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'I can't resist': Incentive salience for ultra-processed food cues matches erotic cues in individuals with food addiction

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ABSTRACT

Environmental cues can guide behavior, which in substance use disorders contributes to maladaptive outcomes. Currently, ultra-processed food (UPF) cues dominate food environments, and growing evidence suggests that their consumption may share characteristics with substance use disorders. The attribution of heightened incentive salience to food cues relative to other highly rewarding stimuli has been linked to food addiction (FA). Here, we investigate whether FA is specifically associated with greater incentive salience for UPF. A remote version of the normative rating procedure for the International Affective Picture System (IAPS) was conducted with 212 Brazilians. The arousal dimension of emotion was used as an index of incentive salience and was assessed through the Self-Assessment Manikin scale. We presented 70 pictures from the IAPS (from various emotion categories, including erotic cues due to their rewarding properties) and an additional set of 11 UPF and 11 unprocessed or minimally processed foods (UMPF) pictures. The modified Yale Food Addiction Scale 2.0 was applied to assess FA. Results indicated that both groups of individuals (with and without FA) attributed greater incentive salience to UPF cues than to UMPF cues. However, only individuals with FA attributed similar incentive salience to UPF and erotic cues. These findings highlight the significance of UPF in the development of FA and could support public policies aimed at overcoming the appealing and potentially addictive aspects of UPF.

1. Introduction

Cues embedded in the environment can guide behavior and, depending on their motivational properties, may contribute to adaptive or maladaptive outcomes. In addictive disorders, such cues become especially powerful, as they are critically implicated in the disruption of self-regulatory mechanisms and the exacerbation of impulsivity (Westbrook & Flagel, 2024). A central framework for understanding how environmental cues gain this disproportionate control over behavior is the incentive-sensitization theory of addiction. Within this framework, incentive salience refers to a specific motivational property attributed to reward-predictive stimuli, turning them into "motivational magnets" that are attention-grabbing, emotionally charged, and capable of eliciting strong "wanting" or approach behavior, even in the absence of increased hedonic "liking" (Berridge, 2007; Berridge & Robinson, 1998; Berridge & Robinson, 2016). Through repeated substance use, a conditioning process occurs in which cues associated with the substance acquire high incentive salience and, consequently, trigger intense urges or cravings when encountered (Berridge, 2001; Perry et al., 2014). When a cue acquires excessive incentive salience, it becomes rewarding in itself and biases behavior toward stimulus-driven seeking of the associated outcome, while other, unrelated rewards become relatively

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less motivationally relevant (Volkow et al., 2010). Such an imbalance in incentive salience attribution is thought to be a key mechanism underlying the maladaptive behavioral patterns characteristic of substance use.

Emotional arousal indexes the intensity of a cue's motivational relevance and is widely employed in cue-reactivity and incentive salience studies (e.g., Delgado-Rodríguez et al., 2022; Versace et al., 2012; Versace et al., 2019). The late positive potential (LPP) is a neuroindex that reflects brain activity over time in response to a stimulus that is associated with emotional arousal (David et al., 2023; Delgado-Rodríguez et al., 2022; Sabatinelli et al., 2006; Versace et al., 2019). In studies of tobacco users, different patterns of incentive salience were identified for different cues depending on the levels of arousal indexed by the LPP. The particular focus was on investigating these patterns for tobacco-related cues compared to erotic cues (Versace et al., 2012). The logic behind this is that erotic cues are experienced as very motivating and pleasing, reliably engaging the appetitive motivational system (Bradley, Codispoti, Sabatinelli, & Lang, 2001). Therefore, they have been used as rewarding non-related cues to investigate possible dysfunctions between incentive salience patterns (Delgado-Rodríguez et al., 2022; Versace et al., 2012). Tobacco users with reduced LPP amplitude for erotic cues and increased amplitude for tobacco cues had greater difficulty quitting smoking compared to those with the opposite pattern (Versace et al., 2012).

Although LPP studies offer strong neurophysiological evidence of incentive salience (David et al., 2023; Delgado-Rodríguez et al., 2022; Sabatinelli et al., 2006; Versace et al., 2019), the present study instead relies on subjective arousal ratings obtained through the Self-Assessment Manikin (SAM) scale (Bradley & Lang, 1994), a well-established tool in affective cue-reactivity research across addiction-related and non-addiction contexts. Consistent findings from affective-rating studies indicate that erotic pictures reliably evoke high levels of subjective arousal SAM ratings (Bradley, Codispoti, Cuthbert, & Lang, 2001). Accordingly, erotic stimuli have been used as an upper benchmark of appetitive motivational activation in cue-reactivity paradigms, including those applied to addiction (e.g., Versace et al., 2012). Importantly, SAM-derived arousal ratings from emotion-calibrated International Affective Picture System (IAPS) procedures (Lang et al., 2008) closely track LPP magnitude, as higher subjective arousal ratings reliably corresponds to larger LPP amplitudes across studies (Lang & Bradley, 2010; Sabatinelli et al., 2006). Although the literature rarely includes direct SAM-based comparisons of erotic and addictive-substance cues in addicted individuals, affective-rating studies in alcohol users (Bates et al., 2020; Pulido et al., 2010) and methamphetamine-dependent individuals (Li et al., 2022) have shown that the SAM methodology reliably differentiates subjective ratings to substance-related versus non-substance-related visual cues.

