

Unwrapped:

Readiness-to-eat in food images affects cravings

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Abstract

Studies investigating the cognitive, behavioural, and/or neurophysiological responses to food images have commonly observed stronger effects for palatable high calorie than low calorie foods. This has been attributed to the higher incentive value of high calorie foods which in turn triggers cravings and thus affects consumption. Yet, food cravings are not solely determined by intrinsic food properties, such as calorie contents, but also depend on extrinsic factors, such as the physical availability of food items. Here we argue that in many studies the images employed to represent high and low-calorie foods often also differ systematically in their depicted readiness-to-eat (i.e., amount of preparation required before consumption) - with low calorie images more frequently showing food in an unprepared state. Thus, we aimed to assess if readiness-to-eat in food images affects self-reported cravings; and therefore, potentially amplifies response differences between food categories unmatched in this aspect. Participants (N=224) rated images of food matched in calorie density either shown in a ready-to-eat state and or in a state requiring some further preparation (cooking, unpacking or peeling, slicing). Readiness-to-eat reliably affected participants' cravings with higher cravings for ready-to-eat foods. Furthermore, a linear regression model revealed that the size of the effect was linked to participants' current hunger levels. Based on these findings, we recommend that future studies interested in comparing the effects of certain intrinsic food properties on cravings, should ensure that stimuli are matched for their readiness-to-eat to avoid confounding effects. Practical implications on food advertising and promotion are also discussed.

Keywords: food accessibility, high and low calorie, impulsivity, preparedness of food, hunger, stimulus selection

1. Introduction

Food is an essential requirement for all living beings as there is an evolutionary need for energy replenishment. However, the prevalence of obesity in humans worldwide – especially in Western countries – suggests an imbalance between energy needs and energy consumption. Indeed, more than 20 years ago, the World Health Organisation described the rise in obesity levels worldwide as an “epidemic” (WHO, 2000), and since then the prevalence of obesity worldwide has continued to rise steadily (Abarca-Gómez et al., 2017; Chooi et al., 2019). Obesity is known to significantly increase the risk for a range of diseases, including cardiovascular diseases, metabolic diseases, and certain types of cancer (see Pi-Sunyer, 2009). It also has been linked to a higher risk of mortality in certain viral infections, including COVID-19 (e.g., Caussy et al., 2020; Simonnet et al., 2020). Thus, obesity constitutes a considerable public health risk, and the consequent need to tackle the obesity issue has sparked a plethora of research investigating factors that may be contributing to the overconsumption of food, particularly of high-calorie, low-nutrient, and energy-dense food.

For example, many studies have focused on examining the differential neurophysiological (e.g., Siep et al., 2009; Stoeckel et al., 2008) and behavioural (e.g., Meule & Kübler, 2014; Meule & Platte, 2016) responses evoked by the calorie content of food images. Neurophysiological investigations suggest that even the mere sight of high-calorie and highly palatable food items elicits a stronger reward response which in turn triggers cravings (Beaver et al., 2006; for review see, Volkow et al., 2011) and is likely to promote a behavioural approach response (Davis et al., 2007). In fact, behavioural studies have consistently found that human participants display a variety of implicit cognitive biases, such as attentional biases, towards images of high-calorie food items (e.g., Meule & Platte, 2016). While approach biases towards food in general have been consistently reported (e.g., Brignell et al., 2009; Knight et al., 2020), the question of whether or not these approach biases are also moderated by calorie contents is less clear-cut (e.g., Kahveci et al., 2020; Kahveci et al., 2021). Importantly, both neurophysiological and behavioural responses to high-calorie foods seem to be mediated by a number of factors, including participants’ physiological state such as their current level of hunger (e.g., Siep et al., 2009), their body mass index (e.g., Stoeckel et al., 2008), and interindividual differences in behavioural inhibition (e.g., Meule & Kübler, 2014).

In particular, the link between behavioural inhibition and food cravings/intake of high-calorie foods has been extensively examined via explorations of the effect of trait impulsivity (for review see, van den Akker et al., 2014). Typically, increased consumption of highly palatable

foods is believed to occur when an individual's sensitivity to food rewards exceeds their ability to inhibit their behaviours regarding the reward stimuli (Appelhans et al., 2011). Consequently, impulsivity, as characterised by both a lack of inhibitory control (Logan et al., 1997) and increased sensitivity to reward (Dawe et al., 2004), has been identified as an important trait when studying the preferences and biases towards certain types of food. For example, to date, there is evidence that higher levels of impulsivity link to increased food intake (e.g., Guerrieri et al., 2007; Guerrieri et al., 2008), unhealthy food choices (e.g., Jasinska et al., 2012; Kakoschke et al., 2015), higher BMI (e.g., Franken & Muris, 2005), and increased attentional and approach biases towards external food cues (e.g., Brignell et al., 2009; Hou et al., 2011; Kakoschke et al., 2017). Though it should be noted that findings are not always consistent, and studies are primarily based on university student samples, or clinically overweight or obese samples (for review see, Maxwell et al., 2020).

