Derivation and development of the MacroPics food picture set

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Abstract

Recent research suggests that the macronutrient composition of foods can influence reinforcement independent of energy density. To further investigate this phenomenon, we developed “MacroPics,” a food picture set depicting processed American snack foods in which items contain: (1) predominantly carbohydrate, (2) predominantly fat, or (3) roughly equal proportions of carbohydrate and fat. We first photographed 60, 120-kcal portions of snack foods falling into one of the three macronutrient categories and asked 61 individuals to rate the images for liking, familiarity, frequency of consumption, healthiness, estimated energy content (in kcal) and expected satiation. A 36-item subset was then selected in an iterative process to minimize differences between the macronutrient categories on these ratings while simultaneously ensuring similar variability within category on a number of food characteristics (e.g., energy density, portion size, retail price) and visual properties (e.g., color and complexity). Item and macronutrient category characteristics of the final MacroPics set are reported.

Keywords: Food pictures, food cue reactivity, reinforcement, macronutrient, eating behavior, ingestive behavior

1. Introduction

The food environment has changed markedly over the past 50 years. Not only are there quantitative differences, such as increased availability and energy density, but there are also qualitative differences in the foods we consume, such as combinations and doses of nutrients that have not been encountered previously in hominin evolution (Cordain et al. 2005). Emerging findings suggest that these qualitative changes may affect food choice. For example, DiFeliceantonio et al. (2018) reported that foods containing carbohydrate and fat are more reinforcing than equally liked and isoenergetic foods containing primarily fat or primarily carbohydrate, implying that fat and carbohydrate interact to potentiate reward. Likewise, at the level of physiology, distinct mechanisms exist to relay reinforcing signals derived from fat and carbohydrate from the gut to the brain (Small and DiFeliceantonio 2019; Han et al. 2018; Tellez, Medina, et al. 2013; Tellez, Ren, et al. 2013; Ren et al. 2010). Further understanding the influence of macronutrient content on food decisions and preference is therefore of interest.

In humans, food choice is often studied using food pictures, especially in the neuroimaging environment. Cognitive, behavioral, and neural responses to food images have been shown to mimic those elicited by actual food stimuli (Blechert et al. 2014). As such, results from meta-analyses suggest similar effect sizes when predicting eating- and weight-related outcomes from food-cue reactivity and craving in response to food pictures and real food stimuli (Boswell and Kober 2016). However, although a variety of picture sets are available (Blechert et al. 2019; 2014; King et al. 2018; DiFeliceantonio et al. 2018; Charbonnier et al. 2016), they are not optimized for studying the effects of macronutrients in American samples in several regards. First, picture sets developed in Europe or other countries contain foods that are frequently unfamiliar to Americans (e.g., DiFeliceantonio et al. 2018; Charbonnier et al. 2016). Second, picture sets appropriate for American populations leave many factors uncontrolled. For example, food choice and intake depend on a complex interplay of perceived factors such as palatability, healthiness, estimated energy content (Labbe et al. 2017; Provencher and Jacob 2016), and expected satiation (Guillocheau et al. 2018; Fiszman and Tarrega 2017; Wilkinson et al. 2012; Brogden and Almiron-Roig 2010; Brunstrom and Shakeshaft 2009). Likewise, food characteristics such as total energy content, energy density, or portion size and visual image properties including brightness, color, and contrast are likely to impact responses to food images and are not equated across different macronutrient types (Blechert et al. 2014). Therefore, the

aim of the current study was to develop a picture set of processed American snack foods in which items contain: (1) predominantly carbohydrate, (2) predominantly fat, or (3) roughly equal proportions of carbohydrate and fat, while also minimizing differences between these macronutrient categories on food characteristics (e.g., energy density, portion size, retail price), visual properties (e.g., color and visual space taken up by the food on the plate), and perceived ratings of liking, familiarity, frequency, healthiness, estimated energy content and expected satiation.