An increasing amount of research has shown behavioral and neurobiological similarities between excessive ultra-processed foods (UPF) consumption and substance use-related disorders (Pursey et al., 2024). UPF are hyper-palatable, appealing and overconsumed. This is achieved by means of their strategic composition and marketing (DiFeliceantonio et al., 2018; Lemos et al., 2022; Monteiro et al., 2019; Schulte et al., 2019). Designed to replace traditional meals based on unprocessed and minimally processed foods (UMPF), the Nova classification defines UPF as convenient, ready-to-eat, low-cost foods that typically contain food substances used exclusively in industry, classes of additives with purely cosmetic functions, as well as excessive amounts of ingredients such as sugars, fats, and sodium (Monteiro et al., 2016, 2019). The Nova classification system supports the recommendations of the Brazilian Dietary Guidelines and has played a major role in guiding public policy in Brazil, where the current study was conducted (Louzada & Gabe, 2025).

A recent review of the existing literature on UPF by Gearhardt and Schulte (2021) concluded that "UPF are created in ways that parallel the development of addictive drugs, including the inclusion of an unnaturally high dose of rewarding ingredients that are rapidly absorbed into the system and enhanced through additives. As with addictive drugs, some (but not all) individuals exhibit an addictive pattern of consumption marked by diminished control over intake, intense cravings, and an inability to cut down despite negative consequences". Moreover, the psychological and behavioral impairments linked to UPF consumption meet the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) criteria for substance use disorder, even though food addiction (FA) is not currently classified as a condition in the DSM-5 (American Psychiatric Association, 2022). The Yale Food Addiction Scale (YFAS) was developed to operationalize the construct of FA in research by applying diagnostic criteria from substance use disorders to eating behavior (Gearhardt et al., 2009; Schulte & Gearhardt, 2017).

Contemporary food environments are saturated with UPF cues (Monteiro et al., 2013; Pineda et al., 2024), a concerning scenario highlighted in the recent Lancet Series on UPF (The Lancet, 2025), which emphasizes their expanding global influence on health and food systems. This proliferation is particularly problematic given the consistent associations between UPF consumption and increased risk of chronic non-communicable diseases and all-cause mortality (Lane et al., 2024). Despite these detrimental outcomes, UPF remain a dominant component of dietary patterns worldwide (Juul et al., 2022; Rauber et al., 2019). UPF cues have been associated with increased motivational engagement, sometimes reflected in higher reported desire or intention to consume them. For instance, visual exposure to UPF pictures elicits stronger motivational engagement and greater consumption intention compared to unprocessed/minimally processed foods (Lemos et al., 2022). Importantly, this pattern aligns with theories of incentive-salience dysregulation observed in substance-use disorders. Neuroimaging studies indicate that individuals with higher YFAS scores display heightened neural responsiveness to food cues in brain markers involved in incentive salience. For example, it has been shown that elevated FA scores were associated with greater caudate and medial orbitofrontal cortex activation during anticipated palatable food reward, a pattern characteristic of amplified cue-evoked incentive salience (Gearhardt et al., 2011). Likewise, Delgado-Rodríguez et al. (2022) demonstrated that participants who displayed heightened brain-based incentive salience event-related potential responses to food cues, comparable to those evoked by erotic cues, reported substantially higher FA symptomatology. Together, these findings reinforce the notion that the intensified arousal responses observed in high-FA individuals, which index heightened attentional and motivational relevance rather than hedonic liking per se, may reflect a broader phenotype of cue-salience sensitization, raising the possibility that UPF cues may potentiate addictive-like incentive salience.

The primary goal of this study was to investigate whether individuals with FA have a tendency to attach high incentive salience to UPF cues. We hypothesized that (i) individuals would attribute a higher incentive salience to UPF cues than UMPF cues. (ii) individuals with FA would exhibit a tendency to attribute high incentive salience to UPF-related cues, similar to erotic cues, whereas individuals without FA would attribute a higher incentive salience to erotic cues than UPF cues. Through these hypotheses, we hope to establish whether UPF may play a key role in dysfunctions of incentive salience, thereby fostering FA.

2. Methods

2.1. Participants

Young adults from different states of Brazil were invited to participate in this online cross-sectional behavioral study. Recruitment was carried out by a Brazilian research company between November 2023 and March 2024. A call for participation was distributed to individuals registered in the company's database to identify potential volunteers interested in the study. The company's online platform hosted the questionnaires developed by the research team and provided participants with access to the picture affective rating task, which was

completed via the Pavlovia platform (https://pavlovia.org/). The inclusion criteria were to have Brazilian-Portuguese as their native language, be omnivorous, be aged between 18 and 30 years old, have a computer/notebook with internet, and have normal or corrected vision. The exclusion criteria were pregnancy or the presence of a clinically diagnosed eating disorder, both of which were assessed through a questionnaire applied at the beginning of the study. An insufficient evaluation of at least 50% of the pictures presented through the access instruments was likewise considered to meet the exclusion criteria.

A total of 250 participants were recruited, but 38 were excluded for not meeting the eligibility criteria for the study, being vegetarian or vegan (n = 10), pregnant (n = 11), having a diagnosis of an eating disorder (n = 16), or not completing the assessment instruments (n = 1). Therefore, the final sample comprised 212 participants with a mean age = 25.18 years (standard deviation = 3.34 years) of whom 121 were women (cisgender = 118; transgender = 3) and 91 men (cisgender = 89; transgender = 2). All participants were naive to the purpose of the study. The hypotheses were specified before the data were collected and the protocols applied in the present study were validated in a previous study (Lemos et al., 2024). This research was conducted according to the Declaration of Helsinki and approved by the Ethics Committee of the University of São Paulo (CAAE: 44805521.0.0000.5421).

2.2. Visual stimuli

Pictures with different levels of motivational relevance (erotic, sports, adventure, nature, puppies, illness, loss, mutilated bodies etc.) were used alongside the UPF and UMPF pictures to investigate possible changes in incentive salience depending on the presence or absence of the FA criteria, based on the modified Yale Food Addiction Scale 2.0 (mYFAS 2.0) (Schulte & Gearhardt, 2017), an instrument that translates the Diagnostic and Statistical Manual of Mental Disorders 5 (DSM-5) criteria for substance use disorder to the context of food intake. Two datasets of standardized affective pictures were used: the International Affective Picture System (pictures of various emotional categories, but not of food) (Lang et al., 2008) and standardized pictures of UPF and UMPF (Lemos et al., 2022). Both are detailed below.