However, food cravings, biases, and intake have not only been found to be moderated by certain individual characteristics (such as impulsivity, hunger levels, food craving tendencies, BMI etc.) but also by a number of external characteristics of the stimuli presented. For example, the colour of food and food images considerably affects our responses towards food (for review see, Spence, 2019) and a recent study has revealed that attentional biases towards food are absent if images are grey-scaled rather than coloured (Del Gatto et al., 2021). Furthermore, in addition to calorie density, food availability seems to affect not only palatability ratings but also the strength of the neurophysiological reward response (Blechert et al., 2016). Food availability in this study was varied by giving participants access to certain foods presented in the study either during or after the experiment. Based on their findings, Blechert and colleagues (2016) argued for a general need to control for food availability when conducting neuroscientific eating research. Other studies have varied food availability by changing the physical distance between individuals and the food available and observed that food consumption decreased as the distance was increased (e.g., Maas et al., 2012; Musher-Eizenman et al., 2010). Interestingly, in the study by Maas and colleagues, participants reported an increase in the perceived effort involved in obtaining the food with larger distances but no effects of distance on their cravings.

Combining the above observations – that both physical availability and perceived effort of consumption affect participants' responses and their behaviour towards food – has potentially important implications on stimulus selection, which may go well beyond the suggestion of merely controlling for the physical availability of food during food studies as proposed by

Blechert and colleagues (2016). While the studies discussed above defined availability in terms of how easily participants could physically get access to the food during the experiment, one could argue that different foods also require varying amounts of effort to become fit for consumption. For example, food images commonly used in eating studies range from berries, grapes, chocolates, biscuits, crisps, nuts, and sandwiches - that are all ready-to-eat - to images of often raw, uncut and/or unpeeled fruit and vegetables or even uncooked meats such as chicken breasts and steaks – that all clearly require some preparation prior to being consumable (see food-pic database by Blechert et al., 2014; and foodcast research image database by Foroni et al., 2013 for examples).

To the best of our knowledge, no study to date has directly tested if and how the effort involved in preparing food for consumption affects participants' cravings, behavioural, and/or neurophysiological responses. Yet, some tentative support for the idea that this may matter comes from a study by Bailey (2015) which found that participants rated unpackaged food higher on a “wanting to eat” scale than comparable food that was packaged suggesting that the readiness-to-eat may indeed affect participants' cravings. Furthermore, Hummel et al. (2017) found that participants showed an increased attentional bias for prepared (i.e., cut up and ready-to-eat) low-calorie foods as compared to unprepared low-calorie foods. Unfortunately, this study did not include a similar distinction for high-calorie food. The authors justify this omission by arguing that while there is a high prevalence of using unprepared low-calorie food pictures in food advertisement (e.g., fruits and vegetables), the same is rarely done for high-calorie foods. Furthermore, they claim that it is in fact “quite difficult to find” (p.113) unprepared high-calorie foods. If their claim was true, this highlights a potential confound in previous studies comparing responses to high and low-calorie food images because accessibility or readiness-to-eat may generally be higher for images of high-calorie foods as compared to low-calorie foods. Consequently, differences in the involved effort of required preparation between the two food groups may, at least partly, be contributing to the observed difference in cravings or biases.

To further explore this argument, we carefully reviewed a number of recent food studies investigating the differential effects of calorie content on participants' neurophysiological responses and behaviour, and that provided complete information about the stimuli sets employed (e.g., Blechert et al., 2016; Georgii et al., 2017; Hofmann et al., 2015) – unfortunately not a common feature in many published food studies. A closer examination of those studies revealed that stimuli in the high-calorie food category were almost always presented in a ready-

to-eat manner (e.g., crisps, cookies, chocolates, nuts, muffins, burgers) whereas the low-calorie food category commonly included at least some items that would require further preparation before eating (e.g., raw bunch of celery, raw heads of broccoli, cauliflower and lettuce, unpeeled bananas, oranges, whole pineapples, peppers, and chillies). Given that, a vast number of food studies are aimed at investigating differences in behavioural and neurophysiological responses depending on calorie contents, the possibility that systematic differences between the amount of preparation required to make the food fit for consumption in high and low-calorie images may confound those findings seems concerning.