2. Materials and Methods

2.1 Participants

Sixty-one healthy, English-speaking participants aged 18-45 years took part in the study. Sample size was oriented towards a prior study aimed to establish a similar picture set for the German population (DiFeliceantonio et al. 2018). To qualify for the study, participants were required to have lived in the United States for the past five years without any interruption of more than nine months to ensure prior exposure to American snack foods. Other exclusion criteria included: a) serious or unstable medical illness; b) current or history of major psychiatric illness as defined by the DSM-IV criteria; c) medications that affect alertness, any psychoactive drugs or anti-obesity agents; d) known taste or smell dysfunction; e) a diagnosis of diabetes; f) food allergies, food sensitivity or dietary restriction for other reasons (religious, choice, etc.); g) current pregnancy/nursing. Eligibility was determined via online questionnaires and follow-up email conversation. On the study day, the severity of depression and anxiety symptoms was assessed by means of the Beck Depression Inventory II (BDI-II; A. Beck et al. 1996) and the Beck Anxiety Inventory (BAI; A. T. Beck et al. 1988), respectively. Altered eating behavior can be one symptom of depression or anxiety (Rosenbaum and White 2015; Mooreville et al. 2014; Frost et al. 1982; Herman and Polivy 1975), so we had planned to exclude participants with scores indicative of severe depression or anxiety post-hoc from the analysis. No participants were excluded on this basis. The experimental protocol was approved by the Yale Human Investigation Committee and all participants provided signed, informed consent.

2.2 Food Pictures

Initial pictures were obtained for 60 processed snack foods selected by a multi-disciplinary team of psychologists, neuroscientists, and nutritionists familiar with typical

American eating habits. All images were taken in-house with a professional camera and photo light box. Each picture contained a 120-kcal food portion arranged in the middle of a white plate as shown in Figure 1A. To provide visual cues for portion size, a paper cup and napkin were placed next to the plate in each photo. All images were color photographs with dimensions of 5760 x 3840 pixels and a resolution of 300 pixels/inch.

2.2.1 Food characteristics

Data on food composition (energy density, total portion size, and gram {g} or milligram {mg} per serving of fat, carb, protein, sodium, or water) were collected using the Nutrition Data System for Research (NDSR) software version 2018, developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, MN. The NDSR provides a complete nutrient profile for all foods in the database. Data on foods not included in the database were calculated using the nutrient content of other nutrients in the same food, a product ingredient list, or estimates from similar foods. All food composition metrics from the NDSR in g or mg per serving were converted to g or mg per 120 kcal (equivalent to the amount shown in each image). Food volume in cm^3 was estimated by using displacement of poppy seeds similar to the method from Segnini et al. (2004). Poppy seeds were first packed into a 250 mL glass beaker. Another glass beaker of the same size was then filled with 40 kcal of a given food in addition to the poppy seeds from the first beaker. Any seeds that overflowed (i.e., no longer fit in the allotted volume) were collected and measured in mL, which was converted to cm^3 and multiplied by three for the volume of 120 kcal of each food. Price in dollars per 120 kcal was determined from unit prices (\$/g) at Walmart.com using the IP address at the lab where all research was conducted.

2.2.2 Visual properties

Visual area, or space taken up by food in the 2-dimensional image (not accounting for food overlap), was calculated using Image J 1.x (Schneider, Rasband, and Eliceiri 2012) first in pixels and converted to cm^2 based on the measured dimensions of the plate. To prevent confounding by low-level visual input, image characteristics were also taken into consideration in the selection of the final picture set. These image characteristics included red, green, and blue color, brightness, within-object contrast, spatial frequency, and complexity, and were computed and normalized using available Matlab R2018b (The Mathworks Inc., Sherborn, MA, USA)

scripts from Blechert et al. (2014). Details on quantifying these image characteristics can also be found in Blechert et al. (2014).

2.2.3 Perceptual ratings

All rating questions and anchors are described in Table 1. We assessed liking, familiarity, estimated energy content, and estimated energy density following a prior study that evaluated a similar food picture set for the German population (DiFeliceantonio et al. 2018). Additionally, we asked participants to rate frequency of consumption, perceived healthiness, and expected satiation. Frequency of consumption was added as another measure of familiarity, framed to inquire explicitly the ingested exposure of the presented food items. Perceived healthiness (Provencher and Jacob 2016) and expected satiation (Brunstrom et al. 2018; Forde, Almiron-Roig, and Brunstrom 2015; Brunstrom and Rogers 2009) are foci of recent research and have been shown to impact food choice and meal size selection. Therefore, we included both variables to satisfy any interest of potential researchers that may use this food picture set or a subset of its images in the future.

2.3 Additional Measures

2.3.1 Eating behavior

The Dutch Eating Behavior Questionnaire (DEBQ; van Strien et al. 1986) was used to assess eating behavior. The DEBQ comprises 33 items to be answered on a five-point scale, and these items are summed to obtain factor scores of restrained, emotional, and external eating. This three-factor structure of the DEBQ has been confirmed among multiple samples and languages, including English (Wardle 1987) with internal consistency for all subscales estimated at an interclass coefficient (ICC) $\geq .79$ (van Strien et al. 1986).

