Stressed is desserts spelt backwards

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Declaration of original authorship

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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2nd September 2025

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Abstract

Understanding what causes emotional eating has been a great research interest for several decades, as unhealthy food consumption poses detrimental health consequences. Some have argued that control of eating relies on limited cognitive resources, which may be depleted under negative affect. On the other hand, recent theories argued that emotional eating reflects a motivational shift, in which people might prioritise feeling better over long-term health goals. However, these theories have not been sufficiently tested by controlled experimental designs, whilst evidence has been inconsistent. Therefore, we conducted three sets of experimental studies to test these contrasting accounts. Firstly, we tested whether negative affect causes impairments in inhibitory control by inducing negative, positive and neutral affect in food and non-food inhibition tasks. We found that negative affect does not deplete cognitive resources for inhibition; however, it selectively impairs inhibition of unhealthy food for restrained eaters and those with emotion regulation difficulties. Secondly, we tested whether a temporary motivational state to eat healthy as opposed to enjoy food impacts inhibitory control ability. We found that participants were better able to inhibit unhealthy food when in a health-oriented motivational state compared to when in an indulgence state. Lastly, we tested whether people eat emotionally because they believe some unhealthy food is the only available way to improve their negative affect. We found that wanting to feel better resulted in an increased tendency to approach unhealthy food that was believed to improve mood, and decreased inhibition of this food for non-dieters only. Dieters, however, showed difficulties learning that some food may not improve their mood. Overall, we provided experimental evidence that emotional eating reflects a shift in priorities to feel better and to indulge, and impaired inhibition under negative affect reflects emotion regulation difficulties rather than general depletion of cognitive resources.

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CHAPTER 1

GENERAL INTRODUCTION

General Introduction

It is not an unfamiliar scene that one indulges in a bucket of ice cream after a heartbreak, goes for a delicious croissant to start a stressful day, or rewards oneself with a huge burger after an overwhelming time at work. These portrayals resonate because they reflect a common reality: people often choose tasty but unhealthy food when they are stressed or upset. This behaviour is conceptualised as “emotional” or “affect-induced” eating (Reichenberger et al., 2020).

Negative affect is an umbrella term for emotionally distressing feelings such as sadness, anxiety, shame, guilt, and anger (Gross, 2015; Stringer, 2020). Even though enjoying tasty foods often results in brief relief from negative affect, such eating patterns have long-term detrimental health consequences, such as obesity, and other obesity related diseases, such as type 2 diabetes, cancer, and cardiovascular diseases (Gal et al., 2024; Konttinen et al., 2019; Puchkova-Sistac et al., 2023; Tsenkova et al., 2013; Vasileiou & Abbott, 2023; Zhang et al., 2021).

Several explanations are proposed to explain why negative affective states lead to such unhealthy food choices. The common consensus is that negative affect comes with a need for regulation (Evers et al., 2010; Gross, 2015). One explanation has argued that regulating negative affect and controlling one’s eating relies on the same limited cognitive resources (cf. Baumeister et al., 2024; Macht, 2008). When it comes to resisting unhealthy food, these resources could be low in trait level and/or are depleted due to the urgent need to regulate negative affect (Troll et al., 2023; Schmeichel, 2007; Wright & Mlynski, 2019). In contrast, others suggest that emotional eating is not necessarily the result of depleted cognitive resources. According to this approach, emotional eating occurs because people may prioritise feeling better over being healthy in situations where they need to regulate negative affect (Hennecke & Bürgler, 2023; Inzlicht et al., 2021; Inzlicht & Friese, 2020; Pimpini et al., 2023; Witt Huberts et al., 2012). Hence, rather than a lack of cognitive resources, it is this shift of motivation resulting in difficulty resisting unhealthy food choices.

In this chapter, I will start by introducing a cognitive function that is key to the control of eating, “inhibitory control”, and how its different measures can be used to examine eating behaviour. Then, I will detail evidence on whether and for whom negative affect may result in increased unhealthy food intake. Following this, I will detail the limited-resources models and alternative motivational explanations for emotional eating. Finally, I will summarise key questions that were investigated in the current PhD project, which aimed to differentiate these two competing approaches and better understand what causes emotional eating.

1. On Stopping Yourself: Inhibitory Control and Unhealthy Food Consumption

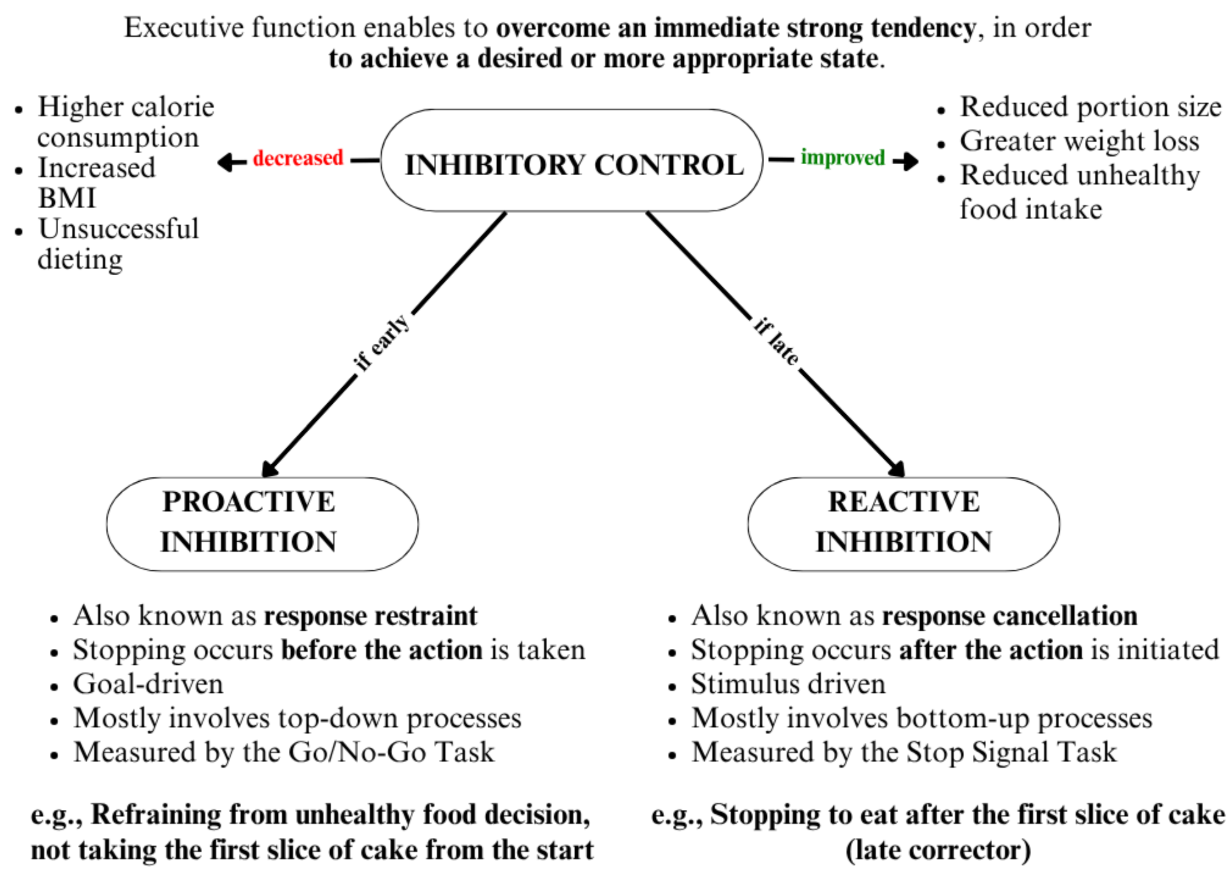
Several cognitive mechanisms are involved in the control of eating (Hofmann et al., 2012). These cognitive mechanisms are working memory operations that are conceptualised under the umbrella term “executive functions” (Dohle et al., 2018). Inhibitory control (also referred to as response inhibition) is one of the executive functions that enables people to overcome an immediate strong tendency, in order to achieve a desired or more appropriate state (Diamond, 2013; Hofmann et al., 2012; Verbruggen and Logan, 2008). Decreased inhibitory control often manifests in difficulties in resisting temptations and delaying immediate gratification (Hofmann et al., 2012). Several problematic behavioural addictions and overeating are associated with reduced inhibitory control ability (Cunningham et al., 2024; Weafer et al., 2017, 2021). In contrast, increased inhibitory control (e.g., by training) is linked to decreased problematic eating behaviours (Iannazzo et al., 2025).

Inhibitory control includes several processes: interference control, response flexibility, response cancellation and response restraint (Sinapoli & Dennis, 2012). Interference control involves the process of suppressing goal-irrelevant information in goal-directed behaviour. Response flexibility involves the process of shifting between different responses required for the same stimulus. Response cancellation refers to withholding an ongoing response to a stimulus, whereas response restraint refers to refraining from action without any response initiation. There are several cognitive measures that map these processes. Most commonly, Flanker and Stroop tasks are used to measure interference control, and the Wisconsin Card Sorting Task is used to measure response flexibility. However, in food-related contexts, these tasks are commonly used as measures of attentional bias (e.g., Dreir et al., 2021) and cognitive flexibility (e.g., Tchanturia et al., 2012), rather than serving as direct measures of inhibitory control, due to mapping other cognitive processes besides inhibition (cf. Paap et al., 2020). The Go/No-Go Task and Stop Signal Task, as measures of response restraint and cancellation, respectively, are considered as direct measures of inhibitory control in the recent literature on eating behaviours (see Figure 1), (Bartholdy et al., 2016; Labonte & Nielsen, 2023).

Go/No-Go Task and Stop Signal task can be employed to measure two different types of inhibitory control ability: (1) general inhibition that refers to trait-level, domain-general ability, and (2) food-specific inhibition, referring to state-level, domain-specific ability to resist food-related impulses. When general inhibition is measured, "neutral" stimuli are used, which typically involve pictures of household items, animals, geometric shapes, letters, numbers or occasionally words (Verbruggen et al., 2019; Teslovich et al., 2014). In order to measure food-specific inhibition, food with high and/or low calories and words describing these food items have been used as stimuli (Bianco et al., 2023).

While some studies found that poorer general inhibition is linked to increased calorie and food intake (Guerrieri et al., 2007; Meule et al., 2011; Nederkoorn et al., 2009), others found that only poorer food-specific inhibition is associated with increased food consumption, unsuccessful dieting, and higher BMI (Houben et al., 2012; Price et al., 2016; Tsegaye et al., 2022). However, a meta-analysis study reported that measures of general vs food-specific inhibition did not differentially predict food intake (McGreen et al., 2023).

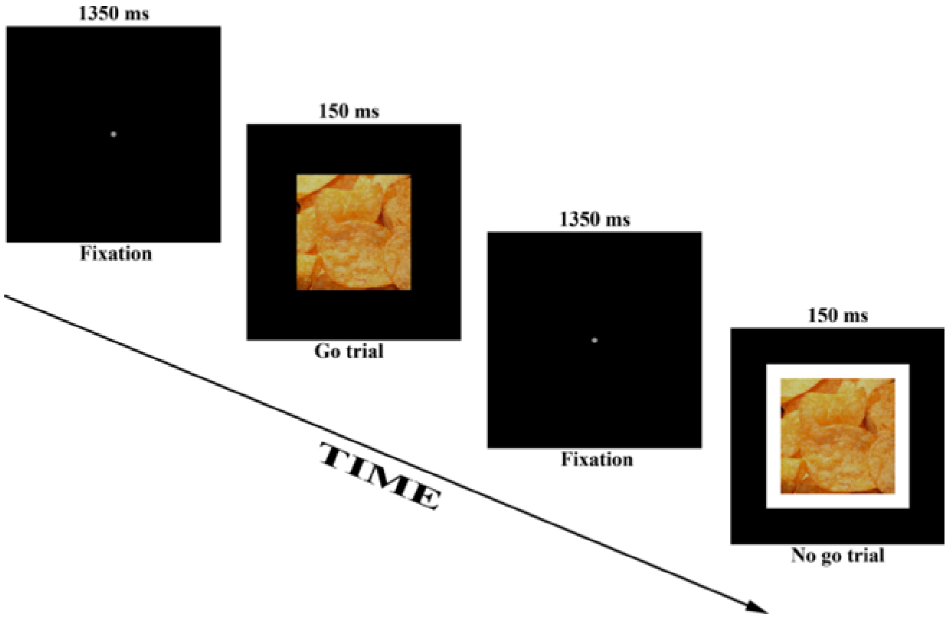
Figure 1. ***Types of inhibitory control in relation to eating behaviours***



1.1. Go/No-Go Task

The Go/No-Go Task involves the presentation of successive stimuli that require quick responding with one key (go-trials) or withholding responses (no-go trials) (Wessel, 2018) (see Figure 2). No-go trials typically occur with a low probability (20-30%) to challenge prepotent response tendencies (i.e., automatic dominant tendency to respond) (Aron, 2007). The outcome measure is the proportion of commission errors (i.e. responding in the no-go trials divided by the total number of no-go trials), with fewer errors indicating better inhibitory control. Decreased proportion of inhibitions and reaction times in this task was associated with higher BMI and increased unhealthy food consumption (Meule et al., 2011, 2014a; Price et al., 2016; Tsegaye et al., 2022). Conversely, training inhibitory control by the Go/No-Go Task resulted in increased healthy food consumption (Adams et al., 2021), reduced hedonic value of the food (Houben & Giesen, 2018) and caused less desire to eat chocolate (Houben & Jansen, 2015).

Figure 2. ***Two trials of the Go/No-Go Task***

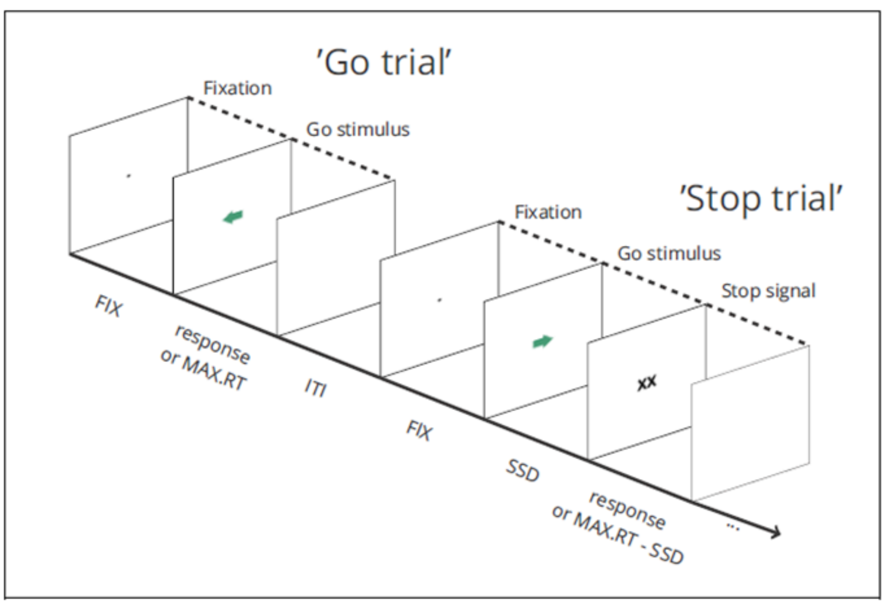


Note. Schematic representation of two trials in the food condition of the Go/No-Go Task, where participants are required to respond with the spacebar to pictures without any borders, and withhold their responses to pictures with white borders. (Tsegaye et al., 2022, p.4).

1.2. Stop Signal Task

The Stop Signal Task involves a go stimulus that is unpredictably followed by a "stop signal", which can either be an auditory stimulus (e.g. a ring tone) or a visual cue (e.g. letter S) (see Figure 3) that is presented in a trending interval. Go stimuli in this task require two distinct key responses to two different types of go stimuli (e.g., right and left arrows requiring response with a right key and a left key). Similar to the ratio of go and no-go trials of the Go/No-Go Task, a stop signal is presented in 25% of the trials in the Stop Signal Task, following 100 to 350 milliseconds after a go trial. This stop-signal delay varies based on the participant's performance by shortening when participants perform worse and increasing when they perform well. This task requires stopping processes to be finished before the go processes for a successful inhibition, which is known as the "horse-race model" (Logan and Cowan, 1984). The outcome measure of the Stop Signal Task is Stop Signal Reaction Time (SSRT). To calculate SSRT, the proportions of incorrect inhibitions are calculated first. Then, the reaction times in go-trials are ranked, and the reaction time at the percentile equal to the incorrect inhibition percentage is detected. For instance, if a person incorrectly pressed the button 40% of the trials, the reaction time at the 40% percentile is used. Then, the stop signal delay is subtracted from this reaction time value. Overall, we estimate how long it takes a person to stop an initiated response. Shorter SSRT indicates better inhibitory control performance by indicating earlier completion of stop processes. Increased SSRT is associated with increased calorie intake and increased food craving (Guerrieri et al., 2007; Houben et al., 2012; Nederkoorn et al., 2009; Meule et al., 2014b). Conversely, Stop Signal Task training might be effective at decreasing food consumption and cravings (Adams et al., 2017; Lawrence et al., 2015).

Figure 3. ***Two trials of the Stop Signal Task***



Note. "Depiction of the sequence of events in a stop-signal task. In this example, participants respond to the direction of green arrows (by pressing the corresponding arrow key) in the go task. On one-fourth of the trials, the arrow is replaced by 'XX' after a variable stop-signal delay (FIX = fixation duration; SSD = stop signal delay; MAX.RT = maximum reaction time; ITI = intertrial interval)." (Verbruggen et al., 2019, p.3).

1.3. Response Restraint vs Response Cancellation

Studies using the Stop Signal Task and Go/No-Go Task differently predicted the relationship between food consumption and inhibitory control (McGreen et al., 2023). For instance, increased laboratory food consumption was associated with poorer inhibition in the Go/No-Go task but not with inhibition performance in the Stop Signal Task (Kelly et al., 2020). In contrast, another study reported no association between inhibition performance in either task and food consumption (Powell et al., 2017). This may indicate that response cancellation and response restraint processes might be differently involved in eating behaviour, as these studies employing both measures showed inconsistent results on whether inhibitory control predicts increased (unhealthy) food intake (Kelly et al., 2020; cf. Meule et al., 2011; Powell et al., 2017).

In fact, some studies have used the Stop Signal Task as a measure of “late-stage inhibitory control” as the stop signal occurs when the response is already initiated (Svaldi et al., 2014) and the Go/No-Go Task as a measure of “early-initiated inhibitory control” as it requires withholding responses prior to initiating any action (Svaldi et al., 2015). In line with this reasoning, some have argued that the Go/No-Go task might involve top-down processes and is a measure of “proactive inhibition”. They suggested that proactive inhibition might be more goal-directed than what is measured in the Stop Signal Task, “reactive inhibition”, which relies more on bottom-up stimulus-driven processes (Braver, 2012; Meyer & Bucci, 2016; Stuphorn & Emeric, 2012; Van Belle et al., 2014). Understanding the role of these distinct processes in the control of eating is informative for interventions, as such interventions may be differently tailored to situations where people can proactively avoid food (e.g., not going to the snack section in the grocery store) or need to control an ongoing action (e.g., not going for a second slice of cake in a birthday celebration).

2. Eating Your Emotions: Affect-Induced Eating

Emotional eating refers to increased consumption of (unhealthy) food in response to negative affect and is a significant concern for public health (Chew et al., 2025). Meta-analyses and systematic review studies on correlational and experimental data found a link between increased negative affect and increased unhealthy food consumption (Cardi et al., 2015; Devonport et al., 2019; Hill et al., 2022). Several theories differentially explained this link. An overview of these theories is provided in Table 1.

Table 1. ***Previous theories of emotional eating***

Theories	Arguments	*Evidence* / Contradictions
Psychosomatic theory (Bruch, 1955)	People may confuse hunger with emotional arousal, therefore they increase their food intake when experiencing negative affective states.	Emotional eating is more about emotion regulation failure than arousal (Evers et al., 2010). *Arousal is only one component that may contribute to eating*, in fact, high arousal emotions reduces appetite (Macht, 2008). Whether people eat to relieve negative affect explain emotional eating better than physiological arousal (Spoor et al., 2007; Tylka & Wilcox, 2006)
Physiological and	Stress related hormones	Not everyone who experience

biological explanations (e.g., Adam & Epel, 2007; Dallman et al., 2005; Wurtman & Wurtman, 1988)	can cause increased desire for fatty or sugary foods to downregulate stress response; as these foods may result in opioid and serotonin release.	negative emotions overeats (Altheimer et al., 2021); *some unhealthy food may sooth physiological stress response* but this may not always result in maladaptive emotional eating.
Restraint theory (Herman & Polivy, 1980; Polivy et al., 2020)	People with rigid diet rules are more prone to emotionally eat because they experience minor indulgent behaviours as complete violation of their diet goals.	*Restrained eaters show increased emotional eating patterns (Evers et al., 2018; cf. Hagerman et al, 2021; Reichenberger et al., 2020; Standen & Mann, 2021).* However, non-restrained eaters may also emotionally eat due to difficulties in emotion regulation (Evers et al., 2010)
Reinforcement accounts (e.g., Macht & Simons, 2011)	Emotional eating is a cue-response association learned through negative conditioning	*Whether people learn to associate the negative emotions with their eating may explain why not everyone increases their food consumption in response to negative affect* (Altheimer et al., 2021). However, disordered eaters may associate unhealthy food with punishment than reward (Rouhani et al., 2025).
Macht's Five Factor Model (Macht, 2008)	(i) cue-elicited desires to eat, (ii) arousal, (iii) motivational congruency (e.g., sadness leading to decreased interest or joy leading increased interest in food), (iv) limited cognitive resources to control eating, (v) learnt coping responses together explain when emotional eating occurs	Hedonic cues do not always result in increased eating (Stroebe et al., 2013); emotions different in arousal may impact food intake differently in every individual (Altheimer et al., 2021; Evers et al., 2010); negative affect may not deplete resources to control (Botvinick, 2007; Dignath et al., 2019, 2020).
Emotion Regulation Accounts (e.g., Altheimer & Urry, 2019; Evers et al., 2018)	People might eat to cope with emotions; and each individual may have different food-feel better associations from previous experiences	*People who report to eat when anxious or sad did not increase their eating, neither in a lab environment when negative affect was induced, nor when tested in real-life environments when they experienced negative*

	rather than uniform effects of negative affect on eating.	*affective states (Altheimer et al., 2021).*
Resource Depletion Accounts (Baumeister et al., 2024; e.g., Boon et al., 2002; Byrne et al., 2021)	Negative affect deplete self-control and cognitive resources. Therefore, not enough resources left to resist food when under negative affect	Depletion effect on self-control could not be replicated in many studies (e.g., Vohs et al., 2021); cognitive control can even be enhanced under negative affect (e.g., Botvinick, 2007; Dignath et al., 2019, 2020).
Motivational Accounts (Inzlicht & Schmeichel, 2012; e.g., Fishbach et al., 2003)	Emotional eating might reflect a motivational shift from long term health goals to short term indulgence goals. People may have justified reasons to indulge (e.g. I need a treat)	*When people are reminded of their health goals they consume less unhealthy food than when they are reminded of indulgence goals (e.g. Veit et al., 2020). Deservingness thinking leads to increased calorie consumption (Prinsen et al., 2019)*

2.1. Physiological Models

The emotional eating concept was first proposed by Bruch (1955). Initially, why people would consume unhealthy food was explained by "interoceptive awareness", referring to people confusing their emotional arousal with hunger, therefore increasing their food consumption to satisfy this misattributed hunger (as cited by Reichenberger et al., 2020). However, the later evidence extensively refuted this assumption; for instance, people may eat to cope with their emotions rather than misattributing emotional arousal to hunger (Spoor et al., 2007; Tylka & Wilcox, 2006). In line with this reasoning, many other explanations have been proposed as to why such coping occurs. For instance, some unhealthy but tasty food may provide a temporary comfort and distraction that may help to reduce negative affect (Macht & Simons, 2000; Litwin et al., 2017; Stijovic et al., 2025). Physiological studies showed that stress hormones may increase the desire to eat sugary or fatty food to downregulate the stress response in the brain circuits (Dallman et al., 2005) and consumption of such food may result in opioid and serotonin release and activation of brain reward circuits, which contributes to persistent disinhibited eating patterns (Adam & Epel, 2007; Wurtman & Wurtman, 1988). Nevertheless, data on these physiological explanations of hormonal responses remained inconsistent across some studies (Bose et al., 2009).

2.2. Restraint Theory

In contrast, restraint theory (Herman & Polivy, 1980; Polivy et al., 2020) argued that emotional eating poses a problem preeminently for those rigidly restricting their food intake, conceptualised as "restrained eating" patterns. From this perspective, restrained eaters are more likely to emotionally eat once they deviate from their diet goal, which occurs due to the "what the hell" effect. Once an initial failure following a diet occurs (e.g., eating a slice of cake), it can lead to loss of control over eating and complete abandonment of the diet goals because restrained eaters may believe that they have already violated their diet goals irreversibly. Many studies associated restrained eating and emotional eating patterns, although it remains unclear whether this is explained only by the "what the hell" effect (Evers et al., 2018; cf. Hagerman et al, 2021; Reichenberger et al., 2020; cf. Standen & Mann, 2021).