Consequently, we designed our study to test if and how strongly the readiness-to-eat of food items (as defined by the effort required to prepare the food for consumption) affects participants' self-reported cravings of this food independent of calorie density of the displayed food items. Based on a review of the previous literature and the stimuli commonly employed in food studies, we identified three different categories of readiness-to-eat: cooked vs. raw, peeled/unpackaged vs. unpeeled/packaged, and sliced vs. whole. Stimuli were mostly selected from the *food-pics(_extended)* database (Blechert et al., 2019; Blechert et al., 2014) which is one of the most commonly used database for food studies (at the of writing the image bank has been cited almost 600 times in scientific publications) and which already provides versions of the same food in different states (see section 2.2 for more information). We tested a sample of female omnivorous eaters as existing research suggests that food cravings, attention, and eating attitudes and habits strongly vary with gender (e.g., Beardsworth et al., 2002; Love & Sulikowski, 2018; Weingarten & Elston, 1991) – and hence studies often employ all-female samples (e.g., Knight et al., 2020; Maas et al., 2012; Tetley et al., 2010). We predicted that participants would report higher cravings for images of foods that are ready-to-eat meaning no further preparation is required prior to consumption. As food cravings have been observed to vary with current hunger levels, general food craving tendencies as well as trait impulsivity, we also assessed those characteristics using self-report (questionnaire) measures. This allowed us to test if these factors predict the preference for ready-to-eat food items. In particular, we expected that lower inhibitory control and higher susceptibility to food rewards due to higher trait impulsivity may predict a stronger preference of ready-to-eat food items.

2. Methods

2.1. Participants

The study was advertised via social media and the internal participant recruitment schemes (SONA) at the University of Aberdeen and the University of Sunderland. Students recruited via SONA received course-credits for their participation. Recruitment messages specified that to be eligible, participants had to be female, older than 16 years, and following an omnivorous diet. Participants with dietary restrictions were excluded as the stimuli in our study contained images of meat and fish and vegetarian eaters have been found to show reduced explicit cravings for non-vegetarian food (e.g., Bleichert et al., 2014; Knight et al., 2020).

A total of 288 participants completed the online survey. Eligibility criteria were checked at the start of the study. Based on this eligibility check, 23 participants needed to be excluded (10 participants reported to be male and 13 participants reported to follow some kind of special diet such as vegan, vegetarian, or pescatarian diets). We also asked participants to report their current body height and weight to calculate BMI. Based on this data, we excluded another 40 participants (15 with a BMI <18.5 classifying them as underweight, and 12 with a BMI > 40 classifying them as severely obese, and 13 where we were unable to calculate BMI as they did not provide information on either body weight or height). Underweight and severely obese participants were excluded from analyses as these individuals likely have additional factors or comorbidities influencing the craving of food (e.g., illnesses such as diabetes or thyroid issues or eating disorders) which is outside the scope of this study. Finally, preliminary data checks (see data analysis section) resulted in the exclusion of one additional participant, who answered all questionnaire data with a value of 1. Thus, all data analysis is based on a final sample size of N=224 participants who were aged between 16 to 66 years (mean age: 28.0 years, SD: 11 years). The average BMI of the sample was 26.0. Half of this sample (N=112, 49.8%) had a healthy BMI (between 18.5 and 24.9, mean BMI=22.0±0.2) in accordance with World Health Organisation guidelines (WHO, 2000) while the other half fell within the overweight (N=64, 28.6%, average BMI=27.0±0.2) and obese (N=48, 21.4%, average BMI=33.8±0.4) categories. This is relatively representative of the UK population, with the Health Survey England 2019 reporting 64% of all adults in England as overweight or obese (average adult BMI of 27.6) and the Scottish Health survey 2019 reporting 66% of adults to fall within the overweight or obese BMI range.

All participants were naïve to the purpose of the study and provided written informed consent before the start of the survey which took about 15 minutes to complete. The experimental

procedures and protocol were in accordance with the Ethics Code of the British Psychological Society and the declaration of Helsinki. The study was reviewed and approved by the School of Psychology Ethics Committee at the University of Aberdeen (PEC/4552/2020/10).

2.2. Stimuli, Materials, and Procedure

The overall aim of our stimulus selection was to select pairs of stimuli that were well matched in the type of food they displayed and thus in their calorie-density (i.e., kcal per 100g) but varied in their readiness-to-eat. Ready-to-eat food pictures were defined as images of foods that would be instantly edible in their presented state while food items defined as unprepared would commonly require some further effort/action before being ready to be consumed. Readiness-to-eat of the depicted food images was varied within three different categories: raw vs. cooked food (N=10 image pairs); packaged/unpeeled vs. unpackaged/peeled food (N=10 image pairs), and whole vs. sliced food (N=10 image pairs; see Figure 1 for examples and Supplementary Material for a full summary). To ensure high comparability to stimuli commonly used in food studies, we selected all but three images from the *food-pics_extended* database (Blechert et al., 2019; Blechert et al., 2014) – a commonly used database for experimental food studies. The remaining three images (i.e., cooked pasta, unpeeled prawn, and peeled banana) were sourced from publicly available image banks and edited to match the formatting of the images from the *food-pics* database.