2.2.1. International affective picture system pictures

A total of 70 pictures from the International Affective Picture System (IAPS) (Lang et al., 2008) were shown to the participants. The pictures could be: (1) pleasant with high arousal (i.e., high incentive salience) such as pictures from the erotic and adventure categories; (2) unpleasant with high incentive salience (e.g., mutilated bodies, animal attacks); (3) pleasant with low incentive salience (e.g., romantic, nature, puppies); (4) unpleasant with low incentive salience (e.g. violence, pollution, illness); (5) and neutral (e.g., objects). These five categories were defined based on the normative pleasantness and arousal values established during the development of the IAPS, as detailed in its technical manual. A total of 10 pictures had pleasant content (3 of which were erotic), 30 had unpleasant content (3 of which were mutilated bodies) and 30 had neutral content. The use of these pictures served as anchor stimuli since each of these categories is expected to evoke specific pleasantness and arousal feelings responses in the participants (e.g., erotic pictures typically evoke high pleasant and arousing responses). Therefore, when the affective pleasantness and arousal (i.e., incentive salience) mean ratings values for each picture are plotted in a cartesian plane, the pictures' distribution in the graph assumes the shape of a boomerang. The upper arm of the boomerang represents the appetitive motivational system (approach motivation) while the lower arm represents the defensive motivational system (avoidance motivation) (Bradley, Codispoti, Cuthbert, & Lang, 2001). The erotic and mutilated bodies pictures symbolize the apex of the appetitive and defensive motivational systems, respectively. Due to their strong capacity to evoke the appetitive motivational system, the erotic pictures served as a rewarding non-food related cue. The list of the IAPS picture codes applied during the study experiments is given in the supplemental material.

2.2.2. Food pictures

In addition to the pictures from the IAPS catalog, we also presented 24 food pictures to the participants. These food pictures were selected from a dataset of standardized pictures developed by our research group (Lemos et al., 2022). In total, participants viewed 12 UMPF pictures (watermelon, apple, mandarin juice, pear, mango, banana, beans, salad, nuts, corn, lettuce and egg) and 12 UPF pictures (a soft drink, a cookie, ice cream, sandwich cookie, chocolate, gummy candy, potato chips, ready-to-eat ultra-processed lasagna, Brazilian ultra-processed cheese bread, hot dogs, margarine, and sausage), which represent foods commonly consumed by Brazilians according to data from the Instituto Brasileiro de Geografia e Estatística (2010). Within each food category, six were sweet foods and six were savory foods. All were depicted in the picture without packaging and in their ready-to-eat form. For further details about the food picture dataset, see Lemos et al., 2022.

2.3. Measures

2.3.1. Using the self-assessment manikin (SAM) scale to measure incentive salience

Incentive salience has previously been associated with the arousal dimension of emotion due to its properties to reflect the intensity of motivational relevance (Delgado-Rodríguez et al., 2022; Versace et al., 2019). Since incentive salience is the study's main focus, we will refer to arousal as incentive salience based on previous studies (Delgado-Rodríguez et al., 2022; Versace et al., 2019). However, instead of the amplitude of the late positive potential evoked by each picture category (Delgado-Rodríguez et al., 2022; Versace et al., 2012, Versace et al., 2019), here we used the arousal dimension of emotion obtained through the Self-Assessment Manikin (SAM) Scale (Bradley & Lang, 1994) as a measure of incentive salience. This decision was based on previous studies finding a relationship between the arousal ratings obtained from emotion-calibrated pictures using the International Affective Picture System (Lang et al., 2008) procedure and late positive potential amplitude (e.g., Lang & Bradley, 2010; Sabatinelli et al., 2006).

The Self-Assessment Manikin scale (SAM; Bradley & Lang, 1994) is a non-verbal pictographic scale that captures two dimensions that reflect drives of motivational systems: (1) Valence (Pleasure-Displeasure) through a series of manikin-like figures ranging from a “smiling-happy face” at one extreme (score = 9) to a “frowning-unhappy face” at the other (score = 1) with the intermediate figures gradually changing from smiling to neutral to frowning. (2) Arousal (Excitement-Calm) which may represent incentive salience (Delgado-Rodríguez et al., 2022; Versace et al., 2019), using manikins that range from an “excited wide-eyed” figure (score = 9) to a “relaxed-sleepy” figure (score = 1). Participants choose the manikin that represents their perceptions of the stimulus in both dimensions. We applied a validated online version of the SAM scale used for remote application of the IAPS methodology (Lemos et al., 2024).

2.3.2. Modified Yale food addiction scale 2.0

To investigate FA, we used the version of the modified Yale Food Addiction Scale 2.0 (mYFAS 2.0; Schulte & Gearhardt, 2017) validated for use in Brazil (Nunes-Neto et al., 2018). This is a shortened version of YFAS with thirteen questions considering the past twelve months. Of these, eleven refer to symptoms such as cravings, tolerance, withdrawal, persistent desire or repeated unsuccessful attempts to quit, and continued use despite social or interpersonal problems, among others. In addition, it has two questions related to diagnostic criteria that capture clinically significant impairment or distress. Each question is scored on an 8-point Likert-type scale (0 = never, 7 = every day). The criteria to determine FA is considered met if two or more symptoms plus at least one of the diagnostic criteria are present. Although we used the

Portuguese wording of the mYFAS 2.0 based on Nunes-Neto et al. (2018), the scoring procedure adopted in our study strictly followed the original threshold criteria published in Schulte and Gearhardt (2017). Specifically, symptom endorsement was determined using the original frequency-based cut-offs: (i) Once a month (≥2): #3, #7, #12, #13; (ii) Once a week (≥4): #1, #4, #8, #10; and (iii) Two to three times a week (≥5): #2, #5, #6, #9, #11, rather than relying on the numerical values reported in the Brazilian scoring table. Our approach therefore directly addresses the concern raised by Silva Júnior and Bueno (2023), who noted that thse numeric thresholds may underestimate symptom endorsement. To ensure psychometric adequacy, we assessed internal consistency of the mYFAS 2.0 symptom scores in our sample. Cronbach's alpha indicated excellent reliability ($\alpha = 0.912$), demonstrating that the translated wording produced stable and homogeneous item responses.

