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Assessing the relationship between food-related mental imagery and appetite

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ABSTRACT

Mental imagery (MI) engages neural and cognitive mechanisms that closely parallel those involved in actual perceptual processing, but it remains unknown whether food-related MI shows similar appetite-dependent modulation as food perception. Across two experiments, we examined (i) whether metabolic state alters the strength of food-related MI, and (ii) whether generating repeated food-related MI influences hedonic evaluations of food (i.e. chocolate cookies). In Experiment 1, participants were asked to generate flavour and texture MI using visual cues, in either a hunger or satiated state. MI strength, indexed by vividness, ease, and generation speed, was greater when hungry than sated for flavour MI only. In Experiment 2, liking and wanting for food samples were measured prior to and following 30 trials of flavour- or texture-specific consumption MI. Repeated MI did not alter the hedonic value of the food samples, but imagined liking declined across trials. Findings demonstrate that (1) metabolic state modulates the generation of multisensory MI, and (2) MI itself selectively adjusts imagined, but not perceptual, hedonic responses. The results reveal new findings on the interactions between MI and appetite, offering insight into the functional architecture linking simulation, reward processing, and metabolic state.

1. Introduction

Mental imagery (MI) – the voluntary or involuntary generation of sensory experiences in the absence of external input – constitutes a core mechanism through which future actions, affective states, and motivational tendencies are simulated (Pearson et al., 2015). While visual MI is most extensively researched, MI extends to all senses and, although previously disputed, sensory MI for smell, taste, and touch are also present and experienced by the general population (Andrade et al., 2014; Floridou et al., 2022; Tiggemann & Kemps, 2005). Phrases like "I can picture it" or "I can almost taste it" when speaking of memories or future ideas reflect the commonality and familiarity of sensory MI. For some, MI may be almost as strong as sensory perception; for others it may be just a whisper (Arnold et al., 2025; Schifferstein, 2009; Sulfaro et al., 2024). MI allows the simulation and anticipation of future experiences and has been shown to activate similar regions of the brain as sensory perception (Avery et al., 2021, 2023; Chen et al., 2016). Intriguingly, Belardinelli et al. (2009) found for visual, gustatory, kinaesthetic, tactile, and somatic senses that higher vividness of MI involved greater activation of the respective brain regions active during sensory perception.

Research on food-related MI is limited, but investigation of taste, olfactory, and visual MI has begun to reveal striking similarities between the processes and effects of food perception and food MI, particularly when the latter is vivid (Avery et al., 2023; Krishna et al., 2013; Steel et al., 2006). These, often automatic, internal simulations contain re-enactments of the sensory experience of eating foods, based on previous experiences (Papies et al., 2020). Importantly, this MI carries reward-related information about such food consumption, with concurrent activation of reward processing regions in the brain (Avery et al., 2021; Kavanagh et al., 2005). Currently, food MI research has largely isolated the basic senses including gustation, olfaction, and visual MI.

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Although important for understanding the basic cognitive processes involved, these neglect the crossmodal experiences inherent to consumption, such as flavour and texture. Flavour can be defined as resulting from the multisensory integration of gustation, olfaction, and, when present, trigeminal sensations (Auvray & Spence, 2008; Delwiche, 2004; Spence et al., 2014), while food texture is a similarly multidimensional property encompassing tactile, mechanical, and sometimes auditory or visual perception (Guinard & Mazzucchelli, 1996; Stokes et al., 2013). While flavour receives the greatest consideration for its hedonic properties (Prescott, 2015), texture is typically referenced for its influence on food aversions and modulating the quantity of food intake (Katsikari & Varela, 2026; Stribiţcaia et al., 2020). Targeting research on food-related MI to these multisensory experiences is crucial for developing insight into cognitive and physiological processes that is applicable to real-life behaviour and experiences.

Human eating behaviour unfolds within a richly cue-laden environment. Modern food environments – from digital media to physical food outlets – continuously expose individuals to food-related information (Spence et al., 2016). The sight, flavours and textures of food interact bidirectionally with appetite to play a prominent part in modulating food behaviours, from inducing cravings to influencing intake (Bilman et al., 2017; Katsikari & Varela, 2026). Sensory specific satiety is a powerful example of the interaction between sensory modalities and appetite, with reduced food pleasantness and wanting of specific foods following their repeated consumption (Havermans et al., 2009; Rolls et al., 1981). Sensory specific hedonic reductions extend beyond the consumed food to others with similar qualities including taste, aroma, and texture (Abeywickrema et al., 2022; Guinard & Brun, 1998).

The effect of appetite on food perception has been repeatedly demonstrated. Being hungry has been shown to enhance sensitivity to food cues, notably altering food cue reactivity, attentional bias, and reward appraisal (Field et al., 2016; Mogg et al., 1998; Siep et al., 2009), increasing the drive to seek and consume food (Berridge et al., 2010; Charbonnier et al., 2018; Steel et al., 2006). Substantial increases in brain activity in response to food cues highlight the brain's sensitivity to food, particularly in a hunger state (Siep et al., 2009; Wang et al., 2004). Direct comparisons of food-related perception between hunger and sated states find increased odour sensitivity, taste sensitivity to pleasant tastes, and visual attentional bias towards food cues in hunger (Hanci & Altun, 2016; Piech et al., 2010; Ramaekers et al., 2015). These indicate that a hunger state enhances the rewarding nature of food, particularly for the chemosensory basis of flavour.

While perceptual food cues interact with appetite and modulate physiological responses (Bilman et al., 2017; Schüssler et al., 2012; Smeets et al., 2010), a substantial portion of food-related cognition depends on internal representations. Kavanagh et al.'s (2005) elaborated intrusion theory of desire brought attention to sensory MI as a prominent factor in the development of desire. They highlighted the ability of MI to produce strong affective reactions both through imagery-containing intrusive thoughts and further cognitive elaboration of food procuring or consumption MI. Imagined consumption of a food induces desire for this food, particularly when vivid (Papies et al., 2020; Peng et al., 2025; Tiggemann & Kemps, 2005), with a positive relationship between vividness of flavour MI and craving frequency (Patel et al., 2015). Additionally, work by Kemps and Tiggemann (2007, 2013) display that mutual competition of both olfactory perception and imagery reduce food cravings. Activation of similar brain processes and cognitions as sensory perception by respective sensory MI (Chen et al., 2016; Hossu et al., 2024; Kavanagh et al., 2005) presents a probable pathway for this MI-craving relationship.

Alongside this conceptual relationship between food MI and craving, MI has also been demonstrated to decrease pleasure and wanting for foods following repeated imagined consumption of the same food, or taste quality, an effect resembling sensory-specific satiety (Andersen et al., 2023a; Larson et al., 2014; Missbach et al., 2014; Morewedge et al., 2010). For example, Andersen et al. (2023a) found that repeatedly imagining consumption of M&Ms 30 times decreased expected enjoyment and desire for these foods as compared to three repetitions. Although these studies illustrate the ability for MI to affect food processing and behaviour in a manner that resembles perception, the influence of MI sensory modalities and conditions remains far less well understood. Whether there are discernible differences of the sensory focus of food MI on the appetitive effects of repeated imagery is unknown.

Indeed, the influence of appetite on the generation of food-related MI itself is not yet understood. Previously, the role of hunger in the spontaneous generation of food MI has been exhibited by induction of vivid food-related MI following initiation of physiological mechanisms of hunger (Schmid et al., 2005). General abilities for and use of sensory MI is known to differ across both individuals and sensory modalities (Andrade et al., 2014; Schifferstein, 2009; Schumacher et al., 2019), yet state differences, such as within hunger and satiety, are currently underexplored. Chemosensory interference on MI generation reduces desire for food equally in hunger and satiety states compared to a control, auditory intervention, signifying that food-related MI generation remains in a sated state, instead the quality or content of MI may differ (Stevenson et al., 2023). Steel et al. (2006) observed that the vividness of visual food MI was rated equally between hunger and satiety, however differences in other sensory modalities have not been explored. Whether the dynamic process of appetite modulating food-related perception generalises to internal multisensory representations remains to be seen.

Perception and appetite interact bidirectionally: physiological state shapes how foods are experienced, and sensory engagement with food feeds back to influence motivation and evaluation. Whether similar bidirectional relationships extend to food-related MI remains unknown. In this study, we investigated both sides of this interaction by asking (i) whether metabolic state modulates the strength of food-related MI, and (ii) whether repeatedly generating MI can, in turn, influence liking and wanting of food.

Because eating is inherently multisensory, we focused on MI of flavour and in-mouth texture, two sensory modalities that play central roles in food experience yet exert their influence over different aspects of eating behaviour. Whether their comparative roles in hedonic mechanisms and satiation are reflected in the relationships between multisensory MI and appetite were explored. In Experiment 1, we examined whether hunger and satiety alter the vividness, ease, and speed with which flavour and texture MI are generated, predicting stronger imagery under hunger. As hunger preferentially heightens sensitivity to reward-related food cues, we expected the effect of metabolic state to be larger for flavour MI than for texture MI. In Experiment 2, we addressed the complementary question of whether repeatedly generating flavour- or texture-specific MI alters the pleasantness and wanting of foods.