	Cooking		Packaging/ Peeling		Slicing	
	kcal/100g	kcal total	kcal/100g	kcal total	kcal/100g	kcal total
Ready-to-eat	115 (18)	197 (44)	348 (77)	282 (104)	153 (47)	369 (184)
Preparation required	118 (32)	437 (161)	340 (77)	420 (165)	156 (50)	841 (292)

Table 1: Average calorie density and total number of calories displayed for the stimulus pictures (SD in parentheses) used in the three different preparation type categories (N=10 pictures in each cell). Note that stimulus pairs (i.e., ready-to-eat and preparation required items) were well matched in their calorie density.

Table 1 shows the average calorie density (kcal/100g) and total amount of calories shown in the images for the ready-to-eat and preparation required foods in all three categories. A paired-samples t-test confirmed that calorie density was similar for ready-to-eat and preparation-required stimuli, $t(29)=0.93$ $p=.93$. However, stimuli varied in their total calorie contents

displayed, $t(29)=2.52, p=.018$. On average, unprepared food items had a higher overall calorie content (566 ± 125 kcal) than ready-to-eat images (283 ± 71 kcal). This is to be expected as ready-to-eat images usually showed single portion sizes (e.g., slice of lasagne or a few slices of cheese or bread) while the unprepared counterpart depicted the complete food item (e.g., tray of lasagne, a block of cheese, and a loaf of bread).

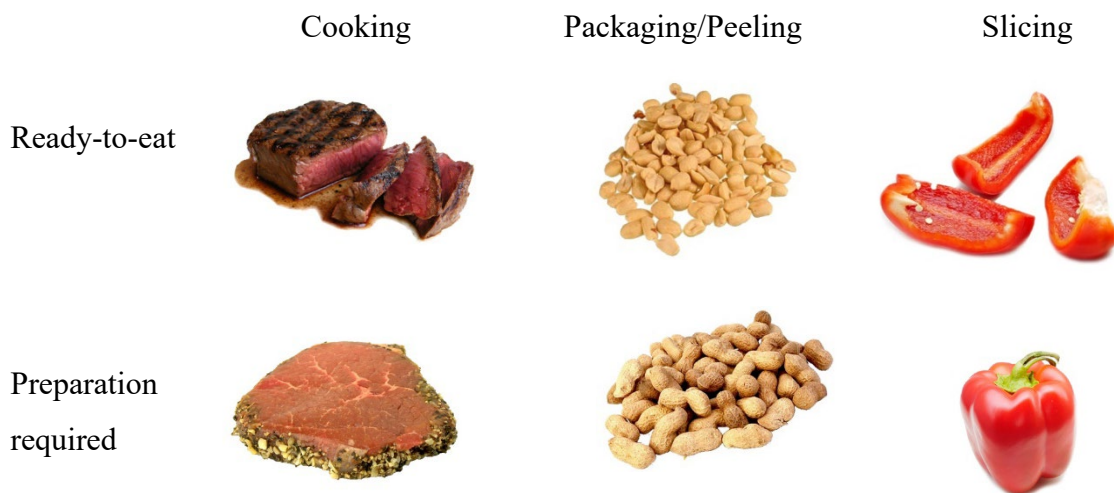


Figure 1: Stimuli: Example of stimuli varying in their readiness-to-eat for each of the three different preparation type categories. For a complete list see Supplementary Material (Section A) to this article.

The study was built using the Testable software (Rezlescu et al., 2020) and run online via www.testable.org. Participants were required to use a laptop or desktop computer to complete the study (i.e., the study could not be completed using hand-held mobile devices such as phones and tablets). Before the start of the study, participants were asked to calibrate their screens to ensure similar presentation sizes of images across different screens and reminded to wear their glasses in case they needed to.

First, participants were asked several demographic questions (i.e., age, gender, diet, body weight and body height) and to rate their current state of hunger and appetite using four questions (as suggested by Friedman et al., 1999) - each rated on a 9-point Likert scale (minimum score of 4 and maximum score of 36). Subsequently, they were asked to rate how much they craved each of the 60 different food items on a 0 to 100-point slider scale: “How much do you crave this food? (0=not at all; 100 = extremely)”. All food images were presented

once, and one at the time, in random order centrally on a grey background. Beneath the food picture was the slider scale that participants needed to click on and adjust before being able to move on to the next trial.

After completion of the rating task, participants were asked to fill in further questionnaires assessing their general food cravings as well as impulsivity: The reduced Food Craving Questionnaire-Trait (FCQ-T-r) consisting of 15 items, each rated on a 6-point Likert scale (Meule et al., 2014), was used to assess food craving tendencies (internal consistency for female sample: Cronbach's $\alpha=.95$). The total craving score is obtained by adding the values across all 15 statements (i.e., minimum score of 15 and maximum of 90). The Barrat Impulsiveness Scale (BIS-11) consisting of 30 items rated on a 4-point Likert scale (Patton et al., 1995) was used to assess the strength of impulsive preferences and behaviours (internal consistency: Cronbach's $\alpha=.83$). The total score is calculated by summing values across all statements (taking into account reverse coded items), with a minimum score of 30 and a maximum score of 120. Higher scores on both scales reflect higher food craving tendencies and impulsivity traits respectively.