2.3. Reinforcement Models

Learning-based models argue that emotional eating is learnt through negative reinforcement (Macht & Simons, 2011). For instance, repeated behaviour of consuming unhealthy food and experiencing soothed negative affect as a result leads to increased motivation to consume such food when negative affect is experienced later on. In other words, people learn to associate negative affect with unhealthy food consumption. In line with these findings, neuroimaging studies show that negative affect may lead to heightened value of the hedonic cues of the food (Ha & Lim, 2023; Wagner et al., 2012). In contrast, people who showed high disordered eating patterns associated high-calorie unhealthy food with punishment rather than reward (Rouhani et al., 2025). Specifically, they found it harder to learn reward-high calorie food cue association than to learn reward-low calorie association in a reinforcement learning task. This may show how previous experiences of maladaptive eating might also represent negative outcomes of unhealthy food, such as guilt or shame for failing to follow a healthy diet, rather than positive consequences, such as relief.

2.4. Macht's Model (2008)

According to Macht's (2008) five-way model accommodating these theories, emotional eating involves several processes. Firstly, food itself may elicit reactions (such as craving, preference) which in turn influence food choices. For instance, rewarding aspects of food can increase the desire to eat unhealthy food (Nederkoorn et al., 2004; but also see Stroebe et al., 2013). Second, emotions that are high in arousal can suppress food intake, and this is considered to be a natural response because the organism is alerted to other changes in the environment rather than satisfying hunger (Schachter et al., 1968; but also see, Rouhani et al., 2025). Third, emotions that are not high in arousal can result in different responses through what he called "congruent modulation", such as sadness leading to reduced interest in food or joy leading to increased motivation to eat (Macht, 1999; but also see: Simmons et al., 2016, van Strien et al., 2013). Importantly, negative emotions may increase eating due to limited cognitive resources necessary to resist food impulses (Bian et al., 2021; Boon et al., 2002; Byrne et al., 2021; Inzlicht et al., 2015; Muraven et al., 1998; Schmeichel, 2007), or due to physiological down-regulation of stress response by fatty and sugary food as outlined previously.

Throughout this section, I used the term "negative affect" to refer to several states of discomfort; ranging from stress to emotions different in arousal and valence. However, it is important to acknowledge that different emotions can elicit different eating responses (Macht, 2008) and which emotions can lead to increased food consumption remains unclear. Participants who were induced with anger and sadness ate more chocolate than those who were in the control condition, where there was no emotion induction (Salerno et al., 2014). Similarly, experiencing tension and fear led to increased everyday food intake compared to joy and relaxation and not being emotional (Macht & Simons, 2000). On the contrary, other studies showed increased self-reported hunger when people experienced anger and joy as opposed to when they experienced sadness and fear, where anger was associated with increased impulsive eating compared to sadness and fear (Macht, 1999).

2.5. Emotion Regulation Accounts

While previous literature provided inconsistent evidence and explanations on how negative affect may result in disinhibited eating, recent work has shown that negative affect does not consistently result in increased food intake, contrary to Macht's model and several other explanations of emotional eating (Altheimer & Urry, 2019). For instance, people who reported that they tend to eat when anxious or sad did not increase their eating, neither in a lab environment when negative affect was induced, nor when tested in real-life environments when they experienced negative affective states (Altheimer et al., 2021). It was argued that emotional eating may depend on whether a person associates a discrete emotion with their eating response as an emotion regulation strategy, rather than such negative states consistently leading to an increase in food consumption. In fact, some have argued that an increase in unhealthy food consumption in response to negative affect might be specific to people with emotion regulation difficulties (Altheimer & Urry, 2019; Brytek-Matera, 2021; Evers et al., 2018; Kopetz et al., 2018; Nolan et al., 2025; Taut et al., 2012). From this point of view, rather than biological components of food or arousal resulting from negative affect, emotional eating reflects people's learnt strategies to cope with negative affect.

Overall, it remains unclear to what extent the negative affect results in increased unhealthy food intake, and for whom, whilst several theories explain the underlying functions of emotional eating differently. In the scope of the current PhD project, I will further evaluate two more contemporary and competing explanations in which emotional eating is either considered a self-control failure or a motivational shift to gratification (see Figure 4).

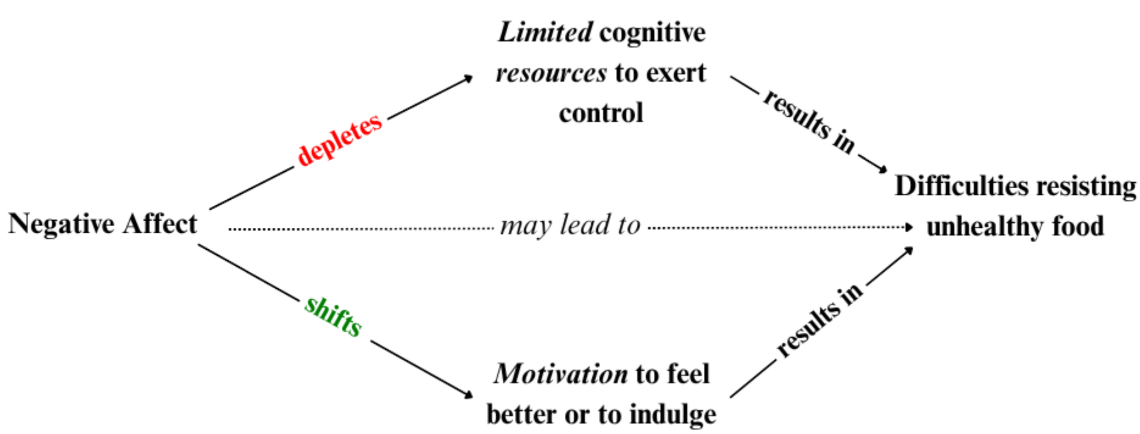
2.6. Limited Resources Accounts

To begin with, limited resources theories argued that negative affect may be demanding on limited cognitive resources that are necessary to resist unhealthy food (cf. Baumeister et al., 2024; Boon et al., 1998; Macht, 2008). Once people experience the negative affect, they use these finite resources to regulate the affect; therefore, not enough resources are left to control their eating. From this perspective, for instance, people who struggle with emotion regulation may be the ones who have higher demands on cognitive resources when they experience negative affect.

2.7. Motivational Accounts

In contrast, an alternative view proposes that emotional eating may reflect a justified shift in priorities from long-term health goals to short-term indulgence (or to feel better) goals. Once people experience negative affect, they might prioritise feeling better and may justify their unhealthy food choices (e.g., "I need a treat"). From this perspective, emotional eating might reflect a strategic affect regulation choice, not depleted resources to resist (Inzlicht & Schmeichel, 2012; Fishbach et al., 2003).

Figure 4. ***Competing explanations for why emotional eating occurs***



3. Resource Depletion: Limited Resources Models of Self-Control and Emotional Eating

Self-control refers to the ability to overcome short-term temptations to reach long-term goals (e.g., choosing healthy food over tasty food with negative health consequences) (Baumeister et al., 1998). Ego-depletion theory, as one of the resource depletion models, has argued self-control to be a finite resource that works like a muscle that tires out (becomes depleted) or like a battery that may run out (Baumeister et al., 1998; but see Carter et al., 2015; Hagger et al., 2016; Vohs et al., 2021). According to this point of view, when people engage in any form of self-control in one situation, they are more likely to fail to control themselves in a subsequent situation. For instance, when people were asked to eat a healthy but not tasty snack (radishes) rather than chocolates, they were more likely to quit a task with cognitive load than the others who did not control their eating (Baumeister et al., 1998). This reflected that resisting unhealthy food compromised the ability to self-control; therefore, healthy food choices rely on the same limited resources that are also used in other contexts where control is needed, such as when negative emotions are experienced (Boon et al., 1998; Macht, 2008).

Some studies showed how negative affect can impair inhibitory processes by depleting cognitive resources (Ding et al., 2020; Patterson et al., 2016; Rebetez et al., 2015). Specifically, when participants viewed negative affective images (sad), they showed decreased performance (reflected by increased SSRT) in a non-food Stop Signal Task (Patterson et al., 2016). Similarly, participants showed poorer performance in an emotional Stop Signal Task to negative affective stimuli than when the task involved neutral images (Ding et al., 2020). It was argued that negative affect heavily taxes inhibitory brain circuits, therefore leading to regulatory failure (Chester et al., 2016).

On the other hand, according to the affective signalling hypothesis, negative affect can signal a need for behavioural regulation; therefore can improve cognitive processes (cf. Botvinick, 2007; Dignath et al., 2019, 2020; Pourtois et al., 2020). In fact, many studies have shown that negative affect can improve cognitive control, reflected by increased neural activity of conflict processing using measures of non-food task paradigms of cognitive control such as Stroop and Flanker Tasks (e.g., Dignath et al., 2019; Yang & Pourtois, 2018). Importantly, these findings extended to other measures of inhibitory control. For instance, participants induced with sadness and anger using emotional pictures showed increased accuracy in a non-food Go/No-Go Task compared to others induced with happiness and viewed neutral images (Storbeck et al., 2024). Negative affect may thus improve inhibition to detect and analyse environmental threats or problems.

Some studies investigated how negative affect may impact inhibitory control and eating behaviour accordingly. It was reported that decreased inhibitory control towards both low and high-calorie food items in a Go/No-Go Task mediated the relationship between increased self-reported negative affect and increased food intake measured in the laboratory in a young sample (ages eight to 17) (Byrne et al., 2021). In other words, it was suggested that trait negative affect may be associated with decreased inhibitory control, which in turn leads to increased food consumption. However, as the study design did not include an affect induction procedure, it was unclear whether negative affect causally resulted in impaired inhibitory control.

Some causal evidence came from experimental studies using neurophysiological measures of inhibitory control. Specifically, it was reported that induced negative affect resulted in greater amplitude in inhibitory brain circuits as opposed to the control (i.e. neutral) condition (Liu et al., 2020). It was interpreted that this difference reflected an increase in cognitive demand initiated by negative affect rather than improved inhibition. The Go/No-Go Task was used as a measure of inhibitory control, with low-calorie food stimuli in go-trials, whereas no-go trials included high-calorie food stimuli. Interestingly, there was no difference between inhibitory control performance in neutral and negative affective states.

To explain these discrepancies on the impact of negative affect on control, Schmeichel and Inzlicht (2013) proposed that negative affect might be incidental (i.e. irrelevant to the conflict situation) or integral (i.e. arising from the conflict). They argued that incidental affect may lead to difficulties resisting immediate reward, whereas integral affect may benefit as it “acts as an alarm” to exert self-control (p.280), in line with the affective signalling hypothesis. However, it remains unclear whether the affect manipulation procedures used in the studies reporting impaired cognitive control under negative affect necessarily included incidental affect that is argued to impair control ability, as affective pictures were part of the cognitive control task rather than presented separately. Although it is yet to be discovered when negative affect reduces or improves cognitive control, counter-evidence from the affective signalling hypothesis shows how negative affect may not lead to depleted resources.

Since ego-depletion theory was first proposed, it has become one of the most cited psychological theories, as thousands of studies have attempted to replicate and test this effect in several contexts; however, it has led to a replication crisis (Englert & Bertrams, 2021). Several meta-analyses of experimental studies have reported very limited evidence that ego depletion was a real effect (e.g., Carter et al., 2015; Hagger et al., 2016). For instance, Vohs et al. (2021) reported a null effect with a sample of 3531 participants in a multilaboratory study where 36 different laboratories tested the ego-depletion effect with well-established paradigms.

Many different alternative explanations have been proposed to explain the mechanisms underlying resource depletion. Firstly, some have argued that such a depletion effect might be “all in your head”. It was argued that failure of a subsequent self-control task might rather reflect people’s beliefs on whether their self-control resources are available or depleted (Job et al., 2010). It was reported that people who were told that they needed to refuel their control resources were more likely to make mistakes in a secondary task than those who were told that a primary task would fuel them for the upcoming tasks. Secondly, others have shown that incentives (e.g., watching a funny video, financial compensation, positive feedback) could prevent depletion effects (Muraven & Slessareva, 2003; Tang et al., 2024; Tice et al., 2007; Wan & Sternthal, 2008). It was suggested that the self-control failure in the secondary task might be a problem of reduced motivation; for instance, participants might disengage from the latter task because they may already feel that they have put considerable effort into the study (Inzlicht & Schmeichel, 2012).

Surprisingly, Baumeister et al. (2024) suggested that the other studies attempting to replicate the depletion effect did not use efficient tasks and measures, and ego depletion is the most replicated effect in social psychology. For example, they argued that the incentives provided in the later studies "refuelled" the control resources rather than the depletion effect to reflect a lack of motivation. Importantly, the alternative motivational explanations of resource depletion were advised to be more thoroughly researched, extending beyond self-report measures.

To address these concerns and inconsistent evidence from other depletion arguments of emotional eating, we tested the resource-depletion models in Chapter 2 by inducing negative affect in an inhibitory control task and using both food and non-food stimuli. The limited resources models suggest that control performance should be reduced by negative affect because regulating the affect also comes with control demands, and cognitive resources necessary to exert control in the inhibition task become depleted (Chester et al., 2016). Therefore, if limited resources underlie the failure to control, then when we induce negative affect, as opposed to positive affect (Tice et al., 2007) and neutral (i.e. control) conditions, participants are expected to show poorer performance in the inhibition task, regardless of whether stimuli used in the task include food or non-food items.

4. Overrated Willpower: Motivational Explanations of Self-Control Failure and Emotional Eating

Contrary to limited resources models, different explanations for why people may struggle to resist unhealthy food have evolved. For instance, they may feel licensed to eat unhealthy but tasty food to relieve their stress or reward their hard work (cf. Kivetz & Zheng, 2006; Prinsen et al., 2019; Witt Huberts et al., 2012). Specifically, it was shown that when participants were reminded of their success, they consumed more calories in a bogus taste test than others who recalled an ordinary day (Prinsen et al., 2019). In addition, participants who were told that the task they engaged in required high effort consumed more calories than those who were told that the given task required low effort (Prinsen et al., 2019). Importantly, Witt Huberts et al. (2012) tested whether engaging in a task that is perceived as effortful leads to resource depletion. They showed that participants in the effort condition, in which they were told to be randomly selected to do the task again, did not perform worse in the Stroop task than the others who completed the same task without perceiving that they were asked to do it once more. However, participants in the effort condition consumed more calories than those in the control condition, while both groups reported comparable negative affect resulting from the same task. Thus, completing the same self-control task or negative affect resulting from doing the task did not lead to resource depletion; instead, it led participants in the effort condition to feel licensed (deserving) to reward their hard work.

Accommodating the licensing arguments, Inzlicht and Schmeichel (2012; see also Kopetz et al., 2018; Moors et al., 2017) have proposed a “process model” alternative to resource depletion. According to this model, the suggested decrease in self-control from Time 1 (i.e., where control is first exerted) to Time 2 did not reflect reduced resources of control, but rather involved heightened impulse. Such heightened impulse occurs due to a motivational shift turning to gratifying impulses and engaging in temptations, away from inhibiting or suppressing them. In addition, a shift in attention occurs by increasing towards rewarding (i.e. temptation) cues and attenuating towards control cues. For instance, once a person experiences negative affect, they struggle when it comes to making a healthy food decision, because their motivation shifts, for instance, to feel better rather than following their long-term health goals or suppressing their impulse to unhealthy food. In addition, their attention increases toward the rewarding properties of the food and decreases toward its long-term negative consequences. This model explained, for example, why ego-depletion beliefs impacted the actual depletion effect as discussed in section 3. Specifically, when there is a belief that one has limited resources, their attention might shift to signs of depletion and fatigue, and motivation might decrease to exert further effort. In line with this reasoning, licensing occurs with a motivational shift to reward oneself, away from controlling their food intake (Inzlicht & Schmeichel, 2012).

Some studies have further tested whether such a motivational shift (e.g., to feel better or to enjoy themselves) can impact how people respond to food. Indeed, when people were reminded of hedonic aspects of the food (i.e., activated indulgence goals), they showed an enhanced attentional bias towards unhealthy food than the others who were reminded of health aspects of the food, in line with the process model (Inzlicht & Schmeichel, 2012; Werthmann et al., 2016). In addition, participants who were primed with stimuli relating to losing control of their eating reported higher cravings for chocolate and consumed more chocolate than the others who were primed with stimuli relevant to being in control of their eating (Franssen et al., 2022). Interestingly, when participants were reminded of the health aspects of the food (i.e. activated health goals), they reduced the size of their portion selection than when they were reminded of the taste aspects of the food (Veit et al., 2020). These studies showed how activated goals (i.e. shifted motivation to short-term temptations or long-term goals) can change the way people respond to food.

The process model of self-control argued for a shift in motivation, rather than a lack thereof (Inzlicht & Schmeichel, 2012). Although these studies provided evidence that an increased motivation to indulge or to eat healthily may explain difficulties in resisting unhealthy food, all studies (except Veit et al., 2020) were limited to between-subjects designs. It is, therefore, also important to understand whether people can shift between such motivations to eat healthy or enjoy tasty food, which in turn can influence other basic automatic behaviours. To address these gaps, we used a motivation manipulation to test its effects on inhibitory control in a within-subjects design in Chapter 3, which is one of the cognitive mechanisms that is linked to control of eating and unhealthy food choices, but has not been investigated in the previous literature to test the motivational shift arguments. For such a motivational shift, we use the term "malleable and temporary motivational states" later in Chapter 3. We aimed to provide causal evidence that a shift in motivation from health to indulgence can impact the ability to resist unhealthy food.

5. Need to regulate: Eating as a Regulation Strategy

As discussed previously, negative affect is an umbrella term for distressing feelings, including stress, moods that involve prolonged experiences of a range of negative emotions such as sadness, anger, or anxiety. Such negative affective states often lead to changes in behaviours, where people exert effort into adjusting their responses resulting from such affective states, conceptualised as affect regulation (Gross, 2015). Emotion regulation refers to one of three aspects of affect regulation, involving people's efforts to adjust the way they express and experience emotions, when to have these emotions and which emotions to have. It differs from the other two aspects of affect regulation, coping and mood regulation in terms of its shorter temporal duration (Gross, 2015).

In line with the evidence described above on motivations to indulge, negative affect can activate emotion regulation goals, which can in turn override or inhibit self-improvement goals, such as keeping a healthy diet (Fishbach & Labroo, 2007). For instance, participants who were induced with negative affect were more likely to abandon their self-improvement goals (e.g., academic success) than others who were induced with positive affect. However, whether such emotion regulation goals can cause difficulties resisting unhealthy food is yet to be explored.

Many studies have tested whether the way emotion regulation goals are achieved can influence how people respond to food. They showed that while using maladaptive strategies to regulate negative affect is associated with increased unhealthy food choices and impulsive eating (Evers et al., 2010; Görlach et al., 2016; Taut et al., 2012; Wolz et al., 2021), use of adaptive strategies can lead to healthier choices (Langley et al., 2023; O'Leary et al., 2023). For instance, when participants were experimentally instructed to engage in adaptive regulation strategies such as reappraisal after a negative memory recall, they were more likely to choose healthier food options than when they did not engage in such adaptive emotion regulation (Langley et al., 2023; O'Leary et al., 2023). Conversely, when participants engaged in suppression (i.e., a maladaptive affect regulation strategy) in response to a sad video clip, they increased their food intake in the laboratory (Taut et al., 2012). Importantly, self-reported measures of increased regulation difficulties in overweight and obese adults are associated with self-reported measures of overeating (Barnhart et al., 2025). However, these studies so far either relied on correlational designs that are limited in causality or have examined how to prevent emotional eating by engaging in different ways of adaptive affect regulation. Therefore, it remains unclear whether people strategically choose unhealthy food because they believe these foods will help them to feel better, and to achieve their emotion regulation goals.

Overall, it is yet to be clarified further whether emotion regulation goals can cause unhealthy food choices, and whether this is caused by people using food to achieve such emotion regulation goals due to beliefs that some unhealthy food has regulatory effects. In addition, measures of food intake in a laboratory setting in previous studies may be influenced by demand effects (Hiraguchi et al., 2023; Robinson et al., 2014). Therefore, we aim to extend these findings by using a measure of automatic response tendencies essential to food choices and eating, which is inhibitory control. In Chapter 4, we used motivational state manipulation (comparable to Chapter 3) to induce emotion regulation goals to test whether emotion regulation goals achieved through eating can cause difficulties resisting and avoiding unhealthy food.

Table 2 provides a summary of the previous research, contradictions in the evidence, and research gaps in the literature. Overall, it is unclear what causes emotional eating and whether the tendency to consume unhealthy food occurs for every person who experiences negative affect. Some recent reviews and meta-analyses find a link between negative affect and increased unhealthy food consumption; however, others suggest that emotional eating is not a universal experience and may be limited to people who struggle to regulate their affective states efficiently. An open question pertains to what causes emotional eating, whilst different opposing models are proposed to explain its mechanisms. Resource depletion models argue that emotional eating occurs because people's regulatory capacity is depleted under negative affect, whereas motivational accounts suggest that emotional eating may reflect a shift in priorities from long-term, being healthy goals to short-term feeling better goals. Inhibitory control, as one of the key cognitive mechanisms involved in the control of eating, can provide a reliable measure of automatic tendencies towards unhealthy food to test these competing explanations.

Table 2. *Summary of Existing Literature*

Subsections	Current Evidence	Contradictions/ Limitations	Research Gaps

On stopping yourself: Inhibitory control and unhealthy food consumption	Poorer inhibition is linked to increased unhealthy food intake, and it provides a reliable measure of automatic responses	Unclear whether early and late initiated inhibition is differently involved in the control of eating Not clear what happens to inhibitory control under negative affect	Do negative affect and motivational processes impact inhibitory control? If so, is it different in the early and late stages of stopping? Does negative affect impair or improve inhibition? If so, is it different in food and non-food contexts?
Eating your emotions: Affect-induced eating	Negative affect can lead to unhealthy food intake, which may reflect a learnt coping strategy or limited resources to resist	Emotional eating is not a universal experience, unclear whether negative affect causes increased eating and for whom	Does negative affect cause increased eating? If so, for whom, when and why?
Resource Depletion: Limited Resources Theories of Self Control	Prior attempts at self-control may result in depleted control capacity. Some studies show that negative affect can compromise inhibitory control ability.	Replication attempts largely failed; some studies show negative affect improves cognitive control, while studies showing impaired control under negative affect lack proper experimental designs	Are difficulties in resisting unhealthy food caused by limited/depleted cognitive capacity to control?
Overrated Willpower: Motivational Explanations of Self-Control Failure and Emotional Eating	Failing to resist is not a capacity problem; it reflects a motivational shift to reward oneself.	Limited experimental evidence, mostly including between-subjects designs, and limited evidence on automatic processes	Can higher-order goals (motivational shift to enjoy oneself or to eat healthily) impact automatic responses (inhibitory control)? Can people switch between motivational states?
Need to regulate: Eating as coping strategy	Negative affect activates emotion regulation goals, the way such goals achieved (adaptively or	Indirect evidence on emotion regulation and food choices, mostly focusing on different strategies	Can motivation to feel better cause increased tendencies to eat unhealthy food? Do people strategically use

	maladaptively) can lead to different (healthy or unhealthy, respectively) food choices	to regulate affect. Unclear whether emotion regulation goals (a motivational shift to feel better) can cause difficulties resisting unhealthy food and whether emotional eating can be a strategic emotion regulation choice.	unhealthy food to achieve emotion regulation goals because they believe such foods can help them to feel better?

The Present Project

This doctoral project aimed to test two competing explanations for emotional eating: (i) resource depletion accounts, suggesting that emotional eating is caused by depleted cognitive resources necessary for self-control, and (ii) motivational accounts, suggesting that emotional eating might reflect a shift in priorities and might be a justified emotion regulation strategy. Existing literature on the resource depletion accounts has shown inconsistent evidence, as some have found that negative affect may even improve control ability. On the other hand, recent motivational accounts have not been adequately tested by within-design experimental paradigms that are less prone to being confounded by individual differences and can directly indicate a shift between state-level motivations or affect. Therefore, we aimed to test both theories in three experimental studies by asking the following questions (also see Table 3):

1- Does negative affect compromise cognitive resources for general and food-specific inhibitory control?

2- Does a motivational state to eat healthy food as opposed to enjoying tasty food impact inhibitory control of unhealthy food in early and late stages of stopping?

3- Does a motivational state to feel better increase the tendency to approach and impair inhibition to unhealthy food under negative affect?

Understanding whether emotional eating occurs due to depleted resources or a shift in motivation is crucial for developing interventions. Specifically, if depleted cognitive resources lead to (over)consumption of unhealthy food, then training cognitive processes involved in control of eating, including but not limited to inhibitory control, could be beneficial. However, if emotional eating reflects a justified emotion regulation strategy, then interventions can focus on motivational processes that highlight health goals and empower adaptive emotion regulation strategies. Considering that obesity and related health problems have been considered a global pandemic over the last few decades, it is important to understand what causes emotional eating in order to develop effective prevention strategies.