2.3.2 Dietary intake

The Dietary Fat and Free Sugar – Short Questionnaire (DFS; Francis and Stevenson 2013) is a 26-item checklist that we used to assess the frequency (monthly intake) of fatty and sugary foods across our participants. Items are rated on a five-point scale and summed to a composite score. Test-retest reliability has been estimated at ICC = .83. Correlations with free sugar and fat intake evaluated via a large established food frequency questionnaire and four-day dietary record were estimated at $r = .35 - .71$ (Francis and Stevenson 2013). Our picture set

contains fat, carbohydrate (carb), and combo foods, and so we selected the DFS for a measure of frequency of consumption specific to these macronutrient types.

2.4 Procedure

Participants were instructed to arrive at the laboratory neither hungry nor full, but at least 1-hr fasted. After obtaining signed informed consent, we asked participants about compliance with fasting; all participants reported compliance. Participants were trained on using our rating scales (Table 1) and received verbal explanations of the terms in the rating scales, specifically “calorie content” (i.e., energy content) and “energy density” to ensure that they understood the difference. Calorie content was described as “a unit of energy that refers to the amount of energy people get from the foods or drinks they consume” and energy density as “the number of calories stored in the food per unit volume.” We gave examples for both constructs and participants had the opportunity to ask further questions. Participants then rated their ‘internal state’ on five items (Table 1). These ratings were used to verify that participants arrived at the laboratory neither hungry nor full (on average). Next, we presented participants with all 60 food image stimuli in a digital task designed in PsychoPy version 3.0 (Peirce 2007) for Python. Participants completed the seven perceptual ratings for each picture on continuous visual analog scales (VAS), with the exception of liking on the Labeled Hedonic Scale (Lim et al. 2009). Food images were presented in a randomized order for each participant. Subsequently, participants provided demographic information (e.g., age, gender, race, education level) and completed digital versions of the DFS, DEBQ, BDI and BAI. Lastly, we collected anthropometric data of height, weight, waist circumference, hip circumference, body fat percentage, and BMI. Height was obtained to the nearest centimeter and weight to the nearest hundredth of a kilogram by means of digital scales. Waist and hip circumference were measured to the nearest centimeter using a tape measure. Body fat percentage was computed via bio-electrical impedance analysis (Seca Medical Body Composition Analyzer mBCA 515, Hamburg, Germany) to the nearest tenth of a percent. BMI was calculated as weight divided by the square of height (in kg/m²) to the nearest hundredth. Each session lasted 1 to 1.5 hours and participants were compensated upon completion.

2.5 Picture selection and data analysis

All perceptual ratings (aside from frequency in days/week, liking on the LHS, and estimated energy content in kcal) for individual food items were scored as a decimal from 0-1 based on position along the 10-cm VAS. Data processing was carried out with Matlab R2018b (The MathWorks Inc., Sherborn, MA). After study completion, we selected 36 pictures of fat, carb, and combo foods (12 food items per category). Items were selected into the final picture set such that macronutrient categories would minimally differ on the food characteristics, visual properties, and perceptual ratings described above. In a first step, we selected items in a way that food categories did not differ on food characteristics, with the exception that differences in fat and carbohydrate content were present according to the fat, carb, and combo category classifications. In a second step, we checked that these categories did not differ on visual characteristics. Using MATLAB's built-in outlier function, we identified items that drove the differences between the categories and iteratively exchanged them, simultaneously checking that categories differed minimally on the previously matched food characteristics. Lastly, we followed the same steps to ensure that as many of the perceptual ratings as possible would be similar across the three macronutrient categories. All category differences were computed with one-way ANOVAs on average values per food item. Post-hoc t-tests were conducted for carb, fat, and protein content as well as for within-object contrast and estimated energy density using alpha levels of .0167 that were Bonferroni-adjusted for the number of comparisons (.05/3). All data were plotted in GraphPad Prism version 8.2.0 (GraphPad Software, La Jolla, California, USA). In the reported plots, each data point represents the average for a food item (12 items per macronutrient category, or 36 items in total). Lastly, as secondary analyses, we examined correlations between mean subjective ratings of each participant with individual differences in terms of age, BMI, body fat percentage, hunger ratings as well as with scores on our measures of eating behavior and fat and sugar consumption. There were no missing data points and no excluded participants. The full analytic plan was developed prior to data collection.

3. Results

3.1 Participants

Participant characteristics of the final sample ($N = 61$) are summarized in Table S1. A summary of participant internal state ratings is shown in Table S2. Although there was participant-to-participant variation, it is important to note that the mean internal state rating of hunger was 0.52 ± 0.25 and of fullness was 0.38 ± 0.24 ($M \pm SD$), suggesting that participants

arrived neither hungry nor full, as instructed.