2.3. Data processing and analysis

Demographic data were screened to ensure compliance with our pre-defined eligibility criteria and participants were excluded if those criteria were not met. Furthermore, we excluded participants whose BMI fell in the underweight or severely obese categories as those may be indicative of underlying illnesses and health issues that may affect food cravings. We further screened the data for potential outliers using boxplots resulting in only one data set being removed from analysis (see participants section for number of all exclusions).

Craving values were determined as the mean craving for each readiness-to-eat and image category for each participant (i.e., average of 10 ratings). This data was analysed using a 2 (ready-to-eat: yes/no) x 3 (preparation type category: cooking, packaging, slicing) repeated measures ANOVA using Greenhouse-Geisser corrections where applicable (Greenhouse & Geisser, 1959). Significant main effects were followed up with paired-samples t-tests and were Bonferroni corrected for multiple testing where applicable. To explore if and how preferences for ready-to-eat food were affected by trait impulsivity, hunger levels, and food craving tendencies, we calculated the *difference value* between the average craving score for ready-to-eat food minus the average craving for food images requiring further preparation for every participant. Thus, a positive difference value indicates a higher average craving for more

instantly edible food and a negative difference value a higher craving for food items needing further preparation. We employed a multiple linear regression model to determine if trait impulsivity, hunger levels, and/or craving scores predicted the magnitude of the preference for instantly edible food items.

Data processing was performed in Matlab (version R2018a) and statistical analysis in IBM SPSS Statistics 27. Values are presented as means \pm 1 standard error of the mean (between subjects). A significance level of $\alpha = 0.05$ was used for all statistical analyses.

3. Results

The primary aim of our study was to determine whether the readiness-to-eat of food items affects the level of craving. Figure 2A shows the mean food craving values averaged across all participants for ready-to-eat food items and food items requiring further preparation separately for all three image categories¹.

The repeated-measures ANOVA on this data revealed a significant main effect of readiness-to-eat, $F(1, 223) = 197.67, p < .001, \eta_p^2 = .47$ (see Figure 2B) as well as a significant main effect of preparation type category, $F(2, 446) = 9.55, \epsilon = .88, p < .001, \eta_p^2 = .041$. There was also a significant interaction between the two factors, $F(2, 446) = 95.05, \epsilon = .88, p < .001, \eta_p^2 = .30$. Post-hoc paired samples tests conducted separately for each of the three preparation type categories confirmed that the effect of readiness-to-eat was statistically significant in each of the preparation type categories (all $p < .001$). As shown in Figure 2A, the effect was largest for the cooked vs. raw variation ($M_{\text{diff}} = 11.0 \pm 0.8, t(223) = 14.5, p < .001$), somewhat smaller for the unpackaged/peeled vs. packaged/unpeeled category ($M_{\text{diff}} = 3.8 \pm 0.5, t(223) = 8.26, p < .001$), and smallest, but still statistically reliable, for the sliced vs. whole category ($M_{\text{diff}} = 1.5 \pm 0.4, t(223) = 3.5, p < .001$). Thus, all our variations of readiness-to-eat reliably affected participants' reported cravings of food items.

One further aspect to consider regarding our selected stimuli is that four out of 10 items in our packaging/peeling category included branded stimuli (preparation required items) which may have potentially impacted our results. Product branding has been found to affect the cortical processing of food stimuli (Bruce et al., 2014; Plassmann et al., 2012) which may in turn alter the experienced food cravings. Similarly, in consumers research, food branding has been linked

¹ Note that findings remain identical when BMI category (normal weight, overweight, obese) was included as a between subject factor in the analysis (i.e., no main effect of BMI category as well as no interactions with any of the within-subject variations). Please refer to the Supplementary Material (section B) for the full analysis.

to purchase intentions and external food cue responsiveness which are again assumed to also impact food cravings (Pollack et al., 2022; Wang, 2010). Note that, if this was the case, higher craving values should be expected for the packaged items than the unpackaged ones (contrasting our hypothesis that unpackaged stimuli should obtain higher craving ratings). To test for this, we run a post-hoc analysis, comparing the average craving ratings of the four branded and non-branded stimuli within the packaging category. A paired-samples t-test on this data confirmed that **even** for this subset of stimuli reported cravings were still higher for the unpackaged/non-branded items than for the packaged and branded items, $M_{diff}=2.6 \pm 0.7$, $t(223)=3.76$, $p<.001$.