2.3.3. Hunger scale

We used a hunger scale (Grand, 1968) to assess the subjective levels of hunger of the participants. The scale includes items asking about: the amount of time since their last meal, subjective hunger, the amount of their favorite food they could consume at the time, and the estimated time until their next meal. All the items were then combined into a score, as proposed by (Tapper & Turner, 2018).

2.3.4. Sociodemographic and individual characteristics questionnaire

We applied a questionnaire that collected information on participants' race/ethnicity, income, and educational level based on parameters defined by the the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e, 2025). Additionally, participants self-reported the following information in the questionnaire: gender, age, pregnancy status, weight, height, medical diagnosis of eating disorder, being omnivorous, and normal or corrected vision.

2.3.5. Procedures

Participation in the study comprised two stages on different days, both fully online and accessed from the participant's personal PC/laptop. On the first day, the Brazilian research firms invited the participants on their database to take part in the survey developed by our team. Participants who agreed to take part electronically signed an informed consent form and accessed the online questionnaires to complete the mYFAS 2.0, and they also provided self-reported body weight and height, along with socio-economic and other individual characteristics. Three days, on average, after the first stage the participants were re-contacted and received a link to complete the affective evaluation task and the hunger scale. The study was divided into two stages to prevent participant fatigue and ensure better task performance, given that the first stage (questionnaires) lasted approximately 20 min and the second (pictures' affective rating task) about 30 min. To ensure methodological accuracy and precision regarding the stimuli presentation and responses collection, we used Psycopy 3.0v® software for programming the affective rating experiment and the webpage (https://pavlovia.org/) to run it online. To safeguard data quality, completion time monitoring and internal consistency checks were systematically applied to each collected response. A preliminary pilot study was also conducted to ensure methodological quality.

The sequences of events of the affective rating task are presented in Fig. 1. Before the visual stimuli were presented, the participant was shown written instructions and an explanatory video about the upcoming task (Lemos et al., 2024). Following that, nine additional IAPS pictures representing various emotional categories were used as training. After the training, the instruction "Click the mouse or touchpad to begin the experiment when you are ready." was displayed. Each experimental trial began with an instructional slide ("Observe the picture") that lasted 2 s. Next, a picture from the IAPS catalog (Lang et al., 2008) or from the food picture dataset (Lemos et al., 2022) was randomly presented for 6 s. Finally, in the 10 s after seeing the picture, the participant rated the picture in the pleasantness and arousal dimension of emotion using the online version of the SAM scale (Lemos et al., 2024). In total, there were 94 trials, featuring all visual stimuli. Once all the pictures had been rated, the participant completed the hunger scale and the experiment ended.

2.4. Statistical analyses

2.4.1. Sample characteristics

Descriptive statistics were used to summarize the characteristics of the sample. Categorical variables were presented as frequencies, such as gender, Body Mass Index category, race/ethnicity, household income, Brazilian geographic region and educational level. The Body Mass Index was calculated using self-reported weight and height and categorized according to World Health Organization parameters (World Health Organization, 2000). Chi-square analyses were applied to the categorical variables to compare the frequencies observed between participants with and without FA diagnostic criteria.

2.4.2. Distribution in affective space

A first experimental step was to ascertain whether the affective mean ratings obtained for the IAPS pictures fit the typical boomerang-shaped distribution in the two-dimensional affective space. To complete this step, the pleasantness and arousal (incentive salience) ratings of each picture were obtained by calculating the mean of the ratings values

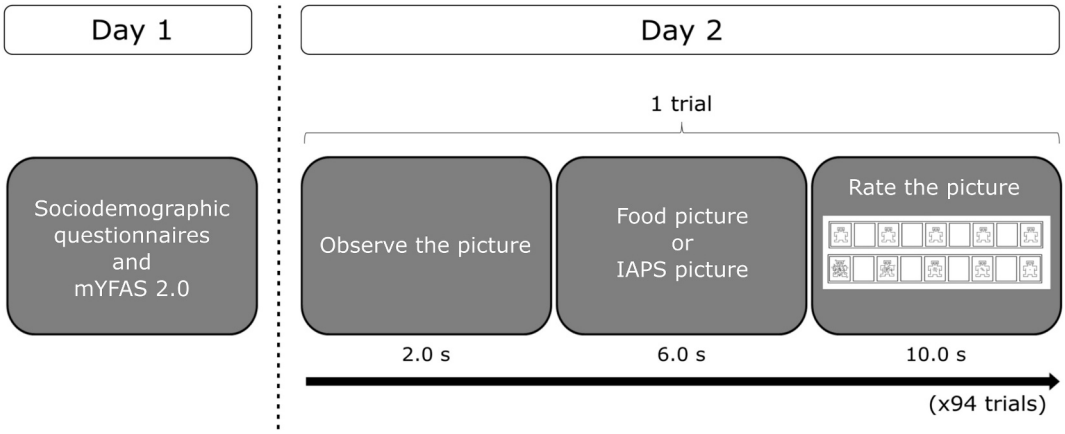

Fig. 1. Schematic representation of the sequence of events of the study. On the first day, the participant completed the questionnaires and the modified Yale Food Addiction Scale 2.0 (mYFAS 2.0 scale). On the second day, the participant rated the pictures through the SAM scale (affective rating task). The right panel represents a trial of the affective rating task, which was repeated 94 times until all the pictures had been rated.

attributed by all the participants for each picture. Spearman's correlations were then performed to test the association between the affective ratings obtained in the present study and those obtained during the original North American study (Lang et al., 2008).

