Happy Snacking: An Investigation Into the Effect of Discrete Emotional Episodes on the Momentary Decision to Snack on Unhealthy but Rewarding Foods

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Abstract

The concept of "emotional eating" refers to food intake that is triggered by negative emotions. While there is supportive evidence for the role of negative affect in eating, the influence of positive emotions has been largely overlooked. Moreover, previous studies on emotion-related eating often focused on sustained affective states and eating behaviour aggregated across longer time windows. Therefore, the current project took a particular focus on positive emotions and aimed to investigate the effect of discrete emotional episodes on the momentary decision to snack on unhealthy but rewarding foods. A novel quiz paradigm was employed in Studies 1 and 3, where participants received real feedback on their responses and provided trial-by-trial ratings of their affect and expectation and then decided whether to snack. Extending previous studies, finding increased consumption following sustained negative moods, momentary positive emotions led to greater snacking rates than negative or neutral emotions. Furthermore, unexpected positive emotions led to a greater snacking likelihood than expected positive emotions. Study 2 used an ecological momentary assessment (EMA) approach to increase the ecological validity of the laboratory findings. Participants reported their real-time emotions and snacking behaviours following the receipt of academic feedback. While no significant association between momentary positive emotions and snacking desire was found, momentary negative emotions were associated with a reduced snacking desire, partially replicating the laboratory findings. Taken together, the results suggested emotional eating following momentary emotions and sustained mood states is based on different mechanisms, with positive momentary emotions being an important trigger for increased snack consumption. The present research has important implications for lifestyle interventions tackling antecedents of eating episodes and future projects should aim to fully establish the mechanisms behind the present effects.

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For Eric and Mary Perkins

with love always.

Statement of Copyright

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List of Abbreviations

ANOVA	Analysis of Variance
BMI	Body Mass Index
DEBQ	Dutch Eating Behaviour Questionnaire
DEBQ-E	Emotional Eating Subscale of the Dutch Eating Behaviour Questionnaire
DEBQ-Ext	External Eating Subscale of the Dutch Eating Behaviour Questionnaire
DEBQ-R	Restrained Eating Subscale of the Dutch Eating Behaviour Questionnaire
EMA	Ecological Momentary Assessment
fMRI	Functional Magnetic Resonance Imaging
GLMMs	Generalised Linear Mixed Models
HPA	Hypothalamic-Pituitary-Adrenal
PANAS	Positive and Negative Affect Schedule
PNEES	Positive-Negative Emotional Eating Scale
ST-IAT	Single Item Implicit Association Test

Chapter 1 General Introduction

Obesity has been associated with a range of adverse health conditions (such as cancer, cardiovascular diseases and mental health conditions), with rates increasing rapidly in recent years (Baker, 2023; Office for Health Improvement and Disparities, 2022). The rates of adulthood obesity have nearly doubled from 14.9% in 1993 to 28.0% in 2023. Consequently, obesity has major implications for health systems which must cater for the increase in people requiring care (Kirk et al., 2010). One explanation given for the rise in obesity rates is the 'obesogenic' modern food environment which promotes obesity through the easy availability of unhealthy foods (= high in fat and sugar whilst low in nutrients) and the high abundance of food-related cues apparent in daily life (Swinburn et al., 1999). However, as some individuals within this obesogenic environment manage to avoid weight gain and obesity, the biological and psychological factors associated with a vulnerability towards overeating need to be investigated (van Strien et al., 2009).

Psychologists have argued that one of the psychological factors contributing to overeating is a tendency to increase food intake when in a negative mood state, which has been referred to as "emotional eating" (Heatherton et al., 1991). Under affect regulation theory, emotional eating has been hypothesised to constitute a form of emotion management where individuals seek rewarding foods to increase their positive affect when experiencing negative emotions (Kemp et al., 2013). In line with this idea, participants only increased their consumption of unhealthy foods after experiencing negative affect if they believed the food would be rewarding, participants who were told the snacks would not increase their positive affect did not show increased consumption (Tice et al., 2001). In addition, negative affect was greater in the four hours before an episode of overconsumption and decreased in the four hours after the eating episode in participants with obesity (Berg et al., 2015). Furthermore, emotional eating has also been linked to the misinterpretation of negative emotions as hunger (Bruch, 1964) or to failures in self-regulation processes when distressed (Wagner et al.,

2012). One way to assess the extent to which individuals have a tendency towards different eating styles, including emotional eating, is the Dutch Eating Behaviour Questionnaire (DEBQ; van Strien et al., 1986).The DEBQ is formed of three subscales measuring emotional eating, dietary restraint and external eating tendencies (DEBQ-E, DEBQ-R and DEBQ-Ext respectively) and individuals are asked to retrospectively rate the extent to which different statements conform with their usual eating behaviours. The DEBQ has been used to inform studies investigating the associations between emotional eating and food intake. In a cross-sectional study, individuals who overconsumed were more likely to score highly on emotional eating tendencies and be at greater risk for obesity (van Strien et al., 2009). Furthermore, it was concluded that emotional eating had a greater role in the rising rates of obesity than the obesogenic environment alone as no significant association between high external eating (= high responsiveness to food cues in the environment) and overconsumption was found. This finding was supported by longitudinal studies which found a stronger association between overeating and weight gain in individuals with a higher emotional eating score (Sung et al., 2009; van Strien et al., 2012). It was suggested that as emotional eating increases individual vulnerability towards consumption of unhealthy foods, this may explain the lack of weight gain associations in individuals who overconsumed but had low emotional eating scores (van Strien et al., 2012).

However, there are important gaps in our understanding of emotional eating which have not been addressed by the previous literature. First, more evidence is needed on the role of positive emotions in eating behaviour (as opposed to negative emotions). Second, it is currently unclear whether eating behaviour is primarily modulated by longer-term mood states (as typically assessed in emotional eating questionnaires) or can also be influenced by shorter-term affective states. Within the current literature, emotional eating is conceptualised as arising from a sustained emotional state, ignoring the fluctuation of affect throughout the

day. Finally, most of the literature so far has used aggregated eating measures (e.g., consumption per day) as in self-report eating behaviour questionnaires, which do not allow the investigation of the effect of emotions on singular eating decisions (i.e., snacking behaviour).

The Role of Positive Emotions in Eating Behaviour

Most of the literature on emotional eating has focused on the impact of negative emotions on eating, which is in line with the original definition of emotional eating, leading to a lack of data surrounding the effect of positive emotions on consumption (Evers et al., 2018). Despite this, increased food intake following positive emotions may be at least as common as negative emotional eating (Macht et al., 2004), although it is likely to occur via a different mechanism (van Strien, Donker, et al., 2016). A systematic review found the effect of general positive emotions on subsequent overconsumption was stronger than the effect of negative affect in studies employing a range of methodologies (Devonport et al., 2019). Furthermore, positive emotional eating seems to be less mediated by scores on the emotional eating scale of the DEBQ and also affects individuals classified as having a healthy weight (Evers et al., 2009). While the heterogeneity of emotion induction measures and eating outcomes used within the literature makes between-study comparisons difficult, experimental data largely supports the presence of positive emotional eating (Evers et al., 2018).

One common method of emotional induction in the laboratory that has been used to demonstrate positive emotional eating is the exposure to movie clips. Positive movie clips were shown to elicit overconsumption in participants of a healthy weight (Evers et al., 2009, 2013) as well as in those scoring highly on emotional eating tendencies (Bongers, Jansen, Havermans, et al., 2013). Furthermore, individuals scoring highly on dietary restraint (characterised by a high concern with food intake to either prevent weight gain or encourage weight loss and assessed using the Revised Restraint Scale) seemed to be particularly

susceptible to the effects of emotions generally, increasing their food consumption following both positive and negative film excerpts (Cools et al., 1992). However, retrospective self-report scales, such as the DEBQ, have been criticised as they are influenced by memory biases and may prime participants towards recalling a certain behaviour to conform with a particular statement rather than reflecting their typical behaviour (Smyth et al., 2001). Therefore, other methods have been employed to characterise emotional eating status before emotional induction procedures. To reduce the impact of response biases in the measurement of emotional eating tendency, two separate single item implicit association tests (ST-IAT; a modified version of the IAT) were used to measure positive and negative emotional eating (Bongers, Jansen, Houben, et al., 2013). Positive emotional eaters consumed more milkshake following the positive as opposed to the negative film clip and also consumed more than those not classified as positive emotional eaters by the positive ST-IAT. Surprisingly, individuals classified as negative emotional eaters by the ST-IAT ate more during the positive as compared to the negative film clip. However, self-reported emotional eaters, as measured by the DEBQ, did not drink more milkshake during the emotional manipulations as compared to a neutral condition, highlighting the effect of self-report biases within the scale. Furthermore, the ST-IAT-assessed emotional eating only affected consumption of the milkshake whilst participants were being exposed to the films and so higher consumption was not found once the films had ended. This may have been due to the artificiality of the use of film clips to induce emotions, suggesting that more ecologically valid procedures may need to be implemented in future laboratory studies. When different methods of emotional manipulation were combined in a meta-analysis of experimental studies investigating real food intake, negative emotions lead to overconsumption, with a stronger effect in individuals scoring highly on dietary restraint and individuals with binge eating disorder (Cardi et al., 2015).This further demonstrated the increased vulnerability of restrained eaters to

overconsumption following the experience of emotion and highlighted the associations of negative emotional eating with concerning eating behaviours. While fewer studies included a positive emotional manipulation, a small effect of increased food intake following positive emotions was found, supporting further investigation of positive emotions in respect to eating behaviours. Evers et al. (2018) criticised the Cardi et al. (2015) meta-analysis for including studies with unsuccessful emotional manipulation procedures as well as only searching for studies investigating 'mood', ignoring other affect terms such as 'emotion'. This linked to a limitation within the literature as emotion has often been wrongly defined as a sustained mental state, ignoring the effects of fluctuating affective states, consequently, many studies have confused the terms emotion and mood despite the fact they represent different concepts (See Section 2: Emotion Seen as a Sustained State). When Evers et al. (2018) improved upon the previous search criteria, a medium effect of negative emotional eating in individuals with a restrained eating style was found however, there was no effect of negative emotions on increased consumption when groups were combined. Furthermore, positive emotions increased food intake in all groups, irrespective of eating style, suggesting positive emotions play an important role in eating behaviour and therefore should be investigated further.

While the laboratory studies reviewed in the previous section above afforded the findings high internal validity, due to the ability to control all variables, the tasks used were often artificial and the 'clinical' feel of the eating environments may have prevented generalisability to everyday situations. Although the findings of positive emotional eating have not been limited to laboratory experiments, there is a lack of naturalistic studies concerned with positive affect, with negative emotions taking precedence (e.g., Altheimer et al., 2021; O'Connor et al., 2008). One naturalistic diary study demonstrated overconsumption following positive and negative emotions relative to neutral emotions, with the comparison between positive and neutral emotions having a larger effect size than negative and neutral

emotions (Patel & Schlundt, 2001). On the other hand, differing effects of restrained eating status were present outside of the laboratory, with individuals scoring highly on restraint eating less following the experience of real-life positive and negative emotions (Tomiyama et al., 2009), highlighting the importance of studies having the ability to consider evidence from laboratory and naturalistic designs to increase the internal and external validity of findings. In one such study, positive emotions led to higher food intake than neutral emotions but comparable intake to negative emotions when emotion was induced using film clips and the recall of memories respectively (Evers et al., 2013). In addition, positive emotions were more likely to be reported as a reason for snacking when participants were asked to report their food intake and eating motivations throughout a week. When the results of four studies (combining experimental and naturalistic methods) were taken together, positive emotions led to greater food intake than negative emotions, irrespective of emotional eating status, indicating positive emotions were more likely to also affect individuals of a healthy weight and supporting the suggestion that positive and negative emotional eating occur via different mechanisms (Evers et al., 2009).

The ecological validity of naturalistic studies, as reviewed above, can be further increased by using ecological momentary assessment (EMA) designs which require participants to fill in measures relating to a particular event close to when it takes place, allowing information to be more easily recalled and reducing retrospective recall bias (Reichenberger et al., 2020). Furthermore, as participants continue to carry out their usual behaviours, the findings can be generalised to real-life events. Accordingly, Chwyl et al. (2021) argued that EMA measures may be better able to draw conclusions about emotional eating as they can account for fluctuations in daily emotions which may influence the amount of food consumed at different times. Using an EMA approach, Wouters et al. (2018) showed that momentary negative emotions were associated with a decrease in subsequent food intake,

which is contrary to the predictions of the original definition of emotional eating. Interestingly, while there was no general effect of positive affect on snacking, positive affect was associated with higher subsequent calorie intake in specific subgroups, namely males and adults aged 20-30 years old. This highlighted the influence of potential moderators on the effect of momentary emotions on snacking behaviour as well as further supporting the presence of different mechanisms behind positive and negative emotional eating. Furthermore, positive and negative emotional eating (as assessed by the Positive-Negative Emotional Eating Scale; PNEES) had different associations with eating behaviour as measured using EMA over three days (Sultson et al., 2017). Scores on the positive scale of PNEES significantly predicted overconsumption in the whole sample, however scores on the negative scale of the PNEES only significantly predicted overeating in individuals more vulnerable to problematic eating behaviours. In another EMA study conducted over 10 days, positive emotions were associated with an increase in unhealthy, rewarding food intake despite participants not reporting being hungry (= increased taste eating) whereas negative emotions led to less consumption of palatable foods (Reichenberger et al., 2018). Therefore, positive emotions have an important role in increasing unhealthy food intake even when hunger signals are not present. On the other hand, while another EMA study found no association between momentary positive or negative affect and food intake, a higher number of daily negative emotional events were associated with increased snack intake (Zenk et al., 2014). This finding can be situated within the affect regulation theory as the sustained negative mood state led to greater subsequent food intake. This again highlights the difference in mechanism behind positive and negative emotional eating, with overconsumption being found after both momentary positive emotional episodes and longer-term negative affective states.

Apart from the conflicting evidence around the effects of different lengths of negative affective states on subsequent eating in the literature, which suggests the presence of different mechanisms behind different valences of emotional eating, an increase in food consumption following the experience of momentary negative emotions seems also counterintuitive from a biopsychological theoretical perspective (Gray, 1987; Lang, 1995): Negative emotions are assumed to engage the brain's defensive motivational system, triggering 'fight or flight' responses, to protect individuals from harm. Importantly, activation of the defensive system is normally associated with halting digestion and reducing appetite (Lang et al., 1998; Torres & Nowson, 2007). On the other hand, positive affect can be seen as reflecting the activation of an appetitive neural system (Lang et al., 1998; which is conceptually the same as the approach reward system), which in turn primes other reward behaviours (such as food consumption). In line with this, joy, but not sadness, was associated with a greater motivation to engage in rewarding activities and therefore, individuals would be expected to increase their snack intake following positive affect due to the highly rewarding nature of food (Macht, 2008). It has been further suggested that the mesolimbic dopaminergic system signals the rewarding attributes of food, and this system is theorised to be involved in approach reward system responses to rewards (Haber & Knutson, 2010). The rewarding properties of food may come about through associative learning processes as food is often involved in celebrations (Davis et al., 2007; Evers et al., 2018). Associations between the activation of the appetitive neural system and increases in food intake have been supported within the literature. Using a questionnaire design, a higher sensitivity to reward (as measured by the Sensitivity to Reward subscale of the SPSR Questionnaire and the Behavioural Activation subscale of the BIS/BAS Questionnaire) was positively associated with overconsumption of unhealthy foods which in turn predicted a higher body-mass index (BMI) score (Davis et al., 2007). Functional magnetic resonance imaging (fMRI) data further

supports the link between activation of the approach reward system by positive emotions and increased preference towards unhealthy foods. When participants were exposed to emotional images and asked to subsequently rate their liking for a series of food and object images, positive emotions led to an increase in preference for food versus object images when compared to a neutral prime (García-García et al., 2020). Furthermore, García-García et al. (2020) found a higher fMRI activity in the left amygdala on the presentation of food versus objects in both the positive and neutral conditions, however activity in response to the two types of images in the negative condition was comparable. Therefore, negative emotions did not cause an increased preference for food images which was is in line with the biopsychological framework (Lang et al., 1998) arguing the activation of the defensive motivation system should increase attention towards important stimuli for survival rather than reward. In addition, when stress was induced using an unsolvable maths puzzle, there was a reduction of fMRI activity in areas implicated in the approach reward system when participants were required to choose food images for their next meal (Born et al., 2010). However, participants ate more energy-dense food in the stress condition as compared to the control condition despite the reduction in reward system activation. This finding highlighted the difference in mechanisms underpinning positive and negative emotion eating by implicating the approach reward system specifically in positive emotional eating in line with biopsychological perspectives.

In addition to biopsychological theories, predictions regarding positive emotional eating can also be derived from neurobiological theories of reward and motivation which suggest expectation modulates the activation of the approach/avoid systems (Schultz, 1997). Reward prediction error is a measure of the discrepancy between expectation and experience and is calculated using the equation: observed outcome – expected outcome (where values can range from -1 to +1). A larger discrepancy between observation and expectation leads to a

larger reward prediction error, with a larger positive prediction error being expected to activate the approach reward system to a greater extent. Based on the reward prediction theory, it can be hypothesised that varying expectations regarding an emotional outcome will modulate reward system activation independently from and/or interactively with an individual's affective experience and thus influence their snacking behaviour. Using this perspective, surprising positive events would be expected to lead to a larger positive reward prediction error, activating the approach system to a greater degree and leading an individual to seek more reward (i.e., snack more) than unsurprising positive events. Although reward prediction errors have been largely understudied within the snacking literature, when expectation around a monetary reward was manipulated, it modulated subsequent food intake (Wanglee, 2013). Participants who experienced surprising monetary rewards for sampling chocolate had a higher subsequent food intake than those who expected the monetary reward. Therefore, the present project will take a special focus on the role of expectation in potentially modulating snacking outcomes.

Emotion Seen as a Sustained State

While emerging evidence in support of the effect of positive emotions on subsequent food intake is convincing, the current emotional eating literature fails to differentiate between longer-term affective states and shorter-term affective states. Retrospective self-report measures used within the literature to assess emotional eating aggregate emotional experience over sustained time periods, neglecting the impact of short discrete affective events on eating behaviours. The idea of shorter affective states having a role in emotional eating is in line with the biopsychological framework where affect is defined as a short period of physiological/behavioural changes combined with the experience of a discrete emotion, which are triggered by a specific stimulus (Lang et al., 1998). According to Gross (1998), a distinction should be made between emotions and mood, with emotions reflecting discrete,

short-lasting affective events and mood representing affect endured over a longer period. Under this view, emotions are prone to fluctuations during the day and therefore, retrospective emotional eating scales (such as the DEBQ) are measuring the effect of mood rather than emotions on food intake as they do not account for the ability of emotions to differ over relatively short periods of time. In addition, retrospective scales, such as the DEBQ, confuse mood and emotion by including items relating to both concepts and by calculating a combined emotional eating score from these (e.g., "Do you have a desire to eat when you are cross?" compared to "Do you have a desire to eat when you are depressed or discouraged"). Similarly, in laboratory procedures assessing emotional eating the impact of short, fluctuating affective events is often neglected as only one type of emotion is induced, which is assumed to remain stable over time (e.g., Evers et al., 2013). The use of between-subject designs further limits the generalisability of findings as it underestimates the high level of individual variability which can occur in emotional reactions as well as eating behaviours (Macht, 2008). Evers et al. (2023) argued that due to the varying nature of both emotions and motivation to eat, multiple measurements per day may be needed to investigate emotional eating. Consequently, a laboratory design which can account for the effect of multiple discrete emotions on multiple, momentary decisions to eat would be more appropriate to capture the process of real-life snacking.

Momentary versus retrospectively rated emotional eating may reflect different constructs as they are negatively correlated (Chwyl et al., 2021). Significant associations between depression and emotional eating suggest a long-lasting negative state may lead to overconsumption (Antoniou et al., 2017; Konttinen et al., 2019). Furthermore, long-lasting stress has been shown to increase unhealthy food consumption, leading to weight gain (Torres & Nowson, 2007). While the induction of a negative emotion in participants with obesity and depression lead to greater snacking on unhealthy foods, this was not the case for participants

with obesity who did not have depression (Privitera et al., 2016). However, momentary emotional eating is better able to account for the timing element within the emotional eating definition where increased intake is expected to be triggered by an emotional event whereas retrospective eating behaviour scales reflect snacking patterns following general emotions and eating during different negative mood states (Chwyl et al., 2021). Momentary and retrospective emotional eating may have differing effects on weight outcomes: whilst a higher self-reported emotional eating score was associated with poorer weight loss outcomes, higher momentary negative emotional eating predicted improved weight outcomes. However, one explanation for the surprising positive association between momentary negative emotional eating and improved weight outcomes could be due to the reliance of EMA on self-report which may still be affected by the inability of participants to accurately recall their motivations and emotions. Therefore, laboratory studies assessing the effect of momentary emotions are needed to validate the findings. The Chwyl et al. (2021) study can be criticised for ignoring the influence of positive emotions which prevented any conclusions about retrospective and momentary positive emotional eating being drawn. Momentary positive affect was found to predict overeating in men but not women (Sultson et al., 2022) although other EMA studies have found a general effect of positive emotions on increased snack intake (e.g., Evers et al., 2013). Therefore, momentary positive and negative emotional eating may comprise different processes.

Momentary positive emotional eating can be predicted to specifically influence the decision to snack on unhealthy but rewarding foods, increasing the frequency of in-between meal food consumption, which is a risk factor for overconsumption and eventual weight gain (e.g., Skoczek-Rubińska & Bajerska, 2021). For instance, EMA studies of emotional eating demonstrated episodes of high-calorie snack intake were more likely to be preceded by transient positive emotions than short-lived negative affective states (Boh et al., 2016; Evers

et al., 2013; Macht et al., 2004). In summary, it seems likely that trait-based emotional eating comprises a different construct to food intake following transient affective states, with the latter being also present in healthy individuals. Therefore, while research into trait-based emotional eating following a constant negative mood is important, the influence of fluctuating emotional states needs to be accounted for as this may also have implications for weight outcomes.

