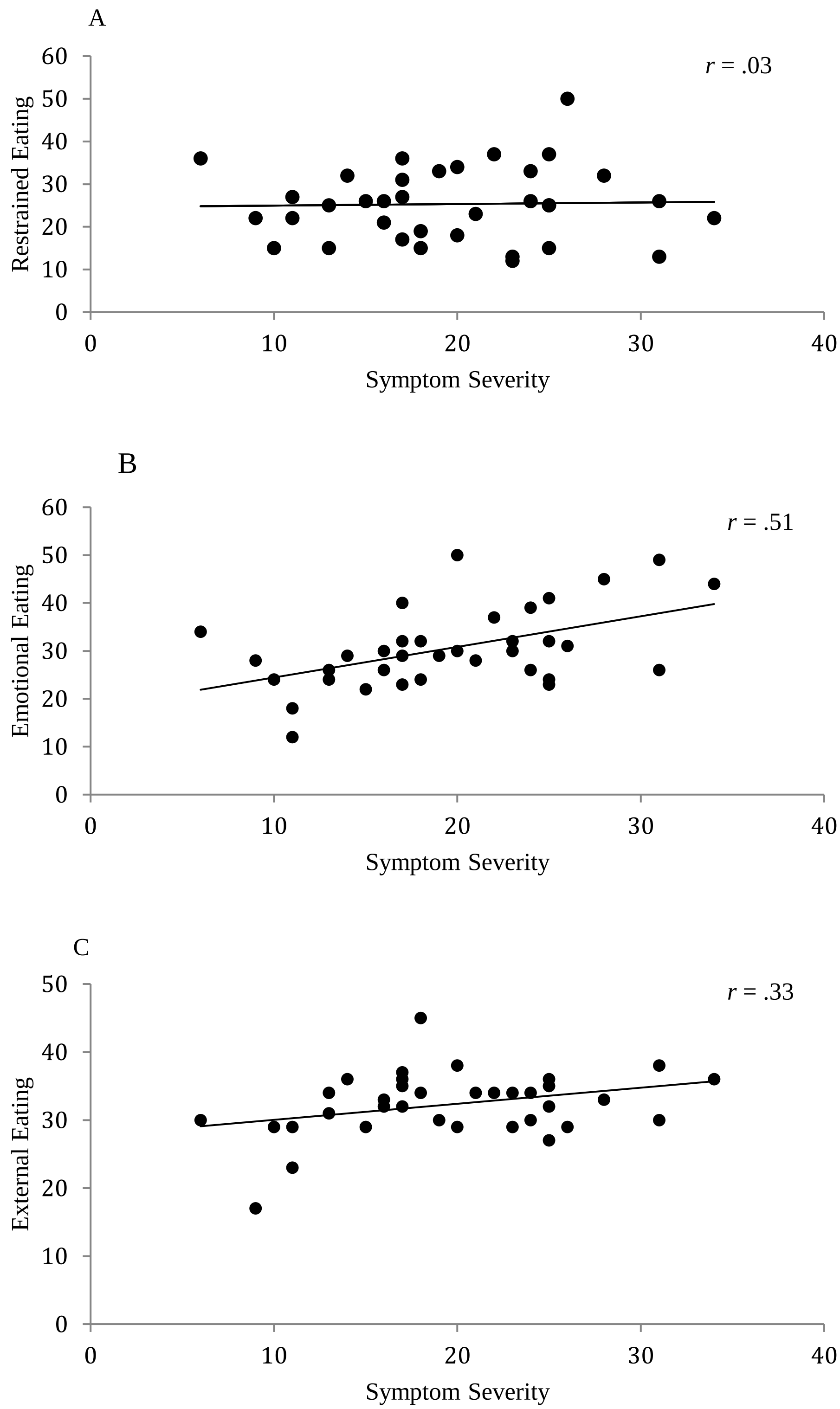

Figure 1. Restrained eating (A), emotional eating (B) and external eating (C) scores on the DEBQ associated with food addiction symptom severity scores of the YFAS.