2.4.3. Ultra-processed foods vs. unprocessed/minimally processed foods

We were also interested in assessing whether UPF stimuli triggered greater motivational salience UMPF stimuli, as previously described (Lemos et al., 2022). Since the data presented a normal distribution for both incentive salience and pleasantness ratings ($p > 0.05$, Shapiro-Wilk test), we conducted two independent samples *t*-tests to compare the affective ratings attributed for UPF and UMPF pictures, one for arousal (incentive salience) and the other for pleasantness. In these analyses, we calculated the mean ratings across all the participants to obtain mean ratings values per picture (12 mean ratings for UPF pictures and 12 mean ratings for UMPF pictures). Furthermore, to check whether the individual's hunger score interfered with the pleasantness ratings and incentive salience of the food images, we conducted a Spearman correlation considering the responses per individual ($n = 212$).

2.4.4. Incentive salience and food addiction

The mYFAS 2.0 scores were used to divide the sample into those with and without diagnostic criteria for FA. Participants who had sufficient symptoms plus the diagnostic criteria were placed in the 'with FA' group and the others in the 'without FA' group. Because arousal was considered here a measure of incentive salience, we focused our analysis on the arousal measure rather than pleasantness. We calculated the mean ratings across the pictures of interest (UPF, UMPF and erotic) from the same category per participant, resulting in 212 mean ratings. A minimum sample size of 140 participants was determined to be required for a repeated measures ANOVA with between-factors, given a power of 0.95, an alpha level of 0.05, and an effect size of 0.25. The *Z*-skewness was calculated to evaluate if the normality assumption was violated, as suggested for medium-sized samples (50 < n ⟨300) (Kim, 2013). The data presented a normal distribution (absolute z-value below 3.29). We performed repeated measures ANOVA, having as the between-subjects variable the FA diagnosis criteria ('with FA' group and 'without FA' group). The pictures' categories (UPF, UMPF and erotic) served as a within-subjects variable. We also applied Bonferroni post hoc tests to further explore significant effects. Partial eta-squared (η^2p) was calculated as a measure of effect size.

The software used to conduct all the analyses was Jamovi (version 2.3.21) and the *p*-value considered for significance was $p < 0.05$.

3. Results

3.1. Sample characteristics

The sample characteristics are described in Table 1. Participants were predominantly female (57.1%), with normal weight (52.1%), and White (51.9%). The largest proportion had a family monthly wage of 2–5 times the minimum wage (43.4%), lived in the Southeast region of Brazil (34.4%), and had completed high school education (50.0%). Frequencies between the groups 'with' and 'without' FA diagnostic criteria were similar for all variables. However, the race/ethnicity variable reached a marginal p-value ($p = 0.05$).

3.2. Distribution in affective space

The results demonstrated that the IAPS pictures (diamond shape) were appropriately dispersed throughout the affective space (Bradley, Codispoti, Cuthbert, & Lang, 2001; Bradley, Codispoti, Sabatinelli, & Lang, 2001; Lang et al., 2008) - Fig. 2. Both the Spearman correlation performed for pleasantness (rho = 0.96, $p < 0.001$) and arousal (incentive salience) ratings (rho = 0.91, $p < 0.001$) confirmed a correlation between the data obtained in this study and those originally established during the development of the IAPS (Lang et al., 2008). This convergence indicates that participants responded to the standardized emotional stimuli in a manner consistent with previously established normative patterns. Establishing this correspondence between normative ratings and those observed in the experimental sample is frequently used as an initial methodological check in studies applying SAM-based assessments (e.g., Betella & Verschure, 2016; Branco et al., 2023; Lemos et al., 2024), indicating that the emotional measures functioned as expected in the present protocol.

Table 1
Frequency distribution between the groups with and without diagnostic criteria.

	Without Food Addiction criteria	With Food Addiction criteria	Total	
Gender	n (%)	n (%)	n (%)	Chi-Square/ *p* value
Female	102 (48.1)	19 (9.0)	121 (57.1)	3.10/0.08
Male	84 (39.6)	7 (3.3)	91 (42.9)	
Total	186 (87.7)	26 (12.3)	212 (100)	
BMI				
With underweight (<18.5)	14 (6.6)	0 (0)	14 (6.6)	5.15/0.16
With normal weight (18.5–24.9)	97 (46.0)	13 (6.2)	110 (52.1)	
With overweight (25–29.9)	50 (23.7)	6 (2.8)	56 (26.5)	
With obesity (≥30)	24 (11.4)	7 (3.3)	31 (14.7)	
Total	185 (87.7)	26 (12.3)	211 (100)	
Race/Ethnicity				
White	98 (46.2)	12 (5.7)	110 (51.9)	7.69/0.05
Black/Brown	86 (40.6)	13 (6.1)	99 (46.7)	
Asian	2 (0.9)	0 (0)	2 (0.9)	
Indigenous	0 (0)	1 (0.5)	1 (0.5)	
Total	186 (87.7)	26 (12.3)	212 (100)	
Household Income				
Class A	21 (9.9)	1 (0.5)	22 (10.4)	2.01/0.57
Class B	31 (14.6)	4 (1.9)	35 (16.5)	
Class C	81 (38.2)	11 (5.2)	92 (43.4)	
Class D/E	53 (25.0)	10 (4.7)	63 (29.7)	
Total	186 (87.7)	26 (12.3)	212 (100)	
Brazilian geographic region				
North	15 (7.1)	2 (0.9)	17 (8.0)	1.51/0.83
Northeast	45 (21.2)	9 (4.2)	54 (25.5)	
Center-West	21 (9.9)	3 (1.4)	24 (11.3)	
Southeast	65 (30.7)	8 (3.8)	73 (34.4)	
South	40 (18.9)	4 (1.9)	44 (20.8)	
Total	186 (87.7)	26 (12.3)	212 (100)	
Education level				
Higher Education	88 (41.5)	12 (5.7)	100 (47.2)	3.81/0.28
High School	94 (44.3)	12 (5.7)	106 (50.0)	
Middle School	3 (1.4)	2 (0.9)	5 (2.4)	
Elementary School	1 (0.5)	0 (0)	1 (0.5)	
Total	186 (87.7)	26 (12.3)	212 (100.0)	