3.2 Final 36-item picture set “MacroPics”

Food items in the full 60-item picture set and in the final 36-item picture set for macronutrient-based comparisons are reported in Table 2 with example food image stimuli depicted in Figure 1. All images portrayed 120-kcal portions in order to keep actual energy content constant. A comparison of food characteristics across macronutrient categories of the selected picture set are presented in Table 3 and Figure 2A. Macronutrient categories did not significantly differ on food characteristics other than fat, carb, and protein content. We were unable to keep protein content similar across the categories and post-hoc tests revealed that protein content in the fat category was greater compared to the carb ($F(1, 22) = 39.67, p \leq .001$) and the combo category ($F(1, 22) = 55.307, p \leq .001$), but no difference existed between the carb and combo categories ($F(1, 22) = 0.88, p = .77$). Intentionally, the carb category contained significantly less fat than the fat category ($F(1, 22) = 819.252, p \leq .001$). The combo category ($F(1, 22) = 149.87, p \leq .001$) and fat category ($F(1, 22) = 52.39, p \leq .001$) contained significantly more fat than the carbohydrate category and less carbohydrate than the carb ($F(1, 22) = 818.286, p \leq .001$) and the combo category ($F(1, 22) = 282.559, p \leq .001$). The combo category contained more carbohydrate than the fat category ($F(1, 22) = 107.296, p \leq .001$).

Macronutrient categories also did not significantly differ on any visual properties, except for within-object contrast (Table 4, Figure 2B). However, post-hoc tests revealed no significant differences in within-object contrast among pairwise comparisons of the carb versus fat ($F(1, 22) = 5.54, p = .084$), carb versus combo ($F(1, 22) = 0.02, p = 1.00$), or fat versus combo ($F(1, 22) = 6.63, p = .052$) categories. Finally, the only significant difference observed across macronutrient categories in perceptual ratings was for estimated energy density (Table 5, Figure 2C). Participants rated the fat category to have significantly greater estimated energy density than the carb category ($F(1, 22) = 16.59, p < .01$), but not the combo category ($F(1, 22) = 6.52, p = .068$). There was also no significant difference in estimated energy density between the carb and combo categories ($F(1, 22) = 1.72, p = .466$). Food characteristics, visual properties, and perceptual ratings of all individual food stimuli (including those in the initial 60-item set but not the final 36-item ‘controlled’ set) can be found in Tables S3-S5, respectively.

3.3 Associations between subjective food ratings and participant variables

As presented in Table 6, we found no associations of BMI or of hunger score with any of the rating variables. Body fat percentage was lower in participants that indicated they ate the presented snacks more often. Older participants indicated greater food familiarity. Participants with greater fat and sugar consumption measured with the DFS reported greater liking and frequency of consumption of our items. Participants with high restraint and external eating in the DEBQ reported greater liking of our food items. Emotional eating was not related to any of the subjective ratings.

4. Discussion

Here we report the development of “MacroPics,” a 36-item picture set depicting American snack foods that are made primarily from: (1) carbohydrate, (2) fat, or (3) a combination of carbohydrate and fat. By design, the food images all show 120-kcal portions and were selected to create three macronutrient categories differing minimally on a number of food characteristics (e.g., nutrient composition, volume, and price), visual properties (e.g., visual area, colors, and intensity), and subjective ratings (e.g., liking, familiarity, and estimated energy content). This strategy optimizes the picture set for testing hypotheses in U.S.-based samples, where the choice, perception, and/or value of the food item may depend upon macronutrient content. Given the accumulating evidence that distinct physiological mechanisms support the reinforcement value of fat compared with carbohydrates in both humans (Small and DiFeliceantonio 2019) and rodents (Han et al. 2018; Zhang et al. 2018; Tellez, Medina, et al. 2013), we anticipate that this picture set will be useful for addressing emerging questions.

MacroPics was developed to parallel a food picture set used in a German sample to show that people bid more for isoenergetic and similarly liked foods that contain both fat and carbohydrate compared to fat or carbohydrate alone (DiFeliceantonio et al. 2018). However, MacroPics presents several strengths over the earlier version. First, it includes measures of food volume, visual area of the food, and actual price based on a national grocery provider. In addition, we obtained perceptual ratings for frequency of food consumption and expected satiation. The former is similar to familiarity but more directly assesses intake rather than visual exposure. The latter serves as a read-out of the feeling of fullness that is learned or remembered from prior experience eating a given food. Second, our food images all contain identical portion calories (120 kcal), rather than approximate amounts that vary from stimulus-to-stimulus. Third,