2. Experiment 1

2.1. Methods

2.1.1. Participants

A total of 64 healthy participants, aged 18 years and above, were recruited from the University of Otago community in 2025. Individuals who lacked the ability to vividly imagine the taste or flavour of food, as predetermined by scoring below 15 (out of 50) on the taste ('flavour') subscale of the Plymouth Sensory Imagery Questionnaire (PSI-Q) (Andrade et al., 2014), were excluded from taking part. The PSI-Q is rated from 0 (no image at all) to 10 (image as clear and vivid as real life), with five items per subscale. Participants were also excluded if they were unable to consume gluten- or dairy-containing foods, or if they adhered to restrictive diets that were incompatible with the study protocol. All eligible participants gave their informed consent prior to the commencement of the study and were offered a $20 voucher upon completion. Ethics approval was obtained from the University of Otago

Human Ethics Committee (Ref. 24/0562, April 2025). This study's design and analysis was pre-registered at OSF 10.17605/OSF.IO/2W6QV.

The minimum sample size was calculated to detect a small to medium effect (Cohen's f = .20) of metabolic state on the strength of food-related MI, with 85% power and a .05 alpha error probability. This effect size has been reported in previous studies on food craving and MI (Steel et al., 2006). This indicated we required a sample of 59 participants, to allow to 10% attrition we required a sample of 64 participants.

2.1.2. Procedure

Prior to in-person sessions, participants completed questionnaires regarding their MI abilities, food behaviours, and demographic information. The PSI-Q was used to measure participants' general MI vividness across seven sub-dimensions, including Vision, Sound, Smell, Taste, Touch, Bodily Sensation, and Emotional Feeling (Andrade et al., 2014). Additionally, five questions formatted identically to the PSI-Q items, specifically targeted MI for the flavour of food. The Food Craving Questionnaire – Trait (reduced version) (FCQ-T-r) assessed participants' tendency for and strength of food cravings (Meule et al., 2014).

Eligible participants were required to complete two in-person sessions to experience both the hunger and satiety conditions. All sessions were held between 8:30am and 11:00am, with sessions separated by a maximum of seven days. The participants were required to fast overnight and minimise their consumption of beverages. The session order was counterbalanced between participants.

Upon arrival at the laboratory, the participants were first asked to confirm their fasting status. Baseline subjective fullness was then measured using the Satiety Labelled Intensity Magnitude Scale (SLIM) (Cardello et al., 2005). The scale ranges from −100 ('greatest imaginable hunger') to +100 ('greatest imaginable fullness').

In the satiety condition, the participants were presented with a standardised selection of common, simple breakfast staples (i.e., toast and spreads, Weetabix, natural muesli, cornflakes, or rice bubbles and dairy milk), and were instructed to eat until they reach a comfortable level of satiation. Following the consumption of the meal, the participants completed the post-meal SLIM rating to confirm the effectiveness of the satiety manipulation. In both sessions, participants completed the General Food Craving Questionnaire – State (G-FCQ-S) (Nijs et al., 2007) which measures momentary food cravings to directly compare between metabolic states.

2.1.3. Mental imagery task

During each session, participants completed both flavour and in-mouth texture imagery in a randomised order. For each MI prompt, the participants were presented with a series of eight distinct snack food pictures selected from a validated stimulus database (Gautier et al., 2019). The foods were chosen to vary across sweet, savoury, healthy and unhealthy dimensions, including apple, dried fruit, celery sticks, nuts, chocolate, donuts, potato chips, and hot chips. Each picture was displayed for 10 s. The order of picture presentation was randomised within the MI Type with the order reversed for the second prompt. During the presentation of each picture, written instructions asked participants to "imagine the [flavour/in-mouth texture] of this food". Participants rated their subjective imagined experience on scales at the end of each stimulus presentation, including vividness (0 - 'Not at all vivid' to 100 - 'As vivid as real life'), ease (0 - 'Extremely difficult' to 100 - 'Extremely easy'), and speed of MI generation (0 - 'Not at all quickly' to 100 - 'Extremely quickly'). The use of these three scales allowed a broader examination of the strength of participants' subjective MI to consider possible changes within an individual's range of abilities. All procedures and stimuli were delivered using Compusense Cloud (Guelph, ONT, Canada).

Following the MI task, participants rated each presented food on their liking (0 - 'Dislike extremely' to 100 - 'Like extremely'), familiarity (0 - 'Not at all' to 100 - 'Extremely familiar'), and frequency of consumption (0 - 'Never' to 100 - 'At least once a day'). Participants then directly compared their flavour and texture MI abilities by the vividness, ease, and speed of generation using a scale from '0 - Texture much [more vivid/easier/quicker]' to '100 - Flavour much [more vivid/easier/quicker]'. Finally, the participants answered a series of four questions about their MI abilities and content for each MI Type, on 0 to 100 point scales (Larson et al., 2014).

1. As you viewed the food pictures and imagined [flavour/texture], to what extent did the image of eating food come to mind (for example, chewing it, tasting it, etc.) [not at all/to a great extent]
2. Overall, while viewing the food and imagining the [flavour/texture], I experienced: [Few or no images of eating the food/Lots of images of eating the food]
3. To what extent while viewing the food pictures and imagining [flavour/texture] could you imagine eating the food? [Not at all/To a great extent]
4. When viewing the food pictures and imagining [flavour/texture], how difficult or easy was it for you to hold a mental image in your head? [Extremely difficult/Extremely easy]

2.1.4. Data analysis

Baseline characteristics (demographic and trait questionnaires) were summarised descriptively. Self-reported measures of MI vividness, ease, and speed of generation were compared using separate Mixed-Effects Models (LMMs) for each dependent variable across Food Items. These models included Metabolic State (Hunger vs. Satiety) and MI Type (Flavour vs. Texture) as within-subject fixed factors. Models controlled for Session Order, Age, Gender, and mean Liking for each food item. Repeated measures ANCOVAs separately examined each of the MI ability and content measures with Metabolic State and MI Type as within-subjects factors, controlling for Age and Gender. Repeated measures ANCOVAs compared food Liking, Familiarity, and Frequency of Consumption between Metabolic State, controlling for Age and Gender. Mediation analyses separately examined the role of Liking on the Metabolic State effect on the vividness, ease, and speed of MI generation. Using bootstrapping procedures with 1000 samples, the Average Causal Mediation Effect (ACME) was calculated as an estimate of the mediation effect. A significant mediation effect was indicated when the 95% confidence interval for ACME did not include 0. Data and analysis code are available at https://osf.io/zun95/overview. Data were analysed using R 4.5.0 (R Core Team, 2025) using aov() function, the lmerTest package (Kuznetsova et al., 2017), and the mediation package (Tingley et al., 2014).

2.2. Results

2.2.1. Participants

A total of 64 individuals completed the questionnaires and both in-person sessions. Of these, three were excluded from the final analysis due to the inability to produce MI for ≥50% of the trials for either MI Type and one was excluded for scoring less than 15 on the PSI-Q taste subscale, as pre-registered. One participant was excluded for non-compliance to the fasting status in the hunger session, defined by reporting "moderately full" on SLIM at arrival. Therefore, the final analysed sample comprised 59 participants, Table 1 provides the summary of demographic and baseline characteristics of the final sample.

To confirm that the self-reported fullness of participants differed pre- and post-breakfast in the satiety session, and between the satiety and hunger sessions, paired-sample *t*-tests were performed on SLIM ratings. The results revealed a significant increase in the SLIM rating from pre- (M = −29.76, SD = 24.41) to post-breakfast (M = 38.69, SD = 26.76) in the satiety session ($t = -14.96$, $p < .001$). Furthermore, this post-breakfast SLIM rating was higher than that of participants in the hunger session (M = −33.63, SD = 18.66; $t = -17.94$, $p < .001$). Therefore, although food intake during the breakfast was not quantified, the

Table 1
Demographic and baseline characteristics of Experiment 1 participants.

Demographics	
Age (yrs)	21.2 ± 3.5
Gender	
Female	52 (88%)
Male	7 (12%)
BMI	25.2 ± 7.7
Ethnicity	
NZ European	30 (51%)
Māori	5 (8.5%)
Chinese	5 (8.5%)
Indian	3 (5.%)
Other Asian	16 (27%)
Other	6 (10%)
Baseline Characteristics	
PSI-Q scores	
Overall	39.6 ± 6.62
Vision	41.15 ± 7.79
Sound	39.12 ± 8.54
Smell	36.39 ± 9.01
Taste	39.08 ± 8.38
Touch	42.12 ± 6.32
Bodily Sensation	39.93 ± 6.74
Emotional Feeling	39.93 ± 8.66
Food	37.81 ± 8.15
FCQ-T-r score	47.20 ± 11.98

change in SLIM ratings supports the effectiveness of the satiety condition. A paired-sample *t*-test also revealed the mean G-FCQ-S score was higher in the hunger session (M = 52.78, SD = 9.68) than the satiety session (M = 38.68, SD = 11.10, $t = 8.79$, $p < .001$), confirming the participants experienced greater cravings following an overnight fast.

2.2.2. *Mental imagery strength*

Separate LMMs for vividness, ease, and speed of generation compared the strength of food-related MI between Metabolic State (hunger and satiety) and MI Type (flavour and texture) (Fig. 1). Vividness of MI was rated higher in the hunger session than ($F_{(1,58)} = 11.49$, $p = .001$, $\eta^2_p = .17$). There was a significant main effect of MI Type on vividness ($F_{(1,57)} = 33.44$, $p < .001$, $\eta^2_p = .37$) with higher vividness ratings for texture MI than flavour. An interaction between Metabolic State and MI Type was observed ($F_{(1,1611)} = 12.11$, $p < .001$, $\eta^2_p = .007$) indicating that there was a significant difference between the effect of Metabolic State on vividness depending on the MI Type. Pairwise comparisons revealed a significant effect of Metabolic State for flavour MI with greater vividness when hungry than sated ($t_{(1,79)} = 4.43$, $p < .001$, $\eta^2_p = .20$), but no effect on texture MI ($F_{(1,77)} = 1.86$, $p = .07$, $\eta^2_p = .043$).