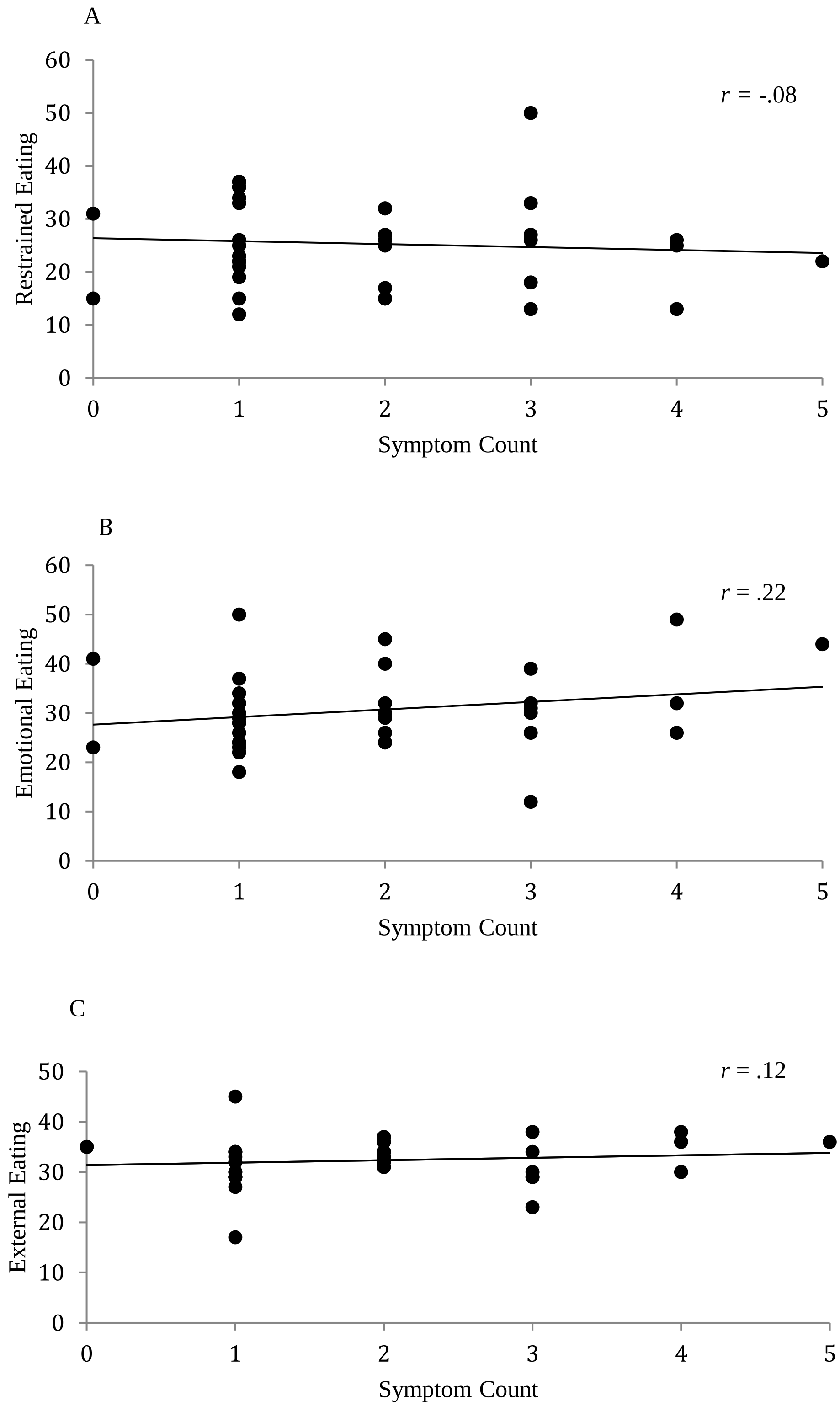

Figure 2. Restrained eating (A), emotional eating (B) and external eating (C) scores on the DEBQ associated with food addiction symptom count of the YFAS.