Table 3. ***Overview of Empirical Studies***

Chapters	Aims & Hypotheses	Affect / Motivation Manipulation	Cognitive Tasks
Chapter 2: Selective Depletion: Negative affect selectively impairs the inhibition of unhealthy food in disordered eating	Testing resource depletion accounts H: if negative affect deplete resources, poorer inhibition should be observed in negative condition compared to positive and neutral conditions regardless of stimulus type	Negative, Positive and Neutral Affect induced by personalised idiosyncratic words, presented in the task trials in a within-subjects design	Go/No-Go Task; Including non-food (i.e. household items) and food (both palatable and healthy) stimuli
Chapter 3: Shifting Priorities: Switching between health and indulgence motivational states	Causal evidence for motivational shift explanations; H: improved inhibition in health-oriented motivational state	Motivational state to eat healthily and to enjoy tasty food; applied as a secondary task rule in a within-subjects	Go/No-Go Task and Stop Signal Task as measures of early and late initiated inhibition. Both

impacts proactive inhibition towards unhealthy food	condition than in indulgence state condition, whether different stages of inhibition might be differently impacted by higher order goals is explored	design	tasks included non-food (i.e. pictures of animals) and food (both palatable and healthy) stimuli
Chapter 4: Testing the causal role of emotion regulation goals in inhibitory control and approach bias toward unhealthy food	Causal evidence for motivational shift explanations; whether emotion regulation goals under negative affect results in difficulty resisting unhealthy food and whether emotional eating is an emotion regulation strategy; H: poorer inhibition and increased approach to food that is believed to improve negative affect when the task rule is to feel better than it is to sustain the current affective state	1- Motivational state to feel better as opposed to sustain the current affective state; applied as a primary task rule in a within-subjects design 2- Beliefs about regulatory function of food (can help to feel better vs no mood effects) manipulated by a deception text and applied as a primary task rule in a within-subjects design 3- Negative affect induced by affective images from NAPS & OASIS	Go/No-Go Task; including high-calorie palatable food items as stimuli and negative affective images for affect induction

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CHAPTER 2

Selective Depletion: Negative affect selectively impairs inhibition of unhealthy food in disordered eating.*

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Abstract

It is often suggested that negative emotions lead to unhealthy eating patterns with detrimental consequences for people's health and well-being. However, it is not yet clear whether negative affect impairs people's capacity to inhibit themselves in general or only towards unhealthy food, with important implications for theory and the development of interventions. The present studies, therefore, tested whether inducing negative (versus positive or neutral) affect impacts inhibition towards various food and non-food stimuli or only towards unhealthy but appealing food items, whilst also measuring individual differences in eating behaviours and emotion regulation difficulties. In two pre-registered studies, participants (study 1 (*N*=40), study 2 (*N*=47)) completed a Go/No-Go Task measuring inhibition towards unhealthy food, healthy food, and non-food stimuli. To induce different emotional states, idiosyncratic emotional words referring to negative and positive daily-life experiences were collected from participants before the main studies and were presented as part of the tasks in a within-subject design. Negative (or positive) affect did not impair inhibition across participants, neither in a food nor a non-food context. However, difficulties in emotion regulation and restrained eating were selectively associated with decreased inhibitory control towards unhealthy food when negative affect was induced. Our findings highlight how emotional eating might not be a consequence of general impairment in inhibition capacity but reflects emotion regulation difficulties in response to negative affect.

Keywords: emotional eating, restrained eating, inhibitory control, emotion regulation, resource depletion

1. Introduction

Emotional eating refers to an increased food consumption in response to negative affect (Chew et al., 2025). Emotional eating currently has a prevalence of 44.6% worldwide, raising a significant concern and need for interventions to prevent related health consequences such as obesity and obesity-related diseases (Chew et al., 2025). However, it is still unclear whether and why negative affect leads to overeating and unhealthy food choices (Altheimer et al., 2021; Reichenberger et al., 2020).

One of the cognitive mechanisms that plays a crucial role in the control of eating is inhibitory control, described as effortful suppression of a certain behaviour (Hofmann et al., 2012; Verbruggen & Logan, 2008). Decreased inhibitory control has been linked to increased food intake (Meule et al., 2011; Powell et al., 2017; Price et al., 2016), poor weight regulation (Houben et al., 2012), and higher BMI (Tsegaye et al., 2022). Negative affect may compromise inhibitory control (Dillon & Pizzagalli, 2007), which might lead to increased food intake. For instance, decreased inhibition performance in a food Go/No-Go Task mediated the relationship between increased self-reported negative affect and greater food intake measured in a laboratory buffet meal (Byrne et al., 2021). In addition, unsuccessful restrained eaters (i.e., people who struggle to follow their dietary intentions, Zhang et al., 2019) showed reduced neural markers of inhibitory control towards food when negative affect was induced experimentally using an emotional video-clip (Liu et al., 2020). Both successful and unsuccessful restrained eaters showed increased N2a amplitude, which is a specific event-related component (ERP) related to cognitive control, in the negative affect condition compared to the neutral condition, reflecting that negative affect may compromise inhibition ability by increasing demand on cognitive resources (Liu et al., 2020).

One explanation of these findings suggests that negative affect may impair cognitive capacity and deplete cognitive resources essential to resisting unhealthy food (Bian et al., 2021; Boon et al., 2002; Byrne et al., 2021; Inzlicht et al., 2015; Muraven et al., 1998; Schmeichel, 2007). For instance, once people experience negative affect, these resources are assumed to be redirected to the regulation of affective states instead of the control capacity necessary for resisting food (cf. Baumeister et al., 2024; Macht, 2008). Indeed, inhibiting emotional responses to a video clip resulted in impaired performance in a memory re-call task, and exaggerating negative emotional responses to a sad video clip resulted in impaired performance in a working memory span task; both reflecting a depletion of resources that are necessary for cognitive control (Schmeichel et al., 2007). However, even though there is some evidence that cognitive resources necessary for control of eating may be depleted by prior attempts to regulate negative affect (e.g., Macht, 2008; Tice et al., 2001), it has not been investigated yet whether inhibitory control or other cognitive control mechanisms are impaired differently in food and non-food contexts, which would inform whether emotional eating is caused by resource depletion.

Even though several studies linked negative affect with disinhibited eating and unhealthy food choices (Devonport et al., 2019; Hill et al., 2022; O'Leary et al., 2023), negative affect does not always lead to increased food intake, neither in real-life nor in laboratory settings (Altheimer et al., 2021; Hill et al., 2022). Recent reviews and meta-analyses of experimental studies have therefore argued that increased food consumption in response to negative affect and poorer inhibition to food might be limited to individuals with emotion regulation difficulties (Brytek-Matera, 2021), such as in restrained eating (Evers et al., 2018; Reichenberger et al., 2020). Interestingly, negative affect can also improve cognitive control by signalling the need for behavioural regulation, which can in turn increase performance monitoring (e.g., Botvinick, 2007; Dignath et al., 2020; Inzlicht et al., 2015; Pourtois et al., 2020; Yang & Pourtois, 2018). For instance, negative affect induced by negative feedback in a non-food Flanker task (i.e., a standard measure of interference control, which is conceived as a component of inhibitory control, Sinapoli & Dennis, 2012) resulted in improved task performance, showing that negative affect can enhance cognitive control processes. In sum, it is unclear whether negative affect causally impairs inhibitory control, especially in non-clinical populations and in both food and non-food contexts.

Alternatively, emotional eating might reflect emotion regulation attempts, which are either unsuccessful or perhaps even maladaptive. For instance, experiencing negative emotions might lead to justifying overeating and unhealthy food choices to regulate the emotional state (Kopetz et al., 2018; Prinsen et al., 2019; Witt Huberts et al., 2012). This means, an increase in unhealthy food consumption may occur due to an active emotion regulation goal (e.g., wanting to treat oneself after a bad day) rather than negative affect resulting in loss of control (Prinsen et al., 2019). For example, Tice et al. (2001) suggested that increased eating in response to negative affective states might reflect a shift in priorities to feel better over long-term health goals. Indeed, in their studies, participants who were put in a negative mood and then instructed to believe that eating would not alter their mood consumed less snacks than those in the control condition in which no information was given on the absence of effects of food on mood. This experimental condition presumably reflected a situation where there would be no use of prioritising emotion regulation goals, suggesting that emotional eating may reflect a choice made to regulate negative affect. However, the manipulation check in this study did not test whether participants believed the deception text. In addition, the experimental and control conditions were not comparable to one another. Hence, it is unclear whether the given information on the mood effects of food might have resulted in increased attention to eating and created demand effects for those in the experimental condition.

Taken together, research has shown that negative affect and decreased inhibitory control capacity are linked to unhealthy food choices and disinhibited eating. Some studies suggested that this association is explained by limited cognitive resources that are, for instance, devoted to emotion regulation. Other studies, however, did not find a link between negative affect and increased eating or unhealthy choices, with studies from non-food contexts even suggesting that negative mood can improve cognitive control processes. Recent explanations (Evers et al., 2018; Kopetz et al., 2018; Prinsen et al., 2019) have argued that increased eating and unhealthy food choices might reflect attempts to regulate negative affective states.

To advance this debate, the present studies experimentally tested whether negative affect (in comparison to other affective states) impacts inhibition in general or only toward unhealthy food to address the following research gaps. First, studies investigating the relationship between poor inhibition to food and negative affect in non-clinical populations are limited to self-report measures of negative affect rather than experimental affect induction (e.g., Barnhart et al., 2025; Byrne et al., 2021) restricting insights into causality. Second, most studies showing this relationship in experimental paradigms did not involve non-food stimuli to test whether negative affect depletes cognitive resources needed for inhibition. They also missed proper control conditions, for instance, positive affect inductions to control for arousal (e.g., Liu et al., 2020). Therefore, it is crucial to understand the causal role of negative affect on inhibitory processes and food choices with fully balanced and controlled experimental designs in un-selected populations, as emotional eating patterns extend beyond clinical populations diagnosed with eating disorders, posing health concerns for the general population (Snuggs et al., 2025).

Building on these arguments, we aim to experimentally examine whether negative affect impairs inhibitory control differently in food as opposed to non-food contexts to allow a direct test of the competing explanations. For instance, the depleted cognitive capacity argument would suggest a decrease in inhibitory control when negative affect is induced, regardless of food or non-food stimuli involved, because cognitive resources would be equally depleted in either case. However and alternatively, if such a response tendency (i.e., decreased inhibitory control) would be observed only towards unhealthy but tasty food, this could imply that emotional eating might not be caused by depletion of cognitive resources.

1.1. The present studies

To pit these two explanations of emotional eating against each other and to address the aforementioned research gaps, we have used a behavioural task paradigm in a non-clinical population and tested whether inhibitory control capacity results in a general impairment when negative affect is induced. Further, by measuring specific individual differences related to eating behaviour, we were also able to account for their role. We compared inhibition performance towards unhealthy food, healthy food, and non-food stimuli in negative, positive and neutral affective state conditions in a within-subjects design.

An adjusted Go/No-Go paradigm was used as a measure of inhibitory control (Tsegaye et al., 2022). Emotional words from participants' recent experiences were presented during task trials to induce negative, positive and neutral affective states in a more ecologically valid way based on recent work (Langley et al., 2023; O'Leary et al., 2022). Participants responded to food and non-food stimuli in separate blocks in which they received each affective state condition of the Go/No-Go task consistently in a counterbalanced order. If negative affect leads to poorer inhibitory control capacity, then it would be reflected by poorer inhibition towards all stimulus types (i.e. depletion argument) in the negative affect condition compared to the neutral (i.e. control) condition. However, if such impairment were limited to unhealthy food, this could support the argument that emotional eating is not caused by reduced cognitive capacity.

To test whether negative affect reduces cognitive capacity to inhibit, preregistered hypotheses predicted decreased inhibition performance in the negative affect condition than in the neutral (control) condition, and towards unhealthy food in the negative affect condition compared to healthy food and non-food stimuli within the same condition. In the first study, this was expected to be reflected by decreased reaction time and the proportion of inhibitions and omissions. Given the mixed findings in the existing literature regarding the impact of positive affect on inhibitory control (Chiew & Braver, 2011; Loeber et al., 2018; Schubert & Bode, 2023), we did not have a specific prediction regarding the inhibitory control performance in the positive affect condition of the Go/No-Go Task. Therefore, the positive affect condition was included for exploratory purposes only and to control for arousal. In the first study, self-report measures of maladaptive eating behaviours (i.e. emotional, restrained and external eating) and emotion regulation difficulties have been included for exploratory analyses. The second study also tested the relationship between inhibitory control towards unhealthy food and self-reported measures of maladaptive eating behaviours.

2. Study 1

2.1. Method

2.1.1. Participants

Forty participants (33 female, 6 male, 1 other; M_{age}= 21.67 years, SD_{age}=4.96 years) from University of Reading took part in return for course credits. For the sample size estimation, power analysis was conducted using G*Power version 3.1.9.7 (Faul et al., 2007) based on a separate pilot study (N = 20) that was conducted to get an estimate of the affective state condition and stimulus type interaction in two-way repeated measures of ANOVA for each dependent variable (reaction time on go trials, proportion of inhibitions, and go-omissions).

G-Power analyses revealed a small effect size for the proportion of inhibitions (η_p^2 =.009), which led to a sample size estimation of N=94; a medium effect size for go-omissions (η_p^2 =.057) leading to a sample size estimation of N=15 and small to medium effect size for reaction time (η_p^2 =.042) suggesting an estimated sample size of N=20, all at an α of .05 and power at .80.[1]

Due to considerable discrepancies in the estimated sample sizes, we followed Von Gunten and Barthalow (2021) to prevent underpowered results. We included 80 trials per condition in this within-subjects design, which suggested a minimum sample size of N=35 in order to reach a medium to large effect size at α = .05 and power = .95. In order to fully counterbalance task order, we eventually recruited N=40 participants.

The study was approved by the Ethics Committee of the University of Reading and followed the Declaration of Helsinki. All participants received informed consent and confirmed it before taking part in the study.

2.1.2. Stimulus Selection

To tailor healthy and unhealthy food stimuli to the target population (Labonte & Nielsen, 2023), a separate survey was conducted with a different sample of students (*N*=100). Participants rated twenty-four (twelve healthy and twelve palatable) food pictures on the 5-point Likert scales for health (1= *not healthy at all*, 5= *very healthy*) and taste (1= *not tasty at all*, 5= *very tasty*) aspects (Hare et al., 2009). Pictures used in the survey were selected from a standardised database, "Food-Pics_Extended" (Blechert et al., 2019). As healthy food stimuli, four pictures rated higher on the health scale were selected. As unhealthy food stimuli, four pictures rated higher on the taste scale but lower on the health scale were selected (see Appendix A for stimulus ratings, and the list of all used stimuli is provided at https://osf.io/mv9nf/). Pictures of household items from the same database were used as non-food stimuli (e.g., scissors, iron, clock, etc.).

2.1.3. Emotional Words

To personalise negative and positive emotional words to present in the different conditions of the task trials, participants were asked to describe recent daily-life experiences with a minimum of 50 words in an initial survey (cf. O'Leary et al., 2023). Firstly, they were instructed to think of a personal, work-related or academic problem that has not been solved yet. They were provided with some examples, such as when they failed an exam or an assignment, argued with a loved one, struggled to find a job or complete a task, or had difficulties with their health. Secondly, they were instructed to think of a recent situation when they felt very good about themselves (Paul et al., 2020). Comparable examples to the first instruction were provided, such as when they were successful in a task, had a celebration or quality time with a loved one, got selected for a satisfying job, received an award for their achievements, or felt very healthy and energetic. Following each memory recall, they were asked to provide ten keywords that would later remind them about the described situation (e.g., "*unfair*", "*defeated*", "*hopeless*"; "*fun*", "*connected*", "*competent*"). We first reviewed these words for spelling errors and relevance to reported stories. Occasionally, participants provided several words as one keyword (e.g., "*start writing", "studying abroad", "wider issues")* or words that might not be perceived as emotional, that is, positive or negative, by themselves (e.g., "*March*", "*computer*", "*Mandarin*"). These words were replaced by other emotional words that the same participants provided in the main text or synonyms of the words they provided in the keywords list. Eventually, ten different keywords per condition were presented between the trials of the Go/No-Go Task for affect induction. In the control condition, same list of ten words for household items were used (e.g., "*curtains*", "*hoodie*", "*laptop*").

2.1.4. Go/No-Go Task

The Go/No-Go Task was adjusted from Tsegaye et al. (2020) to measure inhibitory control capacity towards food and non-food stimuli. A single go trial consisted of a go stimulus (450 x 450 pixels) surrounded by a blue border (25 pixels), which required a keypress on the spacebar and an emotional word (or control) depending on the condition that replaced a fixation dot. A single no-go trial included a no-go stimulus (450x450 pixels) surrounded by a red border (25 pixels), which required withholding the response and an emotional (or control) word. All stimuli and words were presented at the centre of the screen. All stimuli were presented for 200 ms, where go-trials occurred with an 80% probability. Emotional or neutral words were presented on the screen for 250 ms to provide adequate time for word recognition (Hauk et al., 2012), which were all written in the same font and size and without capital letters. Participants were not asked to respond to emotional words, these words simply replaced a fixation dot. Stimulus onset asynchrony (SOA) was 1500 ms and the intertrial interval was 1700 ms.

The Go/No-Go Task consisted of six test blocks where participants responded to three blocks with food (healthy and unhealthy) and three blocks with non-food stimuli. Each block involved only one of the three affect manipulation conditions; negative (1) and positive (2) conditions where emotional words selected from the survey phase were presented, and the control condition (3) where words for household items were presented between stimuli presentations.

Each test block included 80 trials (cf. Batterink et al., 2010; Tsegaye et al., 2022; Su et al., 2019; Zoon et al., 2018). In each condition of the non-food blocks, eight different pictures of the household items were presented eight times as go and twice as no-go stimuli. Similarly, in each condition of the food blocks, four different healthy and four different unhealthy food pictures were presented eight times as go and twice as no-go stimuli.

Initially, participants practiced the task in two blocks consisting of a total of 28 trials with non-food stimuli where they received feedback for go-omissions and commission errors (i.e., when they responded to no-go trials). During this first practice block, they were asked to press the spacebar for pictures with blue borders (12 go trials). Following this block, they were asked to withhold their responses when no-go stimuli were presented (four no-go and 12 go trials). Then, they started either with food or non-food test blocks (counterbalanced). Within the food and non-food test blocks, the order of affective state conditions was counterbalanced consistently. The task included a total of 508 trials, and only test blocks (n=480) have been included in the analyses.

2.1.5. Self-Reported Measures

Questionnaires and several additional questions were used to identify sample characteristics in terms of eating behaviours, motivations, trait level self-control, and emotion regulation difficulties. These measures were further used for exploratory analyses.

2.1.5.1 Dutch Eating Behaviour Questionnaire

Participants completed the 33-item Dutch Eating Behaviour Questionnaire (Van Strien et al., 1986) with scales for restrained eating (e.g., "*Do you take into account your weight with what you eat?),* emotional eating (e.g., "*Do you have a desire to eat when somebody lets you down?*) and external eating (e.g., "*If you walk past the bakery do you have the desire to buy something delicious?*). Participants answered each item on a scale from 1 (*never*) to 5 (*very often*). Cronbach's alpha for the survey was (α =0.92).

2.1.5.2 The Eating Motivation Survey (TEMS)

The Eating Motivation Survey (Renner et al., 2012) included liking (e.g., "*I eat what I eat… because I think it is delicious*"), health (e.g., "*... to maintain a balanced diet"*), pleasure (e.g., "*... in order to reward myself"*), social (e.g., "*... because it makes social gatherings more comfortable*"), visual appeal (e.g.,*"... because it is nicely presented*"), weight control (e.g.,*"...because it is low in calories*") and affect regulation (e.g., *"... because it cheers me up*) subscales (37 items), providing good reliability (α = 0.88). Each item was rated on a scale from 1 (*never*) to 7 (*always*).

2.1.5.3 Brief Self-Control Scale

The Brief Self-Control Scale (Tangney, 2004) was used as an assessment of trait-level self-control. This scale included 13 items (e.g. "*Sometimes I can't stop myself from doing something, even if I know it is wrong.*", "*Pleasure and fun sometimes keep me from getting work done*") rated on a scale from 1 (*not at all*) to 5 (*very often*), providing a statistically reliable measure of individual differences in self-control ($\alpha = 0.90$).

2.1.5.4. Difficulties in Emotion Regulation Survey (DERS)

The DERS included 36 items representing six subscales: non-acceptance of emotional responses (e.g., "*When I'm upset, I become angry with myself for feeling that way*."), difficulties engaging in goal-directed behaviour (e.g., "*When I'm upset, I have difficulty getting work done*."), impulse control difficulties (e.g., "*When I'm upset, I lose control over my behaviors*."), lack of emotional awareness (all reverse coded items; e.g., "*I care about what I am feeling."*), limited access to emotion regulation strategies (e.g., "*When I'm upset, I believe that wallowing in it is all I can do*."), and lack of emotional clarity (e.g., *" I have no idea how I am feeling*.") (Gratz & Roemer, 2003). Each item was rated on a scale from 1 (*almost always*) to 5 (*almost never*). This survey provided excellent reliability ($\alpha = 0.95$).

2.1.5.5. Emotion Regulation Questionnaire

The Emotion Regulation Questionnaire consisted of 10 items measuring reappraisal (e.g., "*When I'm faced with a stressful situation, I make myself think about it in a way that helps me stay calm*.") and suppression (e.g., "*When I am feeling negative emotions, I make sure not to express them*.") (Gross and John, 2003). Each item was rated on a scale from 1 (*strongly* *disagree*) to 7 (*strongly agree*). Cronbach's alpha for reappraisal items was $\alpha = 0.80$, and for suppression items was $\alpha = 0.77$.

2.1.5.6. Additional Measures

Prior to completion of the inhibition tasks, participants were asked to rate their hunger levels on a scale from 1 (*not hungry at all*) to 7 (*very hungry*). After completing the task and aforementioned questionnaires, they reported their weight goals (*lose, maintain,* or *gain weight*) and completed 7-point Likert scales on their current emotional state (1= *very negative* to 7 = *very positive*), the importance (1 = *not important at all* to 7 = *very important*) and difficulty (1 = *not difficult at all* to 7 = *very difficult*) of eating healthily, weight concerns (1 = *not concerned at all* to 7= *very concerned*). Later on, they rated food items used in the inhibition task on a taste (1 = *not tasty at all* to 7 = *very tasty*) and health scale (1= *not healthy at all* to 7= *very healthy*). Finally, they were asked to what extent the situation they described in the survey phase has changed (1 = *remained the same* to 7 = *completely changed*) and how they feel about the situation now (1 = *completely negative* to 7= *completely positive*). These questions were asked separately for negative and positive memories, each providing the keywords that were used in the task trials.

2.1.6. Procedure

Prior to the experiment on a different day, participants were asked to fill out an initial survey, where they reported recent negative and positive personal experiences (as described in section 2.1.3.). In the following (up to) 5 days, they were provided with a link to join the online experiment, including the Go/No-Go Task.

In the experimental part of the study, participants initially answered questions on their gender, age and current hunger level. Then, they proceeded with the Go/No-Go task, which was followed by the self-report measures (outlined in 2.1.5). The experiment and surveys were coded online using the PsyToolkit platform (Stoet, 2010, 2017).

2.1.7. Behavioural Analysis

The outcome measure for inhibitory control was computed by calculating the percentage of no-go trials with commission errors (i.e., when participants pressed when they were supposed to withhold) (Wessel, 2018). Omission rates (where participants did not respond to go-trials) and reaction time in go trials were also included in the analysis (Batterink et al., 2010). Decreased omission rates and reaction times were expected to indicate a higher response tendency. Decreased proportion of inhibitions reflected poorer inhibitory control.

2.1.8. Statistical Analysis

R Studio (version 4.3.2), JASP (Version 0.18.3), and IBM SPSS Statistics (Version 21.0) were used for computing outcome variables and inferential statistical analyses, preregistered at https://osf.io/uz5gf. Values exceeding three standard deviations from the mean were considered outliers, and inhibition scores with omission rates that were three standard deviations away from sample mean were excluded from the analysis (1% of the values) as this reflects poor task engagement rather than better inhibition performance (Labonte and Nielsen, 2023).

Linear Mixed Effects Models with maximal effect structure were preregistered to test our hypotheses. Condition (neutral vs negative vs positive), stimulus type (non-food vs healthy food vs unhealthy food) and condition x stimulus type interactions were included in the models as fixed effects, and subjects were fit as random effects. Our initial models included random subject intercepts and random slopes for condition, stimulus type and condition x stimulus type interaction. Following Akaike and Bayesian Information Criterion and considering singular fit warnings, we carefully simplified our models by removing random slopes for interaction, stimulus type and condition (Meteyard & Davies, 2020). We calculated p-values using F-tests with Satterthwaite's approximation for degrees of freedom, applied to Type III Sums of Squares for all models (Meteyard & Davies, 2020). However, all models have shown values exceeding 10 for the variance inflation factor (VIF), where the severe multicollinearity issue could not be addressed even after several attempts of model simplifications and data transformations. Therefore, we deviated from preregistered analyses and used two-way repeated measures of ANOVA by including affective state condition and stimulus type as within-subjects effects as this approach is not affected by multicollinearity.

In order to assess the relationship between the self-report measures and the behavioural measures of inhibition (i.e. proportion of inhibitions, reaction times and omission errors in the Go/No-Go Task, by using difference scores between conditions), Pearson's or Spearman's correlations were performed and reported by considering pair-wise normality and accounting for outliers.

2.2. Results

Table 1.1. ***Descriptive Data: Self-Reported Measures***

Measure	Mean	SD	Min	Max
Hunger	3.000	1.64	1	6

Measure	Mean	SD	Min	Max
BMI	23.03	3.92	16	32
Restrained Eating	2.28	0.93	1.1	4.7
Emotional Eating	2.43	0.98	1.15	3.92
External Eating	3.13	0.74	1.7	4.5
TEMS Liking	5.6	0.77	4	7
TEMS Health	4.34	1.2	2	7
TEMS Pleasure	4.93	0.88	3.6	6.8
TEMS Social	3.9	1.23	1	7
TEMS Visual Appeal	3.8	1.1	1.2	6.8
TEMS Weight Control	2.87	1.36	1	6.4
TEMS Affect Regulation	3.6	1.45	1	7
Trait Self-Control	3.16	0.67	1.62	4.69
DERS Nonacceptance	3.12	0.97	1.33	5
DERS Goal	2.49	0.79	1.2	4.4
DERS Impulse	3.5	0.8	1.67	4.83
DERS Strategies	3.15	0.87	1.57	4.86
ERQ Reappraisal	4.86	0.93	3.17	6.83
ERQ Suppression	3.83	1.29	1.25	6.25
Weight Concern	4.10	2.15	1	7
Emotional State	4.15	1.37	2	7
Importance of Healthy Eating	5.28	0.9	3	7

Measure	Mean	SD	Min	Max
Difficulty of Healthy Eating	4.28	1.49	1	7

Descriptive data for self-report measures are provided in Table 1.1, descriptive data for the proportion of inhibitions and omissions, and reaction time in go-trials are provided in Table 1.2, Table 1.3 and Table 1.4, respectively. 61.5% of the participants reported their weight goal as losing weight (*N*=24), 35.9% of the participants reported as maintaining weight (*N*=14), and one participant reported as gaining weight (2.6%).