Eating Behaviours Aggregated Across the Day

Related to the critique of emotion being viewed as a sustained state, previous work on emotional eating can be criticised for aggregating eating behaviour measures by focusing on consumption per day and for ignoring the importance of the frequency of in-between meal intake for weight outcomes. Retrospective emotional eating measures ask individuals to report their general eating tendencies (e.g., in the DEBQ-R: “Do you try to eat less at mealtimes than you would like to eat?) and so are unable to determine the effect of emotions on snacking behaviours. Notably, snacking has also been largely overlooked in experimental studies of food intake, especially in studies examining emotional eating, with portion size/amount eaten taking precedence (i.e., bowl weight before and after emotion induction; e.g., Bongers, Jansen, Havermans, et al., 2013; van Strien et al., 2013). Despite snack-type foods (such as crisps) often being used in laboratory studies, the use of an overall food intake measure prevents snacking frequency from being investigated directly even though emotional eating may in fact have a greater effect on snacking behaviours as compared to main meal intake: Snacking often occurs alone and is thus likely to be more affected by affective states than meals, which often occur in the presence of others, who may have a mitigating effect on emotional reactions (Krantz, 1979). For instance, only snacking but not main meal intake was affected by emotional eating in participants with obesity (Lowe & Fisher, 1983). Similarly, Magklis et al. (2019) found that emotional eating was associated with a higher frequency of

snacking but a lower portion size suggesting that the number of snacking episodes was an important measure of emotional eating. In a diary-based naturalistic study, daily stressful events were associated with a higher frequency of unhealthy snacks alongside lower intake at main meals and less fruits and vegetables being consumed overall (O'Connor et al., 2008). This was supported by laboratory studies showing that increased intake following negative emotions may be specific to sweet unhealthy snacks (Domoff et al., 2014).

The importance of considering snacking in the context of emotional eating is further highlighted by studies showing that rates of unhealthy snacking have increased rapidly in many countries over the past decades (Kant & Graubard, 2015; Piernas & Popkin, 2010). Simultaneously, rates of obesity have increased globally over the same time period (Finucane et al., 2011), suggesting that unhealthy snacking may contribute to negative weight outcomes. Due to their high fat and/or sugar content, snack foods are highly rewarding which leads to overconsumption and weight gain when intake is greater than expenditure. Although individuals tend to adjust their portion size according to the amount eaten at a preceding main meal to compensate for any overconsumption, they often ignore in-between meal intake (Cowan et al., 2020; Hess et al., 2016), suggesting frequent snacking may contribute to a positive energy imbalance and thus, potential weight gain. For example, participants with obesity who were compared to peers of normal weight snacked more frequently on food items high in fat and sugar, regardless of their energy expenditure, demonstrating a lack of compensation for the increased food energy intake (Bertéus Forslund et al., 2005). In addition, in adolescents the frequency of unhealthy snacking episodes was the only measure of eating behaviour positively associated with weight gain (Larson et al., 2016). The importance of snacking for weight gain was also demonstrated in an experimental study by Collins & Stafford (2015), in which positive emotions (as induced using film clips) increased snack intake relative to neutral emotions even when participants were reminded of their

consumption at a previous meal, demonstrating positive emotions prevented individuals inhibiting their food intake and would be expected to lead to weight gain when intake was consistently greater than expenditure.

Unhealthy snacks in particular leave individuals susceptible to weight gain with positive associations between meal frequency and BMI status depending on the type of snacks consumed (Larson et al., 2016; O'Connor et al., 2015; Skoczek-Rubińska & Bajerska, 2021). Furthermore, while the effects of stress on increasing the intake of sweet high-fat foods were dependent on self-reported emotional eating status (Oliver et al., 2000), positive affect led to increased snacking in all participants (Collins & Stafford, 2015), demonstrating the difference in the mechanism involved in positive and negative emotional eating. One type of unhealthy food associated with obesity are ultra-processed foods (UPFs: e.g., biscuits and crisps). While a causal link between an increased intake of UPFs and greater risk of obesity development has yet to be determined, there is evidence of a positive association between UPF intake and BMI status (Askari et al., 2020; Valicente et al., 2023).

Although there is strong evidence for a positive association between unhealthy snacking and BMI status/weight gain in cross-sectional studies, the nature of these designs prevent causation being determined (Almoraie et al., 2021). However, longitudinal studies support the conclusions made, with many finding a positive relationship between snacking frequency and weight gain (Bes-Rastrollo et al., 2010; Kahleova et al., 2017). A higher in-between meal intake was associated with significant weight gain and greater risk of obesity, with new cases of obesity developing in frequent snackers who were previously of normal weight (Bes-Rastrollo et al., 2010). Furthermore, frequent snacking was positively associated with BMI scores in adults sampled over a seven-year period (Kahleova et al., 2017), highlighting the importance of investigations into the potential causes for snacking. While longitudinal evidence indicates that snacking frequency and weight gain are positively

associated, other studies find a negative association between in-between meal intake and body weight (Keast et al., 2010) or find no association between in-between meal intake and BMI (Hartmann et al., 2013). However, the use of self-report techniques to measure food intake have been criticised (Cowan et al., 2020) as they may underestimate an individual's true daily intake (Davies & Hill, 2001), with snacking episodes being especially vulnerable to underreporting (Poppitt et al., 1998). After studies finding a negative association were corrected for underreporting, snacking frequency was found to be positively associated with obesity (Mattes, 2018). Furthermore, as underreporting was likely to be present in studies finding a positive association, the effect sizes concluded from those studies may be even larger than reported. This further highlights the importance of laboratory studies for measuring actual food consumption as the highly controlled environment mitigates the risk of underreporting.

While snacking patterns may differ across a person's lifetime, it seems that university students are particularly prone to unhealthy snacking (Almoraie et al., 2021). On university campuses, vending machine provide easy access to food items high in fat and/or sugar whilst low in nutritional value (Byrd-Bredbenner et al., 2012) and therefore, factors which make these individuals susceptible to unhealthy snacking need to be investigated. While a greater ease of access to unhealthy snacks was positively associated with BMI status in college students, there were no significant interactions between frequency of snacking and BMI changes (Prapkree et al., 2023). However, the sample was composed of individuals with a BMI status of overweight or above so ceiling effects may have prevented a significant result being observed. Furthermore, individuals with obesity are highly susceptible to underreporting of actual food intake, further questioning the conclusions drawn (Zizza & Xu, 2012). In a longitudinal study of the first 12 weeks of term for new college students, unhealthy snacking and weight gain were positively associated (Levitsky et al., 2004). The

study design required participants to self-report their intake and therefore, it was expected that this effect would be even larger when underreporting was accounted for. Moreover, the first year of university has been associated with a significant weight gain (Serlachius et al., 2007) and therefore it is important to understand the potential causes of this, such as an increase in unhealthy snacking frequency. Together, these findings suggest that snacking frequency is associated with increased weight gain and obesity but that self-report studies of snacking are prone to underreporting and employ heterogeneous snacking measures. Furthermore, emotional eating is likely to particularly affect snacking episodes as unhealthy snacks are highly rewarding and are usually eaten alone where the effect of emotions is likely to be stronger. Due to its associations with adverse weight outcomes and BMI status, the effect of emotions on unhealthy snacking decisions will be a particular focus of the present project.

Thesis Rationale and Aims

To address the gaps within the emotional eating literature and improve upon the critiques raised against previous studies, as outlined above, the present research aimed to deepen the current understanding of the effects of discrete emotional episodes on the momentary decision to snack on unhealthy but rewarding foods. A particular focus was placed on the role of positive emotions on subsequent food intake as this has largely been ignored within the current literature, despite evidence of positive affect leading to overconsumption in a range of individuals, irrespective of eating behaviour tendencies (Evers et al., 2018). Potential moderation of emotional eating by emotional eating status, dietary restraint, and BMI scores was investigated as the literature currently contains conflicting evidence around their effects. In line with the biopsychological and neurobiological perspectives of reward and motivation, the effect of expectation alone, and in combination with affect, on the subsequent decision to snack was investigated. A combination of

laboratory and naturalistic studies were used to measure the effect of momentary emotional episodes on food intake as the impact of short affective episodes has largely been overlooked within the literature. In addition, snacking behaviours were investigated as unhealthy snack foods are affected by emotions and have been associated with negative weight outcomes (Kahleova et al., 2017). Due to the high associations between university life and weight gain (Serlachius et al., 2007) as well as increases in snacking intake (Almoraie et al., 2021), the effects of academic feedback on emotion and thus, unhealthy snacking was investigated in samples of university students.

To investigate these aims, Study 1 employed a novel paradigm where discrete emotions were induced using real feedback on a quiz task, with trial-by-trial measurements of affect and food intake in a repeated-measures design, reducing the effects of participant variability in consumption (Higgs, 2023) and accounting for the fluctuations of emotions in everyday life. Study 2 aimed to add ecological validity to these findings by employing an EMA-style design to investigate the effect of snacking (and other reward behaviours) following the release of real academic feedback. Finally, Study 3 aimed to replicate the findings of Study 1 whilst improving on the methodology used, placing a greater focus on the effect of expectation as a moderator of emotional eating. In all three studies, it was expected that positive emotions would lead to the greatest increase in snack intake as compared to negative or neutral emotions. Furthermore, it was hypothesised that expectation would modulate the activation of the reward system independently of and in interaction with affective states so that unexpected positive emotions would lead to greater overconsumption than expected positive emotions due to the creation of a larger positive prediction error, eliciting greater activity in the appetitive system.

The effect of potential moderators was explored due to the conflicting evidence within the emotional eating literature. It was expected that trait-based emotional eating (as assessed

using the DEBQ-E) would not moderate the effect of transient emotions on snacking as retrospective and momentary emotional eating are theorised to occur via different mechanisms (Chwyl et al., 2021). Individuals scoring highly on dietary restraint are said to be more susceptible to the influence of affective episodes on snacking due to the strength of the emotional experience disrupting their self-control and preventing them from successfully restricting their intake (Polivy et al., 1994). However, conflicting evidence around the effects of restrained eating on the effects on emotions on snacking is present within the literature, with a higher susceptibility of restrained eaters to overconsumption following the experience of positive and negative emotions being found within the laboratory (Evers et al., 2018) but not always in naturalistic studies (e.g., Tomiyama et al., 2009) and positive emotional eating occurring regardless of restrained eating (Evers et al., 2013). Therefore, the potential moderation of any effects by restrained eating style was investigated within this research. Furthermore, BMI was investigated as another potential moderator as it has been suggested that negative emotional eating is an 'obese' eating style (van Strien, Donker, et al., 2016). While BMI was positively associated with negative emotional eating, it was negatively associated with positive emotional eating, indicating negative emotional eating may occur more often in individuals of higher BMI and that the two processes occur via different mechanisms. On the other hand, positive but not negative emotions lead to a higher subsequent food intake in individuals with a higher BMI (Udo et al., 2013). This again highlights the inconsistency within the literature, making it difficult to differentiate the two processes. When studies within the literature were combined for systemic review and meta-analysis, BMI did not significantly moderate the effect of emotions on snacking behaviours (Cardi et al., 2015; Evers et al., 2018; Greeno & Wing, 1994).

Chapter 2 Study 1

Introduction

As reviewed in the preceding chapter, previous laboratory studies on emotional eating have several methodological limitations, limiting the validity of the conclusions drawn. Therefore, Study 1 employed a novel paradigm using trial-by-trial assessments of eating behaviour to address some of these criticisms. In particular, Study 1 aimed to systematically determine the effect of discrete emotional episodes, elicited by feedback in a quiz task, on the momentary decision to consume unhealthy but rewarding snacks.

As outlined above (See General Introduction), past studies (e.g., Altheimer et al., 2021; Chwyl et al., 2021) have failed to fully account for the effects of positive emotions on food intake and their impact on eating behaviours remains under researched. Furthermore, in previous designs, emotion was seen as a sustained state with one type of emotion being induced and then subsequent eating behaviours being measured across extended time periods (e.g., Evers et al., 2013). However, this fails to account for the potential effects of emotions fluctuating throughout the day. Moreover, it is difficult to control the impact of participant variability in emotional reactions and eating behaviours in between-subject designs, which have been used by most laboratory emotional eating studies so far (e.g., Cools et al., 1992). To reduce the impact of participant characteristics on the results, in the present study a within-subject design was employed so all participants were exposed to all emotional conditions. A further criticism of existing studies on emotional eating is that eating behaviour measures have been aggregated (e.g., van Strien et al., 2013), despite the frequency of in-between meals being an important variable for weight outcomes. Consequently, Study 1 measured snacking decisions individually. Decisions were examined in the context of a quiz task which induced emotion (positive, negative, and neutral) through the use of real feedback based on participant performance. Trial-by-trial measures of affect, expectation and snacking

decisions were then taken to allow analysis of the decision to snack on each trial as well as to account for the variability of emotions.

While laboratory studies afford good control over independent variables and thus high internal validity, they often take place in 'clinical' environments which do not match typical eating contexts for participants, reducing their external and ecological validity. Best et al. (2018) outlined specific conditions which should be utilised to improve laboratory studies measuring eating behaviour, increasing the external validity and thus generalisability of findings. Firstly, participants should not feel like they are being watched as this may lead to social desirability influencing their eating decisions. In the present study, participants were left alone in the laboratory to complete the quiz so the presence of the researcher would not influence their snacking decisions. Furthermore, Best et al. (2018) suggested that the laboratory environment needed to contain features typical of everyday eating environments to encourage participants to display natural behaviours during the study. Therefore, Study 1 was conducted using a laboratory which was set-up to look like a pub/bar (see Figure 2), an environment typically associated with eating as snack foods are often available and displayed behind the bar. To replicate this, snacks were laid out across the laboratory bar (See Figure 3). This set-up also increased perceived food availability, which has also been shown to encourage eating behaviour (McCrory et al., 2012; Rolls, 2018). To encourage increased consumption further, participants were offered a selection of different snacks to prevent sensory-specific satiety which occurs when individuals stop eating because they are bored of a specific flavour rather than because they feel full (Rolls et al., 1981). In Study 1, participants were thus allowed to choose three of their preferred snacks from five available snacks. Furthermore, all participants in the present study were tested around lunch and dinner time to reflect natural eating patterns as recommended by Best et al. (2018). To account for the final recommendation made by Best et al. (2018), that participants should not be made

aware that the study is investigating eating behaviour, Study 1 was advertised as aiming to determine the psychological processes that occur during a quiz task to reduce any influence on participant eating patterns. In Study 1, participants also completed a funnel debrief after all other study measures to determine the extent to which they were aware of the study's purpose, such an approach had been suggested by Robinson et al. (2018). Finally, to standardise hunger levels, which was advised by Robinson et al. (2018), participants were required to fast for four hours before entering the laboratory. Further ecological validity will be added to the results through the use of a naturalistic study (Study 2) to determine the size of any effects found in real-life.

Study Overview

This study aimed to systematically determine the effect of discrete emotional episodes elicited by feedback in a quiz task on the momentary decision to consume unhealthy but rewarding snacks. The study tracked snack intake on a trial-by-trial basis by providing participants with real feedback (positive, negative or no feedback) based on their answers to multiple-choice quiz questions. After each piece of feedback, participants were asked to provide an affective rating, to rate their expectation of a correct response and to indicate their intention to snack from one of the bowls next to them. The method and hypotheses for this study were preregistered on the AsPredicted platform (e4ip4.pdf (aspredicted.org)). The quiz was framed as a test of psychological knowledge containing both Psychology as well as General Knowledge questions. These questions were assumed to have high self-relevance as all participants were undergraduate Psychology students who would be striving for academic success. This in turn was assumed to increase the strength of the emotional impact of the quiz feedback.

We predicted that positive feedback (and/or positive emotions) would lead to more snacking as compared to negative feedback (and/or negative emotions) or a neutral control

condition in which participants were not presented quiz questions or feedback (Hypothesis 1). We also predicted that participants' expectation would modulate this effect so that unexpected positive feedback/emotions would result in more snacking than expected positive feedback as this condition was assumed to elicit a larger positive prediction error, priming the approach system to a greater extent (Hypothesis 2). In additional exploratory analyses, we tested whether dichotomous snacking decisions could be modelled on a trial-by-trial basis using Feedback Type, Affective Ratings, and Reward Prediction Errors as predictors. We also explored whether the above effects varied with individual differences in eating styles (assessed by the DEBQ-E and DEBQ-R) and BMI score. All methods and analyses were pre-registered on AsPredicted (e4ip4.pdf (aspredicted.org)).

Method

Participants

G*Power (Faul et al., 2007) was used to calculate an *a priori* sample size using a statistical power of 95%, a significance level of $\alpha = 0.05$ and an estimated effect size of $f = 0.33$ (obtained from a previous study which employed similar methods; Ihssen, in preparation). This returned a sample size of 44. To account for potential dropouts and exclusions, the final targeted sample was 50-60. We were able to reach the upper limit of this target sample, indicating that the study was sufficiently powered to detect any significant effects.

Participants were asked not to take part in the study if they had a prior/current eating disorder, diabetes, food allergies or any concerns about eating the snacks provided. To ensure these exclusions were followed, the demographic questionnaire verified the presence of any of these conditions. Three participants reported a past/current eating disorder in the demographic questionnaire, therefore their data were excluded from the final analyses. Individuals who had completed our online pilot study (testing the suitability of the paradigm

and the difficulty of the quiz questions) were unable to take part in this study. Furthermore, data were excluded if participants did not snack at all throughout the study, leading to the exclusion of one participant. Finally, individuals with a mean quiz accuracy of above 75% or below 25% were excluded as they were not exposed to enough trials (with positive/negative feedback) for each condition. No participants met the criteria for exclusion based on accuracy.

The final sample size consisted of 56 participants who were all undergraduate Psychology students at Durham University, recruited via the SONA system (https://www.sona-systems.com/) using volunteer sampling. Participants' mean age was *M* = 20.34 years (*SD* = 3.98, *Range* 18 - 49). The sample contained 48 females, eight males and one participant who did not disclose any demographic information. The average BMI of the sample was *M* = 23.46 kg/m^2 (*SD* = 4.42, *Range* 17.6 – 44.1). Four participants had a BMI status of 'Underweight', 34 participants had a 'Healthy' BMI status, 12 had a BMI status of 'Overweight', one individual had an 'Obese' BMI status, and one had a 'Very Obese' BMI status. Eight of the participants were first year students and 47 were second year students. 11 participants were currently dieting/trying to lose weight and 40 had previously been on a diet/tried to lose weight. Nine of the participants smoked/vaped regularly, seven participants smoked/vaped occasionally/socially, and one participant did not provide any information on smoking/vaping.

Participants were required to abstain from eating for four hours before starting the study (see "Procedure") and were asked to bring a water bottle (to avoid them choking) but no other preparation was required. 42 participants adhered to this fast and the average time since last meal in the whole sample was 6.95 hours (*SD* = 4.59, *Range* = 0-17 hours). The average hunger level of the sample was 4.14 (*SD* = 1.43, *Range* = 2–7). The study took around 90 minutes to complete, and participants received course credits for their

participation. Ethical approval was obtained for this study from the Ethics sub-committee of the Department of Psychology, Durham University.

Materials

Quiz Task

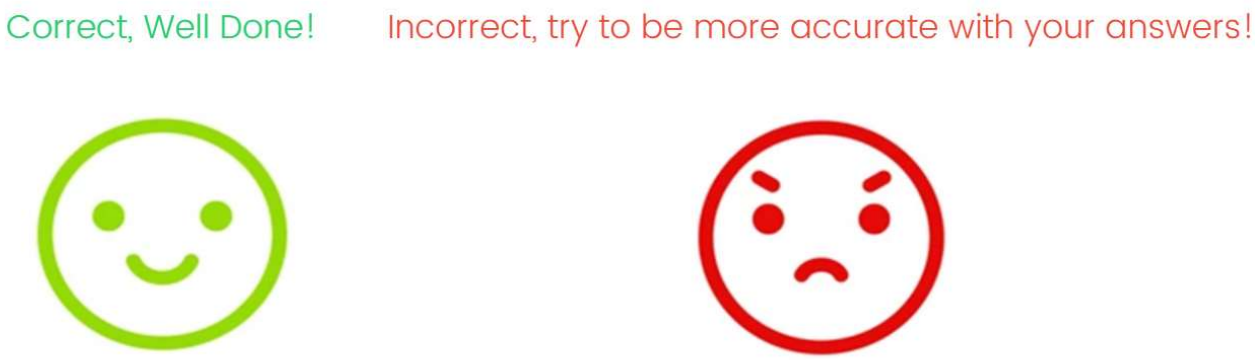
The quiz consisted of 100 multiple-choice questions (a mixture of Psychology, Psychology-related and General Knowledge questions) and 50 neutral trials presented in a randomised order for each participant using the Qualtrics software (Qualtrics XM: The Leading Experience Management Software). Questions were selected based on a pilot study, in which different questions were presented to two groups of Psychology students (Group 1 = 26 participants and Group 2 = 12 participants). Feedback from participants suggested that a higher proportion of Psychology and related questions were needed to increase the believability of the paradigm (see below). Therefore, the final selection was comprised of mainly Psychology and related questions and aimed to include a balanced proportion of easy and difficult questions, where difficulty was extrapolated from mean accuracy results in the pilot study. 46 questions had a mean accuracy of >50%; 47 questions had a mean accuracy of <50% and 7 questions had a mean accuracy of 50%.

Questions were presented in the centre of the screen (Black Text, Arial Font, 12pt Font Size) with four answer options presented below the question. After each question, the quiz provided real feedback (correct vs incorrect answers leading to positive or negative feedback, respectively) for the 100 quiz questions. Alongside each quiz question, the overall percentage of correct responses in the pilot study (conducted in the same student population; see above) were displayed in bold text. This aimed to further increase the self-relevance and importance of the task which in turn was expected to increase the emotional impact of the feedback. 50 trials were pseudo-randomised to form the neutral condition and were comprised of non-quiz questions, all taking the same format: Participants were asked to

"Choose any of the four options" which was followed by the neutral statement "Wait for the next instruction" (Black Text, Arial Font, 36pt Font Size) instead of the feedback screen. In feedback trials, the positive feedback consisted of a green schematic smiley face (size 172 pixels by 172 pixels; see Figure 1 for feedback screens) and the green text "Correct, Well Done!" (Arial Font, 16pt Font Size). The negative feedback screen consisted of a red schematic angry face and the red text "Incorrect, try to be more accurate with your answers!" using the same font parameters. A progress bar was displayed at the top of the screen, demonstrating how many questions were left in the task. See Appendix 1 for an outline of a typical trial from both the feedback and neutral conditions.

Figure 1

Image showing the positive (left) and negative (right) feedback screens.



Demographic Questionnaire

The demographic questionnaire consisted of 16 questions (see Appendix 2), assessing age, gender, and year of study. Participants also reported their height (in cm) and weight (in kg), which were transformed to BMI scores. They also reported their smoking habits, which can reduce appetite and subsequent eating (Gregersen et al., 2011; Jessen et al., 2005). Furthermore, participants were asked if they were currently on a diet/trying to lose weight or if they had ever been on a diet or tried to lose weight. Finally, participants were asked to report whether they had a food allergy/diabetes or a past/current eating disorder, when and what their last meal was and what their current hunger level was (7-point Likert Scale, where 1 = very full and 7 = very hungry).

DEBQ – Emotional and Restrained Scales

The Dutch Eating Behaviour Questionnaire (van Strien et al., 1986) consists of 33 items split into three scales measuring restrained, emotional and external eating. Only the emotional and restrained scales were used in this study (see Appendix 3), which consisted of 10 items for restrained and 13 items for emotional eating, rated on a 5-point Likert scale (from 1 = never to 5 = often; some items also included a “not relevant” response category).