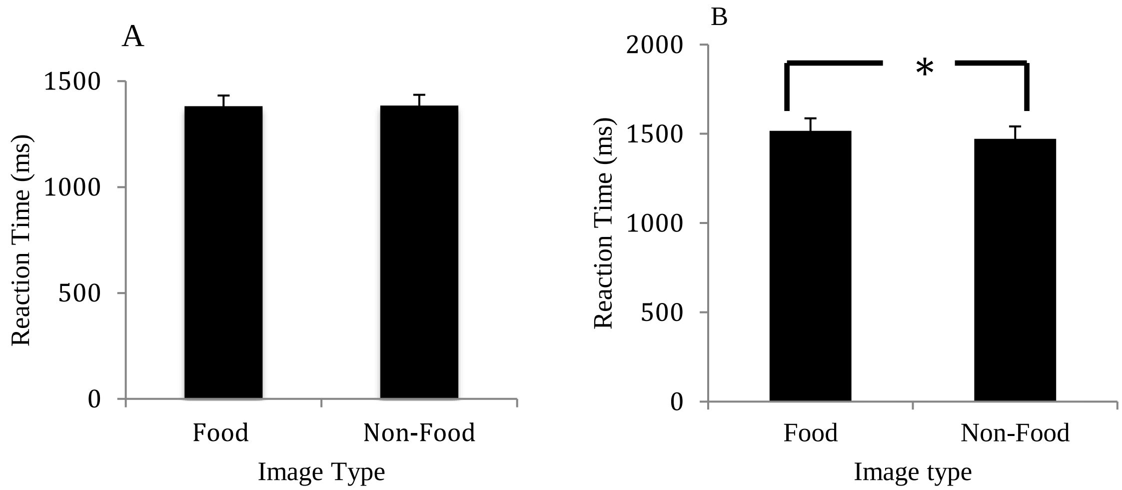

Figure 3. Reaction times during the test phase to (A) target images and (B) distractor images categorized as food or non-food images. For distractor images, food images produced significantly slower reaction times (*$p < .05$) while there was no significant difference for target images. Error bars represent the standard error of the mean (SEM).

The *t* test revealed a non-significant difference between reaction times of food and non-food images, *t* (28) = -0.13, *p* = .90.

Mean reaction time for palatable food (*M* = 1302.32, *SD* = 250.51) and less-palatable food (*M* = 1449.26, *SD* = 321.85) images were compared using a paired samples *t* test (see Figure 4). The *t* test revealed a significant difference between the reaction times, *t* (29) = -3.44, *p* = .002, where palatable foods showed a significantly faster reaction time than less-palatable foods.

Mean reaction times among the six food categories were further analyzed using a repeated measures ANOVA with a within subjects factor of Food Category (6 levels: high sugar, high fat, sugar+fat, fruit, vegetables, and breads) (see Figure 5). The ANOVA revealed a significant effect of Food Category on reaction time, *F*(3.80, 110.28) = 4.10, *p* = .005. LSD post hoc tests indicated that mean reaction time to high sugar foods was significantly faster than fruits, *p* = .02, and vegetables, *p* = .01. In addition, mean reaction time to high fat foods was significantly faster than fruits, *p* = .03, and vegetables, *p* = .003. Finally, mean reaction time for sugar+fat foods was significantly faster than vegetables, *p* = .025.

Distractor Images

Mean reaction time for food (*M* = 1516.98, *SD* = 363.76) and non-food (*M* = 1471.64, *SD* = 372.23) images were compared using a paired samples *t* test (see Figure 3). The *t* test revealed a significant difference between the reaction times, *t* (26) = 2.70, *p* = .01, where food images produced a significantly slower reaction time than non-food images.