2.2.1. Proportion of Inhibitions

Table 1.2. ***Descriptive Data: Proportions of Inhibitions***

Stimulus Type	Condition	Mean	SD	SE	Min	Max
Household Items	Negative	0.90	0.12	0.02	.56	1
	Positive	0.91	0.08	0.01	.69	1
	Control	0.91	0.11	0.02	.63	1
Unhealthy Food	Negative	0.90	0.1	0.02	.63	1
	Positive	0.93	0.09	0.01	.75	1
	Control	0.92	0.1	0.02	.63	1
Healthy Food	Negative	0.90	0.13	0.02	.50	1
	Positive	0.90	0.1	0.02	.63	1
	Control	0.91	0.1	0.02	.63	1

Note. 1% of the inhibition values that showed outlying omissions (*N*=3) and an outlier inhibition value were excluded in the analysis.

A two-way repeated measures ANOVA was conducted to test whether the proportions of inhibitions were decreased in the negative affect condition across all stimulus types or only towards unhealthy food stimuli. Therefore, Condition (three levels: control, negative, and positive) and Stimulus type (three levels: non-food, healthy food and unhealthy food stimuli) were used as within-subjects effects factors. Mauchly's test indicated that assumption of sphericity was violated for both Condition (χ^2 (2) = 10.76, p =.005) and Stimulus type (χ^2 (2) = 6.47, p =.039) but not for Condition x Stimulus type interaction. Therefore, degrees of freedom were corrected by Huynh-Feldt estimates of sphericity (ε =.82 for condition and ε =.89 for stimulus type).

Unexpectedly, analyses revealed no significant effect of Condition (F (1.64, 59.11) = 1.63, p =.31, η_p^2 =.031), Stimulus type (F (1.79, 64.38) = .38, p =.66, η_p^2 =.010) or their interaction, (F (4, 150) = .21, p =.93, η_p^2 =.006).

2.2.2. Proportion of Omissions

Table 1.3. ***Descriptive Data: Proportions of Omissions***

Stimulus Type	Condition	Mean	SD	SE	Max
Household Items	Negative	0.016	0.026	0.004	.12
	Positive	0.014	0.035	0.006	.19
	Control	0.014	0.024	0.004	.11
Unhealthy Food	Negative	0.022	0.042	0.007	.19
	Positive	0.017	0.030	0.005	.19
	Control	0.021	0.035	0.006	.13

Stimulus Type	Condition	Mean	SD	SE	Max
Healthy Food	Negative	0.026	0.043	0.007	.16
	Positive	0.007	0.020	0.003	.09
	Control	0.016	0.035	0.006	.18

Note. Minimum values for all conditions were zero, 1% of the values were outliers (*N*=3) and excluded from analysis.

To test whether omission errors were decreased towards unhealthy stimuli compared to healthy food and non-food stimuli in negative condition, a two-way repeated measures ANOVA was conducted including Stimulus type and Condition as within subject effects. As the assumption of sphericity was violated for Stimulus type (χ^2 (2) = 14.57, p <.001) and for Stimulus type x Condition interaction (χ^2 (9) = 24.99, p =.003), Huynh-Feldt estimates of sphericity was used to correct the degrees of freedom for Stimulus type (ε =.78) and for interaction (ε =.88).

Contradicting our hypothesis, analyses revealed no significant within-subject effects of Condition (F (2, 74) = 2.57, p =.08, η_p^2 =.065) and Stimulus type, (F (1.55, 57.35) = 1.06, p =.33, η_p^2 =.028) nor significant interaction between them, (F (3.5, 129.67) = 1.02, p =.40, η_p^2 =.037).

2.2.3 Reaction Times

Table 1.4. ***Descriptive Data: Reaction Times***

Stimulus Type	Condition	Mean	SD	SE	Min	Max
Household Items	Negative	458.36	52.92	8.7	361.92	604.07

Stimulus Type	Condition	Mean	SD	SE	Min	Max
	Positive	468.94	66.78	10.98	343.17	621.33
	Control	467.73	78.24	12.86	334.8	675.19
Unhealthy Food	Negative	463.91	76.69	12.61	335.29	700.21
	Positive	457.64	68.83	11.32	329.16	665.06
	Control	456.83	72.92	11.99	330.63	656.19
Health Food	Negative	462.22	80.28	13.2	316.91	669.72
	Positive	451.47	61.09	10.04	326.13	615.66
	Control	455.99	65.09	10.7	345	650.38

Note. Less than 1% of the values were outliers and excluded from the analysis (*N*=2).

To test reaction time differences between conditions as a function of Stimulus type, a two-way repeated measures ANOVA was conducted. The assumption of sphericity was violated for the within-subject effect of Stimulus type (χ^2 (2) = 41.1, p <.001) and Condition x Stimulus type interaction (χ^2 (9) = 23.43, p=.005). To correct the degrees of freedom, Greenhouse-Geisser estimates of sphericity were applied for Stimulus type (ε =.59) for stimulus type and Huynh-Feldt for the interaction (ε =.86).

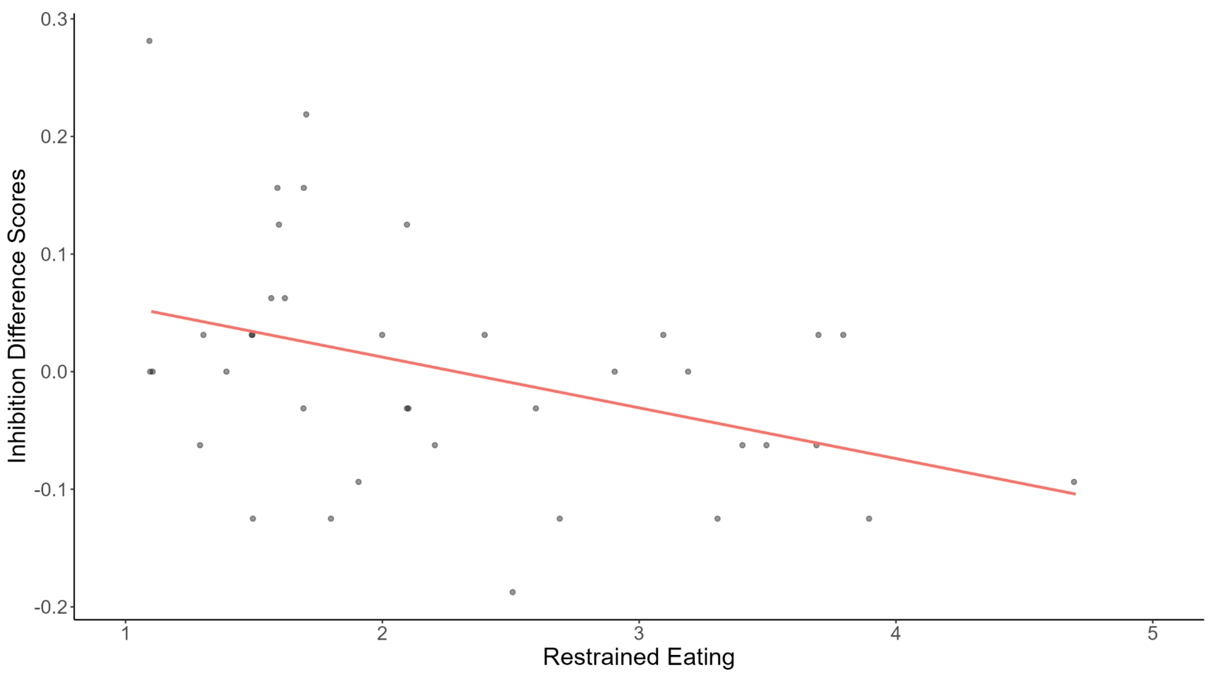
Analysis revealed no significant effect of Condition (F (2, 72) = .067, p =.94, η_p^2 =.002, Stimulus type (F (1.18, 42.58) = 1.1, p =.31 η_p^2 =.030) nor an interaction between them (F (3.45, 124.29) = 1.06, p =.38, η_p^2 =.029), which was not in line with our hypothesis.

2.2.4. Secondary analyses: Self-report measures and inhibition performance

To assess the relationship between self-report and behavioural measures, a series of regression analyses were performed. First, difference scores for the outcome measures in each affective state condition were calculated by calculating the mean of inhibition, reaction time, and omission scores across healthy food and non-food stimuli and subtracting this mean score from the corresponding scores for unhealthy food stimuli. Lower values of this inhibition difference score reflect decreased inhibitory control towards unhealthy food compared to healthy food and non-food stimuli. Lower values of reaction time and go-omission difference scores reflected increased approach tendency towards unhealthy food compared to healthy food and non-food stimuli. Higher values of go-omissions reflected lapse in attention (Meule, 2017). Bivariate correlations were performed by using these difference scores and all self-report measures outlined in section 2.1.5. Considering pair-wise normality and data distributions, Pearson's or Spearman's correlations were performed for computed difference scores and all scale outcomes.

2.2.4.1. Negative Condition

Figure 1. ***Correlation between restrained eating and inhibitions in the negative condition to unhealthy food compared to other stimuli***



Note. Correlation between inhibition difference scores (i.e. proportion of inhibitions towards unhealthy food compared to healthy food and non-food stimuli in negative affect condition) and restrained eating. Please note that the effect remains (r (35) = -.35, p=.036) if the data point on the left is excluded.

Analyses revealed that increased scores of restrained eating were correlated with a decreased proportion of inhibitions towards unhealthy stimuli in the negative condition compared to inhibitions towards other stimuli (i.e. healthy food and non-food stimuli) within the same (i.e., negative) condition (r (36) = -.40, p=.012), (please see Figure 1). No other self-report measures correlated with the difference scores of outcome variables in the negative affect condition (all *p*s>.05).

2.2.4.2. Positive Condition

In contrast, in the positive condition, increased eating motivation to regulate affect was associated with decreased reaction time (r(34)= -.49, p=.002) and increased omissions towards unhealthy food compared to other stimuli (r(37)= .38, p=.017). In addition, increased emotional eating was also associated with decreased reaction time (r(34)= .41, p=.014) and increased omissions towards unhealthy food in the positive condition compared to other stimuli (r(37)= .39, p=.014). This pattern might reflect that the positive affect induction might have resulted in higher response tendency towards unhealthy food and a lapse of attention (Meule, 2017). Increased motivation to eat for pleasure (r(34)= -.35, p=.037) and weight control (TEMS) (*r*s (34)= -.41, p=.014) were also associated with decreased reaction time to unhealthy food stimuli compared to other stimuli. Importantly, inhibition difference scores in the positive condition did not correlate with any self-report measures (all *p*s > .05), reflecting that restrained eating was associated with poor inhibition to unhealthy food only when negative affect is induced. All other correlations with difference scores in this condition were not significant (all *p*s>.05)

2.2.4.3. Neutral Condition

Reaction times, inhibition or omission difference scores in the neutral condition did not correlate with any measures (all *p*s>.05).

2.2.4.4. Restrained Eating and Other Individual Differences Measures

Because restrained eating was correlated with impaired inhibition performance towards unhealthy food in the negative condition, we explored which other individual differences measures were associated with restrained eating to shed some light on this finding. Not surprisingly, increased restrained eating was strongly associated with decreased liking motivation to eat (e.g.,. "*I eat what I eat because it is delicious, I have an appetite for it, it tastes good* ") (r (36)= -.48, p=.02), decreased social motivation to eat ("*...because it makes social gatherings more comfortable*") (r (36)= -.36, p=.02) and increased weight control motivation (r (36)= .79, p<.001). Interestingly, increased restrained eating was associated with increased non-acceptance (DERS), which reflects emotion regulation difficulty (r_s (37) = -.33, p=.042). All other correlations were not statistically significant (all ps>.05).

2.3. Discussion

To address whether negative affect causes decreased cognitive capacity to inhibit, Study 1 tested whether inhibitory control would be impaired in the negative affect condition compared to the control condition and whether this would be extended towards all stimulus types. None of the outcome measures of inhibition differed across negative, positive and neutral affect conditions and towards food and non-food stimuli. However, exploratory correlational analyses suggested that the proportion of inhibitions was decreased towards unhealthy food compared to other types of stimuli (i.e., healthy food and non-food) as restrained eating scores were increased in negative affect.

Indeed, several studies have shown that restrained eaters might show behavioural disinhibition towards high-calorie food compared to low-calorie and non-food stimuli

(Nederkoorn et al., 2004; Zhang et al., 2019). Our results illustrate how the relationship between restrained eating and decreased inhibition to unhealthy food is limited to the negative affect condition, extending findings that restrained eaters might show poorer ability to resist unhealthy food in the presence of negative affective states (Evers et al., 2018; Liu et al., 2020; Reichenberger et al., 2020; Shapiro & Anderson, 2005). Indeed, restrained eating has been shown to be associated with disinhibited eating, and this relationship is mediated by negative ruminative thinking, which is a maladaptive emotion regulation strategy (Brytek-Matera et al., 2021), thus our findings might represent maladaptive emotion regulation.

Even though we did not have a specific prediction regarding inhibition performance in the positive condition, exploratory analyses have revealed potentially interesting patterns that could be tested in future research. Both emotional eating (as measured by DEBQ) and increased eating motivation to regulate affect (by TEMS) were associated with increased response tendency towards unhealthy food in the positive condition, as reflected by decreased reaction times. This may challenge some findings showing that positive affect leads to increased willingness to eat healthy food (e.g., Schubert & Bode, 2023). However, it extends the arguments that positive affect might also lead to justification of unhealthy choices (e.g., "I deserve a treat, I can reward myself") (Taylor et al., 2014; Witt Huberts et al., 2012). Indeed, positive words presented in this condition dominantly consisted of compliments or words about completed tasks, such as "*achieved; successful; smart*", which may lead to justification of unhealthy food choices as rewards.

Importantly, Study 1 has several limitations. Firstly, it is commonly expected that inhibition towards non-food items would be increased compared to food items within the same condition due to response (i.e., approach) tendency towards rewarding stimuli (Tsegaye et al., 2022). However, analyses did not show a significant effect of Stimulus type. This could reflect that the elected Go/No-Go Task might not have successfully challenged the dominant response tendency. Secondly, due to high omission rates reflecting poor task engagement and leading to overestimated inhibition rates, 1% of the data points were excluded from the analyses. This was not expected and, therefore, not pre-registered. It could indicate that, besides go-trials, participants also might not have engaged with the emotional words.

To address these concerns, we conducted a second study with a larger sample and improved the task design, by including attention check trials and faster stimulus representation. We aimed to replicate the exploratory findings in relation to restrained eating, but also to prevent high omission errors and to increase task engagement and error rates that more efficiently challenge automatic response tendencies.

3. Study 2

3.1. Method

3.1.1. Participants

Sixty participants from the Prolific research panel were recruited and financially compensated. Due to drop-outs from the survey phase to the experiment phase, the final sample included a total of N=47 participants (27 female, 20 male; M_{age}= 35.04 years, SD_{age}=12.11 years). In line with the pre-registered outlier criteria, N=3 participants were excluded from the analyses due to missing over 50% of attention check trials.

Data from a separate pilot sample (N=12) was used for sample size estimation by including effect sizes for a Condition x Stimulus type interaction for a two-way repeated measures ANOVA. G-Power analyses revealed a large effect size for proportion of inhibitions (η_p^2 =.117), which led to sample size estimation of *N*=8; a medium effect size for go-omissions (η_p^2 =.057) leading to sample size estimation of *N*=15 all at an α of .05 and power at .80. To replicate the exploratory findings showing an association between restrained eating and decreased inhibitions towards unhealthy food compared to other stimuli in the negative condition, effect size *r* =.40 was used in G-Power analysis. The sample size estimated at an α of .05 and power at .80 was *N*=34, which was also adequate for sample sizes estimated for inhibition outcome measures and analyses. As high omission rates and outliers in Study 1 led to exclusions, we recruited *N*=60 participants to account for potential dropouts. *N*=13 participants did not proceed with the study after the survey phase, and *N*=3 participants were excluded from the analyses due to high errors in attention check trials (i.e., outlier values in attention check trials accuracy).

The study was approved by the Ethics Committee of the University of Reading and followed the Declaration of Helsinki. All participants received informed consent and confirmed it before taking part in the study.

3.1.2. Go/No-Go Task

The Go/No-Go Task was consistent with what was described in 2.2.4, except for some minor changes. First, to increase task difficulty and engagement with emotional words, the Go/No-Go Task included an additional 12 attention check trials. During attention check trials, participants were asked to press the letter b on the keyboard when the presented words were written in all capital cases. Each condition of food and non-food test blocks included two attention check trials, which were placed randomly in each block. Secondly, stimulus duration was decreased by 50 milliseconds (150 ms). In addition, to reduce omission rates, we instructed participants that the task would take longer in case of errors. Lastly, we found no difference across the first and second half of trials in the pilot study, therefore, we reduced the trial number to 40 trials per condition, keeping the same ratio of go to no-go trials (cf. Tsegaye et al., 2022). All remaining self-report measures and main features of the experimental design remained identical to Study 1.

3.1.3. Statistical Analysis

Analyses described in 2.2.8 were consistently applied, including outlier consideration and exclusions due to omission rates by using the same software programs. Planned analyses, hypotheses and data exclusion criteria were preregistered at: https://osf.io/dzrp2. Importantly, hypotheses on reaction times were omitted in this study as Study 1 has revealed some unexpected patterns, potentially caused by post-error slowing (Guan & Wessel, 2022). Therefore, a two way repeated measures ANOVA was conducted on reaction times and reported for consistency and exploratory reasons.

Although Linear Mixed Effects Models were preregistered as planned analyses, due to severe multicollinearity issues, two-way repeated measures of ANOVAs with Condition (negative, positive and neutral) and Stimulus type (unhealthy, healthy and non-food stimuli) as within-subject factors were performed on the proportion of inhibitions and omissions and reaction times. As described in 2.2.8, Spearman's and Pearson's correlations were performed to assess the relationship between self-report measures and inhibition difference scores accounting for outliers and pair-wise normality.

3.2. Results

Descriptive data for self-report measures are provided in Table 2.1. Participants reported their weight goals as follows: *N*=27 to lose weight (61.4%), *N*=11 to maintain weight (25%), and *N*=6 to gain weight (13.6%). Descriptive data for the proportion of inhibitions and omissions, and reaction time in go-trials are provided in Table 2.2, Table 2.3 and Table 2.4, respectively.

Table 2.1. ***Descriptive Statistics: Self-Reported Measures***

	Mean	SD	Min	Max
Hunger	2.91	1.86	1	7
BMI	24.29	5.39	14	39
Restrained Eating	2.71	0.49	1.7	4
Emotional Eating	2.48	1.19	1	5
External Eating	3.07	0.85	1.6	4.9
TEMS Liking	5.46	0.88	3.2	7
TEMS Health	4.56	1.21	2.4	7
TEMS Pleasure	4.62	1.25	1.2	7
TEMS Social	3.61	1.24	1	6.67
TEMS Visual Appeal	3.58	1.31	1.4	6.6
TEMS Weight Control	2.99	1.41	1	6.8
TEMS Affect Regulation	3.15	1.66	1	7
Trait Self-Control	2.98	0.88	1.39	4.85

Table 2.1. ***Descriptive Statistics: Self-Reported Measures***

	Mean	SD	Min	Max
DERS Nonacceptance	3.47	0.89	1	5
DERS Goal	3.05	0.81	1.6	4.8
DERS Impulse	3.42	0.86	1.17	5
DERS Strategies	3.49	0.81	1.57	4.86
ERQ Reappraisal	4.74	0.92	2.5	6.7
ERQ Suppression	4.02	1.44	1	6.5
Weight Concern	4.27	1.81	1	7
Emotional State	4.89	1.33	1	7
Importance of Eating Healthily	5.55	1.11	3	7
Difficulty of Eating Healthy	4.12	1.88	1	7

3.2.1. Proportions of Inhibitions

Table 2.2. ***Descriptive Data: Proportion of Inhibitions***

Stimulus Type	Condition	Mean	SD	SE	Min	Max
Household Items	Negative	0.91	0.1	0.02	0.5	1

Stimulus Type	Condition	Mean	SD	SE	Min	Max
	Positive	0.85	0.15	0.03	0.5	1
	Control	0.85	0.16	0.03	0.25	1
Unhealthy Food	Negative	0.88	0.16	0.03	0.5	1
	Positive	0.90	0.16	0.03	0.33	1
	Control	0.89	0.16	0.03	0.5	1
Healthy Food	Negative	0.87	0.17	0.03	0.33	1
	Positive	0.85	0.27	0.04	0	1
	Control	0.79	0.22	0.04	0.25	1

Note. As preregistered, 1.1% of the values were excluded due to being outliers (N=4), and 1.4% were excluded due to outlier omission rates (N=5). Overall, 2.5% of the values were excluded.

To test the effect of Condition on the proportions of inhibitions across the different types of stimuli, a two-way repeated measures ANOVA was performed. The assumption of sphericity was violated for Stimulus type (χ^2 (2) = 6.17, p =.046) and for the Condition x Stimulus type interaction (χ^2 (9) = 28.17, p =.001). Therefore, degrees of freedom were corrected using the Huynh-Feldt correction (ε =.89 for stimulus type, ε =.78 for interaction effect).

Analyses revealed no significant effect of Condition (F (2, 70) = 2.4, p=.099, η_p^2 =.064) or Stimulus type (F (1.8, 62.83) = 2.9, p=.07, η_p^2 =.077), nor the Condition x Stimulus type interaction (F (3.12, 109.36) = 1.31, p=.27, η_p^2 =.036), which were not in line with pre-registered hypotheses.

3.2.2. Proportions of Omissions

Table 2.3. ***Descriptive data: Proportions of Omissions***

Stimulus Type	Condition	Mean	SD	SE	Max
Household Items	Negative	0.016	0.04	0.006	0.19
	Positive	0.010	0.02	0.003	0.09
	Control	0.013	0.03	0.005	0.16
Unhealthy Food	Negative	0.013	0.04	0.005	0.16
	Positive	0.020	0.04	0.007	0.18
	Control	0.016	0.03	0.005	0.13
Healthy Food	Negative	0.014	0.03	0.005	0.14
	Positive	0.020	0.05	0.008	0.19
	Control	0.022	0.04	0.007	0.13

Note. 1.4% of the values were outliers and excluded from the analysis.

A two-way repeated measures ANOVA was performed by including Condition and Stimulus type as within-subject effects. Mauchley's test showed that sphericity was violated for a within effect of Condition (χ^2 (2) = 10.9, p =.004). Hence, the Huynh-Feldt correction was used to adjust degrees of freedom (ε =.82).

Contrary to our hypothesis, there was no significant effect of Stimulus type (F (2, 78) = .89, p= .42, η_p^2 =.022), Condition (F (1.66, 64.65) = .12, p= .85, η_p^2 =.003), and no significant interaction between them (F (4, 156) = .68, p= .61, η_p^2 =.017).

3.2.3. Reaction Times

Table 2.4. ***Descriptive data: Reaction Times***

Stimulus Type	Condition	Mean	SD	SE	Min	Max
Household Items	Negative	407.33	74.7	11.39	268.61	594.41
	Positive	399.59	66.3	10.12	275.5	572.63
	Control	398.74	73.1	11.14	289.68	539.38
Unhealthy Food	Negative	424.59	100.86	15.38	258.41	713.19
	Positive	409.21	79.79	12.17	279.38	599
	Control	400.09	73.67	11.23	250.44	585.25
Healthy Food	Negative	420.97	108.64	16.57	269.87	758.69
	Positive	407.15	80.12	12.22	268.08	569.63
	Control	407.13	77.76	11.86	252.56	556.31

Note. 2.5% of values were outliers and excluded from the analysis

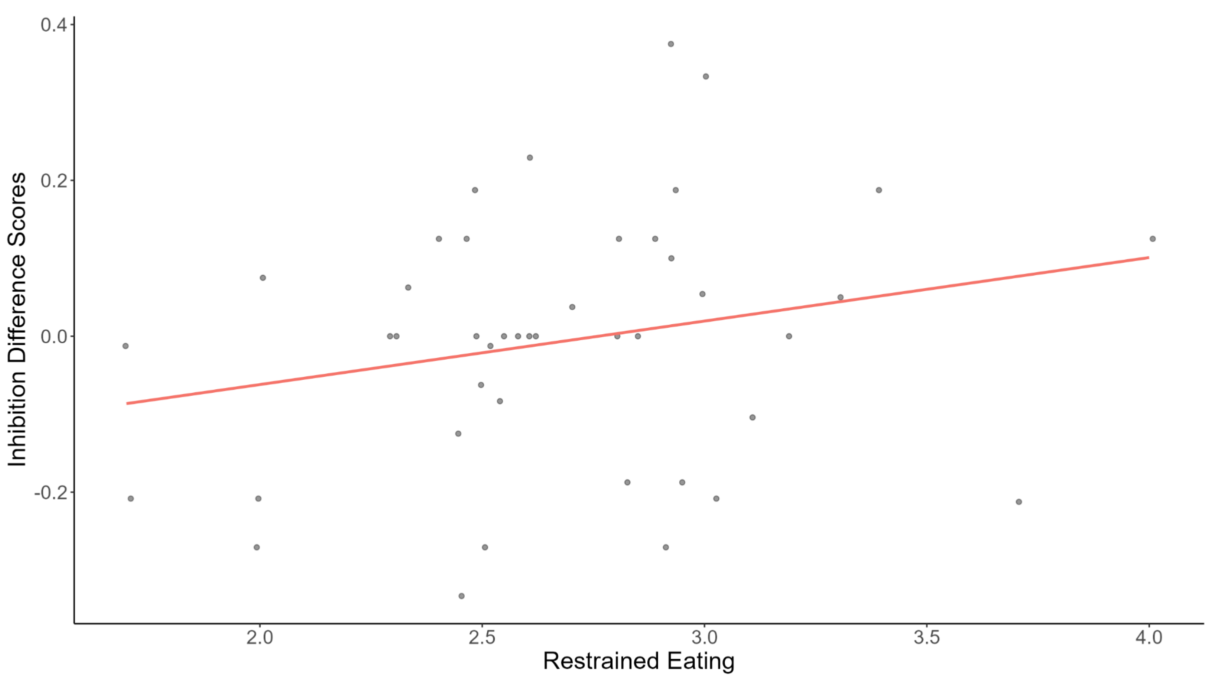
The reaction time differences between conditions as a function of stimulus type were tested by a two-way repeated measures ANOVA. For the within-subject effect of Stimulus type (χ^2 (2) = 32.5, p <.001) and the Condition by Stimulus type interaction (χ^2 (9) = 63.09, p <.001), the assumption of sphericity was violated. Greenhouse-Geisser estimates of sphericity were applied for Stimulus type (ε =.65) and for the Condition x Stimulus type interaction (ε =.57) to correct the degrees of freedom.