Note: The Body Mass Index (BMI) cutoff was based on WHO guidelines (2000). Concerning household income class, the division was based on the value of the Brazilian minimum wage, which at the time of data collection was 1302 Brazilian Reals per month (approximately 240 US Dollars). Class A represents the participant's family income to be more than 10 minimum wages per month; Class B to be 5–10 minimum wages per month; Class C to be 2–5 minimum wages per month; Class D/E to be less than 2 minimum wages per month.

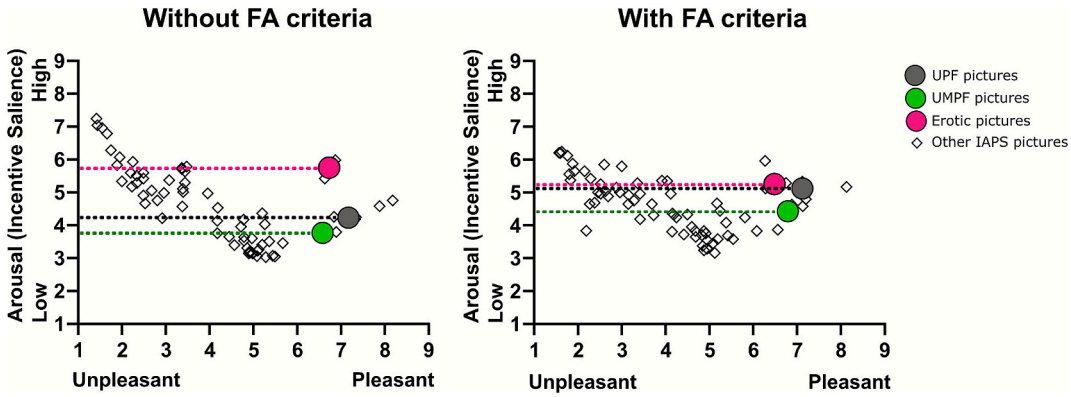

Fig. 2. Affective space for the group with diagnostic criteria for food addiction (right panel) and for the group without diagnostic criteria (left panel). The dashed lines represent the projection values of incentive salience in the y-axis for the UPF and erotic visual cues. Note that the dashed line that corresponds to the UPF cues' incentive salience is near to the dashed line that corresponds to erotic cues' incentive salience in the right panel (individuals who meet food addiction criteria).

3.3. Ultra-processed foods vs. unprocessed/minimally processed foods

UPF pictures showed higher mean pleasantness (Mean = 7.17, SD = 0.31) and incentive salience (Mean = 4.34, SD = 0.24) ratings than UMPF pictures (Mean pleasantness = 6.61, SD = 0,24; Mean incentive salience = 3.85, SD = 0.22). The ratings attributed to UPF and UMPF pictures were statistically significant for both pleasantness $t(22) = 4.93$, $p \leq 0.001$ and incentive salience $t(22) = 5.27$, $p \leq 0.001$. Both demonstrated a strong Cohen's d effect, with d = 2.01 for pleasantness and d = 2.15 for incentive salience. The hunger scores was not associated with the pleasantness ratings (rho UMPF = −0.04, $p = 0.56$; rho UPF = −0.01, $p = 0.87$) nor the incentive salience ratings (rho UMPF = −0.05, $p = 0.50$; rho UPF = 0.01, $p = 0.93$).

3.4. Incentive salience and food addiction

Considering the criteria based on the mYFAS 2.0 scale, 12.3% (n = 26) of our sample reached the cut-off point for FA, which is similar to that found in the literature (Oliveira et al., 2021). The repeated measures ANOVA showed a main effect for pictures' categories (UPF, UMF and erotic) [$F(2, 418) = 26.03$, $p < 0.001$, $\eta^2p = 0.11$]. The erotic pictures demonstrated the highest incentive salience (mean ratings = 5.68, standard deviation (SD) = 2.33), followed by UPF (mean ratings = 4.33, SD = 2.10) and then by UMPF (mean ratings = 3.85, SD = 1.95). All comparisons made through the post hoc tests between the three categories of pictures were significant (p, 0.05). The interaction between groups ('with FA' and 'without FA') and pictures' categories (UPF, UMPF and erotic), [$F(2, 418) = 8.68$, $p < 0.001$, $\eta^2p = 0.04$] was also statistically significant. We then carried out post hoc tests to compare pictures' categories within each group. In the 'with FA' group, the UPF pictures showed higher incentive salience than UMPF pictures. Of note, we found that for the 'with FA' group, the incentive salience ratings attributed to the erotic pictures did not differ from the incentive salience ratings attributed the UPF pictures. The 'without FA' group exhibited variance in the incentive salience for all pictures, indicating that the incentive salience ratings for erotic, UPF, and UMPF pictures were all different from one another, with erotic pictures displaying the highest incentive salience, followed by UPF and UMPF cues. The mean ratings for the 'Without FA' and 'With FA' group are presented in Table 2. The difference between the picture categories in each group can also be observed in the affective space (Fig. 2). Although this analysis was conducted using the mean ratings per participant, in the affective space, the average is applied per picture category, as is typically done for its reproduction.