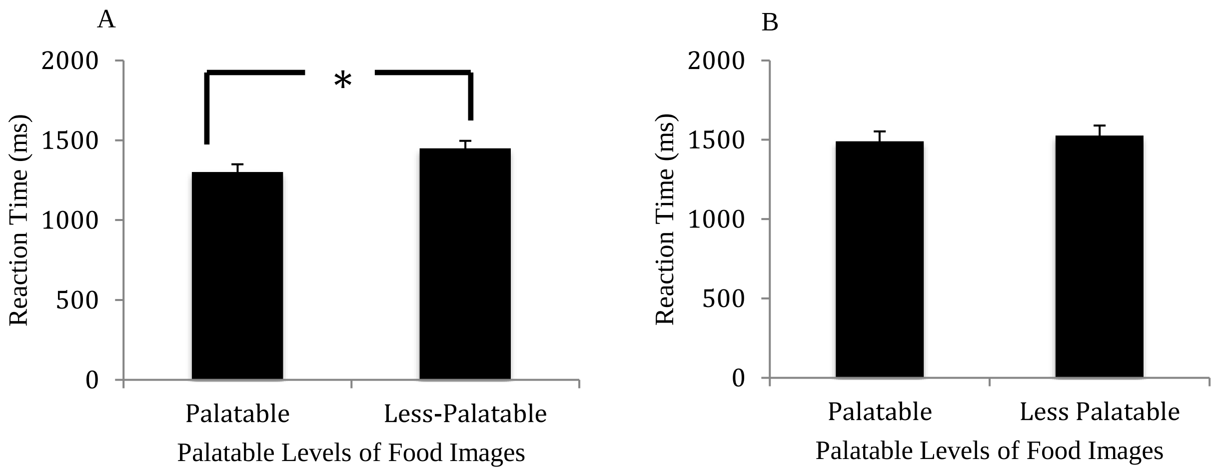

Figure 4. Reaction times during the test phase to (A) target images and (B) distractor images categorized by general palatability of food images. For target images, palatable images produced significantly faster reaction times (*$p < .05$) while there was no significant difference for distractor images. Error bars represent SEM.

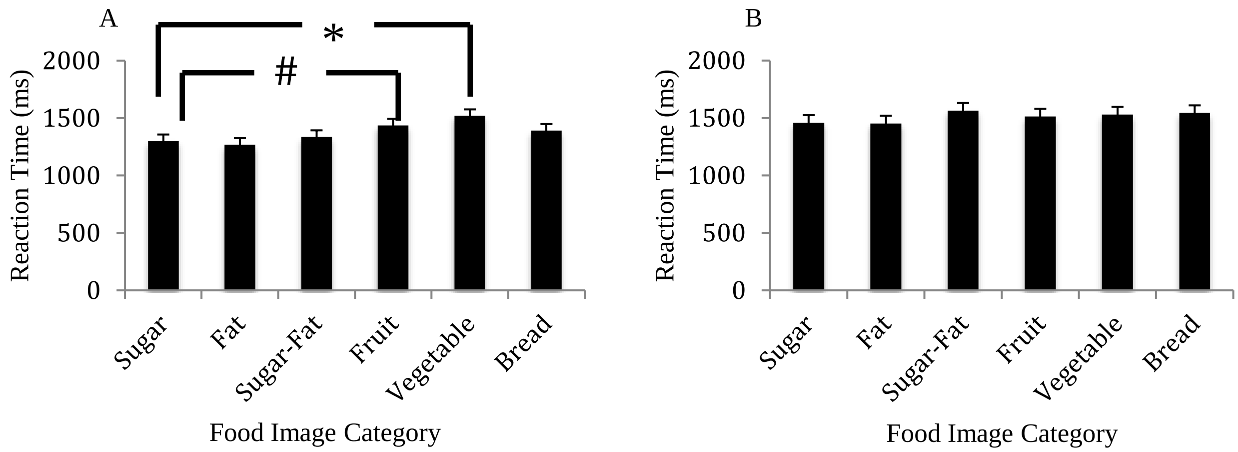

Figure 5. Reaction times during the test phase to (A) target images and (B) distractor images categorized by food category. For target but not distractor images, significant differences were found among food categories. High sugar, high fat, and sugar+fat foods were significantly faster than vegetables (* $p < .05$) and high sugar and high fat foods were significantly faster than fruits (# $p < .05$). Error bars represent SEM.

Mean reaction times for palatable food (*M* = 1490.98, *SD* = 339.83) and less-palatable food (*M* = 1527.99, *SD* = 402.50) images were compared using a paired samples *t* test (see Figure 4). The *t* test did not reveal a significant difference between the reaction times, t (29) = -0.76, p = .46. Mean reaction time among the 6 food categories was further analyzed using a repeated measures ANOVA with a within subjects factor of Food Category (6 levels: high sugar, high fat, sugar+fat, fruits, vegetables, and breads) (see Figure 5). The ANOVA did not reveal a significant effect of Food Category, $F(3.50, 101.45) = 0.71$, p = .57.