Analyses revealed no significant effect of Condition (F (2, 84) = 2.86, p =.06, η_p^2=.064), Stimulus type (F (1.29, 54.29) = 1.62, p =.21 η_p^2=.037) or the Condition x Stimulus type interaction (F (2.28, 95.84) = .57, p =.59, η_p^2=.013).

3.2.4. Secondary analyses: Self-report measures and inhibition performance

As described in 2.2.4, difference scores of outcome measures towards unhealthy compared to the other stimuli in each condition were calculated (e.g., inhibitions in the negative affect condition towards unhealthy food was subtracted by the mean inhibitions towards non-food and healthy food stimuli within the same condition). The relationship between self-report measures and difference scores were assessed by using Pearson's or Spearman's correlation following pair-wise normality and data distribution.

Figure 2. ***Correlation between restrained eating and inhibitions in the negative condition to unhealthy food compared to other stimuli***

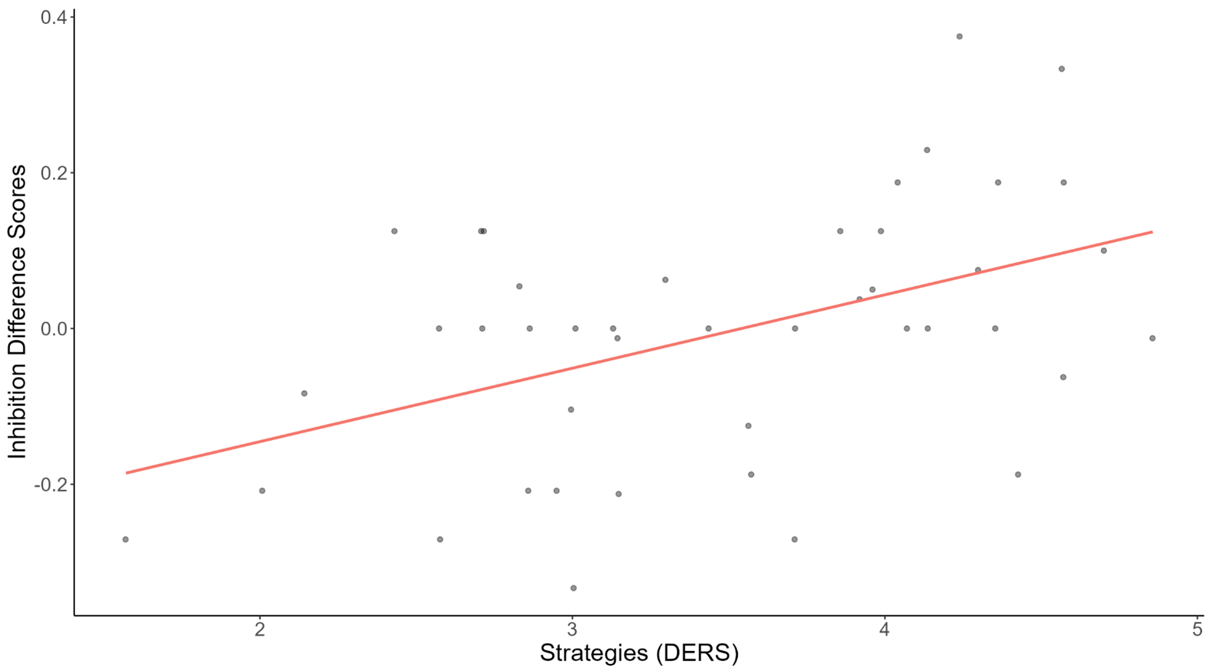


*Note***.** Relationship between inhibition difference score (i.e. proportion of inhibitions towards unhealthy food compared to healthy food and non-food stimuli in negative affect condition, lower values reflecting decreased inhibition to unhealthy food under negative affect only) and restrained eating (lower values reflecting decreased restrained eating).

It was hypothesised that increased restrained eating scores would be associated with decreased proportion of inhibitions towards unhealthy food in the negative affect condition compared to healthy food and non-food stimuli. However, we found no relationship between restrained eating and difference scores of inhibitions (r (41) =.23, p=.13), showing an opposite trend than it was in the study 1, possibly due to sample characteristics that is discussed further in section 4 (please see Figure 2). Restrained eating also did not significantly correlate with difference scores of omissions (r (41) =.05, p=.75) and reaction times (r (38) =.09, p=.60).

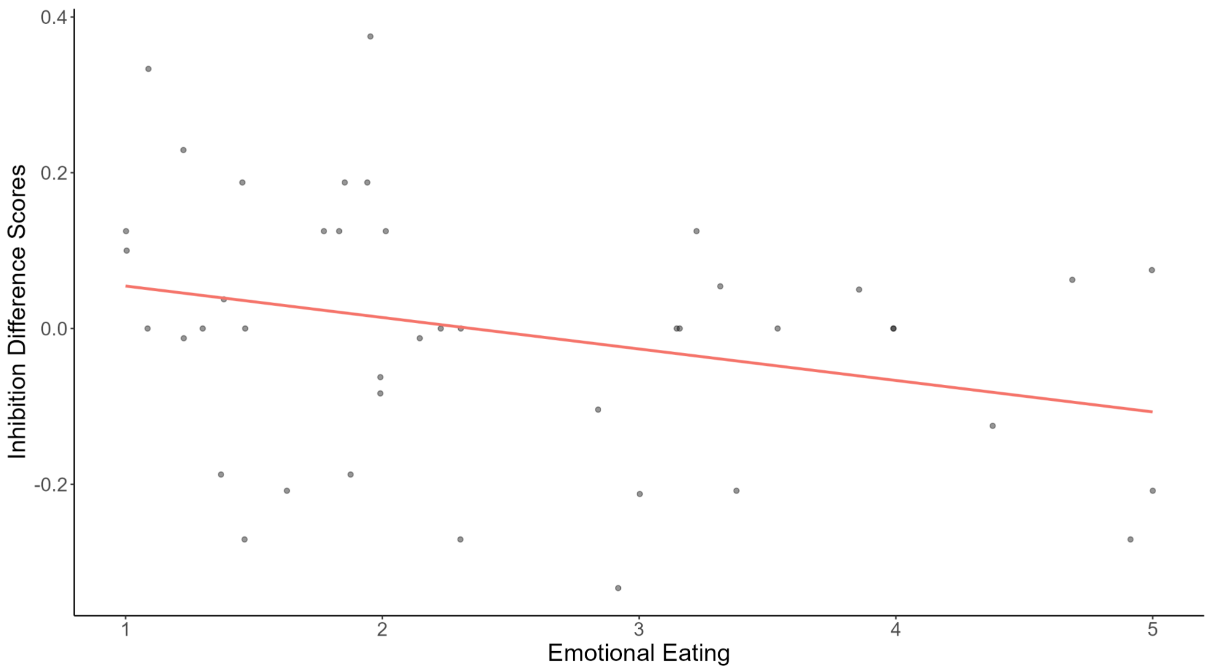
3.2.4.1. Negative Condition

Figure 3. ***Correlation between access to emotion regulation strategies and inhibitions in the negative condition to unhealthy food compared to other stimuli***



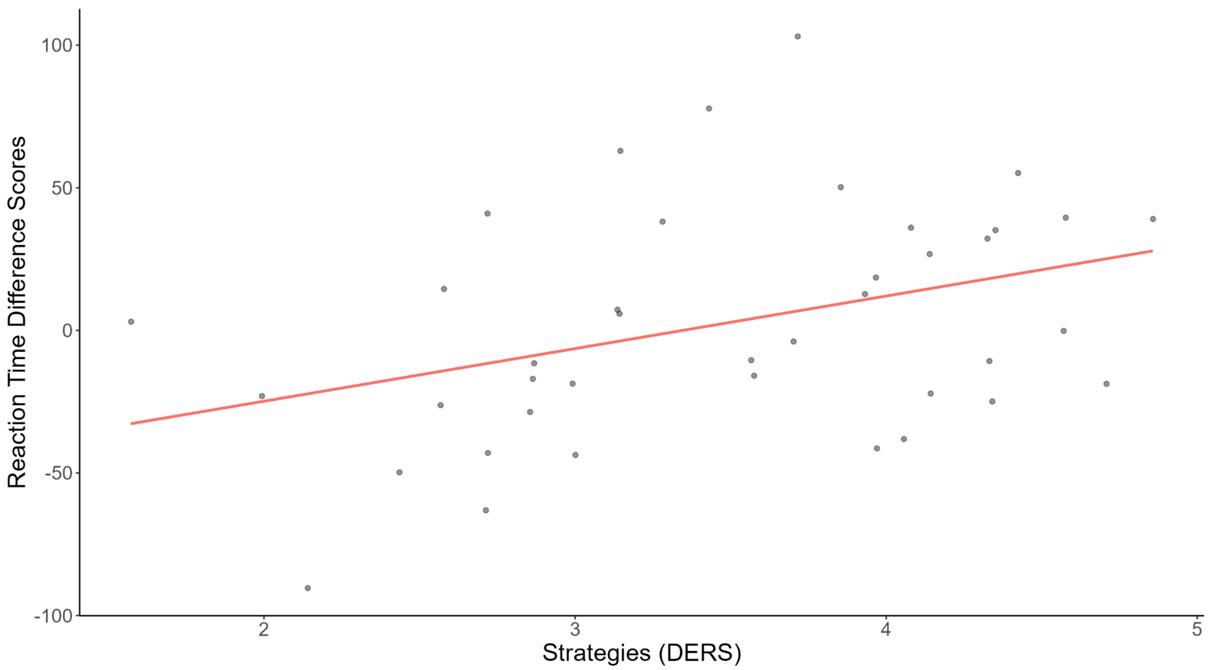
Note. Relationship between inhibition difference scores (i.e. proportion of inhibitions towards unhealthy food compared to healthy food and non-food stimuli in negative affect condition, lower values reflecting decreased inhibition to unhealthy food under negative affect only) and access to emotion regulation strategies (lower values reflecting decreased access to emotion regulation strategies).

Figure 4. ***Correlation between access to emotional eating and inhibitions in the negative condition to unhealthy food compared to other stimuli***



Note. Relationship between inhibition difference score (i.e. proportion of inhibitions towards unhealthy food compared to healthy food and non-food stimuli in negative affect condition, lower values reflecting decreased inhibition to unhealthy food under negative affect only) and emotional eating (lower values reflecting decreased emotional eating).

Figure 5. ***Correlation between access to emotion regulation strategies and reaction times in the negative condition to unhealthy food compared to other stimuli***



Note. Relationship between reaction time difference scores (i.e. reaction time towards unhealthy food compared to healthy food and non-food stimuli in negative affect condition, lower values reflecting increased response tendency towards unhealthy food under negative affect only) and access to emotion regulation strategies (lower values reflecting decreased access to emotion regulation strategies).

We explored whether other predictors of disordered eating would display associations with impaired inhibitions towards unhealthy food stimuli in the negative condition compared to other types of stimuli. Eating motivation to control weight and regulate affect (TEMS), and impulse control (DERS) did not show any significant relationship to inhibition difference score in the negative condition (*p*s>.05). However, as shown in Figure 3, decreased inhibitions towards unhealthy food stimuli in the negative condition compared to other types of stimuli was associated with decreased access to emotion regulation strategies (r (41) =.47, p=.002) and as shown in Figure 4, increased emotional eating (r_s (41) = -.31, p=.042). All other correlations with inhibition difference scores in this condition was not significant (*p*s>.05).

We also performed the same analyses on reaction time and omission difference scores in the negative condition as measures of response tendency. Decreased access to emotion regulation strategies was also associated with decreased reaction times towards unhealthy food stimuli compared to other stimuli (r (38) =.37, p=.018) reflecting higher response tendency to unhealthy food (please see Figure 5). Increased scores for the emotion regulation of suppression were also associated with this enhanced response tendency as reflected by decreased reaction times toward unhealthy stimuli compared to other stimuli (r (38) = -.35, p= .037), all other correlations with reaction time difference scores were not significant (*p*s>.05).

In contrast, increased omissions to unhealthy food stimuli in the negative condition compared to other stimuli was associated with increased importance of eating healthily (r_s (41) = .48, p<.001) and increased reappraisal (r_s (41) = .31, p =.006), reflecting decreased response tendency to unhealthy food. Omission difference scores in this condition did not correlate with any other measures (*p*s>.05).

3.2.4.2. Positive Condition

Reaction time and inhibition difference scores in the positive condition did not show any significant relationship with any individual differences measures (*p*s>.05). However, decreased omissions towards unhealthy food compared to other stimuli in the positive affect condition was associated with increased difficulty of eating healthily (r_s (40) = -.39, *p*=.011), reflecting higher response tendency to unhealthy food. All other correlations with omission difference scores in this condition were not significant (all *p*s>.05).

3.2.4.3. Neutral Condition

We also tested whether these predictors predicted reactions in the neutral condition. Interestingly, in the neutral condition, decreased reaction time to unhealthy stimuli compared to other stimuli was associated with decreased access to emotion regulation strategies (*r* (41) = .36, *p*= .019) and increased non-acceptance of emotions (*r* (41) = .31, *p*= .045), which may reflect that increased response tendency towards unhealthy food in the negative affect condition extend to other emotional states. In addition, decreased reaction time to unhealthy stimuli compared to other stimuli in the neutral condition was associated with increased liking (*r* (41) = -.31, *p*=.044), pleasure (*r* (41) = -.37, *p*= .014), and affect regulation motivations of eating (*r* (41) = -.33, *p*=.028) (TEMS). Omission and, importantly, inhibition difference scores in the neutral condition did not correlate with any self-report measures and all other correlations between reaction time difference scores and self-report measures were not significant (all *p*s>.05).

3.2.4.4. Access to Emotion Regulation Strategies

We further investigated whether access to emotion regulation strategies was associated with other predictors of maladaptive eating to better understand its relationship with increased response tendency and decreased inhibitions towards unhealthy food in the negative condition. Interestingly, decreased access to emotion regulation strategies was associated with decreased trait self-control (*r* (42) = .35, *p*= .022), increased difficulty to eat healthily (*r* (42) = -.45, *p*= .002), increased weight concern (*r* (42) = -.34, *p*= .024) and increased weight control (*r* (42) =

-.35, $p = .019$), increased emotional eating ($r\ (42) = -.39$, $p = .008$) and increased eating motivation to regulate affect (TEMS Affect Regulation) ($r\ (42) = -.42$, $p = .005$) and increased motivation to eat for pleasure ($r\ (42) = -.35$, $p = .021$), all other correlations were not significant (all $ps > .05$).

3.3. Discussion

Study 2 aimed to replicate the exploratory findings of Study 1 and test the inhibition outcome measures in negative, positive and neutral affective state conditions towards unhealthy food, healthy food and non-food stimulus types. First of all, we replicated the null effect showing that there were no differences in reaction times, proportion of inhibitions and omission towards different stimulus types across conditions. The replicated null effect provided additional evidence in line with Study 1 that negative affect may not impair (or improve) inhibitory control capacity towards any stimulus type in all participants.

We did not replicate the relationship between restrained eating and decreased inhibitions towards unhealthy food. Instead, we found that difficulty in emotion regulation was associated with decreased inhibitions towards unhealthy food in the negative affect condition. Specifically, under negative affect, limited access to emotion regulation strategies was strongly correlated with decreased inhibitions and also decreased reaction time towards unhealthy food on go trials in contrast to other types of stimuli (healthy food and non-food stimuli). In addition, suppression, as a maladaptive emotion regulation strategy known to be related to overeating (Görlach et al., 2016), was also associated with increased response tendency towards unhealthy food in the negative affect condition compared to other stimuli, as reflected by decreased reaction times. Conversely, reappraisal, as an adaptive emotion regulation strategy, was associated with decreased response tendency towards unhealthy food in the negative affect condition compared to other stimuli, as reflected by decreased proportion of go-responses (i.e. omissions). Indeed, engaging with adaptive regulation strategies has shown to be associated with decreased preference for unhealthy food (Langley et al.,2023; O'Leary et al., 2023; Taut et al., 2012) while maladaptive emotion regulation strategies leading to disinhibited eating (Evers at al., 2010; Nauman & Svaldi, 2021). Thus, our findings might suggest that if anything maladaptive emotion regulation tendencies are associated with increased response tendency and decreased ability to resist unhealthy food, rather than negative affect itself leading to impaired cognitive ability to inhibit.

4. General Discussion

This study aimed to test whether difficulties resisting unhealthy food under negative affective states are due to compromised cognitive capacity to inhibit. If cognitive capacity to inhibit is depleted, inhibition performance would be decreased (as reflected by decreased proportions of inhibitions and reaction times) in the negative condition regardless of stimulus type (both towards non-food and food items). However, both studies revealed that induced negative affect did not result in an impairment on inhibition performance, indicating that emotional eating may not represent depletion in cognitive resources necessary for inhibition.

In the first sample (Study 1), decreased inhibition towards unhealthy food in the negative affect condition was associated with increased restrained eating. This is in line with recent reviews and meta-analysis based on experimental data suggesting that restrained eating strongly predicts increased food consumption in response to negative states (Evers et al., 2018; Reichenberger et al., 2020). Indeed, it has been shown that unsuccessful restrained eaters show poorer inhibition towards food in a negative affective state compared to a neutral affective state (Liu et al., 2020). However, this finding was limited to neural markers of inhibitory control (e.g., N2a and P3 ERP amplitudes) and did not differentiate between behavioural responses to healthy and unhealthy food and a general inhibitory control impairment. Extending their findings, we show in Study 1 how negative affect results in behavioural disinhibition for restrained eaters, but only towards unhealthy food compared to other stimuli and not in the other affective states (i.e., positive and neutral). This highlights that disinhibited eating for restrained eaters is not caused by a trait-level impairment of inhibition ability or a generic impairment under negative affect.

We did not replicate the effects of restrained eating in Study 2. However, we found there that decreased access to emotion regulation strategies was strongly associated with decreased inhibitory control towards unhealthy food in the negative affect condition, reflected by difficulty inhibiting responses (i.e. higher no-go errors) but also increased response tendency (i.e., decreased reaction time on go-trials) towards unhealthy food compared to other types of stimuli. This might be in line with the arguments that such responses might represent maladaptive emotion regulation, maybe because access to alternative regulation strategies are limited.

It is important to acknowledge the discrepancies between the two studies in the exploratory findings. These might have been caused by the differences in the task designs and sample characteristics. First of all, the second study was more effective in challenging automatic response tendencies as reflected in the increased error rates compared to the first one. Consequently, increased task difficulty may have resulted in increased negative affect and posed more challenges for participants who had more difficulty in regulating emotional states. In addition, there were mostly young female participants (all being university students) in the first sample (82.5%), which is a population suggested to be more vulnerable to maladaptive restrained eating patterns that result in increased unhealthy food consumption and uncontrolled eating (Du et al., 2022; Liu et al., 2020), in contrast to the older and more gender balanced sample in study 2. Interestingly, restrained eating was significantly but inversely correlated with emotional eating in the second study, whereas there was a non-significant but trend for a positive association between emotional eating and restrained eating in the first sample. Some studies suggest that these patterns might indicate the level of success in dietary restraint, for instance, increased emotional eating and restrained eating together might reflect unsuccessful restraint eating, while increased restrained but decreased emotional eating might reflect successful restrained eating (cf. Kong et al., 2015). This is in line with findings that only unsuccessful restrained eaters are more likely to show poorer inhibition to unhealthy food in response to negative affect than successful restrained eaters (Liu et al., 2020). Therefore, demographic differences and possible differences in the success of dietary restraint could potentially explain why the findings on restrained eating did not extend to the second study. Future studies should further investigate whether success in restrained eating might be contributing to food responses differently under negative affect.

Taken together, the presented studies provided evidence that increased response tendency and difficulty to resist unhealthy food might occur selectively when negative affect is induced, but specifically in disordered eating and in the presence of emotion regulation difficulties. Future experimental studies are needed to test more directly, and preferably causally as well, whether for instance, strategic emotion regulation goals could impair inhibitory control towards unhealthy food in restrained eaters, selectively.

Future studies might also investigate the impact of different emotions and arousal levels in relation to difficulties of emotion regulation and its association with difficulties resisting unhealthy food. Although we included a range of emotional words that varied in arousal to ensure external validity, this may be interpreted as a limitation considering previous studies showing that different negative emotions (e.g., anger leading to less food consumption) may lead to different eating outcomes (Macht, 2008). However, including a range of negative emotional words for affect induction allowed us to test the arguments in a more ecologically valid way that cognitive resources redirected to emotion regulation is what impairs inhibitory control capacity in every-day life (O'Leary et al., 2023).

Interestingly, there was a substantial increase in the proportion of inhibitions in the negative condition towards healthy and non-food stimuli compared to the neutral condition in the second study, although not reaching the statistically significant threshold. This pattern overlaps with recent theoretical models suggesting that negative affect could improve cognitive control by signalling a need for behavioural regulation (Botvinick, 2007; Dignath et al., 2020; Inzlicht et al., 2015; Pourtois et al., 2020; Yang & Pourtois, 2018). This provides potential trends for future studies that may further investigate how such affective signalling may differently improve cognitive control in food contexts.

5. Conclusion

The present studies experimentally tested whether negative affect impairs cognitive capacity to inhibit differently in food and non-food context. Induced negative affect did not lead to decreased inhibitory control for any stimulus type. However, emotion regulation difficulties and restrained eating patterns were associated with decreased inhibitory control towards unhealthy food selectively in response to negative affect. Accordingly, we provided evidence that increased eating and unhealthy food choices do not necessarily reflect depleted cognitive resources to control.

Disclosure of Interest

The authors report no conflict of interest.

Data Availability Statement

The data that support the findings of this study are openly available in Open Science Framework at http://doi.org/10.17605/OSF.IO/MV9NF and http://doi.org/10.17605/OSF.IO/B5NWH.

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Footnotes

[1] The pilot study included two different counterbalanced task orders where either food and non-food blocks or emotion conditions were presented successively. *N*=20 participants started either with food or non-food task blocks where each emotion condition was counterbalanced within each stimulus block. *N*=22 participants started either with a neutral condition, negative condition or positive condition where each stimulus type was counterbalanced within each emotion condition. This was implemented in order to identify the most effective counterbalanced design in the full study for affect induction. G-Power analyses were conducted for each dependent variable: proportion of inhibitions and omissions and reaction time for separate two-way repeated measures of ANOVAs. Effect sizes for the stimulus type x condition interaction were used for sample size estimation. For the experiment design where each emotion condition was presented in separate blocks while stimulus type was randomised within each emotion

condition (i.e. emotion in blocks); analyses revealed a large effect size for proportion of inhibitions (η_p^2=.109), which led to sample size estimation of *N*=8; a small effect size for go-omissions (η_p^2=.010) leading to sample size estimation of N=85 and small to medium effect size for reaction time (η_p^2=.049) suggesting a sample size of N=17, all at an α of .05 and power at .80. For the experiment design where each stimulus type was presented in separate blocks where each emotion condition was randomised within food and non-food blocks (i.e. stimuli in blocks). We used stimuli in block design, as the pilot data showed expected patterns in line with hypotheses for each measure in each condition. Therefore, G-Power analyses for stimuli-in-blocks design is reported and was used for sample size estimation.

Appendix A. Stimuli Ratings

Table A.1.

Stimuli ratings for healthy items

	Health		Taste	
Items	Mean	SD	Mean	SD
Whole-wheat bread	3.65	0.89	3.07	1.11
Cucumber-sliced*	4.76	0.55	3.77	1.20
Mixed Vegetables*	4.93	0.29	3.15	1.29
Chicken Soup	4.12	0.66	3.32	1.28
Porridge	3.83	0.87	2.67	1.22
Mozzarella Salad	4.45	0.70	3.64	1.11

Boiled Eggs	4.31	0.69	3.71	1.17
No-sugar Muesli	3.67	0.87	3.12	1.02
Rye Crisp Bread	3.50	0.86	2.77	1.02
Cauliflower*	4.86	0.42	2.79	1.36
Mushrooms*	4.58	0.58	3.11	1.51
Grapefruit	4.62	0.58	3.92	1.13

Table A.2.