Procedure

During recruitment participants were made to believe that the purpose of the study was to investigate the different psychological processes that take place during a quiz task, blinding them to the study’s true purpose and thus allowing for more natural eating behaviours to be measured. Participants were informed of the study’s real aim in the debrief. Participants were tested on a laptop set up in the department’s “bar laboratory” (see Figures 2, 3 and 4). The screen size of the laptop was 19.5cm by 34cm and the laptop was placed about 12cm from the edge of a round table (60cm circumference) with the average head distance from the screen being 60cm. An identical table was placed alongside this with bowls being

arranged in a triangle, about 24cm from the laptop (see Figure 2 for set-up). Following recommendations by Best et al. (2018) for improving experimental studies of eating behaviour, the bar/pub setting provided a more natural eating environment than a standardised cognitive testing lab and contained cues which would be commonly associated with snacking. Participants were tested around typical eating times (lunch or dinner; 11.00-12.30, 12.45-2.15 and 16.00-17.30) to reflect natural eating patterns (see Best et al., 2018). Furthermore, participants were required to fast for four hours before entering the laboratory to standardise hunger levels and encourage eating to occur as their desire to consume the snacks should be heightened.

Figure 2

Image showing the overall set-up of the bar laboratory. Snacks were laid out on the bar with eight packets of each on display. The laptop was placed on a round table with an identical table next to it displaying the snack bowls, information sheet and consent form.

Figure 3

Image depicting the layout of snacks across the bar.

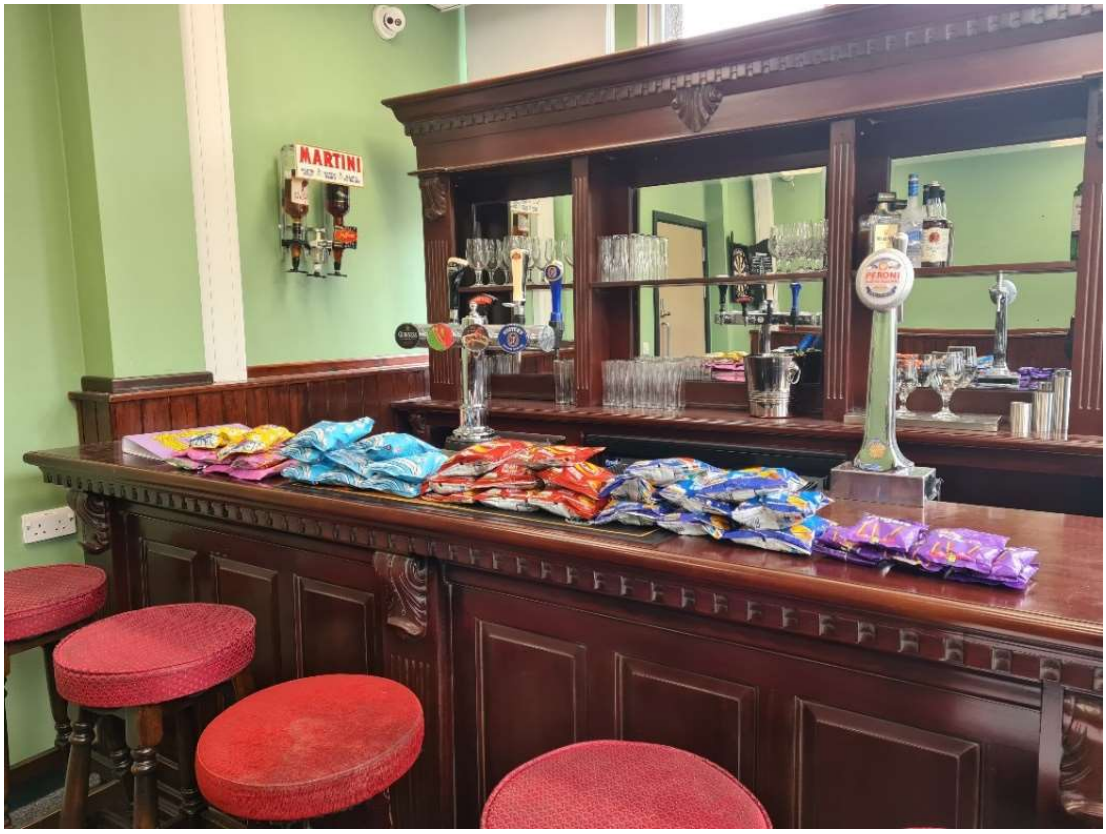


Figure 4

Image showing an example set-up of the snack bowls, each bowl contained a different type of snack, and the spare snacks were placed alongside the bowls.

Upon entering the lab, participants were asked to sit opposite the bar (see view in Figure 2), re-read the information sheet and sign the consent form. Participants were asked to choose three out of five available snacks (Butterkist Sweet Popcorn (12g), Propercorn Lightly Sea Salted Popcorn (10g), Walkers Ready Salted Crisps (25g), Walkers Cheese & Onion Crisps (25g) and Cadbury Animals Chocolate Biscuits (20g)). Due to food supply issues during the course of the study, some participants were offered Propercorn Sweet & Salty Popcorn (14g) instead of the sweet popcorn, and Cadbury Mini Fingers Snack Pack (19.3g) were used as a replacement for the animal biscuits. Multiple snack options were implemented to reduce sensory-specific satiety where food palatability and consumption decreases when only one type of food is consumed (Rolls et al., 1981). Exposing participants to a variety of

foods/flavours has been shown to result in higher consumption of the foods as opposed to when only one type of snack is available (e.g., McCrory et al., 2002; Pliner et al., 1980). Eight packets of each of these snacks were placed on the bar in front of participants (see Figure 3). This aimed to increase the perception of food availability/portion size, which has been shown to increase consumption (Rolls, 2018). The water bottle was placed on a coaster about 5cm behind the bowls and participants were told they could drink this at any point during the study. Two bags of each of the chosen snacks were freshly opened in front of the participant and poured into one of the three bowls on a table next to them. The remaining bags were laid out next to the bowls (see Figure 4) and individuals were told to use the spare snacks to refill any of the bowls if they ran out. Participants were left alone to complete the quiz on the laptop in front of them to reduce potential social pressures on eating (Robinson et al., 2014). Participants were asked to put their mobile phones away into their bags and therefore should not have been able to use them to answer the quiz questions.

All quiz questions were displayed until a response occurred and for a maximum of 25 seconds (after this time the trial was coded as incorrect). A timer alongside each question counted down from 25 seconds to demonstrate to participants how long was left to provide an answer to the question. A blank screen was then presented for one second. Following this, one of the three feedback screens were presented for three seconds dependent on the participant's answer to the question. Immediately after the feedback screens, two consecutive screens were presented assessing affect ("How do you feel currently?"; Very Frustrated = 0 to Very Happy = 6) and expectation ("How much did you expect to get the question right?"; Totally Unexpected = 0 to Totally Expected = 6) using a slider (Likert) scale. The neutral condition did not include an expectation question as there was no correct answer. The affective and expectation ratings were presented until a response occurred, with a prompt being displayed when there was no response after 10 seconds ("Please make your responses now!"; Orange

text, Arial Font, 16pt Font Size). On the next screen, the question “Do you wish to take a snack?” was displayed. A “Yes” response was followed by an instruction to take a snack (“Please take **one** piece of food from **one** of the bowls in front of you”). However, a “No” response was followed by the instruction “Please wait for the next question”. These screens were presented for eight seconds and then the next quiz question was displayed. After completing the quiz, participants filled out the demographic questionnaire alongside the emotional and restraint scales of the DEBQ. Before the main debrief explaining the true study purpose and nature of the quiz, a funnel debrief was used to determine participant awareness of the study’s purpose and to collect data about the effectiveness of the paradigm (e.g., “How important was the feedback to you?”; see Appendix 4). Each of the funnel debrief items were presented sequentially on separate screens using Qualtrics so participants were only able to view the next item once they had provided an answer for the previous item. This prevented the study’s true purpose being revealed whilst allowing the determination of how much participants believed in and were deceived by the paradigm.

Data Analysis

Conditions were assigned post-testing, as the feedback was dependent on the correctness of the response. For the pre-registered confirmatory analyses, apart from the correctness of the response (= positive feedback vs negative feedback vs neutral condition), trials with positive/negative feedback were differentiated according to whether the participant expected the feedback or not (= above/below median of individual expectedness ratings for the two emotional conditions), leading to 5 conditions: expected positive feedback, unexpected positive feedback, expected negative feedback, unexpected feedback and neutral control condition. All relevant analyses of variance (ANOVA) were checked for sphericity and if this assumption was violated Greenhouse-Geisser or Hundt-Feldt corrections were used on the degrees of freedom. To determine the effectiveness of the emotional

manipulation, a one-factorial repeated measures ANOVA investigated the effect of feedback type (three levels: positive, negative and neutral) on the mean affective ratings made by an individual.

For the main analyses, the percentage of affirmative snacking responses ("yes" responses) made by each individual during the study acted as a measure of their snack intake, which served as our primary dependent variable. To determine snacking rates for each condition, the number of snacked trials was divided by the number of trials in that condition for each participant. An initial one-factorial repeated measures ANOVA examined the effects of the feedback type (three levels: positive, negative and neutral) on snacking rates. In addition, planned comparisons (paired t-tests or non-parametric equivalent if normality cannot be assumed) were carried out to directly compare the three trial types. Snacking rates were also analysed using a two-factorial repeated measures ANOVA with feedback type (positive, negative, and neutral) and expectation (high versus low) as factors.

Following the confirmatory snacking rate analyses, data were also analysed using a generalised linear mixed models (GLMMs) to analyse the trial-by-trial likelihood of individual snacking. For these models, expectation ratings were transformed into reward prediction errors (Schultz, 1997) to determine the extent to which the hypothetical activation of the reward (approach) system affected snacking behaviours. To calculate prediction errors, the expected outcome (original expectation rating of a correct response (0-6) divided by 10) was subtracted from the observed outcome (negative feedback = 0 and positive feedback = 1). Feedback (positive and negative), Affective Ratings (0-6, where 0 = Very Frustrated and 6 = Very Happy) and Reward Prediction Errors were included as fixed effects factors. Participant ID was the random effect to account for participant variability in emotional responses, expectation ratings and snacking. The Reward Prediction Error and Affective Ratings were centred within-participant to ensure that the likelihood of an individual

snacking could be investigated and to allow for the easier interpretation of model outputs. The GLMMs were conducted using RStudio (R Core Team, 2023) with the glmer() function from the lme4 package (Bates et al., 2015). The GLMMs were fitted by maximum likelihood (Laplace approximation) using binomial data. The first GLMM included Feedback Type and Reward Prediction Error as fixed effects whereas the second GLMM included Affective Ratings and Reward Prediction Errors as fixed effects. In exploratory analyses, subject-specific conditions were not differentiated based on feedback type but based on individual affective ratings (positive affect = above median across all trials; negative feedback = below median across all trials) and analysed using paired t-tests or non-parametric alternatives. Shapiro-Wilk was used to check for normality within the data. In further exploratory analyses, the relationships between the effect of increased snacking after positive affect and trait-level differences in eating styles as well as BMI were examined. As the data was not normally distributed, a Spearman Rank Order Correlation was conducted.

Results

Confirmatory Analyses

Emotional Manipulation Check

There was a significant large effect of Feedback Type on affective ratings, F (1.42, 77.88) = 99.48, $p < .001$, $\eta^2 = .644$. Post-hoc comparisons, with a Bonferroni correction, revealed that this was due to positive feedback leading to significantly higher affective ratings ($M = 3.86$, $SD = 0.88$) than negative feedback ($M = 2.60$, $SD = 0.80$; $p < .001$, $d = 1.47$) and neutral feedback ($M = 3.28$, $SD = 0.81$; $p < .001$, $d = 1.03$). Negative feedback led to significantly lower affective ratings than neutral feedback ($p = <.001$, $d = -1.26$).

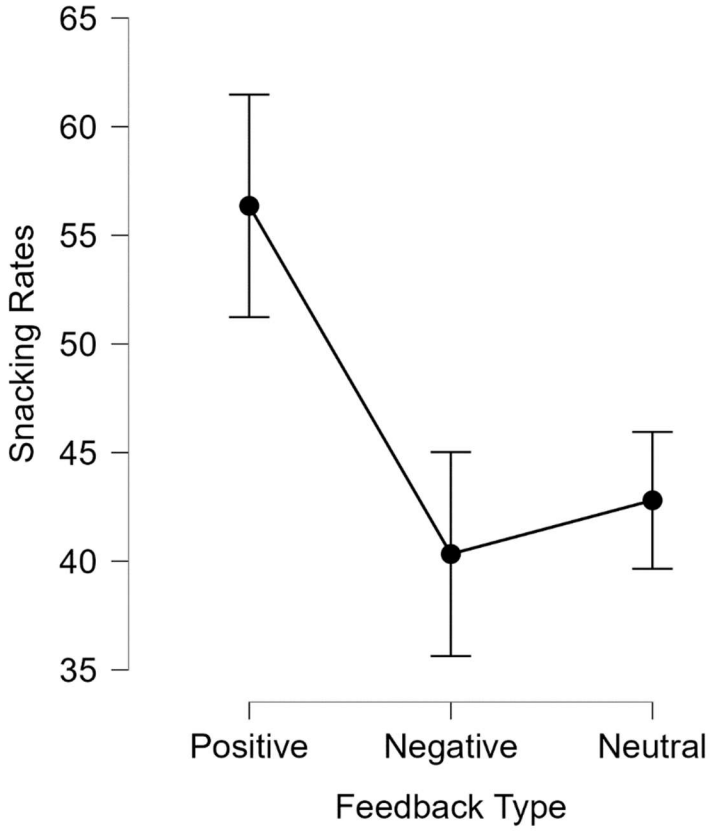
Effect of Feedback Type on Snacking Rates Across Trials

We found a significant large effect of Feedback Type on snacking intake, F (1.63, 89.86) = 15.41, $p < .001$, $\eta^2 = .219$ (Figure 5). Post-hoc comparisons, with a Bonferroni

correction, revealed that this was due to positive feedback leading to significantly higher snack intake (M = 56.35, SD = 27.77) than negative feedback (M = 40.33, SD = 23.85; p < .001, d = 0.57) and neutral feedback (M = 42.80, SD = 25.35; p < .001, d = 0.63). There was no significant difference on snacking rates between negative and neutral feedback conditions (p = .981, d = -0.13).

Figure 5

The effect of feedback type on the mean percentage of snacking across trials. Error bars show 95% confidence intervals.



Effects of Feedback Type and Expectation on Snacking Rates Across Trials

Similar to the one-factorial ANOVA, the two-factorial ANOVA using Expectation (high; low) as an additional factor showed a significant large effect of Feedback Type on snacking intake, F (1, 55) = 17.78, p = .001, η^2 = .176, reflecting higher snacking rates after

positive compared to negative feedback (*Mean Difference* = -16.11, *SE* = 3.82, *t* = -4.22, *d* = -0.563, $p < .001$). Neither the main effect of Expectation, $F(1, 55) = 0.488$, $p = .488$, $\eta^2 = .001$, nor the interaction between Feedback Type and Expectation were significant, $F(1, 55) = 0.522$, $p = .473$, $\eta^2 = .001$.

Funnel Debrief Responses

Overall, participants did not believe the quiz questions were a good test of their ability to be a competent psychologist (*M* = 2.83) however, the questions and feedback were important to them (*M* = 3.10), they answered the questions to the best of their ability (*M* = 3.47), applied effort (*M* = 3.85) and the feedback influenced their mood (*M* = 3.47). Surprisingly, data on their peers' performance did not really influence participants (2.42), however this may have been because many participants reported not noticing the percentages alongside each question. 68% of participants reported realising that the study's true purpose was to assess the effect of induced emotions on snacking behaviour, however no participant had guessed the exact hypotheses of the study and they were all blind to the study's true purpose at the beginning of the session.

Exploratory Analyses

Trial-by-Trial Analysis of the Binary Decision to Snack – Effects of Feedback Type and Reward Prediction Error

To determine the significance of the GLMM, a classic omnibus test was run to compare a compact model (without the fixed effects but with the random effect) with the augmented model (with both the fixed and random effects). The augmented model accounted for significantly more of the variance than the compact model; $X_2(2, 56) = 170.89$, $p < .001$. As there was evidence of high multicollinearity between the predictors, Feedback Type and Reward Prediction Error (*VIF* = 8.20), the results of the model should be interpreted with caution (see Appendix 5 for additional model statistics).

The first order model indicated Feedback Type significantly predicted the likelihood that an individual would snack, with a 174% greater likelihood of snacking following positive feedback (b = 1.01, z = 5.73 and p < .001). However, Reward Prediction Error did not significantly predict snacking likelihood (b = -0.26, z = -1.32 and p = .185). In the second order model, Feedback Type and Reward Prediction Error did not significantly interact (b = 0.62, z = 1.63 and p = .102). Odds ratios for the three predictors are shown in Table 1.

Table 1

GLMM output for model including Feedback Type and Within-Subject Reward Prediction Error as fixed effects to predict the likelihood of snacking on a trial-by-trial basis.

	Snacking		
Predictors	*Odds Ratios*	*CI*	*p*
Intercept	0.56	0.41-0.78	0.001
Feedback Type	2.74	1.94-3.87	<0.001
Reward Prediction Error	0.77	0.53-1.13	0.185
Feedback Type * Reward Prediction Error	1.87	0.88-3.95	0.102

Note. The odds ratios for Feedback Type and Reward Prediction Error were calculated from the first order model and the second order model was used to determine the interaction effect.

Trial-by-Trial Analysis of the Binary Decision to Snack – Effects of Affective Ratings and Reward Prediction Error

A classic omnibus test was conducted to calculate how much variance the independent variables accounted for. The augmented model (fixed and random effects) accounted for significantly more of the variance in snacking decisions than the compact model (only containing the random effect); X_2 (2, 56) = 247.52, p < .001. The predictors, Affective

Ratings and Reward Prediction Error showed low levels of multicollinearity (*VIF* = 1.48) and therefore the assumption was not violated (see Appendix 5 for additional model statistics).

In the first order model, Affective Ratings significantly predicted snacking outcome, showing a 43% increase of snacking likelihood with increasing (more positive) affective ratings ($b = 0.36$, $z = 10.33$ and $p < .001$; Figure 6). Therefore, snacking became more likely as participants experienced greater than usual positive affect and less likely as participants experienced greater than usual negative affect. Reward Prediction Error also significantly predicted the snacking outcome: Snacking likelihood increased by 33% as reward prediction errors became more positive ($b = 0.28$, $z = 3.41$ and $p = .001$; Figure 7). In the second order model, there was a significant positive interaction between Affective Ratings and Reward Prediction Error ($b = 0.44$, $z = 5.66$ and $p < .001$). The reward prediction error had a greater effect on snacking likelihood on trials with a more positive affective rating. Odds ratios for the three predictor variables are shown in Table 2.

Table 2

Table summarising the GLMM output of a model which included Within-Subject Affective Ratings and Within-Subject Reward Prediction Error as fixed effects.

	Snacking		
Predictors	*Odds Ratios*	*CI*	*p*
Intercept	0.91	0.68 - 1.21	0.510
Affective Ratings	1.43	1.34 - 1.54	<0.001
Reward Prediction Error	1.33	1.13 – 1.57	0.001
Affective Ratings * Reward Prediction Error	1.55	1.33 - 1.81	<0.001

Note. Odds ratios for Affective Ratings and Reward Prediction Error were derived from the first order model and the interaction was calculated from the second order model.

Figure 6

Predicted probabilities of snacking on a trial-by-trial basis by individual affective ratings. The shaded area contains the predicted values of snacking at each value of the affective ratings.

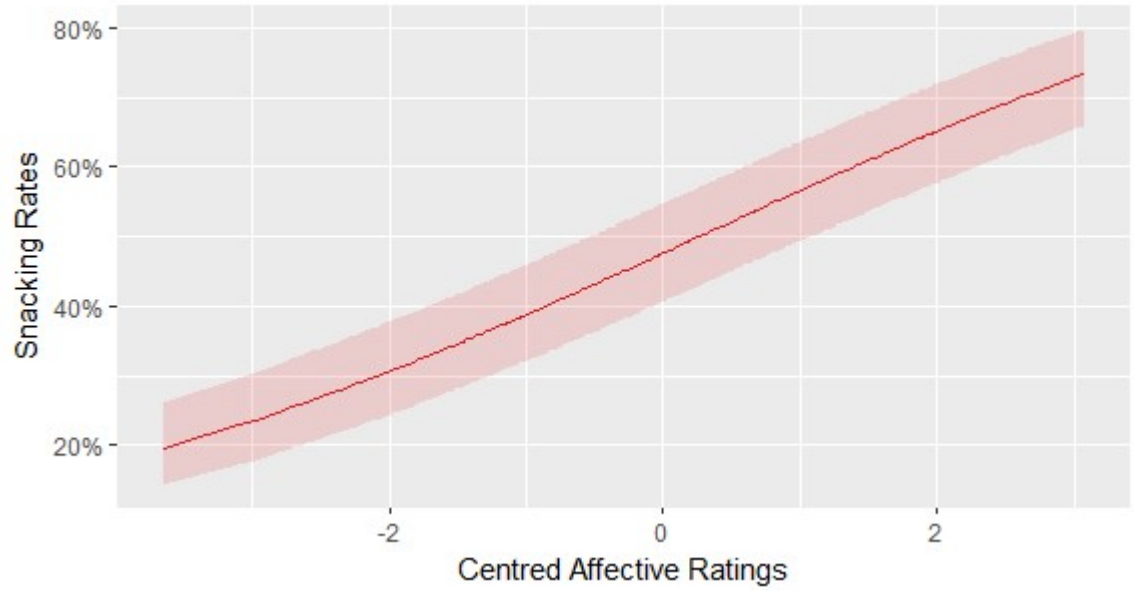
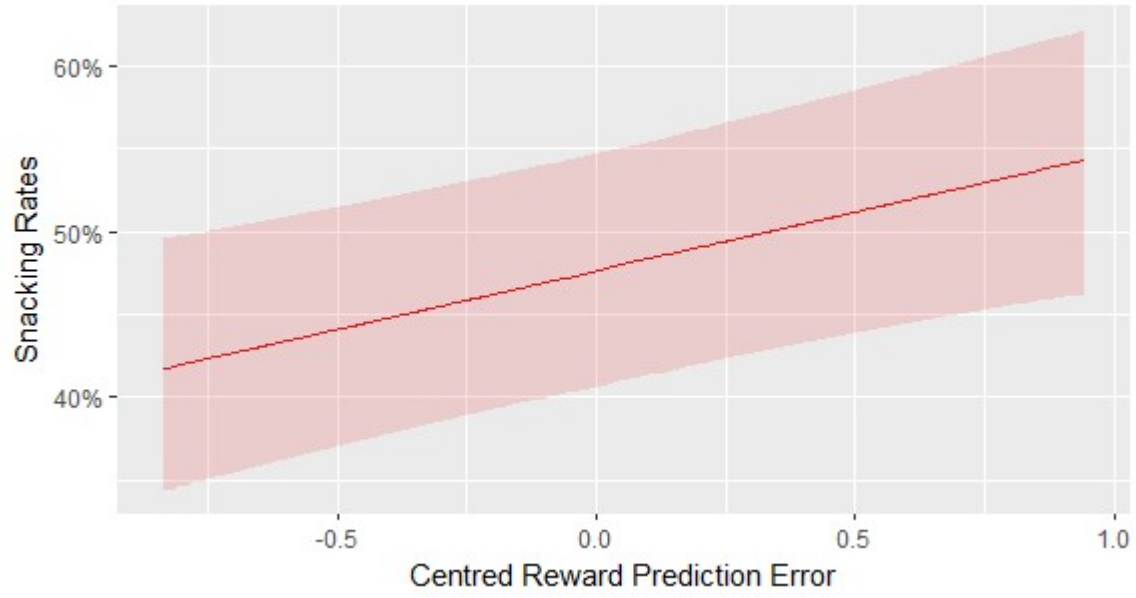


Figure 7

Predicted probabilities of snacking on a trial-by-trial basis by individual reward prediction error. The shaded area contains the predicted values of snacking at each value of the reward prediction error.