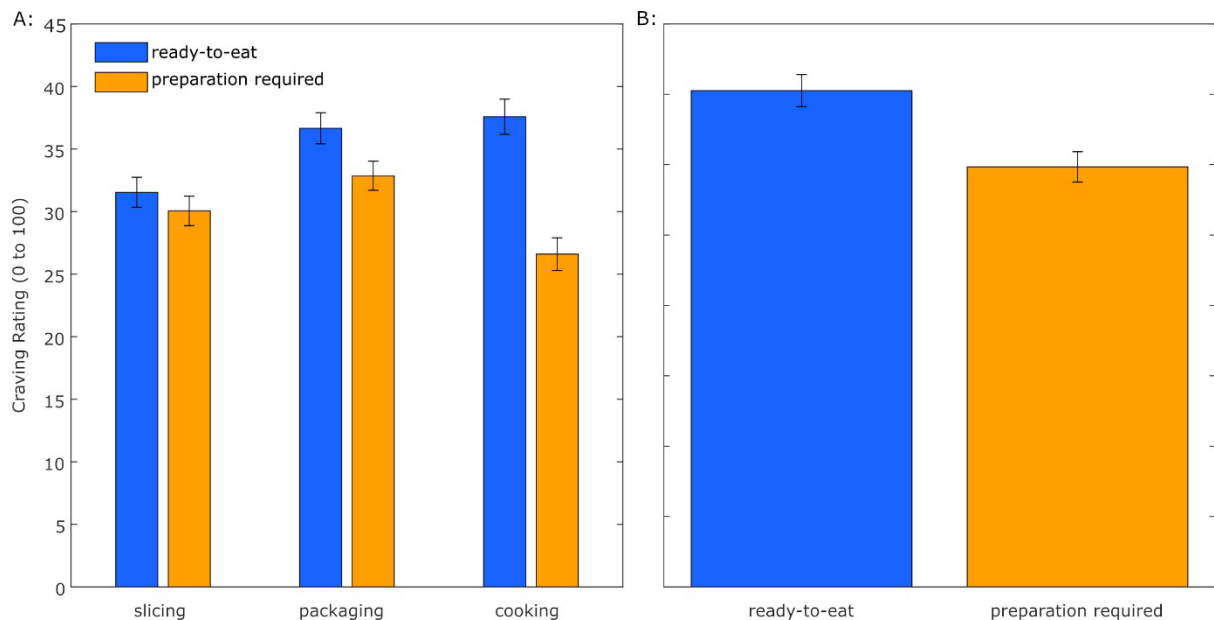


Figure 2: Craving Ratings: A: Craving values for ready-to-eat food items and food items requiring further preparation separately for all three preparation type categories. B: Craving values for ready-to-eat food items and food items requiring further preparation averaged across all preparation type categories. Error bars depict ± 1 SEM (between subjects).

Finally, we further wanted to explore if the increase in reported cravings for ready-to-eat food items is predicted by trait impulsivity (determined by the BIS-11), current level of hunger (state measure), and/or general food craving tendencies (trait measure as determined by the FCQ-T). As previous research suggests potential relationships between trait impulsivity, food craving, and BMI (for a review, see van den Akker et al., 2014), we first determined if any of the collected self-report measures correlated with the BMI in our sample. This analysis confirmed

a significant positive correlation between BMI and food craving tendencies (FCQ-T score), $r(224)=.23$, $p<.001$, but showed no reliable relationships between BMI and trait impulsivity, $r(224)=.09$, $p=.17$, or BMI and current hunger levels, $r(224)= -.007$, $p=.92$.

A multiple linear regression analysis was used to further test whether the increase in craving for ready-to-eat food items (i.e., Craving-Difference score) can be predicted by any of the self-report measures (i.e., BIS-11 scores, hunger scores and FCQ-T scores). Preliminary tests confirmed that there was no evidence of multicollinearity, i.e., there were no substantial correlations between our predictor variables (all $r <.22$), the Variance Inflation Factors (VIF) were well below the cut-off point of 10 (mean VIF: 1.07), and the tolerance statistics well above 0.2 (mean: 0.94). Durbin-Watson statistic indicated that values of the residuals were independent (Durbin-Watson = 1.67), and no cases were biasing our model (all Cook's Distance values under 1, range: 0-0.13). Using the enter method, we found that the three predictor variables explained (only) 5% of the variance in the magnitude of the preference for instantly edible food items which was, however, statistically significant, $F(3,220)=3.48$, $p=.017$, $R^2=.05$. Evaluation of the β coefficients revealed that hunger level was the only significant predictor in the model (standardised β coefficient = .15, $t=2.15$, $p=.033$). That is, participants who reported to be hungrier at the time of testing tended to also report larger craving scores for ready-to-eat food items as compared to food items requiring further preparation.