Ease of MI showed a similar pattern of results. There was a significant main effect of Metabolic State ($F_{(1,58)} = 11.04$, $p = .002$, $\eta^2_p = .16$) indicating greater ease of MI in a hunger state than a sated state, and a significant main effect of MI ($F_{(1,57)} = 28.48$, $p < .001$, $\eta^2_p = .33$), with texture MI rated as easier than flavour. There was also an interaction between Metabolic State and MI Type indicating that the effect of Metabolic State on ease differed significantly between MI Types ($F_{(1,1611)} = 10.45$, $p = .001$, $\eta^2_p = .007$) and again pairwise comparisons displayed a significant effect of Metabolic State for flavour MI indicating greater ease of MI for hunger than satiety ($t_{(1,84)} = 4.33$, $p < .001$, $\eta^2_p = .18$), but not texture MI ($t_{(1,81)} = 1.75$, $p = .08$, $\eta^2_p = .036$).

Finally, for the speed of MI generation there were significant main effects of Metabolic State ($F_{(1,58)} = 10.00$, $p = .002$, $\eta^2_p = .15$) and MI Type ($F_{(1,57)} = 26.79$, $p < .001$, $\eta^2_p = .32$) in the same direction as vividness and ease of MI. The interaction effect was also significant displaying a difference between the effect of Metabolic State on each MI Type ($F_{(1,1611)} = 7.70$, $p = .006$, $\eta^2_p = .005$) and pairwise comparisons revealed a significant effect of Metabolic State for flavour MI ($t_{(1,85)} = 4.01$, $p < .001$, $\eta^2_p = .16$), but not texture MI ($t_{(1,83)} = 1.75$, $p = .08$, $\eta^2_p = .036$). Participants were able to produce flavour MI quicker when hungry than when sated, however rating for texture MI remained stable over Metabolic States.

For each model there was no significant effect of Age although there was a slight trend toward increased age and greater ease ($F_{(1,55)} = 3.81$, $p = .056$, $\eta^2_p = .07$) and quicker MI generation ($F_{(1,55)} = 3.69$, $p = .060$, $\eta^2_p = .06$). There was no significant effect of Age on the vividness of MI ($F_{(1,55)} = 3.07$, $p = .09$, $\eta^2_p = .05$). It is important to note that the age range for this study was 18 to 36 years, therefore this trend may not generalise outside of young adults. Gender did not influence MI strength (all *ps* > .6). Session Order, the order in which participants experienced the hunger and satiety sessions did not influence MI ratings (all *ps* > .2).

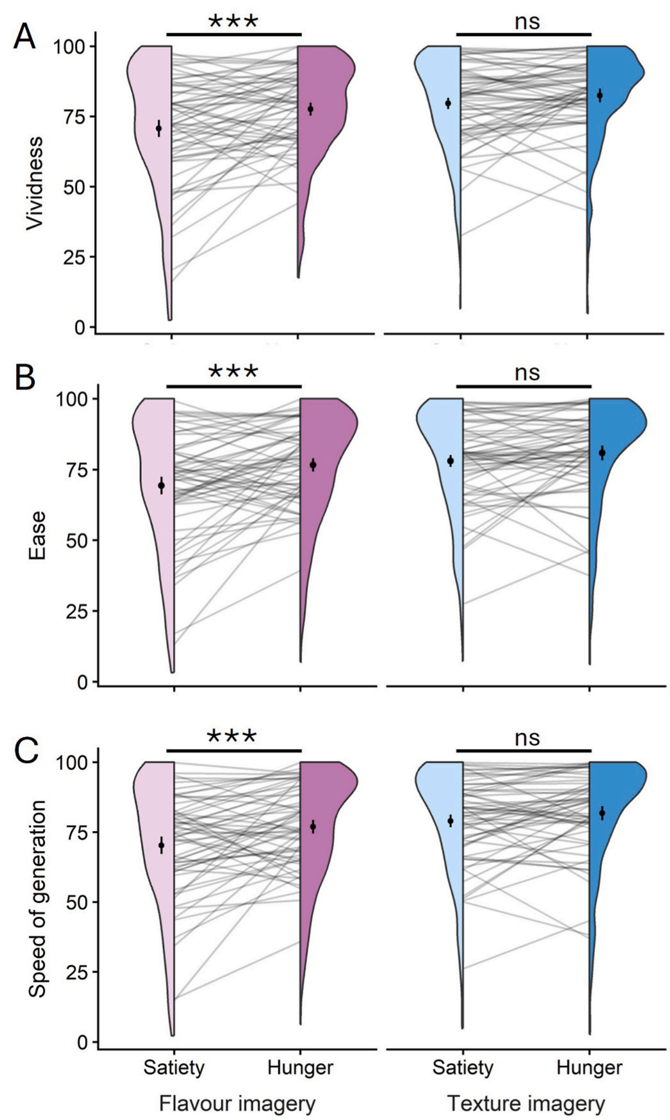

Fig. 1. Paired half violin plots showing the strength of flavour and texture food-related mental imagery in satiety (light colour) and hunger (dark colour) in Experiment 1. **A** Vividness of mental imagery. **B** Ease of mental imagery. **C** Speed of mental imagery generation. Violins show distribution of mental imagery strength for each food item with paired lines for each participant's mean mental imagery strength. Point and range shows mean and within-subjects confidence interval (Morey, 2008) for each measure. **p* < .05, ***p* < .01, ****p* < .001. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

LMM analysis further revealed a main effect of the Food Items for which MI was rated for vividness ($F_{(1,1612)} = 8.69$, $p < .001$, $\eta_p^2 = .04$), ease ($F_{(1,1613)} = 11.38$, $p < .001$, $\eta_p^2 = .05$), and speed of MI generation ($F_{(1,1613)} = 12.63$, $p < .001$, $\eta_p^2 = .05$) indicating that MI strength was not consistent across each food item. However, there was no interaction between the effect of Food Items and Metabolic State (all $ps > .2$) or MI Type (all $ps > .2$). There was a main effect of Liking of food items for vividness ($F_{(1,1638)} = 77.54$, $p < .001$, $\eta_p^2 = .05$), ease ($F_{(1,1643)} = 72.08$, $p < .001$, $\eta_p^2 = .04$), and speed of MI generation ($F_{(1,1641)} = 75.79$, $p < .001$, $\eta_p^2 = .04$). Vividness, ease, and speed ratings each increased with greater liking of the food items. Additionally, repeated measures ANCOVAs displayed a significant main effect of Metabolic State on the liking ratings of food items ($F_{(1,58)} = 12.4$, $p = .001$, $\eta_p^2 = .18$), with greater liking in the hunger session than satiety session. There was no effect of Metabolic State on the Familiarity ($F_{(1,58)} = .04$, $p = .85$, $\eta_p^2 < .001$), or Frequency of Consumption of the food items ($F_{(1,58)} = 1.29$, $p = .26$, $\eta_p^2 = .022$).

Analysis of the content of each MI type and general abilities for MI found a significant effect of Metabolic State on the ability to imagine eating the presented food ($F_{(1,58)} = 5.76$, $p = .02$, $\eta_p^2 = .090$), with a greater capability in the hunger session than satiety (see Fig. 2). There was no effect of MI Type for this content ($F_{(1, 58)} = 2.74$, $p = .10$, $\eta_p^2 = .045$) and no interaction between Metabolic State and MI Type ($F_{(1,58)} = .26$, $p = .61$, $\eta_p^2 = .004$). A main effect of Metabolic State on the extent to which food-related MI came to mind did not reach significance ($F_{(1,58)} = 3.97$, $p = .051$, $\eta_p^2 = .064$). Additionally, there was no main effect of Metabolic State on the ability to hold food-related MI ($F_{(1,58)} = .76$, $p = .39$, $\eta_p^2 = .013$), or the quantity of food MI ($F_{(1,58)} = 2.35$, $p = .13$, $\eta_p^2 = .039$).

Analysis of MI content and abilities across Metabolic State revealed a main effect of MI Type on the extent to which food-related MI came to mind ($F_{(1,58)} = 15.54$, $p < .001$, $\eta_p^2 = .21$), the ability to hold food MI ($F_{(1,58)} = 5.53$, $p = .02$, $\eta_p^2 = .087$), and the quantity of food MI ($F_{(1,58)} = 7.32$, $p = .009$, $\eta_p^2 = .11$) with greater abilities for texture MI than for flavour. There was no interaction between Metabolic State and MI type for any of these measures (all $p > .30$). Paired t-tests compared between self-reported direct comparisons between flavour and texture MI for vividness, ease, and speed of generation (Fig. 3). There was no significant difference between hunger and satiety sessions. Texture MI was rated more vivid ($t_{(58)} = 1.54$, $p = .13$), easier ($t_{(58)} = 1.23$, $p = .22$), and quicker ($t_{(58)} = 1.66$, $p = .10$) to generate than flavour MI in both sessions.