Trait-Level Differences in Eating Styles and BMI

The mean score for the emotional scale of the DEBQ was 2.70 (*SD* = 0.89, *Range* = 1.00 - 4.54). This was above average scores typically found in similar populations (e.g., 2.64 in female students; van Strien et al., 2007) suggesting that our sample tended towards higher levels of self-reported emotional eating. The mean score for the restrained eating scale of the DEBQ was 2.44 (*SD* = 0.80, *Range* = 1.00 – 3.90), which was lower than observed in other similar populations (2.61 in female students; van Strien et al., 2007).

Scores on the DEBQ-E were not found to be significantly correlated with the difference in snacking rates between positive and neutral trials (r (54) = -.02, p = .893). However, scores on the DEBQ-R were positively correlated with the difference in snacking

rates between positive and neutral trials (r (54) = .27, p = .041). Furthermore, scores on the DEBQ-E and DEBQ-R were positive correlated (r (54) = .41, p = .002). We also found no relationship between BMI and snacking differences in positive and neutral trials (r (50) = .02, p = 0.202).

Analysis of Subject-Specific Conditions Differentiated by Individual Affective Ratings on Snacking Across Trials

There was a significant difference between trials with a positive affective rating (M = 56.85, SD = 31.05) and trials with a negative affective rating (M = 37.8, SD = 26.99; t (55) = 3.97, p < .001, d = 0.530), where positive affect led to significantly higher snacking rates than negative affect.

Discussion

Study 1 aimed to investigate the effects of discrete emotional episodes on the momentary decision to snack on unhealthy but rewarding foods, employing a novel paradigm to increase the self-relevance and thus generalisability of the emotional induction task. It was predicted that positive feedback and/or emotions would lead to the greatest subsequent snacking as compared to negative or neutral feedback and/or emotions. The data from Study 1 demonstrated that positive feedback had the largest effect on the momentary decision to snack as compared to negative or neutral feedback, thus confirming the first hypothesis. These findings highlight the important influence of positive emotions on eating behaviour, in line with other emerging research (Evers et al., 2009), despite these effects having been previously overlooked within the literature (Evers et al., 2018). Furthermore, the general effect of positive feedback found within Study 1 corroborated results from previous meta-analyses (Cardi et al., 2015; Evers et al., 2018) whilst adding greater external validity to the results due to the employed design improvements, such as testing participants in a more natural eating environment and focusing on snacking behaviour. The novel emotion induction

procedure, which provided participants with real feedback on a quiz task, significantly affected their self-reported affective ratings, replicating our previous pilot study and supporting its use in further studies. When trials were analysed by affective ratings, positive affect led to significantly higher snacking rates than negative affect, indicating that emotions themselves and not just the feedback condition affected snacking outcomes. A greater snacking frequency following positive as opposed to negative emotions is in line with a biopsychological theoretical perspective of emotional eating as positive emotions are expected to activate the brain's reward (or appetitive/behavioural activation) system which in turn primes individuals towards approaching and seeking further reward (Gray, 1987; Lang, 1995). In the present study, the pre-activated or primed reward system is thus likely to have influenced the decision to snack made shortly after receiving the quiz feedback. As outlined in the introduction, if a biopsychological perspective would be used to make predictions about the effect of momentary negative emotional episodes on eating, negative emotions would be assumed to reduce food intake as they activate processes which prepare organisms for defensive action including halting digestion and a reduction of appetitive behaviours (Torres & Nowson, 2007). Specifically, a reduction of food consumption following negative feedback could be attributed to the "freezing" response, which is a physiological effect associated with defensive activation where behaviours are inhibited following aversive stimuli (e.g., Roelofs, 2017). Importantly however, while in Study 1 snacking rates following negative feedback and/or momentary negative emotions were lower than those following positive feedback/emotions, there was no significant difference between negative feedback/emotions and the neutral condition, which was contrary to the predictions made using a biopsychological perspective. It appears thus that discrete negative emotional episodes may not affect snacking decisions or that the negative emotions in the current study were not strong enough to active defensive processes. The lack of a general effect of negative

emotions on increased snacking is inconstant with the original definition of emotion eating which implicated the experience of negative emotions as a cause of increased food consumption (Heatherton et al., 1991). This lack of agreement with the original definition may in part be due to the nature of Study 1 as the quiz methodology induced momentary affective states and such transient negative affect has previously been shown to lead to less detrimental weight outcomes than retrospectively rated negative emotional eating (Chwyl et al., 2021). In contrast, stress over longer affective states, and of greater severity, activates the hypothalamic-pituitary-adrenal (HPA) axis stimulating the release of cortisol which increases an individual's appetite for unhealthy but rewarding foods, thus increasing the likelihood of weight gain (Torres & Nowson, 2007). This HPA axis activation may underlie comfort eating, where individuals in a negative mood state increase consumption of rewarding food to increase their positive affect and reduce activity in the HPA axis (Dallman et al., 2003). Therefore, the mechanisms behind emotional eating following momentary affect and sustained mood states are likely to be different, with shorter-term affective states showing an effect of increased eating for positive valence while longer-term affective states involve increased consumption for negative valence. Positive momentary emotions may prime the reward system leading an individual to seek further reward and therefore, subsequent consumption is increased. Whereas the mechanism underlying the classic effect of negative mood on eating is better explained using emotional regulation theory where an individual increases food consumption to enhance their mood and feel more positive (Kemp et al., 2013). This distinction between momentary and longer-term affective states would explain the lack of a general effect of negative affect found in previous laboratory studies (e.g., Bongers et al., 2013) as these designs are insufficient to measure mood states and instead measure shorter-term affect (Torres & Nowson, 2007). Furthermore, retrospective measures (such as the DEBQ; van Strien et al., 1986) contain items relating to both mood and discrete

emotional episodes and therefore confuse the effect of shorter-term and longer-term affective states. Retrospective reporting of behaviour is also affected by memory biases (Smyth et al., 2001) and therefore the use of retrospective scales in previous studies may have overestimated the effect of negative emotions on eating (e.g., van Strien et al., 2009). Taken together, the findings suggest that the definition of emotional eating needs to be updated to include a differentiation between momentary and longer-term affective states, which lead to differential effects for positive and negative valence.

The second prediction of Study 1 was that expectation alone, and in interaction with affect, would influence the momentary decision to snack, implementing a neurobiological perspective of emotional eating as surprising outcomes are thought to modulate the activation of approach/avoid systems due to the creation of larger prediction errors (Schultz, 1997). It was therefore hypothesised that unexpected positive feedback and/or emotions would lead to higher rates of snacking than expected positive feedback due to a larger discrepancy between the expected and actual outcome (i.e., creation of a larger positive prediction error), activating the reward system to a greater extent. However initial analyses of the present study, in which expectation ratings were combined into either high or low values, did not provide support for this hypothesis, showing no significant effect of expectation alone or in combination with feedback type on snacking outcomes. On the other hand, in the current study, expectation was rated on a Likert scale and consequently, differentiating trials by high and low expectation ratings removed variation in the data. Therefore, in addition to the above analyses which examined changes in snacking rates across trials, the present data was also analysed on a trial-by-trial basis using Feedback Type, Reward Prediction Error and Affective Ratings as predictors of the binary decision to snack. In the first model (including Feedback Type and Reward Prediction Error as factors), positive feedback led to a significantly higher likelihood of snacking as compared to negative feedback. However, Reward Prediction Error and the

interaction between the two factors did not significantly predict snacking likelihood. Again, this finding was in line with the predictions made using biopsychological theories of reward and motivation (Gray, 1987; Lang, 1995) as it would be expected that positive feedback would increase an individual's desire to snack due to activation of the reward system whereas negative feedback would decrease an individual's desire to snack as defensive processes become more important. However, results of the model using Feedback Type were somewhat limited due to a high correlation between predictors. In the second model, in which predictors (Affective Ratings and Prediction Error) were uncorrelated, Affective Ratings significantly predicted the binary decision to snack, with more positive ratings increasing the likelihood of snacking and more negative ratings decreasing snacking likelihood. Consequently, stronger momentary positive emotions encouraged snacking whereas snacking frequency was decreased in comparison, following stronger negative emotions. In addition, Reward Prediction Error was a significant predictor of the binary snacking decision, with a larger (more positive) prediction error being associated with a greater snacking likelihood. This provided initial evidence to support the second hypothesis however, replication of this effect will be needed due to the exploratory nature of the analysis. This finding was in line with neurobiological theories of reward as they suggested that larger positive prediction errors activate the brain's reward system to a greater degree, leading to more reward being sought out by an individual. Applying these predictions to emotion-induced snacking, it would be expected that surprising positive emotions would lead to greater snacking than expected positive emotions. Supporting this prediction, Affective Ratings and Reward Prediction Error significantly interacted, showing that the effect of the reward prediction error was greater in trials with a positive affective rating. Consistent with the present findings, (Wanglee, 2013) had previously shown that unexpected positive emotions were associated with a larger subsequent food intake. Whether participants received either predictable or surprising

monetary rewards affected their later snack consumption, with participants receiving an unexpected reward consuming more calories than those who were unsurprised by the reward receipt. This demonstrated the ability of expectation to modulate the effect of rewards on food consumption.

Previous work had also implicated different moderators of the effect of emotions on food intake (e.g., Evers et al., 2018). However, the evidence around the actual effects of eating styles and BMI status is conflicting. In the present study, only dietary restraint significantly correlated with positive emotional eating, where individuals scoring highly on the DEBQ-R ate more after the experience of momentary positive emotions than lower scoring non-restrained eaters. Earlier theories of restrained eating suggested that emotions disrupt an individual's self-control processes by increasing their cognitive load and therefore increasing their vulnerability to overconsumption (Polivy et al., 1994). Due to the limited availability of resources, individuals struggle to restrict their eating behaviour whilst simultaneously suppressing their emotions as both processes make use of the same cognitive resources (Bian et al., 2021). Consistent with this idea, restrained eaters (as measured by the Restraint Scale) who were instructed to control their negative emotions during a sad film, ate more ice cream in a subsequent fake taste-test than restrained eaters who were allowed to express their emotions freely (Vohs & Heatherton, 2000). However, applying these predictions to the current paradigm it would be expected that restrained eaters would eat more following the experience of any emotion regardless of its valence which was not found in the present study, where restrained eating scores correlated only with positive emotional eating. More recently, goal conflict theory has been developed to explain the mechanism behind restrained eating (Stroebe, 2022). Goal conflict theory links overconsumption to the rewarding properties of food and suggests that restrained eaters are driven by two conflicting goals, food enjoyment and weight management. Restrained eaters are usually driven by their

desire for weight control, however, in the presence of appetising food, food enjoyment becomes more important leading individuals to eat more. In Study 1, the activation of the reward system by momentary positive emotional episodes may have led to reduced accessibility of the weight management goal in higher scoring restrained eaters due to the emphasis on reward which primed their goal of food enjoyment, leading them to eat more. The lack of moderation of the present study's results by BMI status or emotional eating tendency (as assessed with the DEBQ-E) indicated that positive affect may have a stronger effect on the momentary decision to consume unhealthy but rewarding foods in a wider sample of people. In contrast, negative emotional eating has previously been implicated more strongly in more clinical populations, such as individuals with both obesity and depression but not in individuals with obesity who did not have depression (Privitera et al., 2016). A meta-analysis by Evers et al. (2018) only found convincing evidence of increased food consumption following negative emotions in restrained eaters, rather than a general effect of negative emotions, again highlighting the vulnerability of restrained eaters to the effects of different emotions. As the DEBQ-E scale only measures the tendency of individuals to overeat following the experience of negative emotions (van Strien et al., 1986), the lack of moderation of positive emotional eating by DEBQ-E scores, indicated positive and negative emotional eating occur via different processes. However, as the present study attempted to capture a more natural process of snacking, the lack of an effect of negative emotions suggested that the definition of emotional eating needed to be updated to fully capture both the effects of positive and negative affect, which may reflect different processes and depend on whether momentary or more sustained emotions are considered.

Conclusions and Limitations

In summary, Study 1 addressed certain gaps within the emotional eating literature, such as the role of positive emotions, and broadens our knowledge of eating behaviour. The

study used of a novel paradigm which allowed the effect of discrete (positive, negative and neutral) emotional episodes on the momentary decision to snack to be measured on a trial-by-trial basis, allowing fluctuations in emotions to be accounted for. Not aggregating eating behaviour across sustained time periods and examining temporally discrete fluctuations of eating (i.e., snacking) instead is important as the frequency of in-between meals has been shown to have significant implications on weight gain (Skoczek-Rubińska & Bajerska, 2021). In turn, the measurement of snacking behaviours has thus important consequences for the treatment of obesity and lifestyle interventions.

The present results suggest that momentary positive emotions may increase the likelihood of snacking in participants in non-clinical populations which could have important implications for weight outcomes and lifestyle interventions. Understanding the causes of snacking behaviours in student populations is particularly important as university life is significantly associated with weight gain (e.g., Serlachius et al., 2007). On the other hand, as all the participants in the present study were Psychology students at Durham University, the generalisability of the results to other adult populations was reduced. Therefore, to extend this research further, the paradigm should be replicated on more diverse samples, including those in clinical populations (such as patients with anorexia nervosa), in the future.

While the current thesis and previous emotional eating literature has used the terms positive and negative affect to cover a range of discrete emotions, it can be argued that the two concepts are not unitary and are instead made up of different components with different functions. For example, positive affect can be separated into an affiliative component, characterised by warmth, social closeness and feelings of contentment as well as an agentic component which is related to social dominance and incentive motivation (Morrone-Strupinsky & Lane, 2007). This agentic element may occur when individuals seek out achievement-related rewards and therefore the novel quiz paradigm used in Study 1 was

likely to have induced this incentive motivation in participants when they received the positive feedback following a correct answer, leading them to increase their reward consumption. However, due to the singular measure of emotion that was taken, the current data is unable to conclude that this was the type of positive emotion experienced by participants and therefore, further research is needed. Another interesting avenue of research would be to investigate the effect of the warmth component of positive affect on subsequent eating decisions and other reward-seeking behaviours to determine whether this type of positive emotion has differential effects to the agentic component. In addition to this, negative affect can be subdivided into different types of passive and active emotions. The current quiz paradigm likely induced feelings of disappointment in the participants when their answer was wrong and they received negative feedback instead of the rewarding positive feedback (frustrative non-reward; Papini et al., 2022). These frustrated states can be distinguished from more passive states of negative emotions, such as boredom, which have previously been linked to an increase in food intake relative to a neutral emotional state (e.g., Havermans et al., 2015; Moynihan et al., 2015). Furthermore, boredom was found to increase food intake differently to other types of negative emotion (such as anger; Koball et al., 2012), supporting the presence of the different subcomponents of negative affect. However, further research would be needed to determine exactly which component of negative affect Study 1 induced in participants.

Due to the use of a laboratory designed to look like a pub, which was assumed to feel more realistic to participants, the present results afforded higher ecological validity than some previous laboratory studies examining eating behaviour (e.g., García-García et al., 2020). Nevertheless, despite attempting to create a more realistic eating environment, and testing around mealtimes (following recommendations by Best et al., 2018), it can be argued that the nature of the laboratory setting per se reduced the ecological validity of findings. The

measurement of momentary affect and snacking decisions in Study 1 lends itself well to replication using an EMA design which provides high ecological validity but is less affected by memory biases and other issues of retrospective self-report measures due to the real-time measurement of behaviour in a naturalistic context. Therefore, Study 2 will attempt to replicate the effects found using a naturalistic EMA design with academic feedback as a natural manipulator of emotion. Study 2 will also assess other types of reward behaviour (such as smoking and social media use) to determine the domain-specificity of the effect of emotions on reward behaviour as the mechanisms may not be limited to emotional eating. At the same time, Study 2 will use an independent measure of positive and negative emotion, overcoming the limitation that in Study 1 affect was measured on a bipolar, continuous scale (from very frustrated to very happy). However, previous research has shown that positive and negative affect can occur in tandem (Watson & Clark, 1997) and participants may have experienced different discrete emotions to those measured within the scale.

Chapter 3 Study 2

Introduction

Building on the results from Study 1 and aiming to add ecological validity to the findings, the present study investigated the momentary decision to snack on unhealthy but rewarding foods using real academic feedback as a natural manipulator of emotion. It has been suggested that retrospective measures of emotional eating may have overstated the impact of negative emotions on subsequent food consumption due to the reliance on participants' memory which may bias results (Bongers & Jansen, 2016). For example, diary entries made at the end of the day are likely to overstate the importance of more recent events, preventing an accurate picture of eating behaviours (Shiffman et al., 2008). Therefore, the present study employed an EMA style design which is less affected by memory biases by assessing behaviours in real-time (Reichenberger et al., 2020). Participants were required to report any occurrences of a range of reward-seeking behaviours (snacking, alcohol consumption, smoking/vaping, recreational drug use and social media use) within the 60-minute window following the release of academic feedback at Durham University. The intention was to adopt the same basic study design as Study 1 but to use a naturalistic setting as well as to determine the domain-specificity of the effect of momentary positive emotions on snacking. Due to time constraints within the quiz paradigm, Study 1 had used a single measure of affect on a bipolar continuous scale. However, this does not account for the potential complexities of experienced affect, or the fact that positive and negative affect can occur simultaneously (Watson & Clark, 1997). Therefore, in the present study, participants rated their affect on the 20-item Positive and Negative Affect Schedule (PANAS) scale (Watson et al., 1988).

A few previous EMA studies have demonstrated an important influence of positive emotions on snacking decisions as well as a differentiation between the effects of positive versus negative momentary emotions. When smartphone-based surveys were completed

following five daily signals over the course of 10 days, positive affect was associated with an increased occurrence of taste-eating (= consumption not caused by hunger signals) whereas momentary negative emotions were associated with a decreased intake of unhealthy foods (Reichenberger et al., 2018). Furthermore, despite many studies focusing solely on the effects of negative emotions, positive emotions were reported as more frequently preceding snacking intake than negative emotions when students were required to fill in study measures before every instance of unhealthy snacking over the course of a week (Evers et al., 2013). In support of this effect, when event-triggered and random prompts were combined to collect data on participants' behaviour, affective ratings made before food consumption events were more likely to be positive (Boh et al., 2016). Using the same EMA procedure, momentary negative emotions were also associated with less severe weight outcomes as opposed to retrospectively reported negative emotional eating (as assessed using the DEBQ-E; Chwyl et al., 2021) which was in line with a dissociation between the effects of momentary and sustained emotion-induced eating.

However, another EMA study found that momentary positive and negative affect, as assessed using five random daily signals for seven days, was not associated with subsequent snacking decisions (Zenk et al., 2014). Instead, the overall number of daily stressful events were associated with food consumption, where a higher occurrence of negative affective events led to a greater snacking frequency. This corroborates previous literature in which it was found that a greater number of stressful events, reported using a diary entry at the end of the day, was associated with a higher snack consumption (O'Connor et al., 2008). This can be situated within a biopsychological perspective as more intense emotions (e.g., a greater number of stressful events within a day) are assumed to increase the likelihood of unhealthy food consumption (Torres & Nowson, 2007). As discussed in the previous chapter, the resulting activation of the HPA axis by sustained negative emotions can trigger an increase in

subsequent unhealthy food intake aimed to increase positive emotions and dampen the activation of the HPA axis (Dallman et al., 2003), supporting the ideas of the affect regulation theory. Therefore, the current study will use an EMA design to look at the effect of momentary positive and negative emotions on the decision to snack, predicting that positive emotions will lead to a greater snack intake due to the proposed dissociation between the effects of short-term and longer-term affect states.

Furthermore, while expectation has not widely been studied in relation to snacking as measured using EMA protocols, in this study ratings of expectations were included to replicate the results in Study 1. Interestingly, in an EMA study, the difference between an expectation of a grade and the actual grade received (i.e., the prediction error) had a greater effect on subsequent emotions than the grade itself (Villano et al., 2020). From this and the results from Study 1, it could therefore be predicted that unexpected positive grades would elicit higher activation in the reward system relative to expected positive grades, due to the creation of a larger positive prediction error, leading to higher levels of snacking and potentially other reward-related behaviours.

Study Overview

The purpose of the second study was to use academic feedback and marks as a natural manipulation of affect to investigate the influence of temporary emotional episodes (triggered by discrete events) on subsequent snacking and other reward-related behaviours. The study employed a mobile device methodology similar to EMA studies but with only two timepoints of data collection, comprising a naturally occurring emotional event and a control day. At a pre-specified timepoint after opening their academic feedback, students were asked to complete a short questionnaire relating to occurrence of snacking and other reward behaviour occurrences. As a control (baseline) measure, the same questionnaire was filled out a week later as it was expected that students would not be receiving academic feedback at this time.

The study was intended to build on Study 1 in which snacking behaviour following feedback on a quiz task (framed as a test of psychological knowledge) was measured. The use of a naturalistic design in the present study aimed at increasing the ecological validity of these previous results. Similar to the first study, the present study measured emotions (elicited by the feedback) and expectation (of the received mark/feedback) in addition to the measurement of snacking. The method and hypotheses for this study were preregistered on the AsPredicted platform (e3kd6.pdf (aspredicted.org)).

Recruitment for the naturalistic study occurred during two phases. The first sample was collected at the beginning of Durham University's Easter Term (May/June) and contained undergraduate Psychology students, awaiting summative assessment (essay/report) feedback. The second sample comprised of Durham University students, from different departments, receiving their end of year grades/degree classifications. Data collection for this occurred at the end of the Easter Term. However, the 2023 National Marking and Assessment Boycott in the UK disrupted data collection as feedback for some of the targeted assignments was not released or was delayed and most students did not receive full degree classifications. Therefore, the final sample was smaller than expected and only undergraduate Psychology students who had received summative assessment feedback provided data for both timepoints. Partial data was collected from a small sample of students in other disciplines who were awaiting their degree classifications. Study 2 will therefore act as a pilot and a basis for future work as well as help identifying strengths and weaknesses of the methods used.