4. Discussion

The primary aim of this study was to determine if and how the readiness-to-eat of food items in images affects participants' self-reported cravings. We varied the readiness-to-eat in pairs of stimuli displaying comparable food items of identical calorie density showing them either in a ready-to-eat state or in a state requiring some sort of further preparation prior to being ready for consumption. Based on a review of the previous literature, we identified and defined three distinct categories of required preparation: cooking, unpacking/peeling, and slicing of food items. Our results clearly show that the readiness-to-eat of the displayed food reliably affected participants' self-reported cravings of those items with a general reduction in cravings for food requiring further preparation. While this effect was present across all three preparation categories, it was largest for images of food that required cooking prior to being fit for consumption. One could speculate that the larger effect in this category may be due to cooking/frying/baking arguably requiring more effort as well as a longer preparation times than slicing or unpacking food suggesting that the size of the effect may be moderated by the amount

of overall effort involved in preparing the food. Additionally, some of the food items displayed in the raw vs. cooked food category would ideally need both, cooking as well as peeling (raw vs. cooked potatoes) or slicing as well as cooking (raw vs cooked carrots) to be ready-to-eat.

The finding that the effort/time required to prepare food for consumption affects cravings has important implications for food studies investigating and comparing behavioural and neurophysiological responses to different food groups (such as high vs. low-calorie; processed vs. unprocessed; or sweet vs. savoury foods) as it highlights the importance of matching stimuli across these different groups for their readiness-to-eat or state of preparedness. As discussed in detail in our introduction, this particularly seems to be an issue in studies comparing high and low-calorie food items, as the proportion of instantly edible food items tends to be commonly larger in the high-calorie than in the low-calorie conditions with the latter often including images of whole, raw and/or unpeeled vegetables and fruits (e.g., Blechert et al., 2016; Brignell et al., 2009; Georgii et al., 2017; Hofmann et al., 2015). Thus, previously reported differences in behavioural and neurophysiological responses for high and low-calorie food items may have been amplified by alterations in cravings due to differences in their readiness-to-eat in addition to differences in their caloric contents. Please note that we do not intend to argue that there are no differential responses to images of high versus low-calorie food - which have in fact been found reliably across a large number of studies using a variety of different methodologies (e.g., see Hall, 2016, for review). Rather, we would like to raise awareness for a potential confound that may result in the *overestimation* of effects when using food images that are poorly matched in their readiness-to-eat.

Based on our findings, we would like to encourage researchers to look out for this potential confound in future studies, and to carefully control images across food categories for their state of preparedness. This recommendation further substantiates and extends Blechert et al.'s (2016) advice of controlling the physical availability of food in such studies. Furthermore, we believe that this is a reasonable suggestion/request to make as one of the currently most commonly used food image databases (i.e., food-pics by Blechert et al., 2019; Blechert et al., 2014) already includes versions of the same food in different stages of preparedness (e.g., whole cake vs. sliced piece of cake, whole vs. sliced pepper). In fact, apart from a few exceptions (see section 2.2), all the stimuli used in our study were taken from this database showing that readiness-to-eat can easily be controlled for using the available images (also note that some of the packaged stimuli we used, such as the crisp packet and muesli box are actually classified as objects rather than food images within the database). Similarly, the CROCUFID

image database for cross-cultural food images (Toet et al., 2019) contains many images displaying the same food in various stages of preparedness (in particular whole and sliced versions of fruit, vegetables, sausages, breads etc.). Our findings also imply recommendations for any further extensions to the *food-pics* (and other) image databases; that is to ensure any food images chosen for inclusion depict the food in different/matched levels of preparedness. Notably, we came across one food image database that seemed to control images for their readiness-to-eat as suggested here, but unfortunately the database appears no longer to be maintained and accessible for researchers to use (Charbonnier et al., 2016).

Further, we would like to stress the importance of providing sufficient information about stimuli employed in food studies as our findings show that relatively subtle differences may have considerable effects on findings. When we reviewed recent studies investigating the effects of different food types on neurophysiological or behavioural responses to determine how well they generally are matched for their readiness-to-eat, we noticed that many studies did not provide detailed/ crucial information regarding the selection and inclusion of the images chosen. For example, images of food items were often described by naming the food but without providing information about its status in terms of preparation or processing (e.g., Kemps et al., 2014; Meule & Kübler, 2014; Siep et al., 2009; Stoeckel et al., 2008). That is, images of low-calorie food were specified as being a “melon” or “carrot”, without clarifying whether those fruit and vegetables were chopped, peeled, and/or cooked in any way. Other studies only mention the general characteristics of their stimuli (e.g., “palatable high fat food”), without giving any specific examples at all (e.g., Werthmann et al., 2011). Thus, it is impossible to determine if differences in the readiness-to-eat (or other relevant characteristics) may have contributed to the observed results.

Providing (more) detailed information about the stimuli employed is also beneficial on a more general level as it enhances the overall transparency and replicability of the research conducted (Lindsay, 2020). It should also be noted that this potential confound of showing food at varying levels of preparedness or readiness-to-eat is not limited to studies investigating the effect of calorie content on cravings but is likely also an issue in the comparison of other food groups (e.g., investigations of cravings to sweet vs. salty foods, or food of high vs. low nutritional value). Thus, our recommendation to ensure carefully matched images of food extends to all situations in which different food groups are compared.