Image Accuracy

Only participants who provided a response for all images were included in this analysis (n = 28).

Coding of image accuracy data used a signal detection framework and produced four different possible responses. For target images, correct recognition of an image they had seen before produced a 'Hit'. Failure to recognize a target image that they had seen before produced a 'Miss'. For distractor images, correct identification of these images as novel images produced a 'Correct Rejection'. Failure to recognize a distractor image as novel resulted in a 'False Alarm'.

The relationship between type of response (e.g., hit, miss, correct rejection and false alarm) and whether a food was palatable or not was analyzed using a Chi-Square Test of Independence. These data are shown in Figure 6. The analysis revealed a significant association between type of response and whether a food was palatable or not, χ^2 (3) = 32.91, $p < .001$. Further analysis of the standardized residuals indicated that participants had

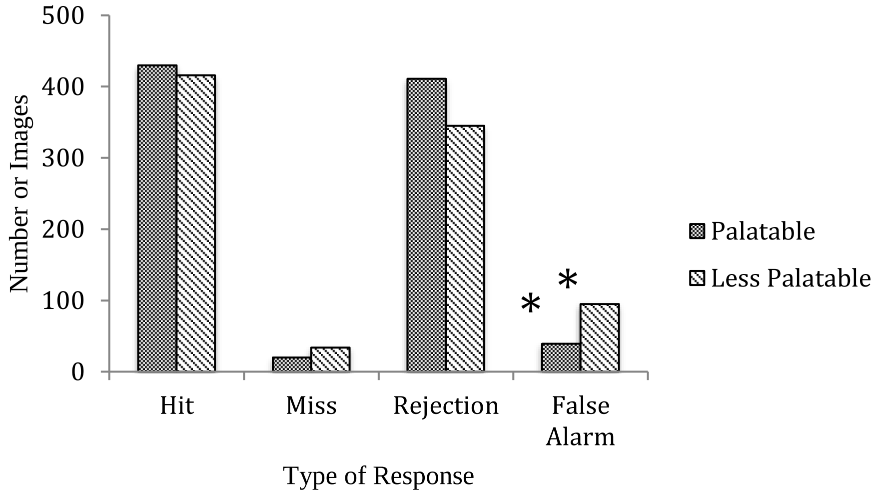

Figure 6. Types of responses to images recorded during the test phase. Participants produced significantly fewer false alarms to palatable foods than expected (*$p < .05$) and significantly more false alarms to less palatable foods than expected (*$p < .05$).

significantly more false alarms for non-palatable foods than expected, $p < .05$ and significantly fewer false alarms for palatable foods than expected, $p < .05$.

A Chi-Square Test of Independence was also used to examine whether there was an association between type of response and image food category. These data are shown in Figure 7. This analysis revealed a significant association between type of response and food category, χ^2 (15) = 196.92, $p < .001$. Further analysis of the standardized residuals indicated that participants failed to recognize significantly more target vegetable images (i.e., produced fewer hits) than expected, $p < .05$. Participants also failed to correctly reject significantly more distractor fruit images (i.e., produced fewer correct rejections) than expected, $p < .05$.

Finally, participants had significantly fewer false alarms than expected to distractor images in the sugar, $p < .05$, fat, $p < .05$, and sugar+fat, $p < .05$, categories and significantly more false alarms than expected to distractor images in the fruit category, $p < .05$. No other significant differences were found among the categories.

Discussion

This study aimed to identify whether hyperpalatable food images are remembered with more accuracy, and recalled faster than less palatable food images. It was predicted that there would be differences between hyperpalatable and less palatable foods as well as among different types of hyperpalatable foods including those high in fat only, high in sugar only, or sugar+fat in combination. The findings of this study will help further the understanding of what factors may contribute to the rewarding nature of particular foods and the heightened motivation to consume them.