in contrast to large online databases of food image stimuli, our food items are each portrayed on an identical ‘standardized’ plate, alongside a paper cup and napkin. Our stimuli thus contain actual food in a realistic presentation style, as opposed to the plain white background or photoshopped colors often employed in images that are gathered from varying internet sources (DiFeliceantonio et al. 2018; Blechert et al. 2019; 2014; King et al. 2018). Fourth, perceptual ratings for all images were made by participants in the same laboratory setting, rather than through online surveys (e.g., Blechert et al. 2019; 2014; Prada et al. 2017 for a Portuguese validation). While this means our overall sample size may be smaller and limited to Americans, we obtained consistent ratings from all participants (rather than ratings for each food from a subset of the sample). Along the same lines, we were able to instruct participants to arrive neither hungry nor full (but at least 1-hr fasted) and could confirm through self-reported ratings during our in-person session that fasting was roughly consistent across our sample. Lastly, in addition to the ANOVA statistics for our final 36-item picture set (of carb, fat, and combo categories), we report here the food characteristics, visual properties, and perceptual ratings for all 60 food images used in our study. We are working further to develop two additional versions of MacroPics, one with multiple portion sizes for each food item, and another that presents the items without the plate, napkin, and cup (with only a gray background). Early examples of these future stimulus types are displayed in Figure S1.

Although we were able to minimize differences between the macronutrient categories, there were several variables that could not be fully equated. These variables are summarized in Table 7. Most notably, the average protein content of the fat items was significantly greater than that of the carb and combo items and sodium followed the same trend. Here the challenge resulted from a limited selection of fat-containing snack foods that do not also contain great amounts of protein or sodium. Current evidence that the valuation of protein is distinct from carbohydrate and fat is limited to binary-choice trials of pairs of relatively healthy and unprocessed foods (e.g., fruits, vegetables, meats, and grains) differing in nutrient composition (Buckley et al. 2019). Similar explorations are warranted for the role of protein in the reward value of highly processed snack foods.

With respect to visual properties, within-object contrast differed across the categories, though pairwise tests corrected for multiple comparisons were not significant. We also found trend-level category differences in brightness, the color blue, visual area covered by the food,

and volume (listed as a food characteristic in Table 7). Since foods with larger visual area or volume are at particular risk of eliciting greater desire to eat (Burger et al. 2011), visual area and volume should be accounted for in future studies using MacroPics. Among our perceptual ratings, participants estimated significantly greater energy density of fat compared with carb items. A trend in liking was also observed. Greater liking of combo foods as our trend shows is consistent with prior work (DiFeliceantonio et al. 2018) and made it particularly challenging to minimize the difference in liking across our categories. Considering the number of variables that we aimed to keep similar, we had to accept these differences in favor of other variables. Researchers are encouraged to consider these factors when using the MacroPics picture set and may elect to use those variables which are trending or different among the macronutrient categories (Table 7) as covariates in their analyses. We have highlighted those which we believe are most important to include as covariates per the reasons above (Table 7).

There are also other caveats to keep in mind with MacroPics. First, it includes only processed snack foods. These foods are more likely to contain added products (especially sugars) and are ubiquitous in US grocery stores. A recent survey of a representative sample of over 9000 individuals concluded that, on average, over half of American daily energy intake comes from ultra-processed foods (Steele et al. 2016). Moreover, while there appears to be a link between obesity and consumption of processed foods (Louzada et al. 2015; Canella et al. 2014; Asfaw 2011), it remains unclear whether this may be a consequence of ‘processing’ itself, or of the modified macronutrient content in these foods (Poti et al. 2017). MacroPics may help to disentangle these possibilities. Future work may further benefit from the creation of picture sets using full meals or healthy snacks that could be better matched on protein. Second, perceptual ratings were obtained from participants who were at least 1-hr fasted. Varying the length of food restriction prior to testing may alter subjective ratings of the stimuli used here. For example, longer food deprivation renders energy dense foods more attractive than their less energy dense counterparts (Goldstone et al. 2009). Although our images each show 120-kcal portions, it is possible that fasting may modulate food reward according to participant ratings of estimated energy content or density.

Our picture set provides researchers with a tool to study human food perception and macronutrient-based responses to food stimuli, including, but not limited to food liking, expected satiation, understanding of portion, reward value, craving, cue reactivity, and emotional valence.

The food picture approach is of particular interest for neuroimaging studies in which exposure to real food is not feasible in the fMRI scanner and/or a highly controlled set of stimuli is necessary. MacroPics images and materials are fully and freely available online at the Modern Diet and Physiology Research Center website (mdprc.org/resources).