We predicted that a positive emotional reaction to the mark/grade received would increase the likelihood of snacking relative to a negative/indifferent emotional reaction, while no such relationship was predicted for the control day (Hypothesis 1). We also predicted that expectation would modulate this relationship so that unexpected positive marks/feedback

would increase the likelihood of snacking as a surprising positive result was anticipated to induce a larger positive prediction error, priming the approach system to a greater extent (Hypothesis 2).

Method

Participants

Due to the novel design, an effect size from a previous study could not be used to make an *a priori* sample size calculation. Instead, G*Power (Faul et al., 2007) was used to compute a power analysis to determine the sensitivity of the study if a sample of 150-250 was implemented. This returned an f^2 value of 0.04-0.07, allowing the detection of small effect sizes. To account for potential dropouts as a result of having multiple time-points or non-adherence with instructions, the desired sample size was set at 250 participants. However, due to the early termination of data collection, the desired sample size was not reached. Participants were recruited using the SONA system (https://www.sona-systems.com/) using volunteer sampling. Participants on selected Psychology modules, from other departments and colleges were also sampled via emails and social media posts.

Participants were excluded if they had a prior/current eating disorder or diabetes. Participants were also excluded if they did not follow the timing instructions of the study, with the first questionnaire being filled in one to two hours after they had opened their academic mark and the second questionnaire being filled in at the approximate same time window a week later. Due to the pilot nature of the study, the pre-registered strict timing criteria were relaxed with a 15-minute window on either side of the two hours being added. Furthermore, data at timepoint two was included if it was within the two-hour window even if it was not reported exactly one week later. 90 participants completed the first timepoint (summative assessment and exam feedback combined) however, 39 did not adhere to the study timings after the mark/feedback release (even when strict criteria were relaxed),

resulting in a sample size of 53 for the feedback release day and 43 for the control day (with 29 participants completing both timepoints). This lack of retainment for the second part of the study meant demographic data for some participants was missing as these measures were collected on the control day. All individuals who participated after the summative assessment timepoint were Psychology students at Durham University. From the individuals who participated after receiving their degree classifications, one student was from the Psychology Department and three students were from other departments at Durham University. The following sample characteristics applies only to participants who gave data for the second timepoint (although they may have been excluded from timepoint one due to timing issues). The mean age of the sample was *M* = 19.86 years (*SD* = 0.77, *Range* 19 - 22). The sample contained 36 females and seven males. The average BMI of the sample was *M* = 22.89 (*SD* = 4.17, *Range* 16.7 – 34.3), which was within the range for a healthy BMI status. Four participants were classified as having an 'Underweight' BMI status, 25 had a 'Healthy' BMI status, five had an 'Overweight' BMI status and four had a BMI classified as 'Obese'. Seven of the participants were first year students and 34 were second year students. 13 participants were currently on a diet and 26 had previously been on a diet. One participant did not fill in the DEBQ scales. The remaining sample average for the emotional eating component of the DEBQ was 2.63 (*SD* = 0.76, *Range* = 1.39 - 4.00) and the average DEBQ-R score was 2.56 (*SD* = 0.88, *Range* = 0.90 - 4.60), showing slightly lower levels of emotional eating and slightly higher levels of dietary restraint than our previous sample (Study 1). At Timepoint 1 (including data from the summative assessment and degree classifications), 26% of participants had eaten a main meal within the hour and at Timepoint 2, 35% of participants had eaten a main meal. 31 participants opened their feedback before 12pm (*Mode* = 9.57am, *Range* = 9.50am – 8pm). Participants received course credits for participation if they adhered

to the study's timings. Ethical approval was obtained for this study from the Ethics sub-committee of the Department of Psychology, Durham University.

Materials

Main Questionnaire

The main questionnaire consisted of a block of general questions and then five other blocks relating to reward-seeking behaviours (snacking, alcohol consumption, smoking/vaping, recreational drug use and social media use). Questions were presented in the centre of the screen (Black Text, Arial Font, 12pt Font Size) with multiple-choice answers or text boxes (for open questions) being presented below this.

Within the general question block, participants were asked to report when they opened their mark and the current time. They also indicated what mark they had received and which assessment they had completed. Participants were then asked to complete the 20-item PANAS scale (Watson et al., 1988) assessing current positive and negative affect; all items were rated on a 5-point Likert scale (Very slightly/Not at all = 1 to Extremely = 5). Participants also indicated their expectation regarding the mark they received, using a slider (Likert) scale ("How did the mark compare to the mark you expected to get?"; Totally Unexpected = 0 to Totally Expected = 6). Finally, participants were asked whether they had discussed their mark with anyone else and if this was the case, whether this discussion had changed their emotions (using three multiple-choice options: "It improved my mood", "It did not change my mood" or "It made my mood worse").

For the snacking block, participants rated the strength of their desire to eat immediately after opening their mark (Extremely Low = 1 to Extremely High = 7) and reported whether they had eaten a main meal (i.e., non-snack food) in the 60 minutes following this and if so, what they had eaten. Participants then indicated how many snacking episodes (separated by five minutes) had occurred during the 60 minutes. For each snacking

episode, data about the type of snack and the personal value of this snack was collected ("How much do you usually like this snack?"; Dislike a Great Deal = 1 to Like a Great Deal = 5).

The other reward-seeking behaviour blocks followed a similar structure: Participants were first asked if they carried out the behaviour (if "No", they were taken to the next block). The next item assessed the strength of their desire to perform the behaviour immediately after opening their results (Extremely Low = 1 to Extremely High = 7). The final items asked for the number episodes of the reward behaviour within the previous 60 minutes and how much of it occurred (i.e., units of alcohol drunk, smoking/vaping episodes, recreational drug use episodes, minutes spent on social media).

Demographic Questionnaire

The demographic questionnaire comprised of seven items and assessed age, gender and year of study. In addition to this, individuals reported their height (in cm) and weight in (kg), which were transformed into BMI scores. Finally, participants were asked to report whether they were currently on a diet/trying to lose weight and if they had ever been on a diet/tried to lose weight.

DEBQ – Emotional and Restrained Scales

For details, see Study 1 (Chapter 2).

Procedure

On the day of the feedback release (first part of study), participants were instructed to access the study link to the Qualtrics questionnaire 60 minutes after seeing their feedback. For the second part of the study (control day), participants were instructed to fill in the same questionnaire, at the same time as on the feedback release day but one week later, and to report any occurrences of snacking and other reward behaviours in the past 60 minutes. In addition to the main questionnaire, on the control day participants also completed the

demographic questionnaire and DEBQ (see Materials). A full debrief was then delivered. The first part of the study took around 20 minutes to complete, and the second part took about 30 minutes.

Data Analysis

Due to an unexpected low number of snacking episodes reported across the sample, we used ratings of snacking desires instead of snacking episodes as the main dependent variable. Due to the limited sample size and incomplete data, hypothesis 1 was analysed using correlations between positive (negative) affect derived from the PANAS and snacking desire scores. Spearman's Rank Order correlations were used instead of Pearson's R correlations when the assumption of normality was violated. Hypothesis 2 was investigated using hierarchical multiple linear regression, assessing whether the addition of expectation added to the predictive validity of (positive) affect in determining snacking desire scores. The data met the assumption of non-multicollinearity. In further exploratory analyses, the relationship between affect and other reward behaviours (smoking/vaping, alcohol consumption and social media use) was examined. As none of the participants reported recreational drug use, this was not included in the analyses.

Results

Exploratory Analysis of Timepoint 1 (Feedback Release Day)

Correlations of Affect and Reward-Seeking Behaviours

Positive affect was not significantly correlated with snacking desire scores following the academic feedback release (r (51) = .21, p = .134). However, negative affect was negatively correlated with snacking desire scores following mark release (r (51) = - .39, p = .004).

Neither positive nor negative affect was significantly correlated with the desire to smoke/vape, (r (2) = .78, p = .225, r (2) = - .78, p = .225). In addition, neither positive nor

negative affect was significantly correlated with the desire to drink alcohol, (r (20) = -.18, p = .412, r (20) = .38, p = .082). Positive affect did not significantly correlate with desire to use social media or the number of social media episodes that occurred during the 60 minutes following feedback release (r (47) = .09, p = .552; r (39) = .15, p = .339). Finally, negative affect did not significantly correlate with desire to use social media or the number of social media episodes (r (47) = .10, p = .502; r (39) = -.02, p = .893).

Hierarchical Multiple Linear Regression of Affect and Expectation on Snacking Desire

The first model included positive and negative affect as predictors of the dependent variable, snacking desire scores. Expectation ratings were then added as a predictor to assess whether this improved the ability of affect to predict snacking desire scores. The data did not violate the assumption of non-multicollinearity with all VIF scores being less than 5 (*VIF* = 1.22, 1.22 and 1.00 for positive affect, negative affect and expectation respectively) and the Q-Q plot showing no evidence of multicollinearity.

The first model was significant F (2, 50) = 4.62, p = .014, R^2 = 0.156. Negative affect was significantly associated with snacking desire (b = -0.371, t = -2.583, p = .013). However, positive affect was not significantly associated with the desire to snack (b = 0.051, t = 0.352, p = .726). The second model (F (3, 49) = 3.13, p = .034, R^2 = 0.161) which included expectation as a predictor (b = 0.069, t = 0.524, p = .603) did not improve the predictive validity of the first model ΔF (1, 49) = 0.274, p = .603, ΔR^2 = 0.11. Therefore, the effect of affect did not differ between surprising and unsurprising academic feedback. Furthermore, expectation did not significantly interact with positive affect (b = 0.378, t = 1.31, p = .197) or negative affect (b = 0.496, t = 1.91, p = .063), indicating that snacking desire did not significantly differ between unexpected and expected positive or negative reactions to the feedback received. The first model explained 15.6% of the variance, a medium effect size.

Exploratory Analysis of Timepoint 2 (Control Day)

Correlations of Affect and Reward-Seeking Behaviours

Positive affect was not significantly correlated with snacking desire scores reported on the control day (r (41) = .22, p = .152). Furthermore, negative affect was not significantly correlated with snacking desire scores (r (41) = - .12, p = .450).

Neither positive nor negative affect was significantly correlated with the desire to smoke/vape, (r (5) = .16, p = .729, r (5) = -.01, p = .982). In addition, positive affect was not significantly correlated with ratings of the desire to drink (r (16) = - .41, p = .09). However negative affective ratings were significantly positively correlated with the desire to drink (r (16) = .50, p = .036). Positive affect did not significantly correlate with desire to use social media or the number of social media episodes that occurred during the 60 minutes following feedback release (r (37) = .16, p = .331; r (24) = -.14, p = .483). Finally, negative affect did not significantly correlate with desire to use social media or the number of social media episodes (r (37) = .15, p = .368; r (24) = .18, p = .392).

Discussion

Study 2 aimed to use academic feedback as a natural manipulator of affect to investigate the influence of temporary emotional episodes on subsequent snacking decisions as well as to determine the domain-specificity of the effect by measuring other reward-seeking behaviours. A naturalistic design was employed to increase the ecological validity of the conclusions drawn from Study 1 by investigating emotion-induced snacking in real-time as triggered by self-relevant events (academic feedback). However, due to the 2023 National Marking and Assessment Boycott, data collection was terminated early, and the desired sample size was not reached. As the final sample size left the study insufficiently powered, all data analyses were exploratory. Furthermore, due to an insufficient number of reported snacking behaviours overall, the analysis of Study 2 focused on snacking desire. Nonetheless,

the present study can be used as a pilot study and a basis for future work, providing methodological improvements and potential avenues for future investigation.

The key prediction of Study 2 was that a positive emotional reaction to the academic feedback received would increase snacking desire relative to a negative/indifferent emotional reaction, with this effect being specific to the feedback release day. However, positive affect was not significantly associated with snacking desire on either the feedback release day or control day and therefore, Hypothesis 1 was not supported by the data. This effect was contrary to the findings in Study 1, showing a substantial increase of snacking following experimentally induced positive feedback, relative to a negative or neutral quiz outcome. Consequently, the generalisability of Study 1 may be questioned as discrete positive emotional episodes may have a weaker effect on real-life snacking decisions than responses in a controlled laboratory environment. On the other hand, further investigation with a sufficiently powered sample - avoiding potential Type 2 errors - is needed before any firm conclusions can be drawn. Furthermore, while there is a lack of EMA studies measuring the effects of positive emotions, there is some evidence that positive emotions are associated with a greater consumption of foods. As reviewed earlier in this thesis, other studies have shown such a relationship (e.g., Evers et al., 2013; Reichenberger et al., 2018). While a biopsychological perspective of reward and motivation is not consistent with the present results (= no increase in snacking desire after positive affect), it could be that the strength of the positive affect experienced was not strong enough to activate the reward system. Previously it has been suggested that only intense stressors activate the HPA axis leading to subsequent snacking (Adam & Epel, 2007) and correspondingly, the intensity of positive emotions may also be crucial to influence eating. However, other processes aside from motivational priming (which usually lasts only for a limited time; Bradley et al., 2001) may have occurred, for example participants may have “self-rewarded” a good academic mark

with reward behaviours outside of the 60-minute window of data collection. Future research should therefore aim to have multiple timepoints of data collection within the same day to get a deeper understanding of reward behaviours.

The current study found that a negative emotional reaction to the feedback received was associated with a reduction in an individual's desire to snack, in line with findings from Study 1 where negative quiz feedback led to a lower subsequent snack consumption than the positive feedback condition. As the EMA protocol measured shorter-term affective states and found a different effect of negative emotions than studies measuring longer term mood states, this again supported the distinction between the effects of positive versus negative emotions that depends on the length of the emotion. A few previous EMA studies have also demonstrated a reduction in the consumption of palatable foods following stress and sadness alongside an increase of unhealthy food following positive emotions, partially supporting the current findings. Men, but not women, and participants aged 20-30 years old were found to decrease their consumption following negative emotions whilst increasing their food intake following positive emotions (Wouters et al., 2018). Additionally, momentary negative emotions were associated with a decrease in snack consumption whereas positive emotions lead to a greater likelihood of unhealthy food intake (Reichenberger et al., 2018). As explained in Chapter 2, predictions for the effects of short-term negative emotions on eating can be derived from a biopsychological perspective according to which negative emotions trigger the activation of a defensive system, which, for instance, leads to a reduction of digestion and appetite (Torres & Nowson, 2007). While the results of Study 1 did not provide support for this account, the findings of Study 2 (showing a negative association between negative affect and snacking desires) are consistent with the biopsychological perspective to some extent. Yet, the lack of a neutral comparison condition in Study 2 makes the results somewhat difficult to interpret. In contrast, sustained stress has been associated with an

increase in food consumption in healthy individuals (Hill et al., 2022), and a greater number of stressful events experienced during the day also led to higher snack consumption (Zenk et al., 2014). These findings of the effects of sustained negative emotions are better explained using notion of affect regulation theory where rewarding food is consumed to reduce negative affect and increase positive affect (Kemp et al., 2013). It has been shown that sustained negative mood states activate the HPA axis and stimulate the release of cortisol, leading to a higher consumption of rewarding foods (Torres & Nowson, 2007). In support of this, stress has been associated with a greater food intake in individuals described as high cortisol stress reactors but not in low cortisol reactors (Epel et al., 2001), highlighting the involvement of the HPA axis and cortisol in negative emotional eating following sustained emotions. Furthermore, negative affect was found to be increased in the four hours before, and decreased in the four hours after, occurrences of binge eating in participants with obesity (Berg et al., 2015). Therefore, short-term and longer-term negative affective states have different consequences for eating behaviour, with momentary negative states being associated with less detrimental weight outcomes (Chwyl et al., 2021). However, replication with a fully powered sample is needed before any firm conclusions can be drawn. In the present study, neither valence of affect was associated with snack consumption on the control day, suggesting that discrete event-related emotional episodes (as triggered by academic feedback) and not variations in general affect may moderate emotion-induced snacking.

The second prediction of the current study was that expectation would modulate the effect of emotion so that surprising positive feedback would increase the desire to snack relative to expected positive feedback. However, expectation did not significantly predict snacking desires independently of, or in interaction with, affect as snacking desire scores did not significantly differ between predicted and unexpected positive academic feedback, disputing this hypothesis. Furthermore, the current finding was contrary to the conclusions

drawn from Study 1 where the reward prediction error independently, and interaction with affective ratings, affected the binary decision to snack on a trial-by-trial basis. One explanation for the lack of effects of expectation could be that participants had already viewed their feedback before reporting how it matched their expectation and therefore their answer may have been affected by a desire to be seen as consistent and correct (Lecky, 1945). Consequently, subsequent studies based on this pilot should aim to collect expectation ratings when the academic work is first submitted instead of once feedback has already been received.

As part of the original exploratory analyses, the effect of emotional episodes on other types of reward behaviours was investigated to deduce the domain-specificity of the mechanisms behind momentary emotional eating. On the day of feedback release (Timepoint 1), no significant associations between positive or negative affect and alcohol consumption, smoking/vaping or social media use were found. However, on the control day (Timepoint 2), negative affect was significantly associated with the desire to drink alcohol, where individuals with a higher negative affect were more likely to show an increased desire to consume alcohol. No other significant correlations between affect and the desire to partake in any reward behaviours were found. One explanation for this result is that alcohol consumption may be less affected by discrete emotional episodes and instead be more affected by general negative affect, not triggered by a specific event, as the significant association was specific to the control day. This was corroborated by a previous study which found a positive association between negative mood and subsequent alcohol consumption, whereas momentary negative emotions were associated with a reduced likelihood of alcohol consumption (Duif et al., 2020). However, it should be noted that in the current study the two timepoints were comprised of different samples and therefore participant characteristics (such

as drinking habits) may have influenced the results found. Further investigation of this effect in a larger sample would be necessary before any firm conclusions can be drawn.

Recommendations for Methodological Improvement

As data collection was terminated early and the resulting sample had insufficient power to investigate the proposed effects, the current study was reframed as a pilot study which can be used as a basis for future studies and to provide methodological improvements. Firstly, smartphone notifications should be employed to remind individuals to complete the surveys, reducing the amount of unusable or lost data and increasing the likelihood of a sufficiently powered sample. Furthermore, it is recommended that the number of measurements taken on both the feedback and control day should be increased, as this would give a better view of fluctuating emotions throughout the day as appetite and food consumption can change over relatively short time periods (Evers et al., 2023). Originally Study 2 was designed to replicate Study 1 and so one point of data collection close to the receipt of academic feedback (as in the quiz paradigm) was used. However, the results from the present study suggest this was insufficient and so a greater number of prompts to report behaviour per day should be used. This methodological improvement would also mitigate the effect of the time of day of data collection as much of the current data was collected during the morning, when the effect of emotions on snacking is assumed to be weaker (Haynes et al., 2016) and snack foods are less likely to be eaten (Evers et al., 2023). The initial design of the present study included data collection following end of year grades where the release of grades is staggered throughout the day between different departments at Durham University. This was not possible due to the Marking and Assessment Boycott and resulting early termination of data collection. Replications should include a range of release times to mitigate the effect of the time of day on responses. The timing of data collection may also be important for other types of reward behaviour (such as alcohol consumption) where there are

social customs over when consumption behaviours are appropriate (Duif et al., 2020). Related to this limitation, as snacking desires were a self-rated measure, they may have been affected by social desirability and therefore may not have accurately reflected actual behaviour. In addition, individuals are often not aware of the motivations behind their actions (e.g., Gantman et al., 2017). For instance, self-reported emotional eaters are more likely to cite negative emotions as the cause of overconsumption even when this was not the case (Adriaanse et al., 2016). Future EMA studies should aim to focus on finding effects on actual snacking episodes, which would be less affected by memory biases and underreporting due to the real-time collection of data in an EMA design (Reichenberger et al., 2020). Furthermore, participants should be trained on EMA procedures before filling out the measures (e.g., Reichenberger et al., 2018) so that they are able to correctly identify their motivations and emotions, giving a more accurate depiction of the studied effect.

Conclusions

Taken together, Study 2 aimed to add ecological validity to the findings of Study 1 by replicating the effects found in a real-life setting. While the effect of momentary negative emotions was partly replicated, the effect of positive emotions on snacking was not. However, as the present study was insufficiently powered, no firm conclusions can be drawn from the data. Study 2 should therefore be used as a basis for future work, with the methodological limitations being addressed in subsequent study designs.

The design of Study 1 and the present study was also limited by the timing of the expectation question, as it occurred **after** participants had already received their academic/quiz feedback, which may have influenced their self-reports. Therefore, future EMA studies should aim to collect information on students' expectations regarding their grade/feedback outcomes at the time of the assessment submission and compare this to the actual feedback received to calculate a more accurate reward prediction error value. To

address the limitation of the quiz paradigm, Study 3 exposed participants to the expectation question before they had been provided with feedback on a particular trial to increase the reliability of the reward prediction error measure.

Chapter 4 Study 3

Introduction

Study 1 demonstrated that discrete positive emotional episodes had a greater effect than negative or neutral emotions on the momentary decision to snack on unhealthy but rewarding foods. Study 3 aimed to replicate the findings of Study 1 whilst also implementing one important methodological modification:

Study 1 had assessed participants' expectation of the quiz feedback **AFTER** the feedback for a specific trial had been presented. This may have biased expectation ratings, for instance, as a result of self-consistency effects or impression management (Bozeman & Kacmar, 1997; Lecky, 1945). In particular, in order to appear in a more desirable light (and/or to be consistent with their self-concept) participants may have downplayed their surprise (increased their rated expectation) when seeing either the positive or negative feedback. Post-feedback ratings may have also been affected by inaccurate memory of the preceding mental state and other confounding factors. Consequently, in Study 3, participants were exposed to the quiz question and then asked to immediately rate their expectation of the correctness of their response before receiving their feedback and rating their affect and desire to snack. This change in design mapped also more closely on the reward prediction error literature, in which predictions naturally precede outcomes (Glimcher, 2011). Therefore, while Study 3 aimed to replicate Study 1, it also aimed to have a greater focus on the role of expectation in moderating subsequent snacking behaviours.

Study Overview

This experiment is a partial replication and follow-up of Study 1, using the same basic experimental paradigm and analysis approach. It investigated the role of expectation in modulating the previously studied effect of discrete emotional episodes (elicited by feedback in a quiz task) influencing the momentary decision to snack on unhealthy but rewarding foods. To account for the limitations of Study 1, participants were asked to rate their

expectation of a correct response **before** they had received any feedback regarding their answer. The methods and hypotheses for this study were preregistered on the AsPredicted platform (v2xg9.pdf (aspredicted.org)).