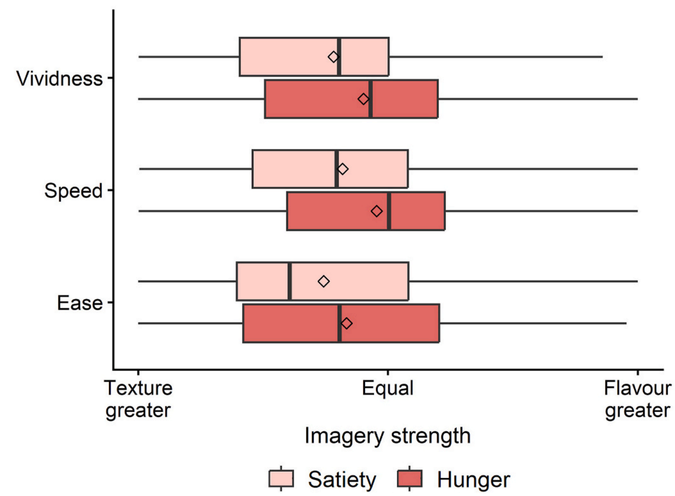

Fig. 3. Boxplots showing self-reported direct comparisons between vividness, ease, and speed of flavour and texture mental imagery in satiety and hunger in Experiment 1. Box limits represent the 25th to 75th percentiles, whiskers extend up to 1.5 times the interquartile range, centre lines represent the median and diamond symbols represent the mean of the data. The scale for each ranged from 0 ('texture much []') to 100 ('flavour much []').

2.2.3. Mediation analysis

Food liking was significantly higher in the hunger session and had significant effect on MI strength. To allow clarification of the mechanism driving the increase in MI strength, mediation analyses using Quasi-Bayesian CI were used to examine the mediating role of Liking on the effect of Metabolic State for vividness, ease, and speed of MI generation. Liking significantly partially mediated the effect of Metabolic State on vividness (ACME = −.47, $p < .001$, 95% CI [−.77, −.19]), ease (ACME = −.49, $p = .002$, 95% CI [−.85, −.20]) and speed of MI generation (ACME = −.50, $p < .001$, 95% CI [−.81, −.21]). The direct effect of Metabolic State remained significant for vividness (ADE = −4.33, $p < .001$, 95% CI [−5.58, −3.13]), ease (ADE = −4.54, $p < .001$, 95% CI [−5.89, −3.18]) and speed (ADE = −4.18, $p < .001$, 95% CI [−5.60, −2.86]) when accounting for the indirect effect of Liking. The

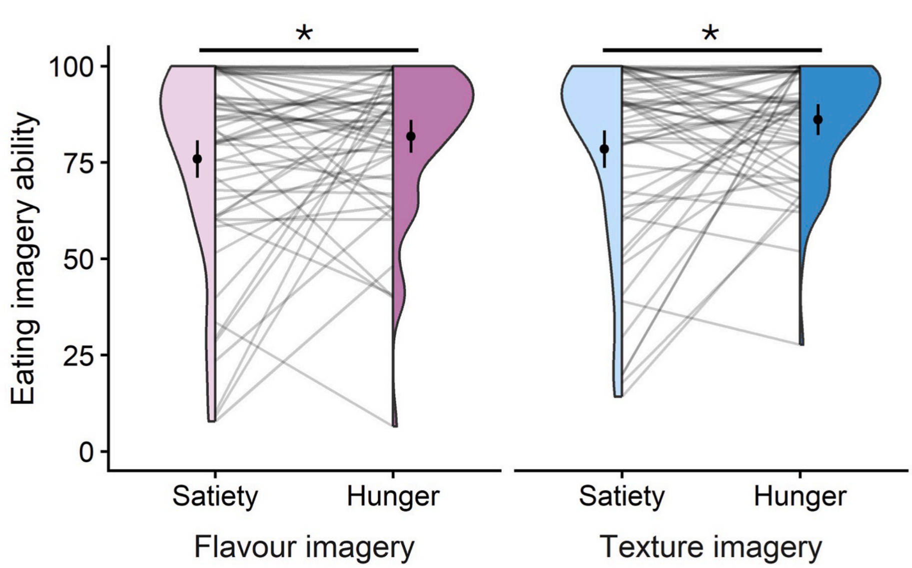

Fig. 2. Paired half violin plots showing participants' ability to imagine eating food in satiety and hunger using flavour and texture mental imagery in Experiment 1. Violins show distribution of mental imagery ability with paired lines for each participant. Point and range shows mean and within-subjects confidence interval (Morey, 2008). *$p < .05$.

proportion mediated indicated that Liking was a minor contributor to the overall Metabolic State effect on vividness (.09, $p < .001$, 95% CI [.04, .17]), ease (.10, $p < .001$, 95% CI [.04, .18]), and speed (.10, $p < .001$, 95% CI [.05, .19]).

2.3. Discussion

Experiment 1 found increased vividness, ease, and speed of generation of flavour MI in hunger state compared satiety but no change in texture MI between metabolic states. These results suggest a physiological influence on MI towards the hedonic aspects of the food consummatory experience. Participants' MI in a hunger state was also more likely to involve eating the food, further implicating the role of hunger in driving food-related MI that provokes strong affective reactions and desire (Kavanagh et al., 2005).

The discrepancy between the effects of appetite on flavour and texture MI strength highlights the importance of considering the relative contributions of different food modalities to food-related cognitive processing. This may present an avenue for targeted, modality-specific food MI interventions for food cognitions and behaviours. However, the effects of flavour- and texture-specific MI on food evaluations, real and imagined, is unknown. Therefore, we designed Experiment 2 to investigate the effect of repeated flavour and texture food consumption MI on the pleasantness and wanting of food samples of the imagined food and foods matched in either flavour or texture. By comparing food sample ratings prior to and following repeated MI, we aimed to determine (i) whether repeated food consumption MI would modulate the hedonic value of the imagined food and (ii) whether changes in pleasantness and wanting would be specific to the MI modality used.

3. Experiment 2

3.1. Methods

3.1.1. Participants

A total of 48 participants, aged 18 years and above, were recruited from the University of Otago community in 2025. Participants were eligible if they were able to speak and understand English, were in good health, and able to eat the stimuli used for the experiment (including gluten and dairy). Participants were excluded if they self-reported any condition that impacted on their ability to generate MI. All eligible participants gave informed consent prior to the commencement of the study and were offered a $20 voucher upon completion. Ethics approval was obtained from the University of Otago Human Ethics Committee (REF 24/0562, December 2024). This study's design and analysis was pre-registered on OSF 10.17605/OSF.IO/VF8CZ.

The minimum sample size was calculated to detect a moderate effect (Cohen's f = .25) of repeated MI on food evaluations, reported in previous repeated MI studies (Andersen et al., 2023a; Morewedge et al., 2010), with 85% power and a .05 alpha error probability. This indicated we required a sample of 38 participants, to allow for attrition we recruited a sample of 48 participants.

3.1.2. Procedure

Participants were asked to complete the same questionnaires as for Experiment 1, i.e., the PSI-Q (Andrade et al., 2014) with a further five food flavour MI questions identically formatted, and FCQ-T-r (Meule et al., 2014). Additionally, they completed the Spontaneous Use of Imagery Scale (SUIS), to measure their use of MI in daily life (Nelis et al., 2014). The frequency of consumption within the previous month for the imagined and unimagined foods in the experimental sessions, was rated from Never/Seldom to Every Day. Participants' height and weight were also measured to calculate BMI.

Participants completed two sessions to perform both flavour and texture MI in a counterbalanced order. Sessions were separated by one to seven days. Participants were asked to refrain from food or drinks other than water for 2 h prior to each session and compliance was confirmed upon arrival to the laboratory. To begin each session, baseline subjective fullness was measured using the SLIM scale (Cardello et al., 2005).

3.1.3. Repeated mental imagery task

A schematic of the repeated MI task is provided in Fig. 4. The task was presented using the E-Prime 3.0 software (Psychology Software Tools, Pittsburgh, PA). Participants were seated in a sensory booth in front of a monitor and given both verbal and written instructions for the task. Participants first rated actual food samples of the imagined food (chocolate cookie; 4 g $\pm$ .4), and unimagined foods matched for flavour (chocolate coated marshmallow; 4.5 g $\pm$ .5) and texture (oat cracker; 3 g $\pm$ .4) on pleasantness and wanting 'right now'. Sample sizes were based on the average consumption of 10 pilot participants when asked to sample the food. Pleasantness ratings were split by appearance, taste, flavour, and texture of the food, and rated overall. Taste was distinguished from flavour by being presented first, with the examples 'sweet', 'salty', to encourage focus on the basic taste properties. Each measure was rated from 0 (Not at all) to 100 (Extremely).

Participants then completed repeated food consumption MI. They were asked to vividly imagine eating the pictured chocolate cookie for the 10 s it remained on screen using flavour- or texture-specific MI, dependent on the session. Ten unique chocolate cookie pictures, collected from copyright free databases, were repeatedly presented three times each in a randomised order for 30 trials. Exposing participants to a range of pictures of the same target food aimed to allow greater mental simulation, continued engagement, and increase generalisability to a real-world context in which people are subject to varying examples of foods. The picture remained on the monitor to reduce the need for visual MI. Following each trial, the participants rated how much they like the food that they had just seen from 0 (Not at all) to 100 (Extremely). This was followed by a 1 s fixation cross, prior to the presentation of the next picture. Following MI, participants repeated the pleasantness and wanting ratings for the three actual food samples following the same procedure as prior.

To end each session, participants rated how vivid their MI during the task was from 0 (No image at all) to 10 (As vivid and clear as real life), in line with their previously completed PSI-Q, and completed a second SLIM rating to examine whether general appetite was affected by the repeated MI task.

Participants were aware that the study was investigating the effect of food-related MI on appetite but were blinded to the study's hypothesis of decreased appetite following repeated MI to minimise social desirability effects. Following the completion of the study, participants were debriefed on the study's purpose. Eighteen participants believed the study was investigating the change in food preferences following repeated exposure to food pictures. Within this group, six believed preferences for the repeated food and/or appetite would increase and none reported that they believed it would decrease.