Conflict of Interest Statement: The authors declare no competing commercial or financial interests.

Statement of Ethics: The study was conducted according to the standards laid down in the Declaration of Helsinki. All procedures were approved by the Yale Human Investigation Committee. All participants provided signed consent to participate in the study.

Data Availability: The following are available at mdprc.org/resources or from the corresponding author upon request: (1) all 60 food images at 120 kcal, (2) all data used to support the findings of the study, and (3) Matlab scripts for analyses.

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Authors' contributions: SF, EEP, KMW, BGG, KDF, AD, and DMS contributed to conception and design of the study; KMW, SF, JT, and BGG photographed food pictures; ZH, JT, and KDF collected food composition data; SF and AK collected participant data; SF, EEP, ZH, and AD performed the statistical analysis; SF and EEP generated tables and figures; SF, EEP, and DMS wrote the original manuscript draft; DMS acquired the funding to support the study. All authors contributed to manuscript revision and read and approved the submitted version.

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370 *Figure 1.* Example MacroPics images selected into the final 36-item picture set. Items were

371 balanced into three macronutrient-based categories: carbohydrate (“carb”), fat, and the

372 combination of carbohydrate and fat (“combo”).

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374 *Figure 2. Mean ± SEM of selected (A) food characteristics, (B) visual properties, and (C)*
 375 *perceptual ratings across macronutrient categories of the final MacroPics 36-item picture set.*
 376 *The gray dotted horizontal line in the plot for estimated energy content depicts the actual energy*
 377 *content of all items shown (120 kcal). Each point represents the average of a food item in that*
 378 *category.*

Tables

Table 1. Anchors and descriptions of internal state ratings and food perceptual ratings. Note that all scales were continuous with ratings possible anywhere along a horizontal or vertical VAS.

Internal state ratings		
<i>Label</i>	<i>Question</i>	<i>Anchors</i>
Hunger	How hungry do you feel?	not at all hungry, extremely hungry
Thirst	How thirsty do you feel?	not at all thirsty, extremely thirsty
Fullness	How full do you feel?	not full at all, extremely full
Potential to eat	How much do you think you could eat right now?	extremely large amount, not another bite
Desire to eat	How much do you want to eat right now?	not at all, extremely
Food perceptual ratings		
<i>Label</i>	<i>Question</i>	<i>Anchors</i>
Liking	Labeled Hedonic Scale (Lim et al. 2009)	see reference
Familiarity	How familiar is this food?	extremely unfamiliar, extremely familiar
Expected satiation	How filling do you expect this food portion to be?	not filling at all, extremely filling
Frequency of consumption	How often do you eat this food?	<1 per month, 2-3 per month, 1-2 per week, 3-4 per week, 5+ per week
Healthiness	How healthy is this food?	extremely unhealthy, extremely healthy
Estimated energy content	How many calories are in this portion?	0, 60, 120, 180, 240
Energy density	How energy-dense is this food?	extremely low, extremely high

385 *Table 2.* Food item list for each macronutrient category, with items of the selected picture set
 386 presented in the upper section and unselected items in the lower section.

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Carb	Fat	Combo
Bagel	American cheese	Banana nut bread
Baked beans	Babybel cheese wheels	Cheese and crackers
Dried apricots	Blue cheese	Chocolate covered pretzels
Froot loops	Breakfast sausage	Chocolate raisins
Frosted flakes	Brie cheese	Doritos
Fruit snacks	Colby jack cheese	Guacamole
Gummy bears	Deviled eggs	Mini nutter butters
Jelly beans	Hardboiled eggs	Mini chocolate chip cookies
Lucky charms	Pepperoni	Pizza rolls
Pineapple rings	String cheese	Peanut butter crackers
Pretzels	Summer sausage	Pringles
Sorbet	Swiss cheese	Roasted red pepper hummus
Life savers	Castelvetrano olives	Apple pie
Lollipops	Kalamata olives	Blueberry muffin
Marshmallows	Smoked salmon (lox)	Croissant
Raisins	Stuffed pimienta olives	Donuts
Rice cakes	Vienna sausage	Donut holes
Sour gummy worms		French fries
Strawberry licorice		Ice cream
		Mini oreos
		Pizza
		Popcorn chicken
		Ramen noodles
		Snickers