We expected to replicate the effect found in Study 1 where positive feedback/emotions led to the largest increase in snacking as compared to negative feedback/emotions or a neutral condition (Hypothesis 1). While expectation did not significantly affect snacking rates in the aggregated analyses across trials in Study 1, this may have been confounded by the timing of the expectation question (as it came after participants had already received feedback) as well as the loss of data variation. Using the new design, it was predicted that expectation would modulate the effect of positive feedback so that unexpected positive feedback led to greater snacking than expected positive feedback due to the elicitation of a larger positive prediction error, activating the approach system to a greater extent (Hypothesis 2). Therefore (as in Study 1), we tested whether the individual dichotomous decision to snack could be modelled on a trial-by-trial basis using Feedback Type, Affective Ratings and Reward Prediction Errors as predictors. Similar to Study 1, additional exploratory analyses were conducted to investigate whether the above effects varied with individual differences in eating styles (assessed by DEBQ-E and DEBQ-R) and BMI scores.

Methodological Changes

Participants

For comparability, we used the same sample size as Study 1, aiming to collect 40-60 participants (to account for dropouts) which allowed us to detect an effect size of $f = 0.33$ at a statistical power of 95%. The same exclusion criteria as in Study 1 were applied with the addition of excluding participants who had taken part in any of the other studies contained within this Masters by Research project. Data from participants who did not snack at all

throughout the study or had a mean quiz accuracy of above 75% or below 25% were excluded, leading to the removal of data from one participant as their accuracy was above 76%.

The final sample size consisted of 46 participants who were all students at Durham University recruited via the SONA system (https://www.sona-systems.com/), emails and social media using volunteer sampling. Participants' mean age was *M* = 20.3 years (*SD* = 3.44, *Range* = 17 – 35; one participant did not report their age). The sample contained 39 females, six males, and one participant who selected 'Other' when asked about their gender. The average BMI score of the sample was *M* = 22.1 kg/m^2 (*SD* = 3.40, *Range* 17.2 - 30.4). Five participants had a BMI status of 'Underweight', 28 had a 'Healthy' BMI status, seven had a BMI status of 'Overweight' and one participant had a BMI status classified as 'Obese'. 39 participants were undergraduates (19 were in first year, 11 were in second year, nine were in third year and one was in fourth year). Four participants were postgraduates. One participant was a post-doctoral student, and one participant did not give information about their year of study. 30 students were from the Psychology Department and the remaining 14 who gave demographic data were from different departments throughout the University. Seven individuals were currently on a diet and 26 reported having previously been on a diet. Nine participants smoked/vaped regularly, and one participant smoked/vaped occasionally.

Participants were required to abstain from eating for four hours before starting the study (see "Procedure" and Study 1). 38 participants adhered to this fast (with two participants not providing details about time and content of last meal) and the average time since last meal in the whole sample was 8.56 hours (*SD* = 5.49, *Range* = 1 – 23.75). The average hunger rating (7-point Likert scale) of the sample after the quiz was 3.45 (*SD* = 1.48, *Range* = 1 - 7). The study took around 90 minutes to complete, and participants received course credits or a £15 Amazon voucher for their participation. Ethical approval was obtained

for this study from the Ethics sub-committee of the Department of Psychology, Durham University.

Materials

All materials used in Study 3 were identical to Study 1 with the following minor exceptions:

Quiz Task

The quiz consisted of 100 multiple-choice General Knowledge questions (from a range of topics such as Maths, Politics and Entertainment) and 50 neutral trials presented in a randomised order for each participant using the Qualtrics software (Qualtrics XM: The Leading Experience Management Software). The quiz content was changed from the first study as psychological knowledge was not relevant to all the students and so instead the quiz was framed as a test of participant ability to be a good student. Difficulty of the questions was extrapolated from mean accuracy ratings from a previous pilot study and the quiz aimed to include a balanced proportion of easy and difficult questions. 56 questions were classified as easy and had a mean accuracy of >50%. 46 questions were classified as difficult and had a mean accuracy of <50%. Two questions had an accuracy of 50%. All other question details were kept the same as in Study 1.

Demographic Questionnaire

In addition to the questions used in Study 1, participants were asked to report which department they were from.

Procedure

The basic experimental paradigm and laboratory set-up was retained from the first study. However, participants were told the quiz was a measure of their ability to be a good student and receive a good degree rather than the aim being specific to psychological success.

Again, all quiz questions were displayed together with a timer (see Methods Study 1) until a response occurred and for a maximum of 25 seconds (after which the trial was coded as incorrect). Participants then rated their expectation of a correct response ("How sure are you that your answer is correct"; 0-10 on a slider Likert scale, where 1 = Not at all and 10 = Very sure) before they received any feedback. Individuals were prompted after ten seconds if they failed to provide a response ("Please make your responses now!"; Orange text, Arial Font, 16pt Font Size). The neutral condition did not include an expectation question as there was no correct response. Once a response had been made, a blank screen was displayed for one second and then participants were presented with one of the three feedback screens dependent on their answer. Immediately after this, participants assessed their affect using a slider (Likert) scale (see Methods Study 1). This screen was presented until a response occurred and then followed by the prompt to decide to take a snack or not (see Methods Study 1).

Data Analysis

Conditions were again assigned post-testing, as the feedback was dependent on the correctness of an individual's response. All relevant analyses were checked for sphericity and if this assumption was violated, Greenhouse-Geisser or Hundt-Feldt corrections were used on the degrees of freedom. To check the emotional manipulation was successful, a one-factorial repeated measures ANOVA determined the effect of feedback type (3 levels: positive, negative and neutral) on mean individual affective ratings for that trial type (0-6 where 0 = Totally Frustrated and 6 = Totally Happy).

As in Study 1, the main dependent variable was snacking rate (number of snacks taken divided by number of trials). To replicate our previous finding, an initial one-factorial repeated measures ANOVA assessed the effect of feedback type (3 levels: positive, negative and neutral) on snacking rates. Following this, planned comparisons (paired t-tests or non-

parametric equivalent if normality could not be assumed) were run to compare the three trial types.

In addition to the ANOVA of snacking rates aggregated across trials, GLMMs were used to predict the likelihood of an individual snacking on a trial-by-trial basis. Expectation ratings were transformed to Reward Prediction Errors (for details see Methods Study 1) and together with Feedback Type included as fixed effects factors in the GLMM, with Participant ID being used as a random effect factor. A second GLMM was computed with Reward Prediction Errors and Affective Ratings as fixed effects, and Participant ID as random effect. To investigate the within-subject effect and to allow for easier interpretation of model outputs, Reward Prediction Errors and Affective Ratings were centred within-participant. The GLMMs were conducted using RStudio (R Core Team, 2023) with the glmer() function from the lme4 package (Bates et al., 2015). The GLMMs were fitted by maximum likelihood (Laplace approximation) using binomial data. In further exploratory analyses the relationships between increased snacking after positive affect and trait-level differences in eating styles as well as BMI were examined using correlation analyses. As the data was not normally distributed, Spearman Rank Order Correlations were used.

Results

Confirmatory Analyses

Emotion Manipulation Check

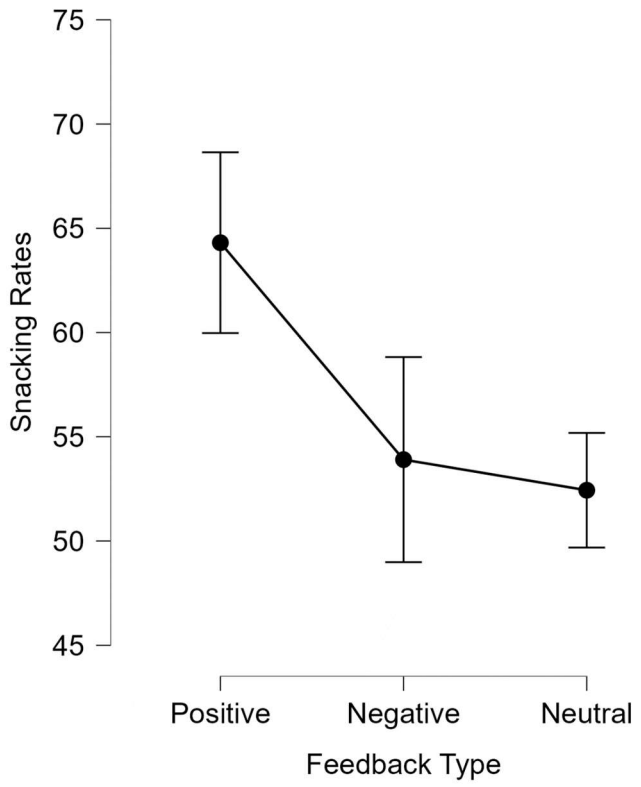
There was a significant effect of Feedback Type on Affective Ratings, F (1.30, 58.64) = 81.61, $p < .001$, $\eta^2 = .645$. Post-hoc comparisons, with a Bonferroni correction, revealed that this was due to positive feedback leading to significantly higher affective ratings (M = 4.16, SD = 0.90) than negative feedback (M = 2.62, SD = 0.70; $p < .001$, d = 1.99) and neutral feedback (M = 3.36, SD = 0.71; $p < .001$, d = 1.03). Negative feedback led to significantly lower affective ratings than neutral feedback ($p < .001$, d = -0.96).

Effect of Feedback Type on Snacking Rates Across Trials

We found a significant effect of Feedback Type on Snacking Rates, F (1.54, 69.06) = 10.09, $p < .001$, $\eta^2 = .183$ (Figure 8). Post-hoc comparisons, with a Bonferroni correction, revealed that this was due to positive feedback leading to significantly higher snack intake (M = 64.31, SD = 24.22) than negative feedback (M = 53.90, SD = 25.42; $p = .017$, d = 0.43) and neutral feedback (M = 52.44, SD = 22.50; $p < .001$, d = 0.49). There was no significant difference between snacking rates in the negative and neutral feedback conditions (p = 1.00, d = 0.061).

Figure 8

The effect of feedback type on mean snacking rates across trials, the error bars show 95% confidence intervals.



Funnel Debrief Responses

When taken together, participants did not believe the quiz questions were a good test of their ability to be a competent student (M = 2.69) and they rated the questions and feedback as less important to them than (M = 2.98) than participants in Study 1 which was expected due to the lower self-relevance of the task. However, they answered to the best of their ability (M = 3.56), applied effort (M = 4.05) and felt their mood was influenced by the feedback (M = 3.07). Surprisingly, participants in this sample had a lower mean rating for the effect of the feedback on their mood despite a similar effect size being found in the statistical analyses which highlights the limitations of self-report methods as participants seem to be unaware of the true motivations behind their behaviours. Again, participants were not as affected by peer performance as expected (M = 2.64) although many did not report paying much attention to the percentage values. 74% reported they realised the study's true purpose was to assess the effects of induced emotions on snacking behaviour, however none of the participants correctly guessed the study hypotheses, and all were blind to the study's aims and hypotheses before entering the laboratory, as recommended by Best et al. (2018).

Exploratory Analyses

Trial-by-Trial Analysis of the Binary Decision to Snack – Effects of Feedback Type and Reward Prediction Error

To determine the significance of the GLMM, a classic omnibus test was run to compare a compact model (without the fixed effects but with the random effect) to the augmented model (with both the fixed and random effects). The augmented model accounted for significantly more of the variance than the compact model; $X_2\,(2, 46) = 60.72$, $p < .001$. The factors, Feedback Type and Reward Prediction Error, showed low levels of multicollinearity (*VIF* = 2.75) and therefore they did not violate the model's assumptions (See Appendix 6 for additional model statistics).

The first order model indicated that Feedback Type significantly predicted snacking likelihood, with a 57% increase of snacking likelihood after an individual received positive feedback ($b = 0.45$, $z = 3.96$ and $p < .001$). However, Reward Prediction Error did not significantly predict an individual's snacking likelihood ($b = 0.10$, $z = 0.86$ and $p = .390$). In the second order model, the interaction between Feedback Type and Reward Prediction Error was not significant ($b = 0.46$, $z = 1.93$ and $p = .054$). Odds ratios for the three predictors are shown in Table 3.

Table 3

Table showing GLMM output for model including Feedback Type and Within-Subject Reward Prediction Error as fixed effects to predict the likelihood of snacking on a trial-by-trial basis.

		Snacking	
Predictors	*Odds Ratios*	*CI*	*p*
Intercept	1.32	0.94-1.87	0.110
Feedback Type	1.57	1.26 – 1.96	<0.001
Reward Prediction Error	1.11	0.88-1.40	0.390
Feedback Type * Reward Prediction Error	1.59	0.99-2.53	0.054

Note. The odds ratios for Feedback Type and Reward Prediction Error are calculated from the first order model and the second order model was used to determine the interaction effect.

Trial-by-Trial Analysis of the Binary Decision to Snack – Effects of Affective Ratings and Reward Prediction Error

In the omnibus, the augmented model accounted for significantly more of the variance in snacking decisions than the compact model; $X_2\,(2, 46) = 97.53$, $p < .001$. The factors, Affective Ratings and Reward Prediction Error, showed low levels of multicollinearity (*VIF*

= 1.29) and so again the model's assumptions were not violated (See Appendix 6 for additional model statistics).

In the first order model, Affective Ratings significantly predicted snacking outcome, showing a 26% increase of snacking likelihood with increasing (more positive) affective ratings ($b = 0.23$, $z = 7.16$ and $p < .001$; Figure 9). Therefore, snacking became more likely as participants experienced greater than usual positive affect and less likely as participants experienced less than usual positive affect. Reward Prediction Error also significantly predicted snacking outcome. Snacking likelihood increased by 21% when the prediction error became more positive ($b = 0.19$, $z = 2.33$ and $p = .020$; Figure 10). Therefore, snacking became more likely as an individual experienced a larger positive prediction error and became less likely as a participant experienced a larger negative prediction error. In the second order model, there was a significant positive interaction between Affective Ratings and Reward Prediction Error on the likelihood that a participant would choose to snack ($b = 0.31$, $z = 4.40$ and $p < .001$). Therefore, reward prediction error had a greater effect on snacking likelihood in trials with a more positive affective rating. Odds ratios for the three predictor variables are shown in Table 4.

Table 4

Table summarising the GLMM output of a model which included Within-Subject Affective Ratings and Within-Subject Reward Prediction Error as fixed effects on the likelihood of snacking on a trial-by-trial basis.

	Snacking		
Predictors	*Odds Ratios*	*CI*	*p*
Intercept	1.63	1.17 – 2.28	0.004
Affective Ratings	1.26	1.18 – 1.34	<0.001
Reward Prediction Error	1.21	1.03 – 1.42	0.020
Affective Ratings * Reward Prediction Error	1.36	1.19 – 1.56	<0.001

Note. To calculate the odds ratios for Affective Ratings and Reward Prediction Error come from the first order model and the interaction was calculated from the second order model.

Figure 9

Predicted probabilities of snacking on a trial-by-trial basis by individual affective ratings. The shaded area contains the predicted values of snacking at each value of the affective ratings.

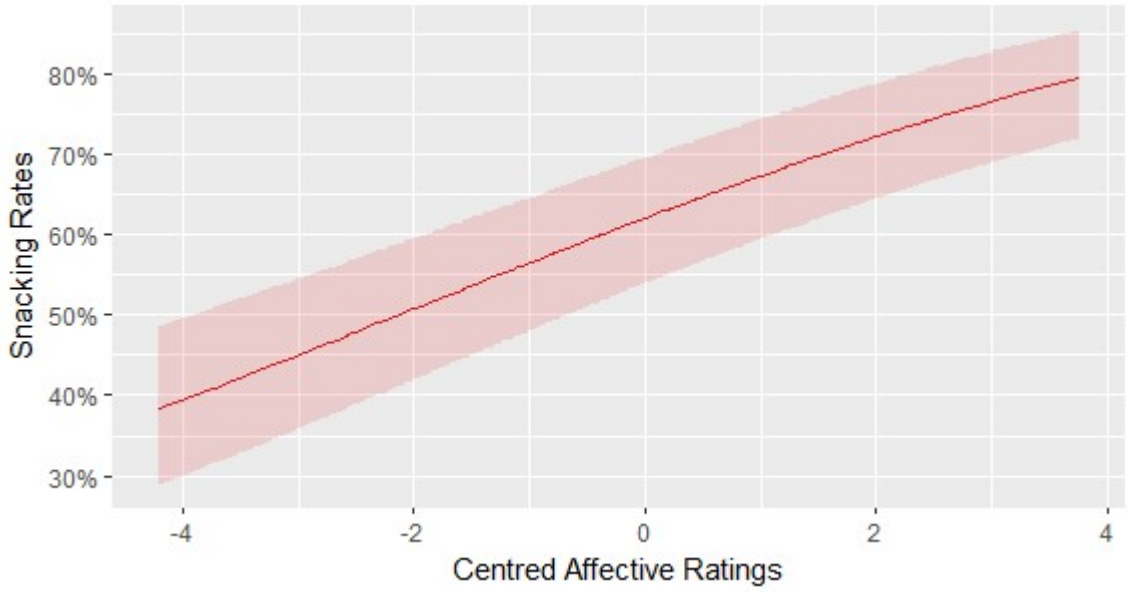
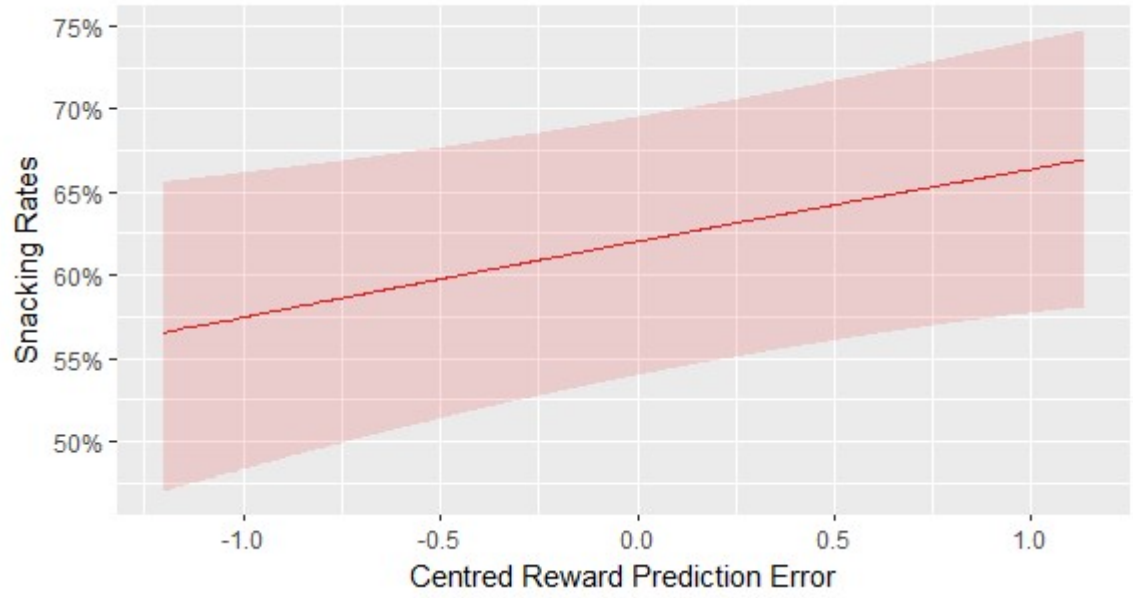


Figure 10

Predicted probabilities of snacking on a trial-by-trial basis by individual reward prediction error. The shaded area contains the predicted values of snacking at each value of the reward prediction error.



Trait-Level Differences in Eating Styles and BMI

The mean score for the emotional scale of the DEBQ was 2.94 (*SD* = 0.87, *Range* = 17.2 - 30.4). This was above average scores typically found in other populations (e.g., 2.64 in female students; van Strien et al., 2007) and slightly higher than in Study 1 (2.70) suggesting that the sample for this study tended towards higher levels of self-reported emotional eating. The mean score for the restrained eating scale of the DEBQ was 2.45 (*SD* = 0.79, *Range* = 1.0 - 3.9) and this was similar to the score of our previous sample (2.44) but lower than that of previous samples (e.g., 2.61; van Strien et al., 2007).

DEBQ-E, DEBQ-R and BMI scores were not found to significantly correlate with the difference in snacking rates between positive and neutral trials (r (44) = -.09, p = .534; r (44) = .13, p = .408; r (40) = -.10, p = .536, respectively).

Discussion

Study 3 aimed to replicate the findings of Study 1 whilst implementing methodological improvements, which included a change in the timing of the expectation assessment to reduce the potential for bias in participant responses. A more general quiz paradigm, which was not specific to Psychology students, was framed as testing an individual's ability to be a good student rather than being a subject-specific test of knowledge. Replicating both the pilot study and Study 1, positive feedback led to the highest (positive) average affective rating and negative feedback led to the lowest (negative) average affective rating. Therefore, the adjusted quiz paradigm was verified as an effective emotion induction procedure. Funnel debrief responses also highlighted that participants had applied effort and were affected by the feedback received. As in Study 1, the present study predicted that positive feedback/emotions would lead to the greatest increase in snacking rates as compared to negative and neutral quiz outcome conditions. This hypothesis was confirmed by the large significant effect of feedback type on snacking rates, where positive feedback led to the highest snacking rates as compared to negative or neutral feedback. The successful replication of the findings of Study 1 in Study 3 increases the validity of the conclusions drawn and also supports previous meta-analyses (Cardi et al., 2015; Evers et al., 2018) which indicated the significant influence of positive emotions on consumption behaviours. Thus, Studies 1 and 3 provide convincing evidence of the fundamental influence of momentary positive emotions on snacking behaviour despite positive emotions being largely overlooked within the current literature. A biopsychological perspective (Gray, 1987; Lang, 1995) can again be used to explain the current results as priming of the appetitive system by discrete positive emotional episodes would be expected to increase the intake of rewarding snacks. As in Study 1, the effects of momentary negative emotions on snacking cannot be accounted by a biopsychological perspective as this would predict that short-term negative emotions would

lead to fewer snacks being taken than in the neutral condition due to the activation of the defensive system, resulting in a reduction of reward behaviours (Torres & Nowson, 2007). Instead, the current result indicated that momentary negative emotions did not significantly affect snacking decisions which was contrary to the findings of Study 2 where a momentary negative reaction to academic feedback was associated with a decreased desire to snack. However, while Study 2 had higher ecological validity due to the naturalistic nature of the study, the sample was not sufficiently powered which increased the likelihood of a false positive result. Therefore, further investigation is needed to determine the influence of momentary negative emotions on laboratory versus real-life snacking decisions. On the other hand, replication of the effects found in Study 1 further supports the distinction between momentary and sustained affective states on consumption behaviours with only discrete positive events being associated with greater snack consumption.