As hypothesized, participants responded faster to hyperpalatable target images than less palatable target food images. This finding suggests that memory for hyperpalatable food

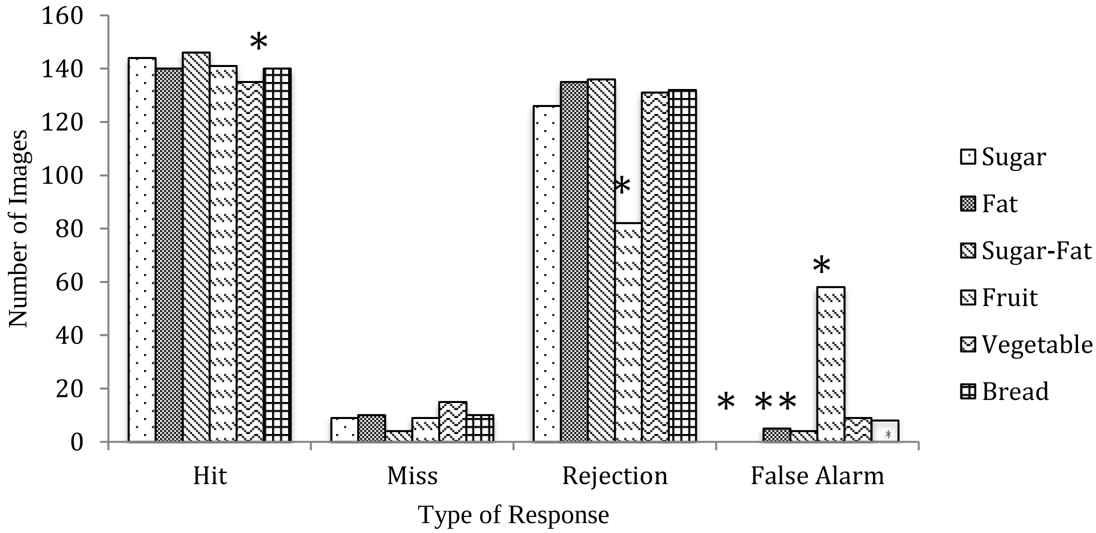

Figure 7. Types of responses to images recorded during the test phase. Participants produced significantly fewer hits than expected for vegetable images ($p < .05$). Participants also failed to correctly reject significantly more distractor fruit images than expected ($p < .05$). Participants had significantly fewer false alarms than expected to images in the sugar ($p < .05$), fat ($p < .05$), and sugar-fat ($p < .05$) categories and significantly more false alarms than expected to distractor images in the fruit category ($p < .05$).

is stronger as studies have shown that when individuals remember seeing something they are faster at responding (Dewhurst, Holmes, Brandt, & Dean, 2005). This stronger memory for hyperpalatable foods aligns with previous work showing that food that is liked is remembered more than any other foods (Laureati et al., 2008). Thus, hyperpalatable foods appear to act as a stronger reward compared to less palatable foods, as rewarding images are remembered better than neutral images (Wittmann et al., 2005). This data also makes sense given previous research on hyperpalatable foods and their affect on the brain. Specifically, hyperpalatable foods increase dopamine in the reward and motivation pathways of the brain (Schulte et al., 2015). Furthermore, it was found that high sugar target images and high fat target images were reacted to faster than fruit and vegetable target images. This finding again supports a stronger memory and stronger rewarding response to these foods as more rewarding stimuli have a better memory consolidation (Wittman et al., 2005), which makes recall faster (Dewhurst et al., 2005). This data coincides with Schulte et al.'s (2015) finding that high sugar and high fat foods are more rewarding that non-processed foods such as fruit and vegetables. In contrast, sugar+fat food images were only reacted to faster than vegetable images. This finding contrasts with the hypothesis that sugar+fat foods would be recalled faster than all food categories given that previous research has shown a preference for foods containing both sugar and fat (Schulte et al., 2015; Tenk & Felfeli, 2015). However, differences in the rewarding nature of different hyperpalatable foods have not been investigated in depth and while hyperpalatable foods are defined by their sugar and fat composition, as well as their overall calorie count (Schulte et al., 2015), palatability is also individually determined (Yeomans & Symes, 1999). This individual palatability may be more important in determining the rewarding value of foods and subsequent memory for them than food composition.