Stimuli ratings for tasty (i.e. unhealthy) items

	Health		Taste	
Items	Mean	SD	Mean	SD
Sweet Bakeries*	1.44	0.66	4.29	0.85
Pizza	2.00	0.90	4.03	1.01
Chocolate*	1.69	0.73	4.42	0.79
Doner Kebab	2.35	0.86	3.83	1.24
Gummy Candies	1.15	0.39	3.81	1.11

Ice cream (in a cup)	1.47	0.72	4.21	0.99
Lasagne	3.07	0.81	4.08	1.10
Burger*	2.16	0.91	4.14	1.07
Cake	1.34	0.56	3.66	1.24
Ice cream popsicles	1.65	0.69	3.77	1.10
French Fries*	1.61	0.68	4.39	0.89
Potato Chips	1.46	0.69	4.17	0.89

Appendix B. Supplementary Data for Study 1

All analyses and data can be accessed at: https://osf.io/mv9nf/

Appendix C. Supplementary Data for Study 2

All analyses and data can be accessed at: https://osf.io/b5nwh/

CHAPTER 3

Shifting priorities: Switching between health and indulgence motivational states impacts proactive inhibition towards unhealthy food.*

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Abstract

Understanding what enables people to resist unhealthy food is crucial for the development of interventions and policies to prevent the detrimental effects of an unhealthy diet on people's health such as obesity and various other diseases. The present study investigated the impact of temporary and malleable motivational states on inhibitory control towards unhealthy food, offering a proof of principle study. To this end, we tested whether a motivational state to eat healthily (versus to enjoy tasty food) facilitates inhibition towards unhealthy food at early (i.e., proactive) and/or later (i.e., reactive) stages of inhibition initiation. In a within-subjects design, participants ($N = 36$) switched between health and indulgence states while performing both a Go/No-Go Task and a Stop Signal Task using pictures of unhealthy and healthy food or neutral content. A health-oriented motivational state facilitated inhibition towards unhealthy but not healthy food items when inhibition was initiated early (Go/No-Go Task) compared to the indulgence state. In contrast, switching between states did not influence reactive inhibition as measured in the Stop Signal Task and this null-effect was replicated in a replication study. Our evidence highlights the potential of interventions targeting people's malleable motivational states in situations that require them to forgo unhealthy food proactively.

Keywords: food-specific inhibition, proactive & reactive inhibition, motivation, state

1. Introduction

Understanding unhealthy eating patterns is crucial for developing interventions and policies that prevent detrimental health problems such as obesity (Moschonis & Trakman, 2023). Impaired cognitive capacity is often assumed to underlie the inability to resist unhealthy food, for instance, due to low trait self-control or having already engaged in control (Baumeister et al., 2024; Inzlicht & Roberts, 2024; Troll et al., 2022; Wright & Mlynski, 2019). Yet, temporary and malleable motivational states (e.g., to eat healthily or to indulge) also account for eating behavior including the amount of food intake, the intensity of cravings, hunger-related hormone levels, or attention allocation towards unhealthy food (Franssen et al., 2022; Veit et al., 2020; Werthmann et al., 2016). The current study aimed to advance this line of research by investigating whether eating-related motivational states will impact the basic cognitive ability to control automatic tendencies and impulses towards unhealthy food. More specifically, we tested whether these states will impact inhibition even when the same participants switched between contrasting motivational states in the same experimental situation and for both reactive (i.e., late) and proactive (i.e., early) measures of inhibition.

It has been widely posited that people fail to resist unhealthy food due to an impairment in cognitive ability described as inhibitory control (Meule et al., 2011; Price et al., 2016; Tsegaye et al., 2022; Zhang et al., 2017). Inhibitory control refers to the effortful suppression of behavior (or thought, emotion, and attention) enabling individuals to overcome an immediate strong tendency, in order to achieve a desired or more appropriate state (Diamond, 2013; Tiego et al., 2018; Verbruggen & Logan, 2008). This ability can be compromised at the trait level (cf. Inzlicht & Roberts, 2024) or at the state level such as under cognitive load and physical exhaustion (Ferreira et al., 2024; Liang, 2021; Zhao et al., 2024). Impaired inhibitory control ability is associated with higher calorie consumption, increased body mass index (BMI), and unsuccessful dieting (Price et al., 2016; Tsegaye et al., 2022; Zhang et al., 2017). Conversely, improved inhibitory control ability (e.g., through training) is linked to greater weight loss and reduced unhealthy food intake and portion size, and is argued to be a potential intervention for obesity (De Klerk et al., 2023; Lawrence et al., 2015a, 2015b; Veling et al., 2014).

Alternative motivational explanations suggest that people fail to resist unhealthy food, not because of a lack of cognitive capacity but because they struggle to be motivated to resist a choice situation (Inzlicht & Schmeichel, 2012; Kopetz et al., 2018; Mayer & Freund, 2021). For instance, people might discard their weight control goals voluntarily when they are able to justify their overeating, such as when they feel licensed to relieve their stress and reward themselves (Prinsen et al., 2019) or to enjoy their free time better (Witt Huberts et al., 2012). According to this approach, self-control failure such as indulging in unhealthy food is led by the temporary shift of motivation from long-term 'have-to' goals to immediate gratification rather than the impaired cognitive capacity to resist temptation (Inzlicht et al., 2014; Hennecke & Bürgler, 2023; Fujita et al., 2024).

Indeed, several studies have shown that temporary motivational states influence eating behavior by affecting hormonal, neural, and cognitive responses, indicating temporary motivational states might be contributing to the self-control of eating more than previously thought (Bhanji & Beer, 2012; Franssen et al., 2022; Kochs et al., 2022; Schroder et al., 2014; Veit et al., 2020). For instance, inducing an indulgence state caused an increase in chocolate craving and intake (Franssen et al., 2022). Similarly, attention bias to high-caloric food was decreased in a health state (Werthmann et al., 2016). However, it is unclear whether states impact relevant processes when participants shift between motivational states in the same experimental situation, underlining their temporary nature and impact as suggested in the theories above. First evidence suggests that switching to a health state from an indulgence state (i.e. focusing on health aspects of food instead of hedonic aspects) resulted in choosing reduced portion sizes (Veit et al., 2020). We aim to extend this line of work to a basic, important response in the food context: inhibitory control.

Food-specific inhibitory control is commonly measured by the Go/No-Go and Stop Signal paradigms. In both of these paradigms, participants are asked to respond to go-trials which occur in high probability. In the Stop Signal Task, participants are asked to withhold their (already initiated) response if a stop signal appears following a go-stimulus (Verbruggen and Logan, 2008). In the Go/No-Go Task, inhibition is required on no-go trials before any go response is initiated and go and no-go stimuli are never presented in the same trial (Wessel, 2018). Although the Stop-Signal Task and Go/No-Go Task have been used to measure food-specific inhibitory control interchangeably, recent studies suggest that they utilize different mechanisms of the inhibition process (Littman & Takacs, 2017; Meule et al., 2011).

Indeed, two distinct inhibitory control processes have been proposed in this context: proactive inhibition, as measured in the Go/No-Go Task, which is a goal-directed mechanism and occurs before response initiation, and reactive inhibition, as measured in the Stop Signal Task, which is a stimulus-driven mechanism and occurs after a response has been initiated, thus acting as a ‘late corrector’ (Braver, 2012; Meyer & Bucci, 2016; Stuphorn & Emeric, 2012; Van Belle et al., 2014). In order to develop efficient interventions for healthy eating, it is important to know which stages of inhibition are impacted by motivational states as they may reflect distinct eating behaviors in everyday life, such as stopping eating after a food decision has been made versus refraining from approaching unhealthy food at all (Meule et al., 2011). Thus, it is unclear whether motivational states influence both inhibitory measures, or only measures of proactive inhibition as it is a goal-directed mechanism.

1.1. The present study

This behavioral study tested whether motivational states can cause failures but also facilitate success to resist unhealthy food using measures of inhibitory control. This would support the assumption that failure to forgo unhealthy food can occur due to not being in a motivational state to eat healthily and conversely, and success can occur due to being in such a temporary health-oriented motivational state. In order to understand whether inducing a motivational state to eat healthily (compared to enjoying tasty food) would affect people's ability to inhibit their impulses proactively (i.e., before ‘going’ for the unhealthy food item), reactively (i.e., after already starting to ‘go’ for the unhealthy food item), or both, we tested their inhibition towards unhealthy food items in early and later stages of inhibitory control initiation. Importantly, we also tested whether we can see the effects of these motivational states even when the same participants switch between them in the same experimental situation. This would suggest that state motivational states might be more powerful than trait motivations (cf. Hardman et al., 2021).

We used Go/No-Go and Stop Signal paradigms as measures of inhibitory control in a counterbalanced order. Employing both tasks enabled us to address the impact of motivational states in different stages of inhibition initiation. Both tasks involved the same set of stimuli, which consisted of unhealthy food, healthy food, and non-food pictures. In order to induce healthy eating and indulgence states, we instructed participants to focus on the health and hedonic aspects of food items. To do so, we included a secondary task rule in the inhibition tasks.

This task rule simply involved categorizing food items as tasty and not tasty, or healthy and not healthy (cf. Golubickis et al., 2021).

We hypothesized that when participants are in the healthy eating state (we will use "the health state" for simplicity), they would show better inhibition towards unhealthy food stimuli compared to when they are in the indulgence state. This would be reflected by an increase in the proportion of inhibitions in the Go/No-Go Task and shorter Stop Signal Reaction Times in the Stop Signal Task. Additionally, we expected that increased motivation towards relevant food items would result in faster reaction times in go-trials (cf. Lyu et al., 2017). Specifically, we expected faster reaction times to unhealthy stimuli in the indulgence state condition and to healthy stimuli in the health state condition in both of the inhibition tasks. In addition, we predicted that inhibition performance towards neutral stimuli would be greater compared to food stimuli due to the increased automatic approach tendency towards rewarding stimuli, indicating the ability of our modified tasks to efficiently measure inhibition ability (Logemann-Molnar et al., 2022; Tsegaye et al., 2022).

2. Method

2.1. Participants

Thirty-six participants (31 female, three male, two other; *M*age = 21.58 years, *SD*age = 6.17 years) from the University of Reading took part in return for course credits. For our sample size estimation, we combined information from different sources as similar studies were not available. First, we used data from a separate pilot study that we conducted with eight participants[1] with the aim of testing whether participants can stay sufficiently engaged throughout the complex design and to get an estimate of the relevant within-subjects effect of condition to be used in an one-way ANOVA (neutral vs health vs indulgence states). The analyses revealed large effect sizes which led to a likely underestimation of the required sample size N=4 (for the proportion of inhibitions η^2_p = .617 in the Go/No-Go Task), and N=21 (for stop-signal reaction time η^2_p = .121), both at an α of .05 and power at .95). The only comparable study using a categorization task as task rule in a Stop Signal Task (Golubickis et al., 2021) reports an effect size of η^2_p = .126 for the effect of stimulus type (comparable to the effect of food type depending on state that we expected) which would suggest a sample size of 18 at an α of .05 and power at .95. In order to not underpower our study, we decided to follow the suggestion by Von Gunten and Bartholow (2021) to use a sample size of N=35 for a within-subjects design with a minimum of 40 trials per condition. Therefore, to fully counterbalance the task order, we eventually recruited 36 participants.

Because we lost participants for the Stop Signal Task (please see 2.9.), we replicated this task in a pilot and full study (please see section 3.2.2.). All participants confirmed informed consent before taking part in the study.

2.2. Stimulus Selection

Stimuli used in food-specific inhibition tasks should be tailored to the target population in terms of their appeal and subjective perception of the relevant qualities (Labonte & Nielsen, 2023). In order to address this, we conducted a pretest with a separate sample of participants from the target population of the main study (as reported in Chapter 2). All pictures were taken from the standardized database “Food-Pics_Extended” (Blechert et al., 2019) which is commonly used by researchers in the field.

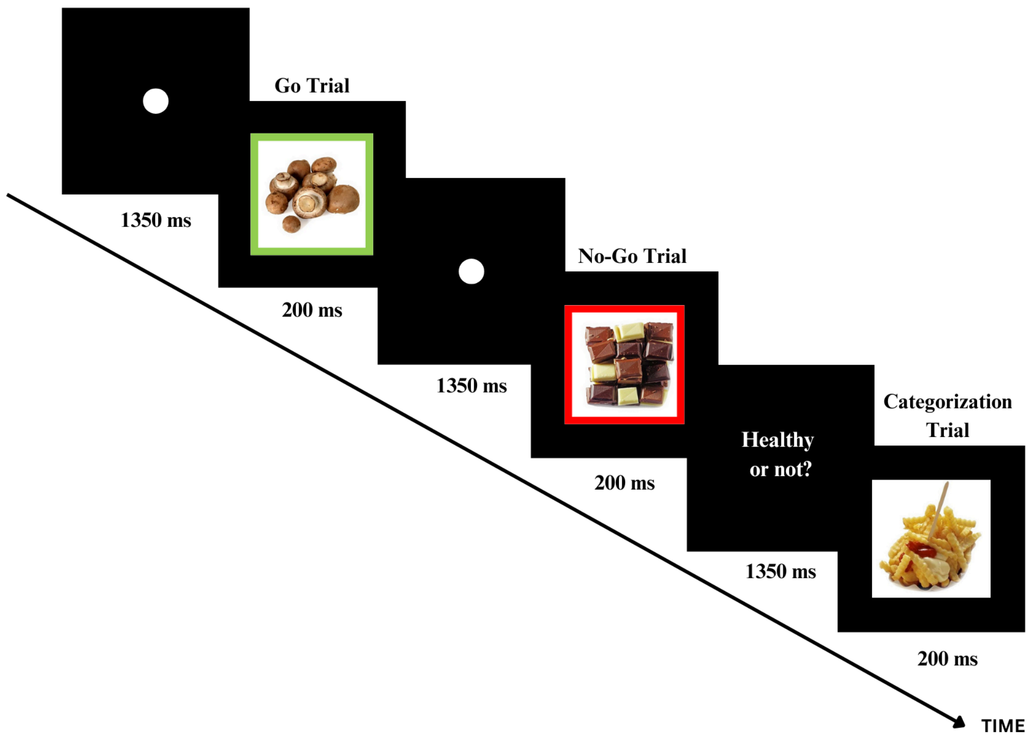
Participants were provided with the instruction to rate twenty-four pictures of food in terms of perceived healthiness from 1 (*not healthy at all*) to 5 (*very healthy*) and perceived tastiness from 1 (*not tasty at all*) to 5 (*very tasty*). We included 12 pictures of healthy and 12 pictures of palatable food in the survey in a randomized order. Ratings for all stimuli are provided in Appendix A.

In order to identify pictures that could be categorized into two separate categories (tasty or healthy) in the main study and to have an equal amount of sweet and savory items; we selected chocolates (*M*taste= 4.42, *SD*taste=.79), French fries (*M*taste = 4.39, *SD*taste = .89), mixed bakeries (*M*taste = 4.29, *SD*taste = .85), and a burger (*M*taste = 4.14, *SD*taste = 1.07) as "unhealthy stimuli" as they scored higher in taste and lower in health scale and we selected mixed vegetables (*M*health = 4.93, *SD*health = .29), cauliflower (*M*health = 4.86, *SD*health = .42), cucumber (*M*health = 4.76, *SD*health = .55), and mushrooms (*M*health = 4.58, *SD*health= .58) as "healthy stimuli" as they scored lower in taste and higher in health scale. To ensure minimum variation of perceived appeal and healthiness, we selected items with low standard deviations on both scales, and ensured that all stimuli were matching in relevant visual aspects such as number of items (i.e. single or several) and background color (white; Labonte & Nielsen, 2023). As neutral (non-food) stimuli, we selected pictures of eight animals (four mammals and four non-mammals) from the same database (see the complete list at: https://osf.io/2qpck/).

2.3. Intermixed Go/No-Go Task

We modified the Go/No-Go Task previously used by Tsegaye et al. (2022) which provides a measure of an individual's inhibitory control and included a secondary categorization task in a block design which was used for the manipulation of motivational state (see Figure 1).

Figure 1. ***Intermixed Go/No-Go Task Trials: Health State Condition***



Note. Figure demonstrates three trials of the intermixed Go-No-Go task. Every fifth go/no-go trial was followed by two categorization trials. Pictures were surrounded by green borders in go-trials (requiring response by the spacebar) and by red borders in no-go trials. In the categorization trials, pictures did not include any borders and required responding with keys F and J. Healthy and unhealthy food pictures were equally presented as go, no-go and categorization stimuli in each motivational state condition. The categorization question presented on the screen was “Tasty or not” in the indulgence state condition and “Mammal or not?” in the neutral condition (also see Figure 2).

2.3.1. Go/No-Go Trials

A single go/no-go trial consisted of a fixation dot, a central go stimulus (400 x 400 pixels with 20-pixel green border) or a no-go stimulus (400 x 400 pixels and surrounded with 20-pixels red border). Each stimulus was presented for 200 milliseconds, and a fixation dot was presented between the presentations of successive stimuli for 1350 milliseconds. The inter-trial interval was 1550 milliseconds. The no-go stimulus was presented with a 20% probability and the go-stimulus was presented with an 80% probability (Tsegaye et al., 2022). The measure of inhibition was the number of successful inhibitions divided by the total number of no-go trials (Tsegaye et al., 2022).

2.3.2. Categorization Trials: Inducing Motivational States

In order to introduce a specific motivational state, we used a secondary "categorization" task (cf. Golubickis et al., 2021). A single trial of the categorization task consisted of a categorization question, and a stimulus (400 x 400 pixels pictures with no borders) that required a keypress of either F or J letters on the keyboard. Stimulus duration was 200 milliseconds and the categorization question was presented in the center of the screen before the stimulus presentation for 1350 milliseconds. A single trial duration was 1550 milliseconds (see Figure 1).

The categorization task rule varied depending on the condition (neutral, health and indulgence states). In the health-oriented motivational state condition, we instructed participants to press one key to indicate the food in the pictures is healthy, nutritious and good for the well-being of their body, and another if they believe the food in the picture is not healthy, not nutritious and not good for the well-being of their body. In contrast, in the indulgence state condition, we asked them to press one key if they believe the food in the pictures is tasty, delicious, a treat, or enjoyable; and to press another key if not. This way, we aimed to evoke a current focal state that would allow us to shift participants' motivational states to indulgence or to healthy eating within the same experimental situation (Sah et al., 2021; Veit et al., 2020; Vogt et al., 2017). In the neutral condition, participants were asked to categorize animals as mammals or not. The keys assigned to each category were counterbalanced across participants.

2.3.3. Intermixed Go/No-Go Task Procedure

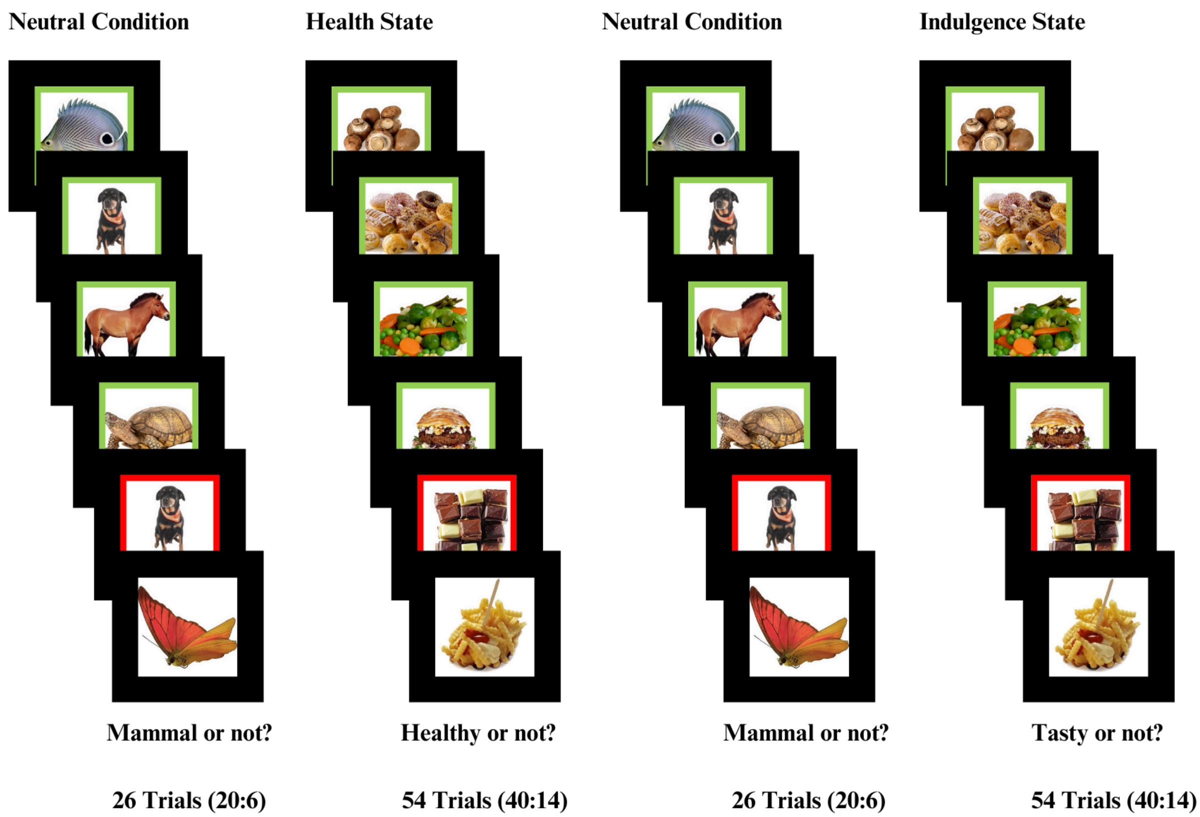
Participants started with a practice block for Go/No-Go trials where they were instructed to press the spacebar when the picture was surrounded by a green border (12 go trials). Then, they proceeded with the same task but this time, they were also asked to withhold their responses if the picture was surrounded by a red border (12 go and four no-go trials). After the practice blocks of the Go/No-Go Task, participants were given a practice block for the categorization task where they were asked to press keys F and J to categorize animals as mammals or not (eight trials). These three practice blocks were followed by an intermixed practice block including 32 trials (12 go trials, four no-go trials, and 16 categorization trials). In this intermixed practice block, participants completed four trials of the categorization task after every fourth go/no-go trial. The images shown in all these practice trials were animals..

Following the intermixed practice block, all participants started with the neutral (i.e., showing animals) condition of the intermixed test block which consisted of 20 go/no-go trials and six categorization trials. This first neutral test block was then followed by either the health state or indulgence state condition in a counterbalanced order. Participants were given 16 trials of the practice block of the food categorization task (i.e. healthy or not vs tasty or not) before they proceeded with a test block that intermixed the go/no-go trials with the categorization trials. In all conditions of the test blocks, every fifth go/no-go trial was followed by two categorization trials.

Both indulgence and health state condition of test blocks contained 40 go/no-go and 14 categorization trials and involved the same pictures of four healthy and four tasty (i.e. unhealthy) food items, each occurring once in the no-go, four times in the go-trials and at least once in the categorization trials in each condition. Between these two food conditions of intermixed test blocks, participants received the second neutral test block consisting of 26 trials in order to leave a time period between motivational states evoked by the categorization task (see Figure 2). At the end, the neutral condition that was split into two blocks included an equal number of trials to the food conditions, involving four mammal and four non mammal stimuli each being presented once in no-go trials, four times in go trials and at least once in categorisation trials.

Neutral blocks addressed general inhibition capacity and the food blocks measured food-specific inhibitory control while manipulating motivational state. Overall, participants completed 260 trials (100 practice and 160 test trials).

Figure 2. ***Overall Task Design for Intermixed Go/No-Go Task***



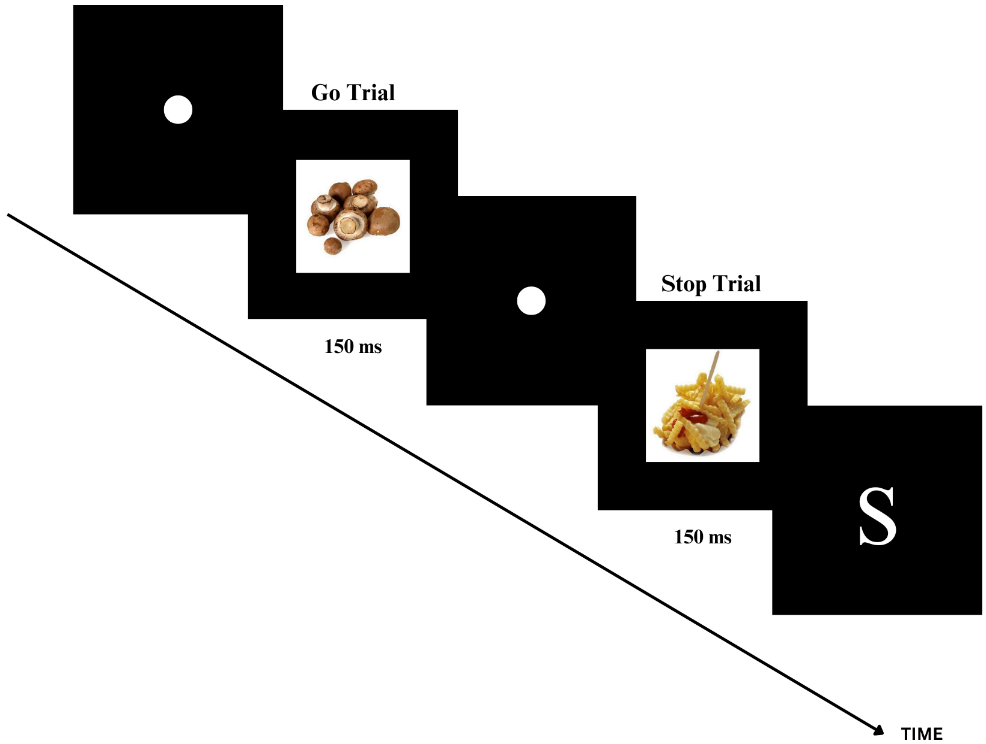
Note. Figure demonstrates 6 trials of each condition of the intermixed task and the order of conditions. Ratio of go/no-go trials to categorization trials are indicated in the parentheses.