One of the limitations of Study 1 concerned the experimental timing of the expectation question: Participants had already received feedback before rating how much they expected their previous answer to be correct. This procedure may not have given a true reflection of their surprise regarding the feedback. Therefore, in Study 3 the expectation question was presented immediately after the quiz question was answered. It was predicted that lower expectation of a correct answer alone, and in interaction with affect, would influence the momentary decision to snack due the creation of larger positive prediction errors by surprising positive feedback. GLMMs were used to model the binary decision to snack on a trial-by-trial basis with Feedback Type, Reward Prediction Error and Affective Ratings as factors. In the first model, including Feedback Type and Reward Prediction Error as predictors, positive feedback significantly increased an individual's likelihood to snack, however, no significant effects were found for Reward Prediction Error (= difference between expected and received feedback) or the interaction between Reward Prediction Error and

Feedback Type, replicating the findings of Study 1. Affective Ratings and Reward Prediction Error were used as predictors in the second model and Affective Ratings significantly predicted the binary decision to snack, with more positive ratings increasing the likelihood of snacking and more negative ratings decreasing snacking likelihood. Furthermore, Reward Prediction Error independently predicted the decision to snack, where larger positive prediction errors increased the probability of snacking. Finally, the interaction between Affective Ratings and Reward Prediction Error was also significant, indicating that reward prediction errors had a greater effect on snacking decisions in positive trials. Therefore, Hypothesis 2 was supported and the findings from Study 1 were replicated. While expectation in relation to emotion-induced snacking has largely been understudied within the literature, the current findings corroborated findings by Wanglee (2013) of the influence of surprise on the activation of the reward system. Using a laboratory design, Wanglee (2013) manipulated expectation by telling some participants they would be paid to sample chocolate and allowing others to believe they had won money in a prize draw during a study aimed to review chocolate. Following the chocolate taste-test all participants watched a film clip, during which snacks were freely available, and their subsequent consumption was measured. The results showed that participants who had not expected the monetary reward ate more calories than those who had expected to be paid. This can be explained using a neurobiological perspective as an unexpected monetary reward would be assumed to create a larger positive prediction error, activating the appetitive system to a higher degree and eliciting more reward consumption behaviours. Furthermore, the present findings again support a valence-based differentiation between the effects of momentary and sustained emotions on snacking, with both positive short-term affective states (Reichenberger et al., 2018) and longer-term negative mood states increasing unhealthy food consumption in healthy individuals (Hill et al., 2022). Therefore, there is strong evidence to suggest the

current definition of emotional eating as eating after negative affect is insufficient and should be updated to account for this distinction.

It has been argued that personality factors (such as eating behaviour tendencies; (Cardi et al., 2015; van Strien et al., 2012) and BMI status may impact emotion-induced eating (Udo et al., 2013; van Strien, Donker, et al., 2016). However, conflicting evidence is also present in the literature, for example with some studies opposing the moderation of emotional eating by BMI status (Cardi et al., 2015; Evers et al., 2018; Greeno & Wing, 1994). In the present study, emotional eating tendency as assessed by the DEBQ-E (van Strien et al., 1986), level of dietary restraint and BMI status were not significantly associated with positive emotional eating, suggesting that positive emotional eating may be a more pervasive effect within the population. This finding was in opposition to Study 1, where scores on the DEBQ-R were positively associated with snacking in positive trials, showing a stronger effect of positive affect in individuals with high levels of restraint. The lack of agreement between the two studies is surprising as the mean DEBQ-R scores for both samples was highly similar. Together, the role of dietary restraint as a moderator of positive emotional eating needs to be further investigated, which is also highlighted by other conflicting evidence within the literature. For example, a meta-analysis by Hill et al. (2022) suggested that higher dietary restraint made consumption following stress less likely whereas a previous meta-analysis found that restrained eating leads to greater subsequent food intake when negative emotions are experienced (Cardi et al., 2015). Furthermore, individuals with higher dietary restraint ate less following positive and negative emotions in a real-life setting (Tomiyama et al., 2009), highlighting the lack of agreement between laboratory and naturalistic studies. On the other hand, the lack of moderation by BMI status and DEBQ-E (general emotional eating tendency) scores replicated Study 1 and indicated positive emotional eating may be a general effect not specific to weight-related or eating style-related subgroups. This is consistent with

a previous meta-analysis (Evers et al., 2018) showing that while negative emotional eating was moderated by restrained eating status, there was a general effect of positive emotions increasing subsequent consumption within the population. The lack of influence of DEBQ-E scores on positive emotional eating further corroborates the suggestion that positive and negative affect are associated with different types of emotional eating with the former leading to consumption following shorter-term affective states and the latter affecting overconsumption during sustained affective states.

Conclusions and Limitations

In summary, based on an improved methodology, the replication results of Study 3 further underscore the important role of momentary positive affect in snacking. As the expectation question preceded the feedback in the modified paradigm, self-reports of expectation were less likely to be influenced by biased responses arising from self-consistency effects or impression management (Bozeman & Kacmar, 1997; Lecky, 1945). Previous laboratory studies have been criticised for creating an unrealistic eating environment (Best et al., 2018) and therefore, in Studies 1 and 3 a more naturalistic set-up was used by conducting the research within a bar laboratory facility and implementing testing sessions around mealtimes where snacks would be typically eaten. The current sample comprised healthy individuals from a student population with a typical range of BMIs. It would be interesting to test whether similar or even stronger effects of positive affect on snacking can be observed in individuals with disordered eating, such as binge eating disorder.

Chapter 5 General Discussion

The overarching aim of the current project was to use a combination of laboratory experimental and naturalistic (EMA) studies to investigate the effect of discrete emotional episodes on the momentary decision to snack on unhealthy but rewarding foods. The studies specifically focused on the effects of positive emotions, which have largely been overlooked within the emotional eating literature, despite evidence suggesting positive affect has a significant influence on appetite (e.g., Macht et al., 2002) and subsequent eating behaviours (e.g., Evers et al., 2013, 2018). Furthermore, the employed designs allowed the measurement of shorter-term affective states as opposed to sustained emotional states taking into account the important influence that momentary emotions have on eating behaviour and weight outcomes (e.g., Reichenberger et al., 2018). Importantly, the present results do not dispute the effects of sustained mental states on emotion-induced eating, which have repeatedly been demonstrated within the literature (e.g., Evers et al., 2018; Hill et al., 2022). Instead, the overall findings of the project suggest that the length of the emotional episodes have different consequences on which emotional valence impacts eating behaviour. Overconsumption appears associated with both positive momentary emotions and sustained negative mood, but these effects are likely to rely on differential mechanisms. Momentary positive emotions may prime the reward system, resulting in an individual seeking out further reward in the form of unhealthy snacks. In contrast, individuals experiencing sustained negative mood states are likely to use the rewarding properties of food to increase their positive affect and regulate their emotions. The present results have implications for lifestyle interventions that specifically target snacking behaviour. This is insofar important as in-between meal intake is often not accounted for in the literature due to the aggregation of eating behaviour measures, despite the importance of snacking frequency for weight gain (e.g., Skoczek-Rubińska & Bajerska, 2021).

The present laboratory studies using a quiz task (Study 1 and 3) showed a large effect of feedback on subsequent snacking, with positive outcomes leading to higher snacking rates as compared to negative or neutral outcomes. Furthermore, when data modelling was used to investigate snacking on a trial-by-trial basis - thus not aggregating eating behaviour across trials - positive feedback and positive affective ratings were significantly associated with a greater likelihood of snacking. Taking a biopsychological perspective, this can be explained by positive emotions priming the reward system which increases the likelihood of subsequent reward seeking behaviours (Gray, 1987; Lang, 1995). However, exploratory analysis of Study 2 questioned the generalisability of the quiz task results to real-life contexts as no significant effect of momentary positive emotions on snacking desire was found, when affective states were measured after the release of academic marks. On the other hand, due to a lack of power in Study 2's sample, further investigation of momentary emotions in real-life settings is needed before any firm conclusions can be drawn. In opposition to the effects of momentary positive emotions, experimentally induced momentary negative emotions were associated with a lower snacking rate than positive emotions but did not significantly differ from the effects of a neutral quiz outcome. Extending this further, Study 2 found a significant negative association between a negative reaction to the grade received and snacking desire ratings. This reduction in likelihood of snacking desire following negative emotions can be partially situated within a biopsychological perspective as negative emotions may have activated defensive motivational systems that have been associated with survival behaviours (such as freezing and halting of digestion), therefore reducing appetite and inhibiting reward-seeking behaviours (Torres & Nowson, 2007). However, the lack of a neutral comparison condition and low power in Study 2 means that further investigation is needed before any firm conclusions can be drawn. Laboratory studies within the literature support the observed dissociation between the different valences of momentary emotions, with positive emotions

being associated with a greater subsequent food consumption (e.g., Evers et al., 2009, 2013). In addition, two meta-analyses found a significant general effect of positive emotions on unhealthy food consumption, despite a limited number of studies examining such effects (Cardi et al., 2015; Evers et al., 2018). Previous EMA studies have also supported the distinction between the effects of positive and negative momentary emotions. In one such study when participants were asked to record every instance of consumption, positive emotions were more likely reported as a cause of unhealthy snacking than negative emotions (Evers et al., 2013). Furthermore, when participants reported their eating behaviour at predetermined times during the day, momentary positive emotions were associated with unhealthy snack consumption whereas discrete negative emotional episodes were not associated with an increased intake of palatable foods (Reichenberger et al., 2018). The reduction in consumption behaviours (or consumption desires) following momentary negative emotions as compared to positive emotions, as demonstrated in all three studies, is in opposition to previous studies finding an increase in reward-seeking behaviours following sustained negative emotional states (e.g., Antoniou et al., 2017; Konttinen et al., 2019). According to the affect regulation theory individuals experiencing a sustained negative mental state increase the consumption of unhealthy but highly rewarding foods to heighten their positive affect, thus reducing their negative affective state (Kemp et al., 2013). Emotion regulation can also be situated within a biopsychological perspective as longer-term negative emotions activate the HPA axis, stimulating the release of cortisol which in turn increases appetite for unhealthy but comforting foods in an attempt to dampen the activity in the HPA axis (Dallman et al., 2003).

The second main hypothesis of the present project was that expectation would independently and in interaction with affect, modulate the snacking decisions. This can be predicted based on research showing that surprising positive outcomes elicit larger positive

prediction errors, which activate the reward system to a greater degree (Schultz, 1997). In Study 1, this idea was initially investigated by splitting trials into high and low expectation conditions based on participants' expectation ratings. No significant effect of expectation on emotional eating was found. However, the employed analysis method can be criticised for removing variance from the Likert-scale expectation data. Therefore, in exploratory analyses GLMMs were used to investigate the effects of Feedback Type, Reward Prediction Error and Affective Ratings on the trial-by-trial binary decision to snack. The results indicated that reward prediction error independently increased snacking likelihood, where larger positive prediction errors made snacking more likely. Furthermore, reward prediction errors interacted with affective ratings so that the value of the prediction error had a greater effect on the snacking decision in positive affect trials. On the other hand, when expectation (of obtaining a good academic mark) was investigated in Study 2, there was no significant effect of expectation alone or in conjunction with affect on snacking desires. One reason for the lack of agreement between the two studies could again be the insufficient power of Study 2. Furthermore, one caveat in the results of Studies 1 and 2 was the timing of the expectation question - participants in both studies rated their expectation regarding the feedback ***after*** they had already received their academic/quiz outcome. Therefore, participants may have falsely remembered their expectation or deliberately concealed (or exaggerated) their surprise when seeing their actual feedback. Such effects can be predicted by impression management and/or self-consistency theories (Bozeman & Kacmar, 1997; Lecky, 1945), according to which individuals wish to be consistent with their self-concept or be viewed in a favourable way by others. To account for these design limitations, Study 3 implemented an adapted quiz paradigm where the expectation rating question preceded the presentation of individual question feedback. It was found that reward prediction error independently influenced snacking decisions where a larger positive prediction was associated with a greater chance of

snacking. Furthermore, there was a significant interaction between reward prediction errors and affective ratings, where reward prediction errors had a greater effect on snacking decisions in trials with a positive affective rating. This effect of expectation alone, and in interaction with affective ratings, replicated the findings of Study 1 supporting a neurobiological perspective of momentary emotional eating as larger positive prediction errors were associated with a larger activation of the reward system (Schultz, 1997). It was also in line with emerging other evidence on the effects of expectation on snacking decisions within the literature. When participants were surprised by the receipt of a monetary reward, they showed greater subsequent food consumption than individuals who had expected the monetary reward (Wanglee, 2013). Further research using an EMA design is needed to investigate the ecological validity of these findings. The present pilot study EMA methodology should be adapted so that expectation ratings are collected before individuals receive their academic feedback.

Further exploratory analyses of the present data examined the contribution of differences in eating style and BMI status to the effect of positive affect on snacking. Neither study found a significant moderation by emotional eating tendency or BMI status. The lack of moderation of positive emotional eating by scores on the DEBQ-E, which measures negative emotional eating tendency, indicated that positive and negative emotional eating are different processes. This is in line with the distinction between the effects of momentary and sustained emotions of different valences on eating behaviour. Furthermore, as BMI status did not moderate positive emotional eating, this suggested the presence of a general effect of positive emotions for increased consumption within the population which was not specific to weight status. It has previously been argued that negative emotional eating is an ‘obese eating style’ due to it being more prevalent in individuals with a higher weight status (van Strien, Donker, et al., 2016). This provides further evidence that positive and negative emotional eating are

distinct processes. While Study 1 and Study 3 found a large significant general effect of momentary positive emotions on subsequent snacking in line with previous meta-analyses (e.g., Evers et al., 2018), in Study 1 it seemed that high scores on restrained eating heightened the effect further. However, in Study 3 this moderation effect was not found, questioning the validity of the presence of a restrained eating style as a moderator of positive emotional eating. Previously, it has been suggested that a restrained eating tendency increases vulnerability to emotion-induced snacking due to a strain on cognitive resources dismantling self-control processes (Polivy et al., 1994). Two meta-analyses found restrained eating moderated negative emotional eating alongside a general effect of positive emotional eating (Cardi et al., 2015; Evers et al., 2018). This is in line with the current findings were momentary emotional eating following positive affect seems to influence a wider sample of individuals as a significant general effect of positive emotions on snack consumption was found in both the laboratory studies. It may therefore be that emotional eating following sustained mental states is more affected by restrained eating due to the gradual break-down of self-control processes, for example emotional eating is more likely to occur in the afternoon when cognitive resources have been more strained (Carnell et al., 2018).

In the current project, exploratory analyses were also used to determine the domain-specificity of the effect of discrete emotional episodes on reward consumption. Biopsychological theories of reward and motivation assume positive emotions prime the activation of appetite systems eliciting subsequent reward behaviours (Gray, 1987; Lang, 1995). Therefore, it would seem reasonable to predict that momentary positive emotions may increase the likelihood of other reward behaviours such as alcohol consumption or social media use. However, Study 2 found no significant associations between momentary positive affect and reward behaviours (alcohol consumption, smoking/vaping or social media use) on either the emotional day or the control day. The only significant effect for negative affect on

other reward behaviours was found on the control day with momentary negative emotions being associated with a higher desire to consume alcohol. This was in line with other findings within the literature where within-subject level increases in negative affect were associated with a higher subsequent consumption of alcohol (Duif et al., 2020). However, due to the low general occurrence of reward behaviours and the underpowered nature of the sample, the data was insufficient to determine the presence of any true effects and further investigations of the domain-specificity of the effect are required.

Future Directions

The present project implicated an (implicit) "pre-activation" of the reward system as the mechanism behind the effects of momentary positive emotions on subsequent snacking. Subliminal priming studies offer support for such a bottom-up mechanism potentially underlying the present findings. Participants who reported being thirsty drank more following a brief presentation of a happy face as opposed to an angry face prime (Winkielman et al., 2005). This suggested that the approach reward system was activated following the occurrence of a short-term positive prime which influenced the value of an offered drink. The difference in reward seeking behaviour following the positive prime was specific to an individual's motivation as non-thirsty participants did not show the same change in behaviour following the primes, suggesting that they may have found the offered drink less rewarding. In addition, participants exposed to happy faces presented subliminally were more likely to make risker gambling decisions as compared to their gambling choices following the presentation of angry or neutral faces (Winkielman et al., 2022). Taken together, these findings suggested that positive primes, even when viewed unconsciously, can increase reward-seeking behaviour corroborating the activation of the reward system following momentary positive emotional episodes. However, it should be noted that other possible explanations may be responsible for the effects found in the current thesis. One such

alternative explanation is that the positive feedback outcome elicited an explicit motivation in participants to seek further pleasurable outcomes as a reward for their "achievement" of the earlier positive outcome. Specifically, snacking may have served as a self-chosen reward for applying effort and answering the quiz question correctly. Additionally, the decision to not take a snack may have served as a self-imposed "punishment" for incorrectly answering the question. These behavioural responses can be viewed as an adaptive response that make the actions preceding the outcome more or less likely in the future depending on the valence of the outcome received, learnt through operant conditioning processes (e.g., Staddon & Cerutti, 2003). While the current methodology was unable to distinguish between the processes of reward system priming (a bottom-up neurobiological mechanism) and self-reward (a top-down cognitive-motivational mechanism), future research should aim to untangle the two concepts to gain a greater understanding of the mechanisms behind the effects of momentary positive emotions on reward-seeking behaviour. One method to distinguish the two effects would be to ask participants to rate a variety of pre-offered snacks based on their personal preferences and then track the consumption of the differently valued snacks throughout a quiz task, similar to the paradigm used in Studies 1 and 3. Some quiz trials would allow participants to have the higher value snacks whereas others would offer the less liked snacks. If a self-reward, achievement-based mechanism was behind the effects of momentary positive emotional eating, increased snacking would only be found in trials were the higher value snacks were offered. In line with the theory of self-reward, it could also be expected that individuals who received unexpected positive outcomes on the effortful quiz trials would seek out higher value rewards as these trials felt like a greater achievement as the questions were perceived as more difficult. In contrast, according to a priming account, intake of both types of food would be expected after positive outcome trials. Another protocol to untangle the effects would be to employ a variation of the previously used paradigm where half of the

trials involved random positive outcomes (such as gambling trials) and the other half consisted of effortful positive outcomes (such as quiz questions). If participants showed higher snacking rates in effortful positive trials as opposed to the random positive outcomes, this would support the top-down cognitive motivational mechanism as participants had self-rewarded themselves based on a positive outcome they had worked for. However, if similar snacking rates were found between the different types of positive trials, this would lend itself to the priming mechanism as the reward system had been activated to seek reward regardless of the expenditure of effort within the task.

Furthermore, the naturalistic EMA study of the current project provided potential avenues to inform subsequent EMA studies by implementing the outlined methodological improvements. To investigate the domain-specificity of the effect of momentary positive emotions on snacking, a longitudinal EMA style could be employed to assess reward behaviours following the release of different academic feedback occasions throughout one academic year. The design of Study 2 was limited by the timing of the mark release (usually in the morning) as some of the reward behaviours may be generally less likely to take place in the morning and therefore feedback release timepoints later in the day should also be investigated. In addition, multiple emotion/snacking assessments per day could be used to account for the fluctuation of emotions throughout the day and participants could be signalled to fill in the measures using smartphone notifications to increase data retention. It would also be beneficial to train participants in EMA procedures to ensure that the self-reports are more accurate representations of the behaviours which took place (e.g., Reichenberger et al., 2018). One recommendation for this training is to allow individuals to practice the protocol before participating in the study as this will increase their ability to answer the questions (Heron et al., 2017). Furthermore, ratings of feedback expectation could be taken before the actual

release of grades to give a less biased reward prediction error value, similar as implemented in Study 3.

Finally, to increase the generalisability of the findings, future investigations should aim to include a more diverse sample (such as the inclusion of different age groups and those from higher BMI-groups or individuals with disordered eating).

Conclusions

Taken together, confirmatory, pre-registered analysis of the data indicated a large effect of experimentally induced momentary positive emotions on increasing subsequent snack consumption, in line with the initial predictions of the project. Furthermore, due to the lack of increased snacking following momentary negative emotions in the laboratory as well as a decreased snacking desire following real-life discrete negative emotional states, the data suggested a distinction between short-term and sustained affective states on snacking decisions as induced by different valences. This key finding increases the current understanding of emotional eating as it can account for the conflicting findings of emotional eating from previous laboratory studies and studies using retrospective questionnaire designs/studies investigating sustained mental states. The present project highlights the importance of momentary positive emotions on increasing in-between meal intake, addressing current gaps within the literature as well as providing potential avenues for future study. Moreover, the use of a student samples has practical implications for understanding the causes of unhealthy snacking which are prevalent in this population. In conclusion, the data suggests that the definition of emotional eating should be updated to account for the differences of momentary emotions and sustained mood states on subsequent consumption, with both shorter-term positive affect and longer-term negative moods increasing the likelihood of snacking. This has implications for lifestyle interventions for weight gain and weight loss (e.g., for individuals with obesity or binge eating) as the effects of different

lengths and valences of emotions should be considered when the modification of eating triggers is targeted as part of the intervention.

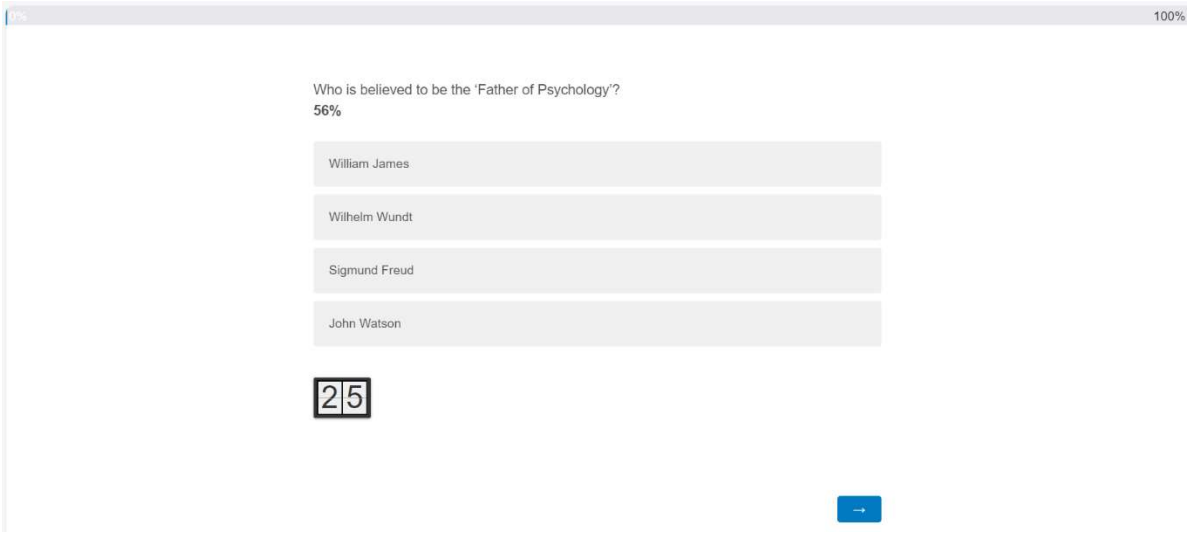
Appendices

Appendix 1: Outline of a Typical Trial from the Quiz Task

In the quiz task, there were two different types of trials. Firstly, there were the multiple-choice quiz question trials where participants received either positive or negative feedback (positive/negative feedback conditions). Secondly, there were neutral trials where participants picked one of the four options and were given neutral 'feedback'/instructions (neutral condition).