3.1.4. Data analysis

Mean pleasantness and wanting ratings were compared across Time (pre- and post-repeated MI) for each pleasantness and wanting measures using separate repeated measures ANCOVAs, with Food Sample and MI Type as within-subject factors and controlling for Session Order, BMI and Hunger through the initial SLIM rating. The trial-by-trial imagined liking was modelled using a linear mixed-effects model (LMM) as a function of trial number (linear and quadratic), MI Type, image repetition, and their interactions with MI Type. Random intercepts and slopes for trial and repetition were included for participants, and a random intercept was included for picture identity with Session Order, BMI and Hunger as covariates. As the maximal random effects structure failed to converge, the correlation between random slopes was removed. Data and analysis code are available at https://osf.io/zun95/overview. Data were analysed using R 4.5.0 (R Core Team, 2025) using the aov() function and lmerTest package (Kuznetsova et al., 2017).

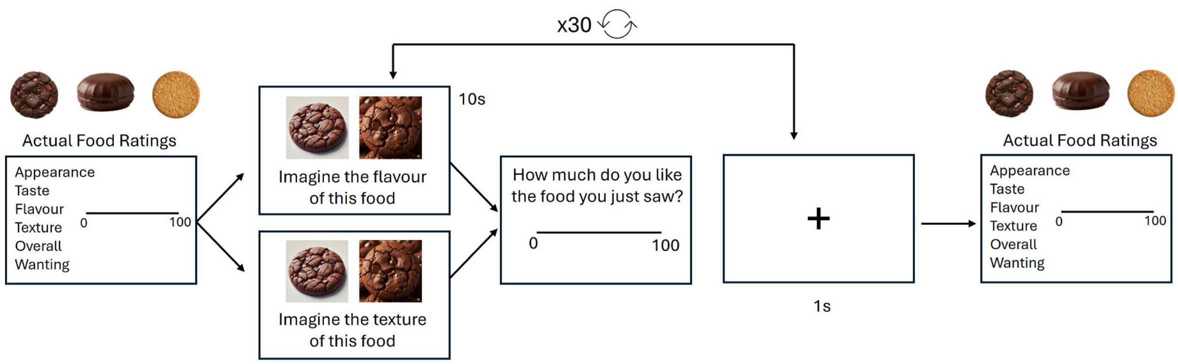

Fig. 4. Schematic of the repeated mental imagery task in Experiment 2. Participants completed pleasantness and wanting ratings of food samples prior to and following flavour- or texture-specific food consumption mental imagery.

3.2. Results

3.2.1. Participants

After screening for missing data points within each of the food sample rating tasks, as pre-registered, data from 44 participants were used for final analysis. Table 2 details the demographic and baseline characteristics of these participants.

The snack food frequency questionnaire found that cookies were more frequently consumed than both oat crackers and marshmallows, ($t = 3.15$, $p = .003$, $t = 4.96$, $p < .001$), but consumption of oat crackers versus marshmallows was not significantly different ($t = 1.75$, $p = .09$). Chocolate cookies were consumed on average 1-3 days per month, while the average rating for oat crackers and chocolate coated marshmallows was closer to never/seldom.

Paired-samples *t*-tests of SLIM ratings confirmed no difference between participants' hunger before beginning each experimental session ($t_{(1,43)} = 1.33$, $p = .19$). Furthermore, there was no change in hunger (SLIM ratings) following the repeated MI task with flavour MI ($t_{(1,43)} = -.54$, $p = .59$) or texture MI ($t_{(1,43)} = -.89$, $p = .38$). A paired-samples *t*-test showed no difference between the self-reported vividness of MI in the flavour and texture MI tasks ($t_{(1,43)} = -1.41$, $p = .16$).

Table 2
Demographic and baseline characteristics of the participants in Experiment 2.

Demographics	
Age (yrs)	32.23 ± 14.11
Gender	
Female	30 (68%)
Male	14 (32%)
BMI	27.07 ± 6.99
Ethnicity	
NZ European	22 (50%)
Pasifika	1 (2.3%)
European	6 (13.6%)
Asian	14 (31.8%)
Middle Eastern	4 (9.1%)
African	1 (2.3%)
Other	2 (4.5%)
Baseline Measures	
PSI-Q scores	
Overall	40.20 ± 6.81
Vision	42.18 ± 6.49
Sound	41.23 ± 8.97
Smell	37.30 ± 8.92
Taste	39.30 ± 7.0
Touch	40.7 ± 9.05
Bodily Sensation	40.61 ± 7.12
Emotional Feeling	39.28 ± 8.50
Food	40.45 ± 7.11
FCQ-T-r score	48.75 ± 15.04
SUIS score	44.95 ± 8.29

3.2.2. Actual food samples

Separate repeated measures ANCOVAs compared all pleasantness and wanting measures across Time and between MI Types for each of the imagined and unimagined foods (see Table 3). Analysis revealed no effect of Time (all $p > .05$) or MI Type (all $p > .30$) on all pleasantness and wanting measures for food samples. There was a main effect of Food Sample (all $p < .001$), but no interactions between any factors. Hunger, measured through the pre-task SLIM rating, BMI or Session Order did not influence pleasantness or wanting ratings.

3.2.3. Imagined liking

A mixed effects ANCOVA compared imagined liking prior to and following MI with MI Type within-subjects, controlling for BMI and Hunger. Participants were presented with a range of chocolate cookie pictures, hence imagined liking was expected to vary slightly trial to trial. This potential variation was accounted for by comparing the mean liking of the chocolate cookies for the first three trials and the last three trials. There was a main effect of Time ($F_{(1,\ 43)} = 9.43$, $p < .01$, $\eta_p^2 = .18$), no main effect of MI Type ($F_{(1,\ 42)} = 1.40$, $p = .24$, $\eta_p^2 = .032$), and no interaction between these factors ($F_{(1,\ 43)} = .12$, $p = .73$, $\eta_p^2 = .003$). Imagined liking decreased from the first three (M = 69.25, SD = 16.87) to last three trials (M = 63.21, SD = 19.13). There was no effect of Hunger or BMI.

A LMM was used to examine the trajectory of imagined liking across the 30 trials and whether this was modulated by MI Type or picture repetition, with BMI and Hunger as covariates. There was a significant linear decrease in imagined liking across trials ($b^* = -.33$, $t_{(425.4)} = -2.34$, $p = .02$, 95% CI [−.60, −.05]), the quadratic term was not significant ($b^* = .005$, $t_{(2532)} = .96$, $p = .34$, 95% CI [−.005, .02]) indicating that liking declined progressively across the trials. There was no interaction of MI Type with the trial trajectory ($t_{(2533)} = .93$, $p = .36$, 95% CI [−.18, .51]) indicating that the decline in liking was consistent across both flavour and texture MI. Picture repetition did not significantly predict the imagined liking ($t_{(731.9)} = .56$, $p = .19$, 95% CI [−.86, 4.36]). There was no effect of Hunger or BMI.

4. General discussion

This study provides new evidence for elucidating the role of appetite on food-related MI. While previous research primarily focused on the consequences of MI, showing that imagining food can trigger cravings and increased consumption (Krishna et al., 2013; Steel et al., 2006; Zorjan & Schienle, 2023), this study extends this work by demonstrating that physiological state also modulates the fidelity and efficiency of the self-reported cognitive stimulation itself. When participants were in a

Table 3
Pleasantness and wanting ratings for food samples pre- and post-repeated MI. As there was no significant effect of MI Type on food ratings, data are collapsed across conditions for descriptive purposes. Values are displayed as means and standard deviations for all food samples (All), chocolate cookies (CC), chocolate coated marshmallows (CM) and oat crackers (OC). F-statistics and p-value are displayed for the comparison pre- and post-MI using repeated measures ANCOVA for each measure and pairwise comparisons within each food type, with Bonferroni corrections, in Experiment 2.

Measure	Food sample	Pre-MI		Post-MI		F	*p*	η_p^2
Appearance liking	All	58.8	21.4	58.6	21.5	.02	.88	.001
	CC	64.0	18.5	61.2	19.9		.33	
	CM	68.1	18.7	67.9	19.2		.83	
	OC	44.1	18.9	46.6	19.9		.67	
Flavour liking	All	64.3	22.8	63.2	23.4	.69	.41	.002
	CC	71.4	17.5	67.3	20.4		.15	
	CM	71.7	20.3	71.0	20.2		.83	
	OC	49.8	23.3	51.4	24.9		.67	
Taste liking	All	65.3	21.6	63.4	22.9	3.03	.09	.066
	CC	70.5	16.5	68.3	18.0		.40	
	CM	72.9	19.6	70.7	20.0		.48	
	OC	52.5	22.4	51.3	25.2		.74	
Texture liking	All	62.8	22.7	62.1	23.5	.41	.53	.009
	CC	67.3	18.3	66.1	19.3		.66	
	CM	69.1	22.5	69.4	23.2		.94	
	OC	52.1	23.2	51.0	23.7		.75	
Overall liking	All	65.1	22.6	63.3	23.6	2.46	.12	.054
	CC	71.1	17.6	68.1	19.8		.30	
	CM	72.6	20.4	70.6	21.5		.53	
	OC	51.7	23.3	51.1	24.5		.89	
Wanting	All	60.6	27.5	59.9	27.1	.18	.68	.004
	CC	67.1	24.9	63.4	25.4		.33	
	CM	67.6	26.8	66.6	26.9		.82	
	OC	47.3	26.1	49.7	26.1		.53	

state of energy deficit (hunger), they reported producing food-related MI that was more vivid, easier, and quicker to generate as compared with when they were satiated. Although these are self-reported measures, this suggests that while hunger alters motivation it may also increase efficiency for accessing and generating stored sensory representations. Furthermore, hungry participants' MI was more likely to involve the sensory experience of eating the food itself, reflecting a relationship between physiological need and the simulation of consummatory action.