2.4. Stop Signal Task

This task was a modified version of the Stop Signal Task previously used by Logemann-Molnar et al. (2022) and provided a measure of inhibitory control.

A single trial of the Stop Signal Task involved a fixation dot, a go stimulus that required a response with keys F and J, and a stop signal (letter S, 115(w) × 200(h) pixels) that followed the go stimuli in 25% of the trials and required participants to withhold their responses. Between the go stimulus presentations, a fixation dot appeared in the middle of the screen. The duration for go-stimulus was fixed at 150 milliseconds throughout the whole task and the go-stop interval in the first trial was fixed at 250 milliseconds. In subsequent stop trials, the go-stop interval was dynamically adjusted using a tracking algorithm. Specifically, in the case of a successful inhibition, the go-stop interval was increased by 50 milliseconds, and in the case of a failed inhibition, the go-stop interval was decreased by 50 milliseconds, effectively resulting in an approximate 50% inhibition rate. The randomization of the stop signal trials was ensured in a way that more than three stop signals would not occur successively. The total duration of one trial in Stop Signal Task was 1500 milliseconds in go trials and 1700 milliseconds in stop trials (see Figure 3).

Figure 3. ***Two Trials of Stop Signal Task: Food Blocks***



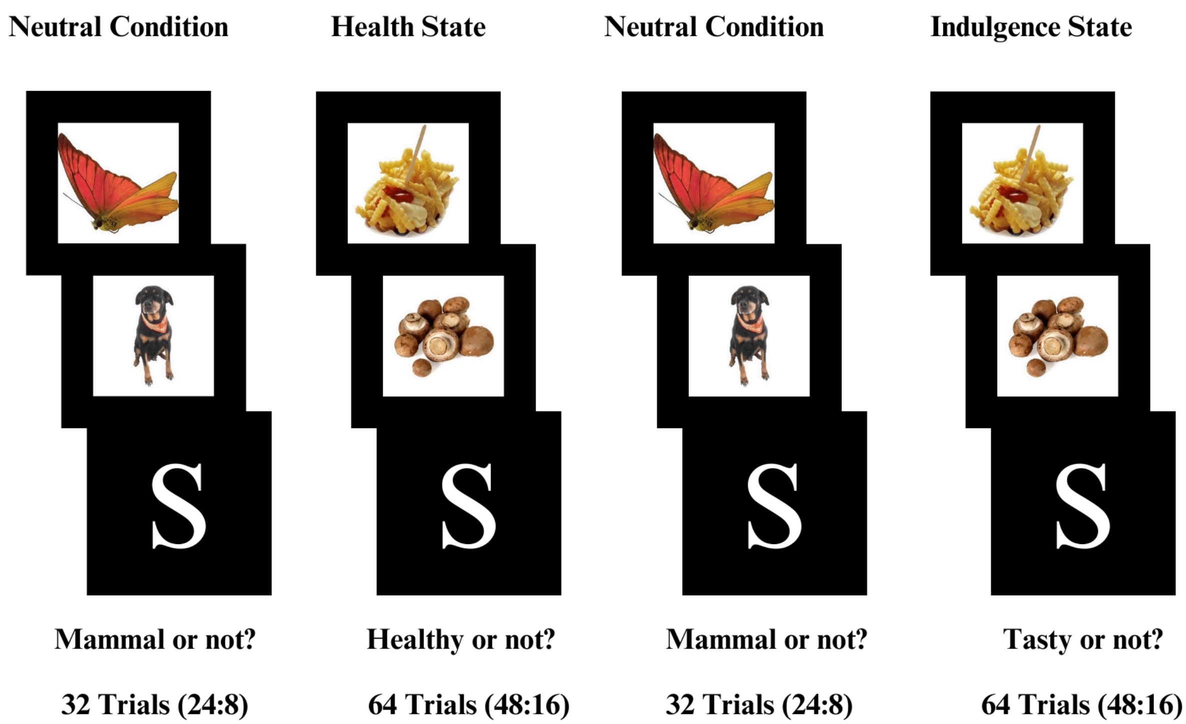
Note. The duration of stop signal and fixation dot presentations and inter-trial interval varied based on a tracking algorithm.

For all participants, the task started with a practice block that included 20 trials where they were asked to press the keys F and J to categorize animals as mammals or not, but not to respond if any of these pictures were shortly followed by the letter S (i.e. the stop signal). During the practice block, ten trials were followed by a stop signal and ten trials were go-trials, where participants would receive feedback when they missed pressing the correct button or when they responded to a stop signal. Following the practice block, participants completed the test blocks.

Test blocks involved three conditions, similar to the Go/No-Go Task: health and indulgence state conditions and a neutral condition. This time, state manipulation was applied as a task rule linked to the required response for a given stimulus.

In the neutral condition, the test block consisted of eight different animal pictures with 64 trials (48 go, 16 stop trials). The test block with food stimuli (eight pictures, four tasty (i.e., unhealthy) and four healthy) consisted of 64 trials with the same ratio of go and stop trials as the neutral block (48:16). In the indulgence state condition, they categorized the food items as tasty or not and in the health state condition, they categorized the food items as healthy or not. In the neutral condition, they categorized the animal pictures as mammals or not. Instructions for the categorization rule were kept identical to the Go/No-Go Task and keys associated with each category were counterbalanced across the participants. The order of conditions was also counterbalanced and the neutral block was segregated into two blocks (32 trials each) in a way that participants would not be given two food blocks successively[2]. At the end of the task, participants completed 64 indulgence state condition trials, 64 health state condition trials and 64 neutral trials (see Figure 4). Overall, the Stop Signal Task involved 212 trials (192 test trials and 20 practice trials).

Figure 4. ***Overall Task Design for Stop Signal Task***



Note. Figure demonstrates 2 trials of each condition of the Stop Signal Task and the order of the conditions. Ratio of go to stop trials are provided for each block.

2.5. Self-Reported Measures

In order to identify the characteristics of our sample in relation to eating behavior, trait self-control, weight goals and concern, difficulty and importance of eating healthily, participants completed questionnaires and Likert scales described below.

2.5.1. Dutch Eating Behavior Questionnaire

Participants completed the 33-item Dutch Eating Behavior Questionnaire (Van Strien et al., 1986) with scales for emotional (e.g., "*Do you have the desire to eat when you are anxious, worried or tense?*"), restrained (e.g., "*Do you deliberately eat foods that are slimming?*") and external eating (e.g., "*If food tastes good to you, do you eat more than usual?*"). Participants answered these questions on a scale from 1 (*never*) to 5 (*very often*). Cronbach's alpha for this questionnaire was (α =0.90).

2.5.2. Brief Self-Control Scale

As an assessment of trait-level self-control, the Brief Self-Control Scale (Tangney, 2004) was used. This scale included 13 items (e.g. "*Sometimes I can't stop myself from doing something, even if I know it is wrong*", "*I do certain things that are bad for me, if they are fun.*"). Each item was rated on a scale from 1 (*not at all*) to 5 (*very often*). It provided a statistically reliable measure of individual differences in self-control (α = 0.86).

2.5.3 Additional Measures

Participants were asked to answer some additional questions. Prior to task completion, participants were asked to rate how hungry they were feeling on a scale from 1 (*not hungry at* *all*) to 7 (very hungry) (cf. Houben et al., 2012; Nederkoorn et al., 2009; Tsegaye et al., 2022). After task completion, they were asked to report their weight goals (*lose weight, maintain their weight, or gain weight)*. They also rated how they were feeling at the moment from 1 (*very negative*) to 5 (*very positive*), how important and how difficult it is for them to eat healthily from 1 (*not important/difficult at all*) to 5 (*very important/difficult*), and how concerned they are about their weight from 1 *(not concerned at all*) to 5 (*very concerned*). They were asked to rate the food pictures in inhibition tasks on a 5-point Likert scale on tastiness and healthiness from 1 (*not tasty/healthy at all*) to 5 (*very tasty/very healthy*). They also reported their BMI by following a provided chart using their weight and height. Additional exploratory analyses were conducted to address the relation of hunger, BMI, current emotional state, and perceived features of presented food items, existing health goals and concerns to inhibition performance.

2.6. Procedure

All participants were tested in person, individually, in the same experiment room. After agreeing on the presented informed consent, they answered questions on their gender, age and current hunger level. Then they proceeded with the inhibition tasks in counterbalanced order. Following the inhibition tasks, they completed the aforementioned questionnaires and Likert Scales. The experiment and surveys were coded online using the PsyToolkit platform (Stoet, 2010, 2017).

2.7. Behavioral Analysis for Go/No-Go Task

The outcome measure for inhibitory control was computed by calculating the percentage of no-go trials with commission errors (i.e., when participants responded but were supposed to withhold) (Wessel, 2018).

2.8. Behavioral Analysis for Stop Signal Task

We followed an integrated method as described by Jong et al. (1990) when calculating stop signal reaction time (SSRT) to minimize the bias of stop signal reaction time estimation regarding variation in go reaction time variation. In order to rectify the successful stop rates for the rate of go-omission (i.e. when they missed responding to go stimuli), the formula below was used:

> "*proportion of inhibitions – (proportion of omissions × proportion of inhibitions) / (1 – (proportion of omissions × proportion of inhibitions)*" (Logemann-Molnar et al., 2022, p.4)

Afterwards, reaction times varying from 150 to 1500 milliseconds were ordered based on their length (from shortest to longest). The precise reaction time from this vector was decided by multiplying the number of reaction times by (1- the corrected stop rate). Eventually, the calculation of subtracting the average go-stop stimulus asynchrony onset from the decided reaction time on the reaction time vector gave the stop-signal reaction time outcome. SSRT values were averaged across experimental blocks for each participant.

2.9. Statistical Analysis

R Studio (version 4.3.2), JASP (Version 0.18.3), and SPSS IBM (Version 21) were used to compute outcome variables and to perform inferential statistical analyses, which are pre-registered at: https://osf.io/sektx. Scripts for behavioral analyses, statistical analyses including exploratory findings and data can be found at: https://osf.io/2qpck/.

In line with our preregistration, inhibition values exceeding three sample's standard deviations from the sample's mean were considered outliers and deleted from the analyses (3%). We also excluded inhibition scores of two participants that showed go-omissions exceeding three sample's standard deviations from the sample's mean for go-omissions as this indicates poor task engagement (cf. Labonté & Nielsen, 2023). Eight negative values (3.6%) in Stop Signal Reaction Time were also excluded from the analyses due to reflecting anticipation, and N=7 participants were excluded from the analyses due to showing below 25% or above 75% correct inhibitions (Verbruggen et al., 2019). For eight participants, stimulus-type (healthy or unhealthy) information for SSRTs in health and indulgence state conditions was not available in the output. Consequently, 2x2 repeated measures of ANOVA on SSRT was conducted with a reduced sample size (N = 20). Please note (as outlined in Footnote 4) that we also replicated the Stop Signal Task.

In order to compare the reaction times, the Stop Signal Reaction Times and the proportions of inhibitions between conditions (i.e. indulgence state vs. health state vs. neutral condition), separate one-way repeated measures analyses of variance (ANOVAs) with three levels were performed. To test the impact of state condition x food type interaction on reaction time, SSRT and proportion of inhibitions, separate 2x2 repeated measures of ANOVAs were conducted.

3. Results

Table 1. *Descriptive Data: Self-Reported Measures*

Measure	Max	Min	Mean	SD

Age	48	18	21.58	6.17
Hunger	6	1	3.14	1.62
BMI	42	18	23.77	5.05
Emotional State	5	2	3.33	0.86
Restrained Eating	4.50	1.20	2.54	0.85
Emotional Eating	5	1	2.40	1.02
External Eating	4.50	1.80	3.09	0.72
Self-Control	4.39	1.62	2.97	0.64
Importance of Healthy Eating	5	2	4.03	0.81
Difficulty of Healthy Eating	5	1	2.72	1.21
Weight Concern	5	1	3.44	1.18

Descriptive data for age, hunger, BMI, current emotional state, Dutch Eating Behavior Questionnaire Subscales and Brief Self-Control Scale, difficulty and importance of eating healthily, and weight concern are provided in Table 1. Descriptive data for outcome measures of inhibition tasks are provided in Table 2 and Table 3. $N = 22$ participants reported that their weight goal was to lose weight (61.11%), $N = 8$ reported that they aim to maintain their weight (22.22%) and $N = 6$ reported that they aim to gain weight (16.67%).

3.1. Go/No-Go Task

Table 2. ***Proportion of Inhibitions in the Go/No-Go Task***

Condition	Stimulus Type	Max	Min	Mean	SD
Neutral (Control)	Animals	1.00	.50	.86	.13
Indulgence State	Unhealthy Food	1.00	.25	.74	.22
Indulgence State	Healthy Food	.75	.25	.63	.15
Health State	Unhealthy Food	1.00	.25	.84	.22
Health State	Healthy Food	.75	.25	.64	.15

Note. 3% of inhibition score data points were omitted; *n*=2 data points were excluded due to being outliers, and *n*=5 data points were excluded showing high omission rates and poor task engagement.

A one-way repeated measures ANOVA was conducted to compare the effect of Condition (neutral vs indulgence vs health) on proportion of inhibitions across all stimuli. Results showed a significant effect of Condition, F (2, 64) = 16.89, p <. 001, η^2_p = .345. As expected, post hoc analyses with Bonferroni corrections indicated that participants showed significantly increased inhibition in the neutral condition (M=.86, SD=.13) than in the health state condition (M=.76, SD=.13), t (64) = 3.46, p =.003, d = 0.76, and compared to the indulgence state condition (M=.69, SD=.14), t (64) = 5.77, p < .001, d = 1.27. This shows that food stimuli challenged participants and were thus effective in our design. There was no statistically significant difference between health and indulgence state conditions, t (64) = -2.31, p = .072, d = -0.51.[3]

We then conducted another repeated measures ANOVA test our prediction that a health state facilitates inhibition towards unhealthy food (but not healthy food). Therefore, the within-subject effects of Condition (health vs indulgence states) and Food type (healthy vs unhealthy food) on proportion of inhibitions was tested. The analysis revealed a significant effect of Condition (F (1, 33) = 4.35, p=.045, η^2_p =.116), reflecting an increase in the proportion of inhibitions in the health state condition (M=.74, SD=.18) compared to the indulgence state condition (M=.68, SD=.19), and a significant effect of food type (F (1, 33) = 34.31, p<.001, η^2_p =.510), reflecting that proportion of inhibitions towards unhealthy food stimuli (M=.79, SD=.21) was increased compared to healthy stimuli (M=.64, SD=.15). Of greater theoretical importance was the predicted significant interaction between Condition and Food type (F (1, 33) = 4.34, p=.045, η^2_p =.116). As expected, post hoc analyses with Bonferroni corrections showed an increased proportion of correct inhibitions towards unhealthy food stimuli in the health state condition (M=.85, SD=.21) compared to the indulgence state condition (M=.73, SD=.22), t (33) = -2.94, p = .027, d = -0.63. In contrast, and as expected, the conditions did not differ in proportions of inhibitions towards healthy food, t (33) = -.18, p= 1.00, d = -0.04.

We then performed the same series of analyses on the reaction times. Reaction times in neutral, health, and indulgence state conditions did not significantly differ, F (2, 66) = 1.82, p = .17, η^2_p =.052. There was no significant effect of Condition (health vs indulgence) (F (1, 33) = .52, p=.48, η^2_p =.016) and Food type on reaction time, (F (1, 33) = 3.26, p =. 08, η^2_p =.090). There was also no significant interaction between Condition and Food type, F (1, 33) = .07, p =.79, η^2_p =.002.

3.2.1. Stop Signal Task

Table 3.1. ***Average performance in Stop Signal Task***

Condition	Stimulus Type	SSRT	Reaction Time	SD RT	Correct Inhibitions	Correct Answers	Omissions
Neutral (Control)	Animals	261.12	881.63	218.99	0.52	0.83	0.09
Indulgence State	Unhealthy Food	318.26	862.23	205.75	0.45	0.84	0.07
Indulgence State	Healthy Food	296.04	875.04	204.65	0.53	0.53	0.09
Health State	Unhealthy Food	308.76	897.06	205.93	0.46	0.74	0.10
Health State	Healthy Food	254.44	855.51	203.13	0.46	0.76	0.09

Note: Values 3 standard deviations away from the mean were considered as outliers for SSRT (2.7%). Respectively, negative values were excluded from the analyses. Finally, *N*=7 participants were excluded from the analyses due to showing below 25% or above 75% correct inhibitions.

In order to understand whether the manipulation of state impacted not only proactive inhibitory control (as measured in the Go/No-Go Task), but also reactive inhibition, we tested the differences in Stop Signal Reaction Time (SSRT; shorter values reflecting better inhibition) between conditions (neutral, indulgence and health states). Therefore, we conducted a one-way repeated measures ANOVA on the SSRT. Even though SSRT was shorter in the neutral condition, the difference across conditions did not reach the statistically significance threshold, F (2, 50) = .27, p=.76, η^2_p =.011.

Then, we run repeated measures of ANOVA with Condition (health and indulgence states) and Food type (healthy and unhealthy) as the within factors on SSRT. We did not find a significant effect of Condition (F (1, 17) = .65, p=.43, η^2_p = .037) or Cood type (F (1, 17) = 4.22, p= .056, η^2_p= .199), nor an interaction between Condition and Food type (F (1, 17) =2.78×10^{-4} p=.98, η^2_p = .00002).

We performed the same series of analyses on reaction times. One-way repeated measures of ANOVA revealed no significant effect of Condition on reaction time across all stimuli (F (1.65, 46.23) = .30, p=.70, η^2_p = .011). Two-way repeated measures of ANOVA with Condition (health vs indulgence) and Food type as within-subjects effects factors showed no significant effect of Condition (F (1, 21) = .06, p=.81, η^2_p = .003), food type (F (1, 21) = 2.71, p= .11, η^2_p = .115), and no significant interaction between Condition and Food type (F (1, 21) = 3.81, p=.064, η^2_p =.154).

3.2.2. Replication of Stop Signal Task

Although the Stop Signal Task was adjusted from comparable studies (cf. Golubickis et al., 2021; Logemann-Molnar et al., 2022), the lower number of trials led to negative SSRT values and the tracking algorithm did not result effectively in 50% accuracy. Therefore, we replicated Stop Signal Task with two separate samples (preregistered at: https://osf.io/gpb4t, all information and data are available at Appendix C: https://osf.io/bmwzx/) to confirm the robustness of the findings. We increased the trial numbers to 50 stop and 150 go trials for each condition allowing better within-group comparisons (cf. Verbruggen et al., 2019), and included different pictures of the same food stimuli to avoid habituation. Except for the number of trials, all procedures were performed consistently following the main study including behavioral analyses, outlier consideration and statistical analyses. As increased trial number resulted in longer procedure, we did not include Go/No-Go Task in the replication study.

A separate pilot study was conducted for sample size estimation (N=9) for the replication of the Stop Signal Task. For one-way ANOVA to test within-subjects effect of Condition (neutral vs health vs indulgence states) on SSRT, effect size was η^2_p =.21, yielding to sample size estimation of N=12. For two-way ANOVA to test Condition x Food type interaction on SSRT, effect size was η^2_p =.30, yielding to sample size estimation of N=7. We recruited N=30 participants accounting for potential exclusions due to outliers and poor task engagement. Descriptive data for performance in the Replication of Stop Signal Task are provided in Table 3.2.

Table 3.2. ***Average performance in Replication of Stop Signal Task***

Condition	Stimulus Type	SSRT	Reaction Time	SD RT	Correct Inhibitions	Correct Answers	Omissions
Neutral (Control)	Animals	287.79	813.94	202.04	0.45	0.86	0.07
Indulgence State	Unhealthy Food	292.63	781.17	210.72	0.44	0.86	0.07

Indulgence State	Healthy Food	269.64	782.31	211.39	0.46	0.50	0.07
Health State	Unhealthy Food	309.35	817.43	200.39	0.45	0.81	0.06
Health State	Healthy Food	297.24	805.58	202.29	0.44	0.82	0.05

Note: Data points that are 3 standard deviations away from the mean were considered as outliers for SSRT (5%). Respectively, SSRT values corresponding with lower than 25% and higher than 75% inhibition accuracy were excluded (5%). There were no outliers for reaction times.

Consistent with the main analyses, we performed one-way repeated measures of ANOVA with Condition (neutral, indulgence and health states) as the within-subjects effect factor for SSRT. As expected, there was no significant difference on SSRT across conditions (F (2, 54) = .125, p=.88, η^2_p =.005).

We then compared SSRT towards unhealthy and healthy food types in health and indulgence state conditions. There was no effect of Food type (F (1, 19) = 2.54, p=.13, η^2_p =.118) and Condition on SSRT (F (1, 19) = .43, p=.52, η^2_p =.022). As expected, there was also no interaction between food type and condition (F (1, 19) = .39, p=.54, η^2_p =.020).

To compare reaction time across conditions (neutral, indulgence and health state) in go trials, we performed one-way repeated measures of ANOVA. There was no statistically significant difference across conditions for reaction time (F (2, 58) = 1.31, p=.28, η^2_p =.043).

We performed repeated measures of ANOVA with Food type (healthy vs unhealthy) and Condition (health vs indulgence) as the within-subjects effect factors on reaction time. There was no statistically significant effect of Food type (F (1, 29) = .89, p=.35, η^2_p =.030), and Condition on reaction time, (F (1, 29) = 1.53, p=.23, η^2_p =.050). As predicted, there was also no significant Food type x Condition interaction, F (1, 29) = 1.53, p=.23, η^2_p =.050.

Negative SSRT outcomes were not observed in the replication sample and the replication study yielded similar results to the main study, indicating no significant difference in SSRT towards unhealthy food in health and indulgence states, supporting the validity of the observed effects.

4. Discussion

This study aimed to investigate whether a motivational state to eat healthily compared to an indulgence state focused on enjoying tasty food would improve inhibitory control towards unhealthy food in the early and later stages of inhibition initiation. Our main hypothesis suggested that participants would show better inhibition performance towards unhealthy food in the health state compared to the indulgence state. Indeed, our analyses revealed that when the health state was induced, participants were better at inhibiting unhealthy but not healthy food stimuli than when in an indulgence state. Interestingly, these results were limited to measuring proactive inhibitory control with the Go/No-Go Task, and there was no evidence of improved inhibition in the presence of a health state in the Stop Signal Task that measures reactive inhibitory control.

Our results provide evidence how states influence basic and automatic reactions, that is inhibitory responses towards unhealthy food. Specifically, people were better at inhibiting go responses towards unhealthy food when in a health oriented motivational state compared to when the same participants switched to indulgence state (or the other way around). This extends previous research on the effects of motivational states (Franssen et al., 2022; Veit et al., 2020) by showing that states impact implicit reactions towards food and when switching between states in the same experimental situation, highlighting a strong influence of state rather than trait motivations (cf. Hardman et al., 2021) that cannot easily be explained by demand effects because the measures tap into automatic processes. This way, our data provide support for recent conceptualizations of self-control (e.g., Hennecke & Bürgler, 2023; Inzlicht et al., 2020; Inzlicht & Friese, 2021) that emphasize the causal role of state motivations and beliefs and not necessarily ability on control in a current situation. Further, we replicate previous findings showing that food stimuli result in poorer inhibitory control performance compared to neutral stimuli in the Go/No-Go Task (Teslovich et al., 2014; Tsegaye et al., 2020) by finding that participants were significantly better at inhibiting neutral stimuli than food stimuli. This confirms that the task was able to address inhibitory control efficiently.

Our effects did not extend to the Stop Signal Task and this null finding was replicated in a subsequent Stop Signal Task study. This might be surprising given that the manipulation of the motivational state was arguably more robust in this context, as it was integrated into the task rule rather than being presented as a secondary task. However, as the Stop Signal Task required inhibiting after the initiation of a go-response, it thus involved "reactive inhibition" while the Go/No-Go Task involved "proactive inhibition" by requiring inhibition before any response initiation (Brevers et al., 2017; Perri, 2020). Indeed, proactive inhibition has been shown to be a type of cognitive control where goal-relevant information is actively held and sustained prior to the occurrence of a critical event (Miller & Cohen, 2001). On the other hand, reactive inhibition may not involve such goal-relevant processes and acts more like a late correction mechanism (Jacoby et al., 1999, Braver, 2012). In different terms, these two inhibition tasks might be measures of different constructs of inhibitory control, Go/No-Go Task being a measure of response restraint that mostly relys on top-down processes and the Stop-Signal Task as a measure of response cancellation that predominantly engages bottom-up systems (Sinapoli et al., 2011). Our findings support this framework, showing that the temporal motivational state induction specifically influenced proactive, goal-directed inhibition (i.e., response restraint) but did not affect reactive inhibition that is mostly stimulus-driven (i.e., response cancellation). Further supporting these assumptions, exploratory analyses confirmed that inhibition performance towards unhealthy food in the health state condition were not correlated in these two tasks [4]. Indeed, Meule et al. (2011) suggested that inhibition involved in these tasks may reflect different real-life behaviors, as it is often more challenging to inhibit an already activated response (e.g., traffic lights turning red while speeding) than to refrain from initiating the behavior in the first place (e.g., putting a foot on break while the light is still orange) (Van Den Wildenberg et al., 2022). Therefore, we argue that inducing a state before an action is taken may be more effective in enhancing proactive inhibitory control. This is important because it suggests that interventions targeting motivational processes and situational beliefs and cognitions (cf. Wiers et al., 2020) might be most effective for situations where people can proactively avoid food.