Feedback (Positive or Negative) Trials

Screen 1: Multiple-Choice Quiz Question



Participants were shown a multiple-choice quiz question (see the above example) with four possible answers. The percentage in bold beneath the question text displayed the 'peer accuracy value' which was a measure of question accuracy taken from the pilot study.

Each question was displayed for a maximum of 25 seconds or until the participant provided a response. The timer below the answer options counted down from 25 seconds to show participants how long they had left to provide an answer.

The correct answer would lead to positive feedback and the other three incorrect responses would lead to negative feedback. The failure to provide a response was coded as an incorrect answer.

Once they had submitted their answer (or the timer had run out), participants were shown a blank screen for one second.

Screen 2: Feedback Screens

After the blank screen, participants were shown one of two feedback screens dependent on the correctness of their response to the quiz question. The feedback screen was displayed for three seconds.

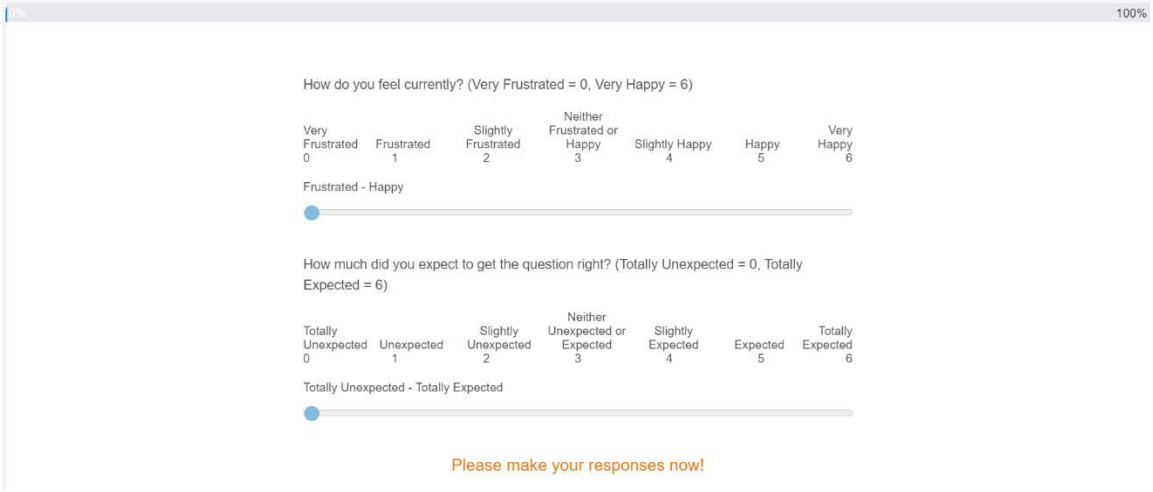
1. Incorrect responses were followed by the negative feedback screen showing a red angry face and the text “Incorrect, try to be more accurate with your answers!”:

2. Correct responses were followed by the positive feedback screen, showing a green smiley face and the text “Correct, Well Done!”:

Screen 3: Affect and Expectation Questions

After the feedback screen, participants were asked to rate their affect and expectation on 7-point Likert scales. The two questions were displayed simultaneously, and participants were unable to move on to the next screen until they had answered them both.

After 10 seconds on the screen with no response, they were prompted to answer the questions with the orange text “Please make your responses now!”:



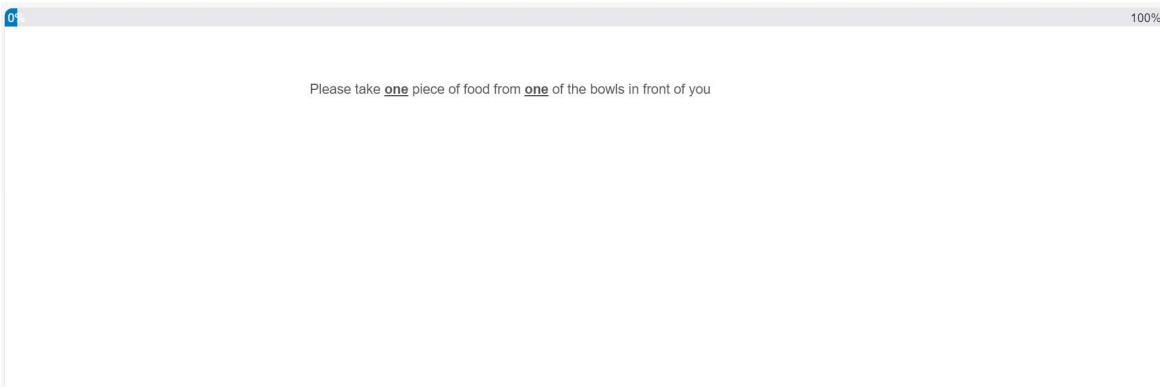
Screen 4: Snacking Question

Participants were then asked if they wanted to snack. This question was displayed until they provided a response, and they were unable to skip it:

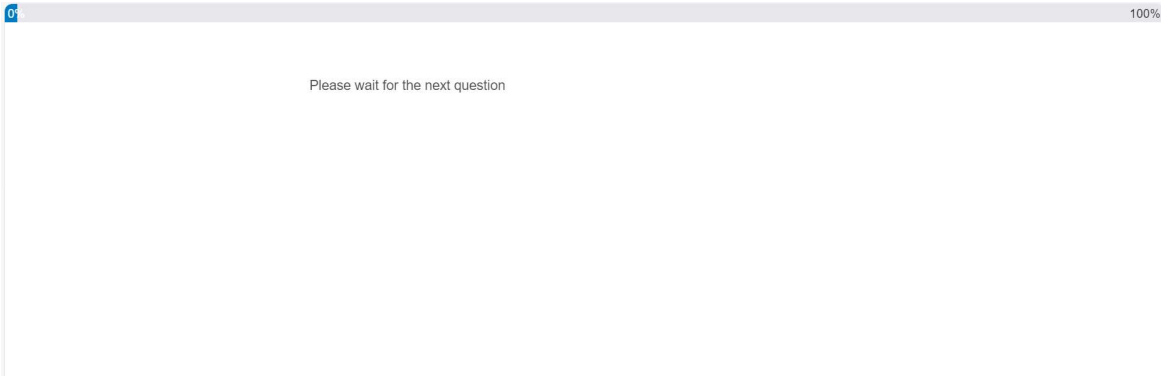
Screen 5: Snacking Outcome

Depending on their answer to the snacking question, participants were then shown one of the two following screens for five seconds:

1. If participants responded ‘yes’ to the snacking question, they were given the following instruction:



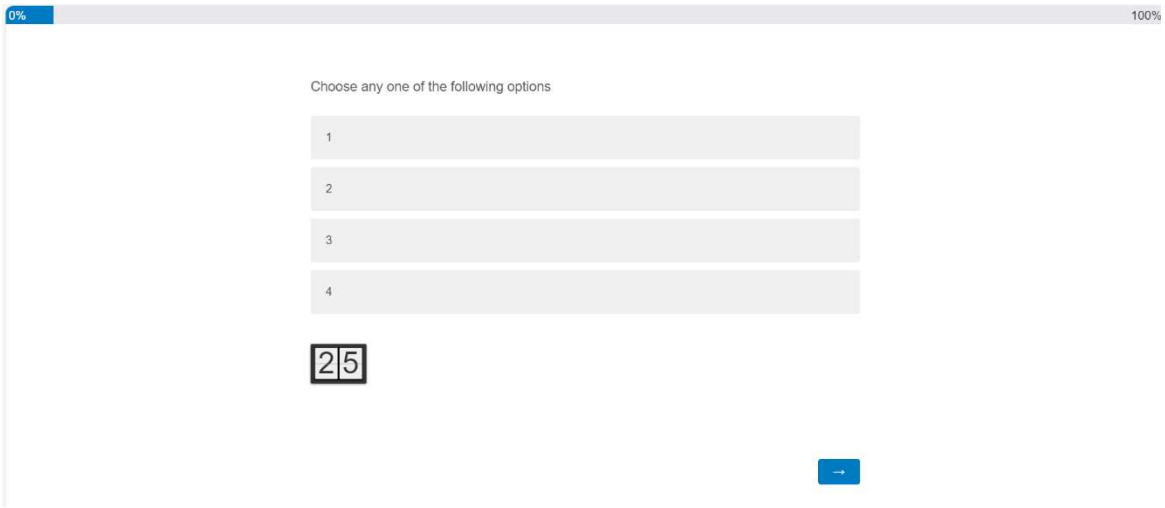
2. If participants responded ‘no’ to the snacking question, they were given the following instruction:



After whichever of the two screens were displayed, participants were then given another randomised quiz or neutral question.

Neutral Trials

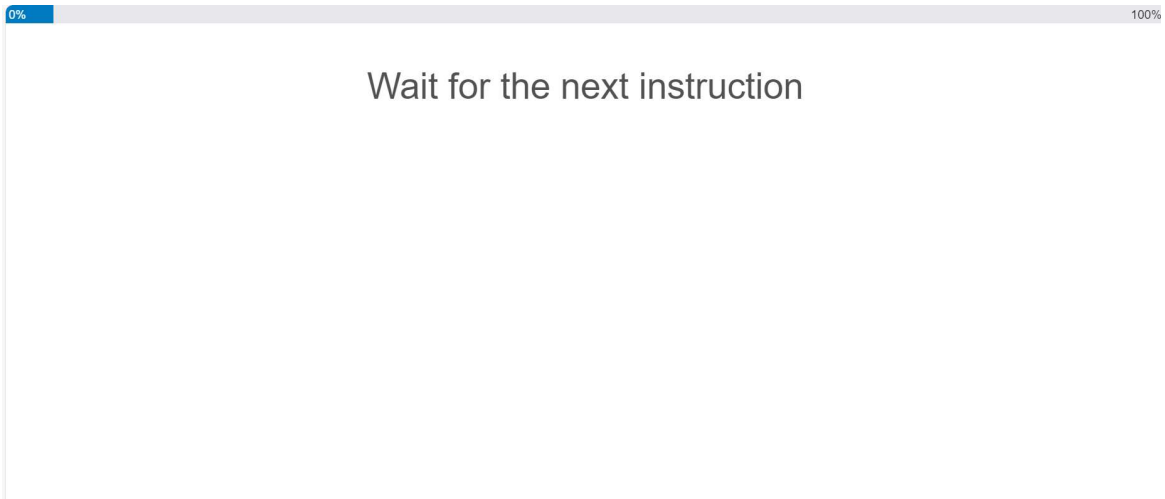
Screen 1: Neutral Question.



Participants were asked to pick any of the four options. Again, this question was displayed for a maximum of 25 seconds or until the participant provided a response. The question screen was followed by a blank screen displayed for one second.

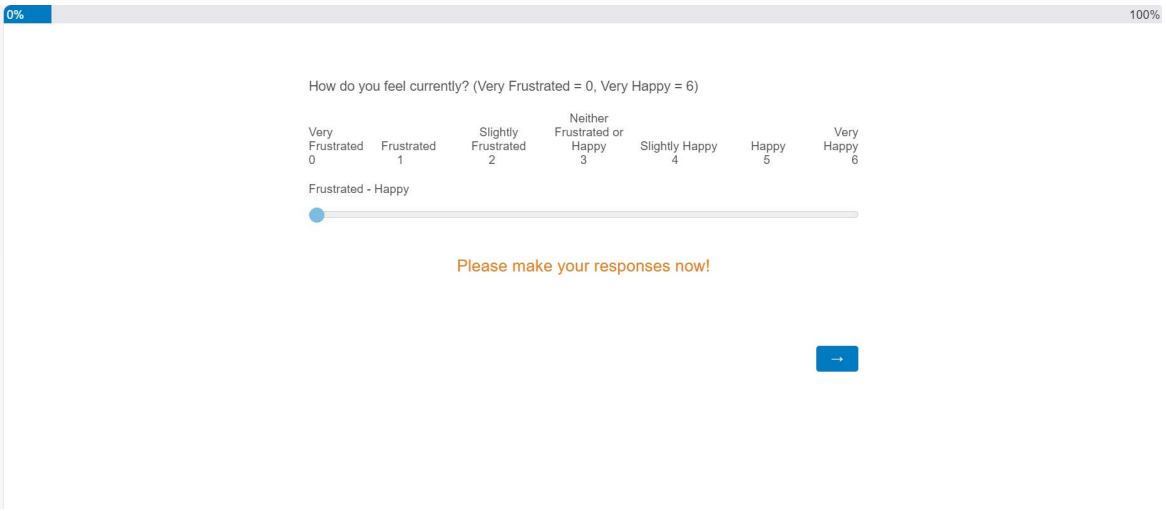
Screen 2 – Neutral 'Feedback' Screen.

Following the blank screen, participants were shown the neutral 'feedback' screen which was displayed for three seconds and asked them to wait for the next instruction.



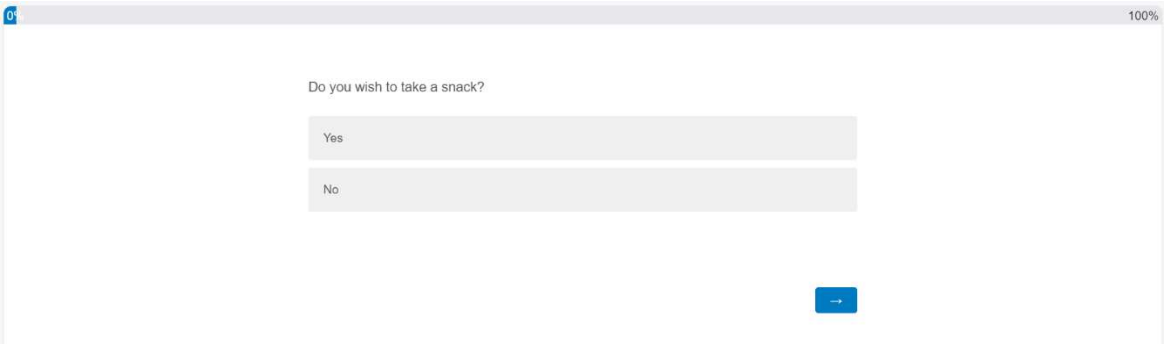
Screen 3: Affect Question

In the neutral condition, participants were only asked to rate their affect. After 10 seconds they are prompted to answer the question ('Please make your responses now!" displayed in orange text) and they had to provide an answer before they were shown the next screen.



Screen 4: Snacking Question

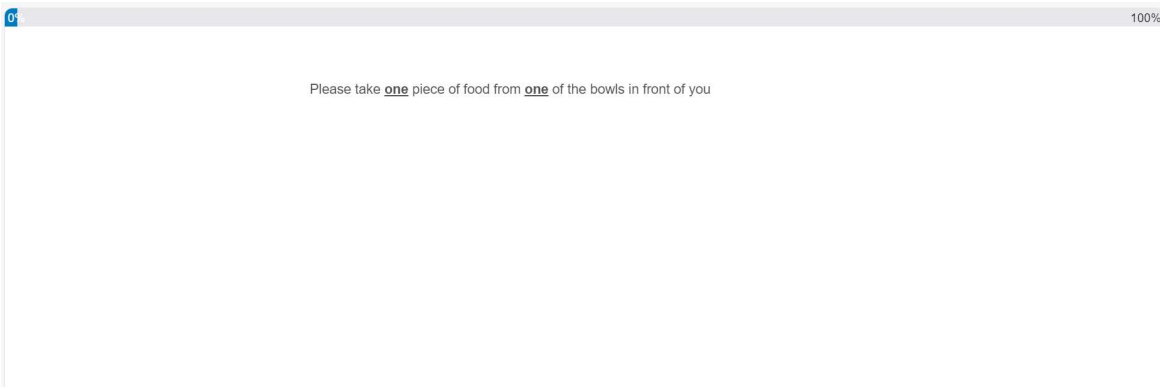
Participants were then asked if they wished to snack. This question was displayed until they provided a response, and they were unable to skip it.



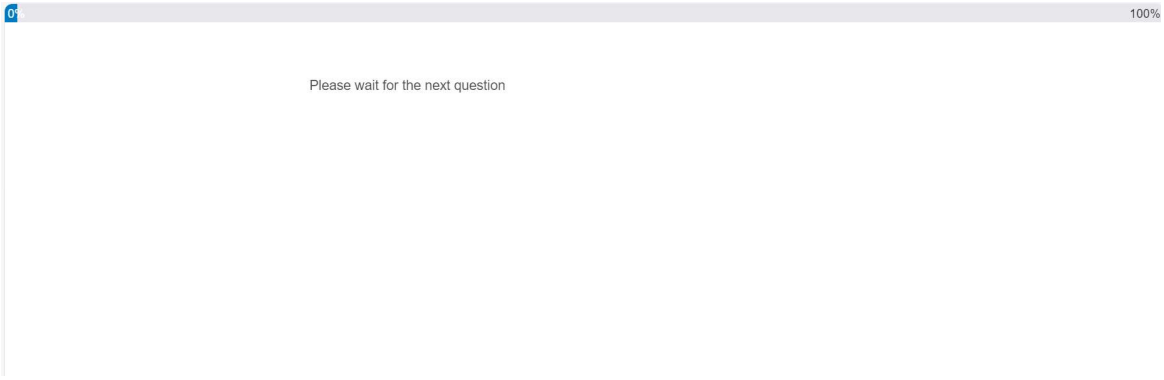
Screen 5: Snacking Outcome

Depending on their answer to the snacking question, participants were then shown one of the two following screens for five seconds:

1. If participants responded ‘yes’ to the snacking question, they were given the following instruction:



2. If participants responded ‘no’ to the snacking question, they were given the following instruction:



After whichever of the two screens were displayed, participants were then given another randomised quiz or neutral question.

Appendix 2: Study 1 Demographic Questionnaire

Demographic Questionnaire

This questionnaire allows for the collection of demographic data. The questionnaire is voluntary, and you may omit any questions that you do not wish to answer. The data collected will be strictly confidential and unidentifiable.

1. Age _____
2. Gender _____ (Male, Female, Other, Prefer not to say)
3. Year of Study _____
4. Height _____
5. Weight _____
6. Do you smoke or vape? _____
7. When was the last time you smoked or vaped? _____
8. Are you currently on a diet or trying to lose weight? Yes/No
9. Have you ever been on a diet or tried to lose weight? Yes/No
10. When did you last eat before coming into the lab? _____
11. What did you last eat? _____
12. How hungry are you currently, on a scale of 1-7 (1=Not at all, 7=Very hungry)? _____
13. Do you have any food allergies? _____
14. Do you have diabetes? _____
15. Do you have a current or past eating disorder? _____

Appendix 3: Emotional and Restrained Scales of the DEBQ

Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien et al, 1986)

This questionnaire allows for the collection of information about eating behaviours. This questionnaire is voluntary, and you can omit any questions that you do not wish to answer. The data collected will be strictly confidential and unidentifiable. All questions are rated on a 5-point Likert Scale (where: 1 = never, 2 = seldom, 3 = sometimes, 4 = often and 5 = very often). In addition, some questions have a not relevant category, as they are not applicable to all participants, these questions are marked with a star (not relevant coded as 0).

1. If you have put on weight, do you eat less than you usually do?* _____
2. Do you try to eat less at mealtimes than you would like to eat? _____
3. How often do you refuse food or drink offered because you are concerned about your weight? _____
4. Do you watch exactly what you eat? _____
5. Do you deliberately eat foods that are slimming? _____
6. When you have eaten too much, do you usually eat less than usual the following days?* _____
7. Do you deliberately eat less in order not to become heavier? _____
8. How often do you try not to eat between meals because you are watching your weight? _____
9. How often in the evening do you try not to eat because you are watching your weight? _____
10. Do you take into account your weight with what you eat? _____
11. Do you have the desire to eat when you are irritated?* _____
12. Do you have a desire to eat when you have nothing to do?* _____
13. Do you have a desire to eat when you are depressed or discouraged?* _____
14. Do you have a desire to eat when you are feeling lonely?* _____
15. Do you have a desire to eat when somebody lets you down?* _____
16. Do you have a desire to eat when you are cross?* _____
17. Do you have a desire to eat when you are approaching something unpleasant to happen? _____
18. Do you get the desire to eat when you are anxious worried or tense? _____
19. Do you have a desire to eat when things are going against you or when things have gone wrong? _____
20. Do you have a desire to eat when you are frightened?* _____
21. Do you have a desire to eat when you are disappointed?* _____
22. Do you have a desire to eat when you are emotionally upset?* _____
23. Do you have a desire to eat when you are bored or restless?* _____

Appendix 4: Study 1 Funnel Debrief

Funnel Debrief

The questionnaire is voluntary, and you can choose not to answer any questions. All data will be confidential and unidentifiable. Please answer questions 1-6 on a scale from 1(= not at all) to 5 (= very much) and provide any additional details if possible.

1. Were the questions presented to you a good test of your ability to be a competent psychologist? _____
2. How important were the questions and feedback to you? _____
3. How much do you feel you answered the questions to the best of your ability?_ _____
4. How much effort did you apply? _____
5. How much did the feedback after each question influence your mood? _____
6. How much did the data about your peers' performance affect you? _____
7. Did you notice anything unusual about the study, if so, what?

   _____

   _____

   _____

8. What do you believe the purpose of the study was?

   _____

   _____

   _____

9. Did you realise that the study's true purpose was to assess the effect of induced emotions on snacking behaviour? YES/NO

*Questions were presented sequentially online (on Qualtrics) so that participants were only able to view the next question once the previous one had been answered.

Appendix 5: Study 1 Additional Model Statistics

For the first model (Feedback Type and Reward Prediction Error as predictors), a histogram showed the distribution of responses for the binary decision to snack was similar for both values. The random effects were distributed normally as assessed using a Shapiro-Wilks test ($W = 0.978$, $p = .395$).

For the second model (Affective Ratings and Reward Prediction Error as predictors), a histogram showed the distribution of responses to the binary decision to snack was similar for both values. The normality of the random effects did not violate the assumption of normality as assessed by a Shapiro-Wilks test ($W = 0.980$, $p = .462$).

Appendix 6: Study 3 Additional Model Statistics

For the first model (Feedback Type and Reward Prediction Error as predictors), a histogram showed the distribution of responses for the binary decision to snack was similar for both values. The random effects were distributed normally as assessed using a Shapiro-Wilks test ($W = 0.964$, $p = .166$).

For the second model (Affective Ratings and Reward Prediction Error as predictors), a histogram showed the distribution of responses to the binary decision to snack was similar for both values. The normality of the random effects did not violate the assumption of normality as assessed by a Shapiro-Wilks test ($W = 0.964$, $p = .162$).

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