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389 *Table 3. Descriptive statistics and one-way ANOVAs on food characteristics of images across*
390 *macronutrient categories*
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Food characteristics	Carb	Fat	Combo	Category difference
	Mean $\pm$ SEM, <i>Range</i>	Mean $\pm$ SEM, <i>Range</i>	Mean $\pm$ SEM, <i>Range</i>	
Carb (g/120 kcal)	28.33 $\pm$ 0.94, 23.83-31.81	0.98 $\pm$ 0.20, 0.16-2.26	15.36 $\pm$ 0.83, 10.46-20.96	F(2,33) = 349.41, $p \leq .001^*$
Fat (g/120 kcal)	0.47 $\pm$ 0.13, 0.02-1.19	9.72 $\pm$ 0.29, 8.01-11.01	5.96 $\pm$ 0.43, 4.54-9.55	F(2,33) = 225.72, $p \leq .001^*$
Protein (g/120 kcal)	2.01 $\pm$ 0.58, 0-6.58	6.93 $\pm$ 0.53, 4.17-9.77	2.21 $\pm$ 0.35, 0.73-4.97	F(2,33) = 31.72, $p \leq .001^*$
Sodium (mg/120 kcal)	142.69 $\pm$ 50.46, 1.36-558.44	291.33 $\pm$ 34.46, 97.06-523.94	188.82 $\pm$ 39.65, 10.81-535.38	F(2,33) = 3.27, $p = .051$
Water (g/120 kcal)	27.21 $\pm$ 12.18, 0.81-121.72	20.98 $\pm$ 4.66, 6.79-57.94	17.87 $\pm$ 9.13, 0.57-108.38	F(2,33) = 0.27, $p = .770$
Energy density (kcal/g)	2.81 $\pm$ 0.35, 0.78-4.08	3.37 $\pm$ 0.28, 1.55-5.04	3.83 $\pm$ 0.42, 0.89-5.13	F(2,33) = 2.04, $p = .146$
Portion size (g/120 kcal)	58.72 $\pm$ 12.43, 29.39-154.09	39.77 $\pm$ 4.80, 23.79-77.65	41.54 $\pm$ 9.36, 23.41-134.43	F(2,33) = 1.24, $p = .303$
Volume (cm ³)	88.38 $\pm$ 16.64, 25.50-187.50	53.77 $\pm$ 7.57, 30.06-120.90	57.20 $\pm$ 8.83, 30.60-137.40	F(2,33) = 2.65, $p = .086$
Price (\$/120 kcal)	0.55 $\pm$ 0.03, 0.22-1.23	0.65 $\pm$ 0.02, 0.25-1.03	0.59 $\pm$ 0.05, 0.18-2.13	F(2,33) = 0.190, $p = .827$

392

Table 4. Descriptive statistics and one-way ANOVAs on visual properties of images across macronutrient categories

Visual properties	Carb	Fat	Combo	Category difference
	Mean $\pm$ SEM, <i>Range</i>	Mean $\pm$ SEM, <i>Range</i>	Mean $\pm$ SEM, <i>Range</i>	
Visual area of food (cm ²)	65.54 $\pm$ 8.41, <i>31.98-108.72</i>	42.21 $\pm$ 5.06, <i>22.4-84.05</i>	49.18 $\pm$ 6.79, <i>27.66-99.49</i>	F(2,33) = 3.021, p = .062
Red	0.34 $\pm$ 0.00, <i>0.34-0.35</i>	0.34 $\pm$ 0.00, <i>0.34-0.35</i>	0.34 $\pm$ 0.00, <i>0.34-0.36</i>	F(2,33) = 1.97, p = .156
Green	0.34 $\pm$ 0.00, <i>0.33-0.34</i>	0.34 $\pm$ 0.00, <i>0.33-0.34</i>	0.34 $\pm$ 0.00, <i>0.33-0.34</i>	F(2,33) = 0.36, p = .698
Blue	0.32 $\pm$ 0.00, <i>0.31-0.33</i>	0.33 $\pm$ 0.00, <i>0.32-0.33</i>	0.32 $\pm$ 0.00, <i>0.31-0.33</i>	F(2,33) = 2.57, p = .092
Brightness	65.25 $\pm$ 1.61, <i>55.67-76.20</i>	63.43 $\pm$ 1.38, <i>58.32-71.02</i>	69.94 $\pm$ 2.59, <i>61.12-87.04</i>	F(2,33) = 3.02, p = .063
Within-object contrast	27.96 $\pm$ 1.57, <i>19.74-40.60</i>	23.04 $\pm$ 1.38, <i>18.93-35.59</i>	27.69 $\pm$ 1.17, <i>20.76-34.30</i>	F(2, 33) = 4.00, p = .028*
Spatial frequency	14.64 $\pm$ 0.20, <i>13.41-15.55</i>	14.66 $\pm$ 0.18, <i>15.48-17.19</i>	14.98 $\pm$ 0.10, <i>14.53-15.53</i>	F(2,33) = 1.35, p = .274
Complexity	0.02 $\pm$ 0.00, <i>0.01-0.04</i>	0.02 $\pm$ 0.00, <i>0.01-0.03</i>	0.02 $\pm$ 0.00, <i>0.01-0.04</i>	F(2,33) = 2.43, p = .104