A notable finding from Experiment 1 was that the influence of metabolic state was present for flavour MI but not texture MI. Flavour is recognised as a multisensory construct, based on olfactory, gustatory, and trigeminal sensory inputs (Auvray & Spence, 2008; Spence et al., 2014). Although flavour is influenced by various other perceptions including texture, temperature, and colour (Delwiche, 2004; Tournier et al., 2007) arguably, smell and taste contribute primarily to flavour perception and is more aligned with lay perception of the semantic term 'flavour'. The enhancement of flavour MI suggests that appetite selectively modulates the cognitive simulation of primary sensory attributes necessary for driving appetitive behaviour. This modality-specific effect is consistent with findings showing that hunger enhances the salience of food cues specifically linked to reward (Charbonnier et al., 2018; Reichelt et al., 2015; Siep et al., 2009), suggesting a mechanism whereby internal physiological state potentiates the cognitive simulation of these critical sensory attributes. In contrast, texture MI showed no change in strength between a hungry and sated state. As the effect sizes for this interaction were noticeably small, this should be interpreted with caution, and it is important to note is that texture MI was rating as stronger than flavour MI. Possibly this resulted in a ceiling effect for texture, with little enhancement possible when hungry. Nevertheless, this remains an interesting distinction between the effects of appetite on internal representations of the chemosensory, reward related flavour and the mechanical, tactile texture.

Increased MI strength and food liking in a hunger state was likely influenced by greater attention to the internal food-related MI or to the displayed food picture (Mogg et al., 1998; Montagrin et al., 2021; Piech et al., 2010). Moreover, food liking was determined to be a minor partial mediator of the relationship between metabolic states and the vividness, ease and speed of the generation of food MI, with the proportion mediated reflecting around 10% of the total effect. The visual food cue perhaps generated greater activation of flavour processing brain regions, contributing to the flavour specific effect on the strength of MI. Stronger food-related MI in a hunger state aligns with Kavanagh et al.'s (2005) elaborated intrusion theory of desire, inducing both stronger affective links and sense of deficit through greater activation of perception-like brain processes (Belardinelli et al., 2009), therefore sustaining cognitive elaboration to drive consumption. Concurrently, decreased liking of food stimuli in satiety aligns with the theory of a memory inhibition effect in satiety, involving reduced retrieval of food memories to make these judgements (Davidson et al., 2005; Stevenson et al., 2023). Memory inhibition is a strong contender for reducing MI strength and eating-related content in satiety through integrated physiological inhibitory processes to suppress retrieval of food-related memories and their linked affect (Stevenson et al., 2024). The manipulated states within this study are likely to represent an alteration towards the extremes of each participant's food MI ability, with a state of neither hunger nor satiety lying within the middle of these.

A particularly noteworthy finding from Experiment 2 is that there was no significant effect of repeated flavour or texture MI of food consumption on the pleasantness or wanting for actual food. Ratings of food samples remained stable before and after 30 MI trials. In contrast, the hedonic value of food MI reduced following repetition, with decreased liking of the imagined food between the first and last three MI trials through a linear decrease across the 30 trials. Interestingly, the null effect of picture repetition on imagined liking suggests that this decline was not moderated by repeated exposure to each picture, but rather the repeated eating MI generation. This finding is in line with previous studies, indicating that imagined satiation occurs through simulation of the sensory experience but does not require the cue to be identical (Andersen et al., 2023a; Larson et al., 2014). There was no difference in the effects of flavour- or texture-specific MI on imagined liking, suggesting that although modulated differentially by appetite, they may not produce differential effects in this context. However, only general imagined liking was measured, leaving modality specific changes possible. Additionally, in consideration of the appetite-dependent changes in MI strength it is possible that the results of Experiment 2 would differ in under greater hunger or satiety states. This should be considered in future research concerning food MI and appetite. Despite the lack of an effect on readily available foods, decreased imagined liking could signify reduced motivation for food craving or seeking behaviours.

The literature contains a wide variability of protocols used to induce decreased liking and wanting for imagined foods. In fact, many studies have only compared prospective self-report ratings, such as "How much would you enjoy eating [imagined food] right now?", without actual food samples (Andersen et al., 2023a). This has left the effect of MI on actual food evaluations and consumption tenuous. For example, although Andersen et al. (2023b) saw decreased enjoyment of an actual M&M following repeated imagined consumption, this was no different from a control group imagining inserting tokens into a laundry machine. The number of repetitions used in the present study may not have been sufficient to produce a change, considering the variation in displayed cookie pictures. Although 30 repetitions have previously been effective, these protocols used either identical or stimuli differing slightly in flavour but not texture (Skittles) (Andersen et al., 2023a, Andersen et al., 2023b). While the variety of pictures in the present study did not modulate the decline in imagined liking, the effects on actual food were not evaluated. Larson et al. (2014) used a range of pictures with the same taste quality but compared 60 repetitions to 20, therefore our protocol was in fact closer to their 'low' repetitions than high. A similar study by Haasova et al. (2016) found that imagining a food just 15 times led to increased consumption relative to only three repetitions. Furthermore, in the present study, to avoid potential effects of repeated consumption of the food samples, we chose not to add a third rating task after a small number of trials (e.g., following three out of 30). This meant we were both unable to determine whether a priming effect from the food MI occurred and limited in our ability to compare our results to those who had solely compared actual food ratings between a small and large number of repetitions. Instead, our method allowed direct comparison prior to, and following, food consumption MI, rather than after potential priming by a small number of trials. Overall, repeated imagined food has shown ranging effects and it is likely that if food-related MI is to be used as an intervention for food behaviours, different techniques would be required (Larsen et al., 2024).

4.1. Limitations

A limitation to consider when interpreting the results of the present study is the use of only self-reported measures of MI strength in Experiment 1. Although these were analysed within-subjects, the subjective nature of MI remains an important consideration. This restricts the ability to distinguish between participants' greater objective strength of MI, or other cognitive processes rendering greater appraisal of food-related MI. The use of vividness, ease, and speed of MI generation as an index of MI strength broadened our investigation of participants' subjective experience and each presented similar increases in a hunger state. Future research could extend these findings by implementing objective measures of MI speed such as reaction times or the ability to complete tasks that require food-related MI. Additionally, future research could consider the effects of metabolic state on the strength of involuntary food MI, such as through the 'interference effect' of olfactory MI on weak incongruent odours (Perszyk et al., 2023).

The effectiveness of the hunger and satiety conditions in Experiment 1 were determined through subjective hunger/satiety ratings only and meal intake was not specifically measured. Individual variation in breakfast intake may have produced variability in the satiety condition and future work should record the amount consumed to better characterise individual variability in satiety induction. Furthermore, characterisation of food cravings between the hunger and satiety conditions would have benefited from the inclusion of the Craving Experience Questionnaire (May et al., 2014), to consider not just the strength of food MI between these states but the use.

The limitations of our sample should also be noted when considering the generalisability of our results. Particularly in Experiment 1, our sample was predominantly young women. Women are reported to experience more frequent food cravings and greater difficulty regulating these (Hallam et al., 2016; Weingarten & Elston, 1991). Furthermore, previous literature has documented gender differences in mental imagery abilities (Kozhevnikov et al., 2026), although differences in sensory imagery are undetermined (Schifferstein & Hendrik, 2009**)**. The influence of these differences on the results of our study is unknown and should be considered in future research.

5. Conclusion

This study highlights the interdependence between food MI and appetite through physiological and cognitive processes. Food-related flavour MI is stronger in a hunger state than satiety, and involves more food consumption MI. The results provide further evidence of greater food liking within hunger and satiety states, which acts as a minor partial mediator between appetite and MI strength. Additionally, repeated flavour or texture specific food consumption MI does not reduce the hedonic value of actual food despite the reduction of imagined liking. Together, these findings develop the relationship between MI and appetite, demonstrating the state-dependent nature of MI and suggests possible distinctions between interactions of internal and perceptual representations on eating behaviour and reward processing.

CRediT authorship contribution statement

Maggie Hames: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Conceptualization. **Jessica C. McCormack:** Writing – review & editing, Resources, Project administration, Methodology, Conceptualization. **Reece Roberts:** Writing – review & editing, Supervision. **Jamin Halberstadt:** Writing – review & editing, Supervision. **Charles Spence:** Writing – review & editing, Funding acquisition, Conceptualization. **Mei Peng:** Writing – review & editing, Supervision, Funding acquisition, Formal analysis, Conceptualization.

Ethical statement

This study was conducted according to the guidelines laid down in the Declaration of Helsinki and all procedures involving research study participants were approved by the University of Otago Ethics Committee (Ref. 24/0562) in December 2024 for Experiment 2 and April 2025 for Experiment 1. Informed consent was obtained from all participants.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Mei Peng reports financial support was provided by Royal Society of New Zealand Marsden Fund. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data and analysis code are available at https://osf.io/zun95/overview.

References

Abeywickrema, S., Oey, I., & Peng, M. (2022). Sensory specific satiety or appetite? Investigating effects of retronasally-introduced aroma and taste cues on subsequent real-life snack intake. *Food Quality and Preference, 100*, Article 104612. https://doi.org/10.1016/j.foodqual.2022.104612

Andersen, T., Byrne, D. V., & Wang, Q. J. (2023a). Imagined eating – An investigation of priming and sensory-specific satiety. *Appetite, 182*. https://doi.org/10.1016/j.appet.2022.106421. Article 106421.