Another novel finding was that distractor food images were responded to slower than distractor non-food images. In contrast, there was not a significant difference in reaction time between target food and non-food images. Thus, novelty appeared to play a role in reaction time to food images. This could perhaps be because individuals spend significantly more time attending to food images than non-food images (Frayn, Sears, & von Ranson, 2016), therefore they take longer to distinguish and decide whether an image is novel or not. It also suggests that there is more cognitive processing for food items than for non-food items. Evolutionarily humans are trained to investigate their food more thoroughly than non-food items since eating the wrong food can potentially cause death (Gerber et al., 1999). Cognitive processing of a familiar image may be less, thus speeding up reaction time to familiar compared to non-familiar food images. Studies investigating reaction time to familiar and non-familiar images find that familiar objects are recalled faster when there is less cognitive load (Crowell & Schmeichel, 2014).

Results also showed there were significantly fewer false alarms for hyperpalatable food and significantly more false alarms for less palatable foods than predicted by the analysis. This means that individuals are better at correctly recognizing hyperpalatable foods as novel than less palatable foods. This is most likely due to the stronger consolidation of memory for hyperpalatable foods compared to less palatable foods because of the rewarding nature of the hyperpalatable foods which trigger an increase in dopamine levels that less palatable foods do not (Gearhardt et al., 2011). Therefore, participants were less certain for less palatable images and relied more on guessing. This finding supports the hypothesis that hyperpalatable foods would be remembered the best.

Further analysis between food categories reiterate the finding that hyperpalatable foods are remembered with the fewest mistakes and further support the hypothesis that hyperpalatable foods would be remembered the best. However, they also highlight an interesting finding that fruits have significantly more false alarms and significantly fewer correct rejections. This suggests that accurate memory performance is weaker for fruit images despite no differences in reaction time. This difference in performance accuracy for fruit may be due to interference from other images. As previous research shows, similar stimuli can interfere with recollection, whereas dissimilar stimuli do not cause interference and therefore result in better performance (Blalock, 2013). These data highlight putative differences in memory interference for different categories of food which not only support the current hypotheses that memory for different categories of food is dissimilar, but also suggests the need for further investigation of these potential differences.

This study also investigated the participants' eating behaviours as evaluated by the YFAS and DEBQ, as well as the relationship with participant BMI. First, it was found that as scores of restrained eating increased, so did BMI. This finding agrees with previous literature demonstrating that the more an individual attempts to control their eating, the less control they seem to have, and therefore the higher their BMI becomes (Dietrich, Federbusch, Grellmann, Villringer, & Horstmann, 2014). Oftentimes individuals that restrain their eating by dieting will eventually lose strength in their control over their food intake and they will overeat (Strien et al., 1986). Moreover, this study found that normal weight (BMI > 18.5 & < 24.9) and overweight (BMI > 25 & < 29.9) individuals also exhibited more restrained eating behaviours than underweight individuals (BMI < 18.5) exhibited. While these results also coincide with previous research into eating behaviour and weight (Dietrich et al., 2012) it is important to note that the small sample size used in the study did not provide extensive representation in each weight class, specifically in the obese class suggesting the need for caution interpreting these data.

Finally, symptom severity on the YFAS showed a significant positive relationship with both emotional eating and external eating scores of the DEBQ. This means that individuals that exhibit more severe symptoms of food addiction on the YFAS also exhibit more emotional and external eating habits. This is the first study to our knowledge to demonstrate these specific data; however, other studies have linked external eating with behaviours related to food addiction. For example, Burton, Smit and Lightowler (2007) found a strong relationship between food cravings and external and restrained eating behaviours. It has also been demonstrated that cravings for foods go hand in hand with restrained eating (Rogers & Smit, 2000). In addition, studies have found an increase in neural responsivity to external food cues in individuals with higher scores on the YFAS (Gearhardt, Yokum, Orr, Stice, Corbin, & Brownell, 2011). This novel finding shows an important link between food addiction as measured by the YFAS and external eating on the DEBQ and suggest a potential starting point for the prevention and treatment of "food addiction" and obesity.