Table 2
Mean incentive salience rating for Erotic, UPF and UMPF pictures for the groups 'Without FA' and 'With FA'.

	Without FA		With FA	
	Mean (SD)	Bonferroni post hoc	Mean (SD)	Bonferroni post hoc
Erotic	5.76 (2.31)	Erotic vs UPF: $t = 9.96$, $p < 0.001$* Erotic vs UMPF: $t = 12.55$, $p < 0.001$*	5.16 (2.41)	Erotic vs UPF: $t = 0.14$, $p = 1.00$ Erotic vs UMPF: $t = 1.76$, $p = 1.00$
UPF	4.22 (2.11)	UMPF vs UPF: $t = -6.60$, $p < 0.001$*	5.10 (1.94)	UMPF vs UPF: $t = -3.73$, $p < 0.05$*
UMPF	3.77 (1.93)	–	4.41 (2.00)	–

Note: Incentive salience ratings could range from 1 (very low) to 9 (very high). Bonferroni post hoc comparisons were made within each group (Without and With FA). The asterisk (*) symbol indicates comparisons that were statistically different. Within the group Without FA, the analyses showed that all comparisons differed statistically. Within the group With FA, there was only a statistical difference between the comparison UPF vs UMPF. SD, Standard Deviation; UMPF, unprocessed/minimally processed foods; UPF, ultra-processed foods; FA, Food Addiction.

4. Discussion

The primary hypothesis of this study was that individuals who report FA would attribute greater incentive salience to UPF than UMPF cues. Consistent with this hypothesis, we found that UPF cues generally elicited higher incentive salience than UMPF cues. We also confirm our secondary hypothesis that individuals with FA would exhibit a tendency to attribute high incentive salience to UPF-related cues, similar to erotic cues, whereas individuals without FA would attribute a higher incentive salience to erotic cues than UPF cues. Thus, individuals with FA were especially prone to assigning elevated salience to UPF cues, comparable to their responses to erotic cues. Finally, both groups, those with and without FA, kept the natural motivation rating UMPF cues as less salient than UPF cues. These results suggest that UPF cues may acquire heightened motivational relevance among individuals with FA, since they were the specific class of cues that elicited elevated incentive salience relative to other rewarding stimuli, such as erotic pictures in those individuals. Importantly, this pattern may have implications for FA, as cues that become disproportionately salient can bias attention and motivational resources toward UPFs, potentially reinforcing cue-driven eating tendencies and making it harder to disengage from UPF-related stimuli in everyday environments.

In line with a previous study conducted on a university sample (Lemos et al., 2022), UPF evoked higher approach motivation (i.e.,

higher pleasantness and incentive salience ratings) than UMPF. It is interesting to note that we were able to reproduce this result in a larger sample that was more diverse in terms of demographics, socioeconomic status, education level and race/ethnicity. This indicates that, even in a more diverse sample, UPF is the only category of the Nova Classification capable of generating pleasantness and incentive salience at levels above the natural expected for food (UMPF). This may be related to the fact that in order to maximize consumption and palatability, UPF industrial formulations blend chemical additives with calorie-dense ingredients (Pan American Health Organization, 2015). Furthermore, UPF undergoes extensive marketing promotion, which could make them more emotionally appealing (Folkvord, 2019). It is also important to emphasize that, in the present study, UPF cues elicited higher pleasantness and incentive salience ratings than UMPFs among individuals classified with FA, indicating that UMPF cues are not the primary cues associated with addictive-like symptoms.

Individuals classified as meeting the criteria for FA, based on the scoring procedures of the mYFAS 2.0 (Schulte & Gearhardt, 2017; Portuguese wording adapted from Nunes-Neto et al., 2018), attributed similar incentive salience to erotic and UPF visual cues, whereas among individuals without FA the incentive salience attributed to erotic cues was higher than that attributed to UPF cues. According to the theory proposed by Volkow et al. (2010) individuals with substance addiction are characterized by an intensified sensitivity to substance-related cues in relation to other rewarding positive cues (Volkow et al., 2010). As observed in the affective space (results in Fig. 2 - right panel), despite the fact that erotic cues remained pleasant, the level of incentive salience was reduced, but the incentive salience to UPF cues remained heightened. This reflected a shift in which, among those with FA, UPF cues elicited arousal comparable to erotic cues and exceeded the level of arousal typically associated with food (i.e., more arousing than UMPF). These findings are similar to motivational patterns found in studies of smokers who struggled to stop smoking and had higher rates of relapse, reflected by a shift in attractiveness between tobacco-related and non-related cues (Versace et al., 2012). It also resembles previous findings in which individuals with FA showed similar late positive potential amplitude for food cues and erotic cues, due to an increase in the former and attenuation of the latter (Delgado-Rodríguez et al., 2022). However, this shift did not occur in participants without FA, who maintained higher incentive salience for erotic cues (Fig. 2 - left panel). This is consistent with previous psychophysiological studies that compared general food cues with erotic cues and found that the latter elicit greater incentive salience in individuals in the general population, as expected (Bradley, Codispoti, Cuthbert, & Lang, 2001; Lang et al., 2008). Thus, findings indicate that, similar to substance addiction, the exacerbation of the incentive salience of UPF cues is associated with changes in the motivational relevance of other rewarding stimuli, making UPF cues more likely to trigger addictive behaviors.