Andersen, T., Byrne, D. V., & Wang, Q. J. (2023b). Think yourself slim? Assessing the satiation efficacy of imagined eating. *Foods, 12*(1), 36. https://doi.org/10.3390/foods12010036

Andrade, J., May, J., Deeprose, C., Baugh, S. J., & Ganis, G. (2014). Assessing vividness of mental imagery: The plymouth sensory imagery questionnaire. *British Journal of Psychology, 105*(4), 547–563. https://doi.org/10.1111/bjop.12050

Arnold, D. H., Hutchinson, M., Bouyer, L. N., Schwarzkopf, D. S., Pellicano, E., & Saurels, B. W. (2025). Don't think of a pink elephant: Individual differences in visualisation predict involuntary imagery and its neural correlates. *Cortex, 183*, 53–65. https://doi.org/10.1016/j.cortex.2024.10.020

Auvray, M., & Spence, C. (2008). The multisensory perception of flavor. *Consciousness and Cognition, 17*(3), 1016–1031. https://doi.org/10.1016/j.concog.2007.06.005

Avery, J. A., Carrington, M., & Martin, A. (2023). A common neural code for representing imagined and inferred tastes. *Progress in Neurobiology, 223*, Article 102423. https://doi.org/10.1016/j.pneurobio.2023.102423

Avery, J. A., Liu, A. G., Ingeholm, J. E., Gotts, S. J., & Martin, A. (2021). Viewing images of foods evokes taste quality-specific activity in gustatory insular cortex. *Proceedings of the National Academy of Sciences, 118*(2), Article e2010932118. https://doi.org/10.1073/pnas.2010932118

Belardinelli, M. O., Palmiero, M., Sestieri, C., Nardo, D., Di Matteo, R., Londei, A., D'Ausilio, A., Ferretti, A., Del Gratta, C., & Romani, G. L. (2009). An fmri investigation on image generation in different sensory modalities: The influence of vividness. *Acta Psychologica, 132*(2), 190–200. https://doi.org/10.1016/j.actpsy.2009.06.009

Berridge, K. C., Ho, C.-Y., Richard, J. M., & DiFeliceantonio, A. G. (2010). The tempted brain eats: Pleasure and desire circuits in obesity and eating disorders. *Brain Research, 1350*, 43–64. https://doi.org/10.1016/j.brainres.2010.04.003

Bilman, E., van Kleef, E., & van Trijp, H. (2017). External cues challenging the internal appetite control system—overview and practical implications. *Critical Reviews in Food Science and Nutrition, 57*(13), 2825–2834. https://doi.org/10.1080/10408398.2015.1073140

Cardello, A. V., Schutz, H. G., Lesher, L. L., & Merrill, E. (2005). Development and testing of a labeled magnitude scale of perceived satiety. *Appetite, 44*(1), 1–13. https://doi.org/10.1016/j.appet.2004.05.007

Charbonnier, L., van Meer, F., Johnstone, A. M., Crabtree, D., Buosi, W., Manios, Y., Androutsos, O., Giannopoulou, A., Viergever, M. A., & Smeets, P. A. M. (2018). Effects of hunger state on the brain responses to food cues across the life span. *NeuroImage, 171*, 246–255. https://doi.org/10.1016/j.neuroimage.2018.01.012

Chen, J., Papies, E. K., & Barsalou, L. W. (2016). A core eating network and its modulations underlie diverse eating phenomena. *Brain and Cognition, 110*, 20–42. https://doi.org/10.1016/j.bandc.2016.04.004

Davidson, T., Kanoski, S. E., Walls, E. K., & Jarrard, L. E. (2005). Memory inhibition and energy regulation. *Physiology & Behavior, 86*(5), 731–746. https://doi.org/10.1016/j.physbeh.2005.09.004

Delwiche, J. (2004). The impact of perceptual interactions on perceived flavor. *Food Quality and Preference, 15*(2), 137–146. https://doi.org/10.1016/S0950-3293(03)00041-7

Field, M., Werthmann, J., Franken, I., Hofmann, W., Hogarth, L., & Roefs, A. (2016). The role of attentional bias in obesity and addiction. *Health Psychology: The Official Journal of the Division of Health Psychology, 35*(8), 767–780. https://doi.org/10.1037/hea0000405. American Psychological Association.

Floridou, G. A., Peerdeman, K. J., & Schaefer, R. S. (2022). Individual differences in mental imagery in different modalities and levels of intentionality. *Memory & Cognition, 50*(1), 29–44. https://doi.org/10.3758/s13421-021-01209-7

Gautier, Y., Meurice, P., Coquery, N., Constant, A., Bannier, E., Serrand, Y., Ferré, J. C., Moirand, R., & Val-Laillet, D. (2019). Implementation of a new food picture database in the context of fmri and visual cognitive food-choice task in healthy volunteers. *Frontiers in Psychology, 10*, 2620. https://doi.org/10.3389/fpsyg.2019.02620

Guinard, J. X., & Brun, P. (1998). Sensory-specific satiety: Comparison of taste and texture effects. *Appetite, 31*(2), 141–157. https://doi.org/10.1006/appe.1998.0159

Guinard, J.-X., & Mazzucchelli, R. (1996). The sensory perception of texture and mouthfeel. *Trends in Food Science & Technology, 7*(7), 213–219. https://doi.org/10.1016/0924-2244(96)10025-X

Haasova, S., Elekes, B., Missbach, B., & Florack, A. (2016). Effects of imagined consumption and simulated eating movements on food intake: Thoughts about food are not always of advantage. *Frontiers in Psychology, 7*. https://doi.org/10.3389/fpsyg.2016.01691. Article 1691.

Hallam, J., Boswell, R. G., DeVito, E. E., & Kober, H. (2016). Gender-related differences in food craving and obesity. *Yale J Biol Med, 89*(2), 161–173.

Hanci, D., & Altun, H. (2016). Hunger state affects both olfactory abilities and gustatory sensitivity. *European Archives of Oto-Rhino-Laryngology, 273*(7), 1637–1641. https://doi.org/10.1007/s00405-015-3589-6

Havermans, R. C., Janssen, T., Giesen, J. C., Roefs, A., & Jansen, A. (2009). Food liking, food wanting, and sensory-specific satiety. *Appetite, 52*(1), 222–225. https://doi.org/10.1016/j.appet.2008.09.020

Hossu, G., Fantin, L., Charroud, C., Felblinger, J., Jacquot, M., & Ceyte, H. (2024). Neural mechanisms of odour imagery induced by non-figurative visual cues. *Neuropsychologia, 196*, Article 108836. https://doi.org/10.1016/j.neuropsychologia.2024.108836

Katsikari, A., & Varela, P. (2026). Individual differences in sensitivity to texture as drivers of food preferences and eating behaviour. *Food Quality and Preference, 136*, Article 105752. https://doi.org/10.1016/j.foodqual.2025.105752

Kavanagh, D. J., Andrade, J., & May, J. (2005). Imaginary relish and exquisite torture: The elaborated intrusion theory of desire. *Psychological Review, 112*(2), 446. https://doi.org/10.1037/0033-295X.112.2.446

Kemps, E., & Tiggemann, M. (2007). Modality-specific imagery reduces cravings for food: An application of the elaborated intrusion theory of desire to food craving. *Journal of Experimental Psychology: Applied, 13*(2), 95. https://doi.org/10.1037/1076-898X.13.2.95

Kemps, E., & Tiggemann, M. (2013). Olfactory stimulation curbs food cravings. *Addictive Behaviors, 38*(2), 1550–1554. https://doi.org/10.1016/j.addbeh.2012.06.001

Kozhevnikov, M., Bonavita, A., & Piccardi, L. (2026). Sex differences in the development of object imagery abilities across age groups. *Scientific Reports, 16*(1), 7409. https://doi.org/10.1038/s41598-026-37983-0

Krishna, A., Morrin, M., & Sayin, E. (2013). Smellizing cookies and salivating: A focus on olfactory imagery. *Journal of Consumer Research, 41*(1), 18–34. https://doi.org/10.1086/674664

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2017). Lmertest package: Tests in linear mixed effects models. *Journal of Statistical Software, 82*(13), 1–26. https://doi.org/10.18637/jss.v082.i13

Larsen, J. K., Hollands, G. J., Moritz, S., Wiers, R. W., & Veling, H. (2024). How can imaginal retraining for modifying food craving be improved? *Appetite, 202*, Article 107639. https://doi.org/10.1016/j.appet.2024.107639

Larson, J. S., Redden, J. P., & Elder, R. S. (2014). Satiation from sensory simulation: Evaluating foods decreases enjoyment of similar foods. *Journal of Consumer Psychology, 24*(2), 188–194. https://doi.org/10.1016/j.jcps.2013.09.001

May, J., Andrade, J., Kavanagh, D. J., Feeney, G. F. X., Gullo, M. J., Statham, D. J., Skorka-Brown, J., Connolly, J. M., Cassimatis, M., Young, R. M., & Connor, J. P. (2014). The craving experience questionnaire: A brief, theory-based measure of consummatory desire and craving. *Addiction, 109*(5), 728–735. https://doi.org/10.1111/add.12472

Meule, A., Hermann, T., & Küubler, A. (2014). A short version of the food cravings questionnaire-trait: The fcq-t-reduced. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.00190

Missbach, B., Florack, A., Weissmann, L., & König, J. (2014). Mental imagery interventions reduce subsequent food intake only when self-regulatory resources are available. *Frontiers in Psychology, 5*. https://doi.org/10.3389/fpsyg.2014.01391 [Original Research].