Two major limitations of the current study included the participant sample, and the food images used. The participants in this study were female Brescia University College students, and the study was investigating food memory. Brescia is one of a few Food and Nutrition (F&N) schools in Ontario, and therefore has a high density of F&N students. In this study 28.6% of included participants were from the F&N faculty, and additional 14.3% of included participants were from the Health Science faculty. Thus, 42.9% of the sample was well educated, familiar with the human body, nutrition, calories, and has an understanding of what foods are healthy and which are unhealthy. There is a higher chance of nutrition-oriented participants reporting falsely on the YFAS and DEBQ, as well as the desirability and palatability ratings of the food images. Importantly, food consumption and palatability may be different in such a nutrition-oriented cohort. Wang, Worsley, & Cunningham (2008) found that if healthy behaviours and attitudes were of high importance to an individual, food consumption is directly affected. Thus, half of the current sample may not accurately share the general perception of what foods are hyperpalatable. This highlights the self-report measures of the study. Previous research indicates that social desirability is an important factor when investigating self-report involving body image (Ambwani & Chmielewski, 2012). In female participants especially, as it has been indicated that impression management is of large importance, as women will often regulate themselves to appear healthier (Hermans, Larsen, Herman, & Engles, 2008). Therefore, it would also help the generalizability of the findings if the study were replicated with males, and females of a wider education variety. For example, to see if the finding is the same between children, adolescents, and middle-aged individuals, as well as university educated, college educated, and high school only educated individuals.

Another limitation of the study involves the images selected from the *food-pics* database (Blechert et al., 2014). This study utilized images from the original database of standardized images, which had a large quantity of European foods in contrast to more typical North American foods. This limited the number of possible image options per category of food due to a large number of unfamiliar food images. Hyperpalatable foods are defined by their sugar and fat composition, as well as their overall calorie count (Schulte et al., 2015), but palatability is also individually determined (Yeomans & Symes, 1999). In order to improve upon the images selected it is recommended to find more images of hyperpalatable foods from all around the world and then analyze the images by ratings of desirability and palatability by a large sample prior to their use. Hyperpalatable foods could then be chosen based on these ratings. This will help to eliminate any bias in the selection of images, as well as help to standardize the criteria for future research.

The data presented in this study serve as the first steps for investigating memory of hyperpalatable foods. Future research in this area should be aimed at brain Functional Magnetic Resonance Imaging (fMRI) to investigate the levels of dopamine activity in response to seeing the images of hyperpalatable foods. As demonstrated by Wittmann and colleagues (2005), the human brain will trigger dopamine activation in the reward pathways upon viewing a reward stimulus. This study concluded that hyperpalatable images are remembered better and recalled faster; these responses are similar to responses of reward stimuli. Brain imaging upon viewing of hyperpalatable food images can establish hyperpalatable foods as reward stimuli that activate stronger memory processing. This research would help to better understand “food addiction”, and which foods specifically may trigger dopamine surges that drive individuals to consume food.

Findings of this study also suggest that future research can be aimed at investigating the role branding plays in remembering hyperpalatable foods. It is suggested that research investigate brand logos for hyperpalatable foods, such as McDonalds, Oreos, Lays, and Pizza Hut.

In conclusion, participants remembered hyperpalatable foods the best and the fastest, in particular the high sugar only and high fat only foods had the highest accuracy and fastest reaction times. It is likely that hyperpalatable food images form stronger memories because of the increase in dopamine seen in response to these foods is higher than for less-palatable foods. Thus, these findings suggest that type of food may be a key factor in motivation to consume food as driven by dopamine mediated responses. In addition, results support the link between external and emotional eating behaviours and food addiction symptom severity. With increasing ease of accessibility and availability of hyperpalatable foods, it has never been easier for people to become overweight and unhealthy from the ingestion of these foods. Despite the significance of these findings, there is a substantial amount of research still needed to be done in this area to help increase our understanding of which foods may create stronger memories, and subsequently trigger stronger drives to consume food. The present study was a good starting point for further research that has potential implications for reducing unhealthy eating in the general population.

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