Finally, we should point out, however, that even though we attempted to match ready-to-eat and preparation-required food items as well as possible ensuring identical calorie density

within our selected image pairs, matches were not always perfect. For example, some of the cooked food items had some small decorations added (e.g., parsley or basil leaves added to cooked salmon, cooked carrots, fried steaks, etc.) that may have contributed to the food looking more appealing and thus also affecting reported cravings. Similarly, whilst we tried to make sure that the same food items were shown in each calorie-density matched stimulus pair, there were some subtle differences in certain pairs such as the block of cheese and full lettuce head depicting slightly different sorts of hard cheese and lettuce than the sliced and prepared counterparts. However, as cravings are commonly assumed to generalise to certain food groups and types such as sweet, savoury, chocolate-based, snack, or whole foods (e.g., Reichenberger et al., 2018; Richard et al., 2017; Rolls, 2005), we believe that those minor differences are unlikely to have had a significant effect on our findings. Furthermore, studies seem to suggest that larger portion sizes (or portions perceptually appearing as larger) result in individuals perceiving food as more appetizing and thus also in increased food cravings (Petit et al., 2018). Hence, the larger portion sizes for our unprepared stimuli would be expected to work against our predictions (i.e., lower cravings for unprepared food items). Nevertheless, with further development and extension of existing food image databases, we would like to encourage the replication of our findings using the exact same food in different stages of preparedness thereby also matching them not only in their calorie density but also in the number of total calories displayed.

We also collected several self-report measures that we expected to potentially affect the preference for instantly edible food items, namely trait impulsivity, current hunger levels, and general food craving tendencies. While the overall regression model using those factors as predictors for the preference score for instantly edible food images was significant, only the current hunger level was identified as a significant predictor within the model. Thus, the hungrier our participants indicated to be at the time of testing, the larger were their differences in craving between ready-to-eat food items and food items requiring further preparation. As most food studies require participants to abstain from eating for several hours prior to testing (i.e., test them on an empty stomach), this suggests that differences in the readiness-to-eat between stimuli may have even larger effects in those studies than observed here. Contrary to our expectations, we did not find that preferences for ready-to-eat foods were predicted by participants' trait impulsivity levels. However, it is worth pointing out that our sample scored relatively low overall on trait impulsivity (mean score of 65, SD=10, with the maximum achievable score in the questionnaire being 120). In a previous study that observed differences

in food intake between high and low impulsivity individuals, the average BIS-score of the low impulsivity group was 59 ± 0.8 while the average score of the high impulsivity group was 74 ± 0.8 (Guerrieri et al., 2007). Thus, there may have been too few individuals with high impulsivity scores in our sample to detect a potential influence.

Last but not least, in addition to the methodological implications of our study for food research in general, our findings also have some practical implications with regard to consumers' research and food advertising. Interestingly, food advertisements for high-calorie, energy-dense, low-nutrient foods often depict foods which are fully prepared – i.e., sliced, cooked and unpeeled/unpackaged – and thus visually appealing for consumers (see Hummel et al., 2017 for a similar argument). For example, advertisements for high-calorie foods such as pizza, burgers, French fries, and cake will depict cooked and ready-to-eat versions of these foods, rather than an image of the packaged or uncooked food. On the other hand, health campaigns aimed at increasing the consumption of nutrient dense foods (such as fruit and vegetables), often depict food as whole items – i.e., unpeeled, whole and/or raw. A simple web-image search of healthy eating campaign posters revealed that food is commonly depicted as full raw heads of broccoli, unpeeled bananas and oranges, or whole apples. Even worse, several of those posters also included pictures of raw lean meats and uncooked chicken and fish. Given that our findings show that food cravings increase with the readiness-to-eat of the depicted items, advertisements and campaigns that aim to encourage the consumption of low-calorie, nutrient-dense, healthy foods should be mindful of this and ensure that the food advertised to consumers is presented in a ready-to-eat fashion. While these observations may be potentially important, we must, however, stress that they currently rely purely on anecdotal evidence. Future research is needed to systematically determine the scale and impact of the issue discussed here. This could potentially also provide an avenue to increase the effectiveness of image-based health campaigns, of which success rates seem currently quite mixed (Abril & Dempsey, 2019).

In conclusion, the readiness-to-eat of foods in images significantly affects self-reported food craving. This finding has wide ranging ramifications for a variety of fields including the investigations of cravings towards different food groups, neurophysiological and behavioural responses to certain food categories, marketing, advertising, and healthy eating campaigns. It also highlights the importance of being detailed and explicit about stimulus choice in eating/food studies to allow for direct comparisons between food categories as well as between different studies by ensuring that all stimuli are matched in their readiness-to-eat.

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