Mogg, K., Bradley, B. P., Hyare, H., & Lee, S. (1998). Selective attention to food-related stimuli in hunger: Are attentional biases specific to emotional and psychopathological states, or are they also found in normal drive states? *Behaviour Research and Therapy, 36*(2), 227–237. https://doi.org/10.1016/S0005-7967(97)00062-4

Montagrin, A., Martins-Klein, B., Sander, D., & Mather, M. (2021). Effects of hunger on emotional arousal responses and attention/memory biases. *Emotion, 21*(1), 148–158. https://doi.org/10.1037/emo0000680

Morewedge, C. K., Huh, Y. E., & Vosgerau, J. (2010). Thought for food: Imagined consumption reduces actual consumption. *Science, 330*(6010), 1530–1533. https://doi.org/10.1126/science.1195701

Morey, R. D. (2008). Confidence intervals from normalized data: A correction to cousineau (2005). *Tutorials in Quantitative Methods for Psychology, 4*(2), 61–64. https://doi.org/10.20982/tqmp.04.2.p061 (IN FILE).

Nelis, S., Holmes, E. A., Griffith, J. W., & Raes, F. (2014). Mental imagery during daily life: Psychometric evaluation of the spontaneous use of imagery scale (suis). *Psychologica Belgica, 54*(1), 19–32. https://doi.org/10.5334/pb.ag

Nijs, I. M. T., Franken, I. H. A., & Muris, P. (2007). The modified trait and state food-cravings questionnaires: Development and validation of a general index of food craving. *Appetite, 49*(1), 38–46. https://doi.org/10.1016/j.appet.2006.11.001

Papies, E. K., Barsalou, L. W., & Rusz, D. (2020). Understanding desire for food and drink: A grounded-cognition approach. *Current Directions in Psychological Science, 29*(2), 193–198. https://doi.org/10.1177/0963721420904958

Patel, B. P., Aschenbrenner, K., Shamah, D., & Small, D. M. (2015). Greater perceived ability to form vivid mental images in individuals with high compared to low bmi. *Appetite, 91*, 185–189. https://doi.org/10.1016/j.appet.2015.04.005

Pearson, J., Naselaris, T., Holmes, E. A., & Kosslyn, S. M. (2015). Mental imagery: Functional mechanisms and clinical applications. *Trends in Cognitive Sciences, 19*(10), 590–602. https://doi.org/10.1016/j.tics.2015.08.003

Peng, M., McCormack, J. C., Abeywickrema, S., Wang, Q. J., Roberts, R., & Spence, C. (2025). Craving what you imagine: How sensory mental imagery relates to trait food craving and bmi. *Appetite, 210*, Article 107990. https://doi.org/10.1016/j.appet.2025.107990

Perszyk, E. E., Davis, X. S., Djordjevic, J., Jones-Gotman, M., Trinh, J., Hutelin, Z., Veldhuizen, M. G., Koban, L., Wager, T. D., Kober, H., & Small, D. M. (2023). Odour-imagery ability is linked to food craving, intake, and adiposity change in humans. *Nature Metabolism, 5*(9), 1483–1493. https://doi.org/10.1038/s42255-023-00874-z

Piech, R. M., Pastorino, M. T., & Zald, D. H. (2010). All i saw was the cake. Hunger effects on attentional capture by visual food cues. *Appetite, 54*(3), 579–582. https://doi.org/10.1016/j.appet.2009.11.003

Prescott, J. (2015). Multisensory processes in flavour perception and their influence on food choice. *Current Opinion in Food Science, 3*, 47–52. https://doi.org/10.1016/j.cofs.2015.02.007

R Core Team. (2025). _R: A Language and environment for statistical computing_. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Ramaekers, M. G., Verhoef, A., Gort, G., Luning, P. A., & Boesveldt, S. (2015). Metabolic and sensory influences on odor sensitivity in humans. *Chemical Senses, 41*(2), 163–168. https://doi.org/10.1093/chemse/bjv068

Reichelt, A. C., Westbrook, R. F., & Morris, M. J. (2015). Integration of reward signalling and appetite regulating peptide systems in the control of food-cue responses. *British Journal of Pharmacology, 172*(22), 5225–5238. https://doi.org/10.1111/bph.13321

Rolls, B. J., Rolls, E. T., Rowe, E. A., & Sweeney, K. (1981). Sensory specific satiety in man. *Physiology & Behavior, 27*(1), 137–142. https://doi.org/10.1016/0031-9384(81)90310-3

Schifferstein, H. N. J. (2009). Comparing mental imagery across the sensory modalities. *Imagination, Cognition and Personality, 28*(4), 371–388. https://doi.org/10.2190/IC.28.4.g

Schmid, D. A., Held, K., Ising, M., Uhr, M., Weikel, J. C., & Steiger, A. (2005). Ghrelin stimulates appetite, imagination of food, gh, acth, and cortisol, but does not affect leptin in normal controls. *Neuropsychopharmacology, 30*(6), 1187–1192. https://doi.org/10.1038/sj.npp.1300670

Schumacher, S., Kemps, E., & Tiggemann, M. (2019). The food craving experience: Thoughts, images and resistance as predictors of craving intensity and consumption. *Appetite, 133*, 387–392. https://doi.org/10.1016/j.appet.2018.11.018

Schüssler, P., Kluge, M., Yassouridis, A., Dresler, M., Uhr, M., & Steiger, A. (2012). Ghrelin levels increase after pictures showing food. *Obesity, 20*(6), 1212–1217. https://doi.org/10.1038/oby.2011.385

Siep, N., Roefs, A., Roebroeck, A., Havermans, R., Bonte, M. L., & Jansen, A. (2009). Hunger is the best spice: An fmri study of the effects of attention, hunger and calorie content on food reward processing in the amygdala and orbitofrontal cortex. *Behavioural Brain Research, 198*(1), 149–158. https://doi.org/10.1016/j.bbr.2008.10.035

Smeets, P. A., Erkner, A., & De Graaf, C. (2010). Cephalic phase responses and appetite. *Nutrition Reviews, 68*(11), 643–655.

Spence, C., Auvray, M., & Smith, B. (2014). Confusing tastes with flavours. In D. Stokes, M. Matthen, & S. Biggs (Eds.), *Perception and its modalities* (pp. 247–274). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199832798.003.0011.

Spence, C., Okajima, K., Cheok, A. D., Petit, O., & Michel, C. (2016). Eating with our eyes: From visual hunger to digital satiation. *Brain and Cognition, 110*, 53–63. https://doi.org/10.1016/j.bandc.2015.08.006

Steel, D., Kemps, E., & Tiggemann, M. (2006). Effects of hunger and visuo-spatial interference on imagery-induced food cravings. *Appetite, 46*(1), 36–40. https://doi.org/10.1016/j.appet.2005.11.001

Stevenson, R. J., Francis, H. M., Wylie, F., & Hughes, A. (2023). The psychological basis of reductions in food desire during satiety. *Royal Society Open Science, 10*(5), Article 221404. https://doi.org/10.1098/rsos.221404

Stevenson, R. J., Yeomans, M. R., & Francis, H. M. (2024). Human hunger as a memory process. *Psychological Review, 131*(1), 174–193. https://doi.org/10.1037/rev0000413

Stokes, J. R., Boehm, M. W., & Baier, S. K. (2013). Oral processing, texture and mouthfeel: From rheology to tribology and beyond. *Current Opinion in Colloid & Interface Science, 18*(4), 349–359. https://doi.org/10.1016/j.cocis.2013.04.010

Stribiţcaia, E., Evans, C. E. L., Gibbons, C., Blundell, J., & Sarkar, A. (2020). Food texture influences on satiety: Systematic review and meta-analysis. *Scientific Reports, 10*(1), Article 12929. https://doi.org/10.1038/s41598-020-69504-y

Sulfaro, A. A., Robinson, A. K., & Carlson, T. A. (2024). Properties of imagined experience across visual, auditory, and other sensory modalities. *Consciousness and Cognition, 117*. https://doi.org/10.1016/j.concog.2023.103598

Tiggemann, M., & Kemps, E. (2005). The phenomenology of food cravings: The role of mental imagery. *Appetite, 45*(3), 305–313. https://doi.org/10.1016/j.appet.2005.06.004

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). Mediation: R package for causal mediation analysis. *Journal of Statistical Software, 59*(5), 1–38. https://www.jstatsoft.org/v59/i05/.

Tournier, C., Sulmont-Rossé, C., & Guichard, E. (2007). Flavour perception: Aroma, taste and texture interactions. *Food, 1*(2), 246–257.

Wang, G.-J., Volkow, N. D., Telang, F., Jayne, M., Ma, J., Rao, M., Zhu, W., Wong, C. T., Pappas, N. R., Geliebter, A., & Fowler, J. S. (2004). Exposure to appetitive food stimuli markedly activates the human brain. *NeuroImage, 21*(4), 1790–1797. https://doi.org/10.1016/j.neuroimage.2003.11.026

Weingarten, H. P., & Elston, D. (1991). Food cravings in a college population. *Appetite, 17*(3), 167–175. https://doi.org/10.1016/0195-6663(91)90019-O

Zorjan, S., & Schienle, A. (2023). Temporal dynamics of mental imagery, craving and consumption of craved foods: An experience sampling study. *Psychology and Health, 38*(11), 1443–1459. https://doi.org/10.1080/08870446.2022.2033239