This finding is significant because it shows that industrial food processing according to the Nova classification system (Monteiro et al., 2016) plays a crucial role in the changes in incentive salience observed in individuals who meet the FA criteria. Taken together, our results support the construct of the association between FA and UPF (LaFata et al., 2024). Elevated components in UPF such as refined carbs such as sugar and added fats may activate the brain's reward centers in ways that appear to be analogous to nicotine and alcohol (De Luca, 2014; De Ridder et al., 2016; Zawertailo et al., 2020), with individuals often having significantly more desire to consume UPF rather than UMPF (Lemos et al., 2022).

Confirming that FA is linked to UPF rather than UMPF may enable a transformation in the public's perception of the importance of public policies in addressing issues associated with UPF consumption, similar to what happened with tobacco (Moran et al., 2016; Roberto et al., 2015). In this vein, strategies could be adopted that supported the restructuring of food environments to minimize exposure to UPF cues and prevent consumers from becoming susceptible to FA symptoms induced by UPF. For instance, by establishing policies that assist UMPF food producers and distributors in order to promote the availability, access, promotion and low price of these foods. These actions could bring great benefits since diets based on UMPF are related to human health protection (Guasch-Ferré & Willett, 2021) and greater sustainability (Fardet & Rock, 2020). In parallel, alerting individuals to the risks of consuming UPF, for example by making front-of-pack labeling systems mandatory, could be also advantageous to policies adopted in respect of smoking, and countries that have done this have found positive awareness-raising results (Alcantara et al., 2020; Ang et al., 2019; Jáuregui et al., 2020). Another important point is the regulation of advertising and marketing of UPF, since these often involve the use of neuromarketing techniques, targeting implicit emotional processes to influence its consumption (Cairns et al., 2013; Gamboa-Gamboa et al., 2019), which could be stimulating an increase in their incentive salience.

Our study has some limitations. We focused on the intrinsic factors of food, but did not investigate the effects of advertising, brands, and packaging on motivational systems. It would be interesting for future studies to focus on these factors, as they may be increasing the attractiveness of food and stimulating motivation to consume it. The low ecological validity is also a limitation of our study. Instead of real stimuli, we employed pictures to ensure the control required to promote high internal validity. To draw more conclusions, evidence from future larger ecological real-environmental studies should be considered alongside the current findings. In respect of strengths, we had a more diverse sample than other studies which tend to comprise largely female samples. We also had the advantage of the use of remote methodology. Although the LPP approach to measuring incentive salience has been highly successful (Versace et al., 2012; Versace et al., 2019), its traditional in-person implementation has relied predominantly on university settings, which substantially limits sample diversity. The adoption of SAM in a remote protocol in the present study broadened recruitment beyond typical laboratory-based convenience samples (Lemos et al., 2024). Nonetheless, our sample was still largely composed of individuals with high school or higher education, which represents a limitation, as lower-educational strata remained underrepresented. This is a common challenge in remote research, where participation requires digital access, familiarity with computers, and comprehension of written instructions (Lefever et al., 2007; Meho, 2006). Despite this limitation, the current study constitutes a methodological advance relative to most event-related potential studies, which typically involve only university students recruited in face-to-face contexts. Our sample included participants from different regions of Brazil and was not restricted to individuals currently enrolled in higher education, thereby enabling the examination of cue-elicited emotional reactivity in a comparatively more heterogeneous group. Future studies should further expand recruitment strategies to achieve a more balanced representation across educational levels and thereby strengthen generalizability. Finally, the exclusion of individuals with diagnosed eating disorders should be underscored as a methodological strength, as it allowed the present findings to reflect FA-related responses independent of established eating disorder pathology. Evidence indicates that patients with eating disorders exhibit substantially higher rates of FA relative to nonclinical populations (Wiss, 2022), suggesting that eating disorder symptoms could amplify cue-elicited responses to UPFs. By focusing on a nonclinical sample, the current results provide insights into the specific contribution of FA symptoms, without the confounding influence of eating disorder-related psychopathology. It is possible that individuals presenting both FA and eating disorder characteristics may demonstrate even greater incentive salience to UPF cues, representing an important avenue for future investigation.

5. Conclusions

In conclusion, our results provide new evidence that the degree and

purpose of food processing is important for the shift in the attribution of incentive salience from non-food cues to food cues in individuals with FA. UPF were particularly responsible for inducing this shift, with individuals with FA exhibiting increased sensitivity to UPF-related cues in comparison to other rewarding positive cues, such as erotic cues. This evidence could help to encourage the development of public policies that prioritize UMPF consumption while limiting UPF consumption by controlling its production, distribution, advertising, and sale in order to promote the creation of healthier and more sustainable food environments.

CRediT authorship contribution statement

Thayane Carvalho Lemos: Writing – review & editing, Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Guilherme Macedo Soares Coutinho:** Writing – review & editing, Software, Methodology, Formal analysis, Data curation. **Neha Khandpur:** Writing – review & editing, Software, Methodology, Funding acquisition, Conceptualization. **Maria Fernanda Gombi-Vaca:** Writing – review & editing, Software, Methodology, Conceptualization. **Eliane Volchan:** Writing – review & editing, Methodology, Investigation, Conceptualization. **José Luis Mata-Martín:** Writing – review & editing, Visualization, Supervision, Methodology, Investigation, Conceptualization. **Isabel Antunes David:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Ethics statement

The data presented in the article entitled "'I can't resist': incentive salience for ultra-processed food cues matches erotic cues in individuals with food addiction." was conducted according to the Declaration of Helsinki and approved by the Ethics Committee from University of São Paulo (CAAE: 44805521.0.0000.5421). The article follows the ethical guidelines stated in Elsevier's Publishing Ethics Policy, and Food Quality and Preference's Ethics and Policy guidelines.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2026.105866.

Data availability

The data that has been used is confidential.

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