397 *Table 5. Descriptive statistics and one-way ANOVAs on perceptual ratings of images across*
398 *macronutrient categories*
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Perceptual ratings	Carb	Fat	Combo	Category difference
	Mean $\pm$ SEM, <i>Range</i>	Mean $\pm$ SEM, <i>Range</i>	Mean $\pm$ SEM, <i>Range</i>	
Liking	0.58 $\pm$ 0.02, 0.50-0.67	0.58 $\pm$ 0.01, 0.51-0.64	0.62 $\pm$ 0.02, 0.53-0.77	F(2,33) = 2.54, p = .094
Familiarity	0.81 $\pm$ 0.02, 0.66-0.91	0.75 $\pm$ 0.03, 0.52-0.88	0.79 $\pm$ 0.02, 0.69-0.89	F(2,33) = 1.73, p = .193
Frequency (days/week)	2.47 $\pm$ 0.41, 0.67-6.15	2.83 $\pm$ 0.41, 0.84-6.65	2.33 $\pm$ 0.45, 0.74-6.09	F(2,33) = .38, p = .689
Healthiness	0.38 $\pm$ 0.06, 0.11-0.71	0.49 $\pm$ 0.04, 0.29-0.76	0.37 $\pm$ 0.05, 0.18-0.71	F(2,33) = 1.75, p = .189
Expected satiation	0.46 $\pm$ 0.05, 0.22-0.76	0.38 $\pm$ 0.03, 0.26-0.53	0.36 $\pm$ 0.03, 0.21-0.56	F(2,33) = 2.28, p = .118
Estimated energy content(kcal)	137.62 $\pm$ 7.28, 103.04-183.96	127.54 $\pm$ 4.66, 113.07-160.31	128.52 $\pm$ 4.96, 105.08-160.37	F(2,33) = 0.93, p = .403
Estimated energy density	0.50 $\pm$ 0.02, 0.41-0.64	0.61 $\pm$ 0.01, 0.54-0.70	0.54 $\pm$ 0.02, 0.43-0.67	F(2,33) = 7.54, p < .01*

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Table 6. Pearson r correlations and p-values of all subjective ratings with participant characteristics

Participant characteristics	Liking		Familiarity		Expected satiation		Frequency		Healthiness		Estimated energy content		Estimated energy density	
	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
BMI	.228	.078	-.159	.221	.018	.892	-.108	.406	.015	.908	.013	.918	.006	.965
Body fat %	.01	.942	.106	.418	.04	.759	-.272	.034	-.155	.232	-.018	.888	-.211	.102
Age	.024	.857	.385	.026	-.162	.212	-.228	.077	-.032	.807	-.079	.543	-.209	.105
Hunger score	.129	.324	-.028	.83	.042	.749	.128	.327	.233	.071	.035	.788	.216	.094
DFS	.29	.023	.017	.895	.095	.465	.473	<.001	.235	.068	-.065	.62	.311	.015
Restraint	.277	.031	-.057	.66	.184	.156	.249	.053	-.139	.285	.047	.717	-.004	.977
Emotional eating	0.13	.318	.007	.96	-.028	.828	.193	.136	.04	.758	-.195	.131	.013	.922
External eating	.378	.003	.192	.138	.047	.72	.071	.588	-.149	.25	-.121	.351	.175	.177

Table 7. Summary of food characteristics, visual properties, and perceptual ratings that were similar ($p > 0.1$), trending to be different ($0.05 \geq p \leq 0.1$), or different ($p < 0.05$) among the three macronutrient categories (carb, fat, combo) according to between-category ANOVA comparisons.

	Similar	Trending	Different
1. Food characteristics	Water Energy density Portion size Price	Sodium <i>Volume</i>	Carb* Fat* <i>Protein</i>
2. Visual properties	Red Green Spatial frequency Complexity	<i>Visual area</i> Blue Brightness	Within-object contrast
3. Perceptual ratings	Familiarity Frequency Healthiness Expected satiation Estimated energy content	<i>Liking</i>	Estimated energy density

Italicized variables highlighted in yellow are suggested for inclusion as covariates in analyses that emerge from use with MacroPics. *Note that carb and fat content of the categories differed by design.

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