Based on studies which found that increased motivation might lead to decreased reaction times (cf. Asci et al., 2019; cf. Lyu et al., 2016), we expected that participants would react faster towards healthy stimuli in the health state condition while reacting faster towards unhealthy food stimuli in the indulgence state condition. Contrary to our hypothesis, reaction time did not differ across conditions towards different food types. However, reaction time is not a commonly utilized outcome measure in inhibition experiments. Importantly, the effects of motivational states are present for the main outcome measure (i.e., proportion of inhibitions). Therefore, the lack of significant findings for reaction times does not necessarily conflict with the conclusions for the observed effect of states as many additional factors such as post-error slowing (Guan & Wessel, 2022) and attentional bias (Meule et al., 2014) might have influenced the reaction times.

Of course, our study is not without limitations. For instance, future studies will hopefully replicate this finding using a variety of measures and extend it to, for example, a more in-depth analysis in various populations to understand whether motivational states are impactful regardless of individual differences or whether they will be more or less effective in certain groups (cf. Papies et al., 2008). Future studies might also want to use more naturalistic manipulations of motivational states. However, it is important that our study was designed as a proof of principle study using a strong manipulation of motivational state that could be applied to all participants. More naturalistic manipulations or interventions will likely have to be created for participants individually taking into account specifics of their relevant goals and triggers to eat (un)healthily (cf. Wiers et al., 2020).

5. Conclusion

In summary, our research has shown that switching between a health and indulgence motivational state impacts the proactive execution of inhibitory control towards unhealthy food, providing evidence for recent models of self-control of eating behavior emphasizing the importance of state motivations using an automatic process, that is, inhibitory control. Future investigations should explore how interventions focusing on motivational states and proactive inhibition can improve eating behaviors.

Ethical Statement

The study was approved by the Ethics Committee of the University of Reading and followed the Declaration of Helsinki [2023-042-EF].

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Declaration of competing interests

The authors declare no competing interests.

Appendix A. Stimuli Ratings (as reported in Chapter 2, also below).

Appendix B. Supplementary Data

All analyses and data can be accessed at: https://osf.io/2qpck/

Appendix C. Data for replication of Stop Signal Task

Report of analyses, additional stimuli and data can be accessed: https://osf.io/bmwzx/

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Footnotes

[1] Pilot sample size was mistakenly noted as *N*=6 in the preregistration on OSF.

[2] Half of the participants received 64 more neutral trials due to an error in coding. However, when controlling for this difference, we did not find an impact in the observed results (see output provided in Appendix B).

[3] Using Holm correction in the post hoc analysis has shown a significant difference between health and indulgence state conditions, p=.024. This could indicate that the indulgence state manipulation evoked an approach tendency to all types of food stimuli.

[4] We performed correlations between the Z-scores of outcome measures of the two inhibition tasks in each condition. There was no significant correlation between the SSRT and proportion of inhibitions in the health state condition towards unhealthy food. Besides, this null effect was present for the neutral condition, further supporting that two tasks might be involving different inhibition processes. These results are available at Appendix B.

For Appendix A

Table A.1

Stimuli Ratings for Healthy Items

	Health		Taste	
Items	Mean	SD	Mean	SD
Whole-wheat bread	3.65	0.89	3.07	1.11
Cucumber-sliced*	4.76	0.55	3.77	1.20

Mixed Vegetables*	4.93	0.29	3.15	1.29
Chicken Soup	4.12	0.66	3.32	1.28
Porridge	3.83	0.87	2.67	1.22
Mozzarella Salad	4.45	0.70	3.64	1.11
Boiled Eggs	4.31	0.69	3.71	1.17
No-sugar Muesli	3.67	0.87	3.12	1.02
Rye Crisp Bread	3.50	0.86	2.77	1.02
Cauliflower*	4.86	0.42	2.79	1.36
Mushrooms*	4.58	0.58	3.11	1.51
Grapefruit	4.62	0.58	3.92	1.13

Table A.2

Stimuli Ratings for Tasty (i.e. Unhealthy) Items

	Health		Taste	
Items	Mean	SD	Mean	SD
Sweet Bakeries*	1.44	0.66	4.29	0.85

Pizza	2.00	0.90	4.03	1.01
Chocolate*	1.69	0.73	4.42	0.79
Doner Kebab	2.35	0.86	3.83	1.24
Gummy Candies	1.15	0.39	3.81	1.11
Ice cream (in a cup)	1.47	0.72	4.21	0.99
Lasagne	3.07	0.81	4.08	1.10
Burger*	2.16	0.91	4.14	1.07
Cake	1.34	0.56	3.66	1.24
Ice cream popsicles	1.65	0.69	3.77	1.10
French Fries*	1.61	0.68	4.39	0.89
Potato Chips	1.46	0.69	4.17	0.89

CHAPTER 4

Testing the Causal Role of Emotion Regulation Goals in Inhibitory Control and Approach Bias Toward Unhealthy Food*

* Cam, H., & Vogt, J. (2025). Testing the Causal Role of Emotion Regulation Goals in Inhibitory Control and Approach Bias Toward Unhealthy Food. *Manuscript under review.*

Abstract

It is often assumed that people consume unhealthy but tasty food to regulate their emotional state, this means, because they believe this will make them feel better and improve their moods. However, causal evidence demonstrating that emotion regulation goals and beliefs compromise responses to unhealthy food is sparse. To provide a proof of principle study, we manipulated participants' emotion regulation goals (to feel better versus to maintain a negative mood as a control condition) and their beliefs about whether different categories of unhealthy food can improve their mood or not. To do so, participants (N = 74) completed a modified Go/No-Go Task in a within-subject design, in which they responded to unhealthy food items while being instructed to feel better or to maintain their current mood. Before this, participants learned about the presumably mood-regulating function of different categories of unhealthy food. Negative emotional images were presented between trials to induce negative affect. Wanting to feel better increased the approach tendency towards the category of unhealthy food that was believed to enhance mood and, in non-dieters only, poorer inhibition of this food. Dieters' inhibition performance towards unhealthy food was not impacted by the information on the function of the food, suggesting problems to learn that unhealthy food is not mood improving. These findings provide causal evidence that emotion regulation goals to feel better can undermine the ability to avoid and inhibit responses to unhealthy food.

Keywords: emotional eating, restrained eating, inhibitory control, emotion regulation

1. Introduction

Negative emotions are one of the barriers to healthier habits, especially a healthier diet. Experiencing negative emotions leads to increased intake of unhealthy but tasty food; people often report eating to get over a stressful day or an upsetting event (Cleobury et al., 2014; Devonport et al., 2019; Snuggs et al., 2025). However, eating in response to negative affect is not a universal experience (Altheimer et al., 2021; Dalton, 2024) and might be limited to individuals with emotion regulation difficulties (Brytek-Matera, 2021). Some researchers have therefore argued that eating in response to negative affect might reflect a coping or emotion regulation strategy that people feel licensed or justified to use (Evers et al., 2018; Kopetz et al., 2018; Prinsen et al., 2019; Witt Huberts et al., 2012). However, whether such motivations to feel better can indeed cause changes in people's responses to unhealthy food remains unclear. Causal evidence on the impact of emotion regulation goals and beliefs about whether unhealthy food can help to achieve them is crucial for the development of theories and interventions targeting increased unhealthy food consumption in response to negative affect, as such eating patterns pose significant health concerns (Chew et al., 2025; Ljubičić et al., 2023).

There is much theorising on the link between emotion regulation and food choice, with an emphasis on the differential effects of maladaptive versus adaptive emotion regulation on how people respond to food. Adaptive emotion regulation refers to regulation strategies benefiting social, physical and psychological well-being, whereas maladaptive emotion regulation involves strategies with detrimental effects in these domains (Gross, 2015). When an emotion regulation strategy fails (or is maladaptive), eating may become a complementary or compensatory strategy to regulate emotional states (Taut et al., 2012). For instance, increased levels of self-reported reappraisal (i.e., an adaptive strategy aiming to re-evaluate the meaning of the situation) were associated with increased self-reported healthy eating and decreased unhealthy food consumption (O'Leary et al., 2023). Conversely, increased levels of self-reported use of avoidance (i.e., a maladaptive strategy involving self-distraction and denial, Dalton et al., 2024) and of suppression (i.e., a maladaptive strategy aiming to refrain from expressing any feelings, Görlach et al., 2016) were linked to self-reported increased eating in response to negative affect. Experimental studies supported these findings. When negative affect was induced, people who engaged in suppression started eating sooner than others who engaged in no emotion regulation or an adaptive emotion regulation strategy (i.e., reappraisal) (Evers et al., 2010; Taut et al., 2012), suggesting that eating served as a secondary regulation strategy. In contrast, when engaging in an adaptive strategy in response to a personal problem, participants were more likely to choose a healthy snack option (as opposed to candy) compared to those who were asked to sit and think of their problem (Langley et al., 2023). Indeed, in dietary decision-making tasks, people valued the taste aspects of food more (Maier et al., 2015) and the benefits of healthy food options less following a negative affect induction (O'Leary et al., 2023). However, an instructed reappraisal reversed this effect, where people evaluated the health benefits of the food options higher than they did prior to downregulating their negative affect (O'Leary et al., 2023). Overall, correlational and experimental findings have shown that engaging in different forms of emotion regulation may lead to different food choices. Where adaptive regulation leads to a preference for healthy food, maladaptive strategies can lead to unhealthy food choices. However, it is not clear whether people choose unhealthy food because they believe these foods can help them achieve their emotion regulation goals when other strategies to regulate fail or because of, for instance, self-control breaking down (cf. Maier et al., 2015).

Indirect evidence comes from studies testing whether goals to enjoy oneself influence food responses (Franssen et al., 2022; Kochs et al., 2022; Veit et al., 2020; Werthmann et al., 2016). When people were reminded of situations where they would enjoy unhealthy food (e.g., when they think of a celebration or having a good time), they reported more cravings for palatable food and increased their unhealthy food intake (Kochs et al., 2022; Veit et al., 2020; Werthmann et al., 2016). However, these studies were limited to indulgence goals, not including emotion regulation goals and experimental affect manipulations. Importantly, only one study has used a within-subjects design to control for individual differences when indulgence goals were induced (Veit et al., 2020). Therefore, it is not yet clear whether emotion regulation goals to feel better can causally impact automatic responses to unhealthy food under negative affect.

Tice et al. (2001) aimed to directly test whether people consume palatable food as a regulatory strategy because they believe that such foods can help to feel better. Specifically, some of the participants in their studies were informed that scientific evidence suggests that eating would not help with emotions, and their mood was very likely to stay the same until the end of the experiment. In the control group, participants were not given any information on the mood effects of the food. It was revealed that participants who were told that their mood would not change by eating were less likely to consume unhealthy food in the laboratory than those who were not given any information. This suggests that when people would not see food as a means to regulate their emotions, they would be less prone to use it as a regulatory strategy. However, as suggested by the authors, the experimental condition might not have been comparable to the control condition. For instance, receiving information on the mood effects of food might have resulted in demand effects (e.g., participants in the experimental condition paid more attention to their eating) that were not evoked in the control condition (cf. Robinson et al., 2014).

Taken together, previous research has shown that active indulgence goals might influence how people respond to food, and there is indirect evidence that people might be adopting food as an emotion regulation strategy. However, the latter evidence has been limited to correlational designs or focused on the effects of different emotion regulation strategies. We aimed to extend these findings with a proof-of-principle study testing whether emotion regulation goals to feel better and beliefs about food being instrumental in achievement of these goals impact how people respond to food. Therefore, we tested whether strategically choosing unhealthy food to feel better (i.e. as a means to emotion regulation goals) can increase the tendency to approach unhealthy food and impair the ability to resist such dominant tendencies. Establishing such causality is informative for interventions targeting emotion regulation strategies in maladaptive eating.

1.1. The present study

To test whether emotion regulation goals to feel better and relevant beliefs about food can impair the ability to resist unhealthy food, we used an adjusted Go/No-Go Task paradigm as a measure of inhibitory control and approach tendencies (Hofmann et al., 2012; Verbruggen & Logan, 2008). Inhibitory control is described as a cognitive function that permits suppressing an immediate and strong tendency to reach a more desired state, and is one of the key cognitive mechanisms in the control of eating (Diamond, 2013). Improved inhibitory control is associated with decreased consumption of unhealthy food and greater weight loss (De Klerk et al., 2023; Lawrence et al., 2015a, 2015b; Veling et al., 2014), whereas poorer inhibition is linked to higher calorie consumption and increased BMI (Price et al., 2016; Tsegaye et al., 2022). Importantly, faster reaction times in go-trials to food stimuli were associated with increased BMI and increased hunger, reflecting a higher approach tendency (Batterink et al., 2010; Meule et al., 2014; Teslovich et al., 2015). Therefore, the Go/No-Go Task provides a reliable measure to understand automatic responses to food, including approach tendencies to unhealthy food and the ability to suppress such dominant responses.

People may use unhealthy food to achieve relief from negative affect due to believing that these foods will help them to reach their desired emotional state (Klatzkin et al., 2022). Therefore, prior to the inhibition task, participants received information on how sweet (or savoury) food could improve people's mood temporarily, while savoury (or sweet) food may not change how people feel at the given moment, as a means to simulated emotion regulation goals to feel better (cf. Tice et al., 2001). Following the deception text, we asked participants to remember this information during the study. Later in the inhibition tasks, sweet or savoury food stimuli functioned as a means to achieve the simulated emotion regulation goals to feel better.

In a within-subjects design, participants received two conditions of the Go/No-Go Task in a counterbalanced order. In the feel better condition, we asked participants to improve their mood by accepting the food items that would make them feel better. In the control condition, they were asked to stay in the same mood by accepting the food items that would not change how they felt. During the task trials, participants responded to 16 different unhealthy food items with key presses to accept or reject the food. In-between go/no-go trials, we presented negative affective images to induce negative affect. Outcome measures of the Go/No-Go Task were reaction times in go-trials and proportions of correct inhibitions in the no-go trials. Decreased reaction time reflected increased approach tendency. Decreased proportion of inhibitions reflected impaired inhibitory control of dominant responses.

We expected (preregistered at: https://osf.io/wmv8k) that when participants were asked to feel better, they would show decreased reaction times (i.e., heightened approach tendency) and lower proportions of inhibitions towards the food with supposed mood-enhancing effects, as opposed to when they were asked to stay in the same mood. We also compared erroneous key presses across two conditions towards different food stimuli (i.e. food with mood-enhancing effects vs food with no mood effects) for exploratory purposes (e.g., to see whether the emotion regulation goal to feel better resulted in higher task conflict). Measures of individual differences in maladaptive eating (Dutch Eating Behaviours Questionnaire, van Strien et al., 1986) and eating motivations (Eating Motivations Survey, Renner et al., 2012) were also included in exploratory analyses.

2. Method

2.1. Participants

Eighty participants from the UK were recruited on Prolific and financially compensated. Following pre-registered exclusion criteria, *N*=6 participants were excluded due to showing outlier values in erroneous key presses, which reflects poor task comprehension (cf. Labonté & Nielsen, 2023). The final sample included *N*=74 participants (38 female, 36 male; M_{age}= 37.77 years, SD_{age}=12.28 years).

G*Power version 3.1.9.7 7 (Faul et al., 2007) was used to perform power analyses to estimate the required sample size at an α of .05 and power at .80. Effect sizes for two-way repeated measures of ANOVAs (Condition: feel better, sustain mood; Stimulus type: food with mood effects, food with no mood effects) for proportion of inhibitions and reaction times were calculated. A separate pilot study included 40 go/no-go trials per condition of the Go/No-Go Task. Analyses revealed a small effect size for Condition x Food type interaction for proportion of inhibitions (η_p^2=.015), resulting in a sample size estimation of *N*=91 and a large effect size for

Condition x Food type interaction for reaction time (η_p^2=.456), leading to a sample size estimation of *N*=4.

Due to differences in estimated sample sizes for each dependent variable, guidelines by Von Gunten and Barthalow (2021) were followed. We used the observed effect size in Condition x Food type interaction from the pilot study for proportion of inhibitions (i.e., η_p^2=.015 corresponding to a 7.5% within-subjects effect) for sample size estimation to reach power at .80 in the Go/No-Go Task. Therefore, we increased the trial number to 160, including 32 no-go trials in each condition and recruited *N*=80 participants.

All participants received informed consent and confirmed it before taking part in the study. The study was approved by the Ethics Committee of the University and followed the Declaration of Helsinki.

2.2. Food Stimuli

In a pre-test survey (as reported in Chapter 2, Cam et al., 2025) conducted with a separate sample, 24 images were selected from "Food-Pics_Extended" database (Blechert et al., 2019) and *N*=100 university students rated these pictures in randomised order on a taste and a health scale, from 1 (*not tasty/ not healthy at all*) to 5 (*very tasty/ very healthy*) to tailor food-stimuli to target population (Labonte & Nielsen, 2023). Four palatable food pictures (two sweet and two savoury) that rated higher in the taste scale were selected to be presented in the Go/No-Go Task. These pictures included chocolates (*M*= 4.42, *SD*=.79), French fries (*M*=4.39, *SD*= .89), mixed bakeries (*M*=4.29, *SD*=.85), and a burger (*M*=4.14, *SD*=1.07).

We increased the variability of the food stimuli to avoid habituation, as the selected four stimuli would need to be presented 40 times across the inhibition task (cf. Epstein & Carr, 2021).

Therefore, twelve different additional pictures (six sweet and six savoury) involving similar food items selected from the survey (i.e., chocolates, fries, bakeries and burgers) were included, following the palatability ratings above the mean provided within the database (Blechert et al., 2019). Eventually, eight sweet and eight savoury food items were selected as unhealthy food stimuli (the list of used stimuli is available at: https://osf.io/y2pd6/).

To ensure that participants perceived these food images as palatable, they rated each image at the end of the task completion from 1 (*not tasty / not healthy at all*) to 7 (*very tasty / very healthy*). Ratings of all food items are provided in Appendix A.

2.3. Negative Affect Induction

To induce negative affect, participants were asked to rate affective images in two separate questionnaires before the inhibition tasks on an anchored scale, from 1 (*not negative at all*) to 7 (*extremely negative*) (Storbeck et al., 2024). We selected n=46 affective images to present as part of this affect induction procedure, including pictures of humans, animals, faces, and scenery. n=22 of the images were selected from The Nencki Affective Picture System (NAPS; Marchewka et al., 2014), and n=24 were selected from Open Affective Standardized Image Set (OASIS; Kurdi et al., 2017). Images were selected based on valence below M_{NAPS}=4.30; M_{OASIS}=2.97 and arousal below M_{NAPS}=4.98; M_{OASIS}=5.46, and in iteration of discussion with the wider research team to ensure that participants can relate to images and recognise their emotional value. A list of the selected pictures and normative ratings is available in Appendix B.

The selected affective images were grouped into two different blocks, each including 23 items with comparable normative ratings of valence and arousal (see Appendix C). Then, each block of images was used in two different questionnaires, which were presented before each condition of the Go/No-Go Task.

Each questionnaire instructed participants to engage with the emotions in the images as much as possible; by putting themselves in the shoes of the people or animals they see in the image and thinking of what might have happened, by trying to remember similar situations they might have experienced themselves, or by imagining themselves to witness such sceneries in real life. Then, participants were asked to rate the images that were presented separately and in randomised order on an anchored scale, from 1 (*not negative at all*) to 7 (*extremely negative*) (Storbeck et al., 2024). Afterwards, these images were randomly presented in the following conditions of the Go/No-Go Task trials (cf. Saad et al., 2024).

2.4. Induction of Emotion Regulation Goals and Regulatory Function of Food

Participants were given information on the mood effects of sweet and savoury food items to create food categories that functions as a means to achieve emotion regulation goals (cf. Tice et al., 2001). In a counterbalanced design, they received instructions as follows:

"Salty (or sweet) foods often come in forms that are hearty and satisfying: think of well-seasoned fries with many different dips (or a layered cake with many different fruit and chocolate flavours). The range of tastes that we can get from a savoury (or sweet) dish is very diverse. Eating salty (or sweet) food can uplift our mood instantly, giving us a quick burst of happiness. You may relate to what other participants have told us: for instance, they enjoyed a delicious pizza (or a delicious piece of chocolate) after a busy day, they went to grill (or for icecream) on a sunny day with their friends, they experienced joy with their loved ones by sharing a plate of fries (or a birthday cake) or walked into their favourite takeaway place (or

bakery) after they smelled freshly cooked burgers (or baked croissants). Even though sweet (or savoury) foods can also be tasty, eating sugary (or salty) food can leave us more irritable and tired, as opposed to the quick burst of energy and mood uplift of savoury (or sweet) food. You may relate to what other participants have told us: they felt very tired after eating heavy pancakes (or a burger) or when they had chocolate (or chips) after a stressful day, but nothing seemed to change about how they felt that day. Indeed, it has been suggested that sodium (or sugar) in salty (or sweet) food can stimulate our brain's reward system, putting us in a better mood for a short time, while high sugar (or sodium) in sweet (or savoury) dishes can increase cortisol and stress levels in our bodies temporarily, not making our mood any better."

Following the manipulation text, participants were instructed to remember the given information during the study. Therefore, they were asked to answer four multiple-choice questions correctly to continue with the experiment. Each question presented four pictures of experimental stimuli in which participants were required to detect the presumably mood-improving food and the food with no mood effects in line with the given manipulation text. The questions that were not answered correctly were presented again until participants selected the correct answers.

2.5. Go/No-Go Task

An adjusted Go/No-Go Task was used as a measure of inhibitory control (cf. Tsegaye et al., 2022; Saad et al., 2024). A single trial of the Go/No-Go task included a text reminding the task rule, and one of the following stimulus depending on the trial type; (i) go stimulus which required a response with the key F or J, or (ii) a no-go stimulus that required withholding the response, or (iii) an affective stimulus that did not require any response. All stimuli were presented for 200 milliseconds at the centre of the screen at 400 x 400 pixels, where no-go stimuli included a 20x20 pixel border in red colour. The inter-trial interval was 1500ms.

Each unhealthy food stimulus (*n*=16, *n*=8 sweet and *n*=8 savoury) was presented eight times in go-trials and twice in no-go trials. Therefore, each experimental condition of the Go/No-Go Task included 160 trials in total, 128 go trials and 32 no-go trials. Trials with affective stimuli (i.e. affect induction trials) were placed in the Go/No-Go Task for negative affect induction, which randomly occurred approximately every third trial. In each condition of the Go/No-Go Task, 23 different affective images were presented twice. In total, each condition of the Go/No-Go Task consisted of 206 trials.

Before completing the experimental conditions, participants were provided with two practice blocks. Initially, they were asked to accept the food they like and reject the food they do not like with keys F and J (16 trials). This rule in the practice block was applied to support them in learning that key presses represent accepting and rejecting responses as necessary for the subsequent experimental task rules. After each response, they received feedback "*you accepted/rejected the food*" in green or red colour, respectively. They also received feedback when they missed responding (i.e. omission errors). Then, they received the second practice block. This block included 16 additional no-go trials. Participants were instructed to apply the same rule, but this time, to withhold their responses to the images with red borders (32 trials, 50% no-go trials). Feedback was provided when they responded in no-go trials (i.e. commission errors), when they missed responding, and for each key response. During the task trials, the task rule was written in text and presented at the centre of the screen: "*accept F* (or J), *reject J* (or F)". These practice trials were not included in the analyses and did not include affective images.

Following the first two practice blocks, participants received the manipulation text on the mood effects of sweet and savoury food as outlined in section 2.4. Then, they rated the first block of affective stimuli on the anchored scale as outlined in section 2.3. Following this first affect induction procedure, participants proceeded with the experimental test blocks.

In the experimental test blocks, the task rule differed depending on the condition. To induce emotion regulation goals to feel better, we instructed participants to improve their mood. They were instructed that they could do this by accepting the food items that would make them feel better and rejecting the food items that would not change their mood. Conversely, in the control condition, they were instructed to stay in the same mood, this time by accepting the food items that would not change their mood and rejecting the food items that would make them feel better. Participants "accepted" or "rejected" the food items by using keys F or J during the go-trials, but withheld their responses to pictures that were surrounded by red borders in the no-go trials. They were also instructed that they do not need to respond to pictures with emotional content, and that these pictures were there to worsen their mood. A text was placed at the centre of the screen to remind the task rule: "*feel better*" or "*sustain your mood*".

Prior to each experimental test block of the Go/No-Go Task, participants were given two additional practice blocks to practice the respective task rule. Similar to the initial practice blocks, they first practised go-trials and received feedback for erroneous key presses and omission errors (16 go trials and 10 affect induction trials). Then, they were asked to withhold their responses to no-go trials where they also received feedback for commission errors (eight go, eight no-go, and 10 affect induction trials). Feedback to erroneous key responses reminded them of the task rule, "*sweet* (or savoury) *to feel the same* (or better)". Once they practised the experimental rule, they proceeded with the test blocks. During the test blocks, text reminders of the task rule and the feedback to erroneous key responses were provided. However, no feedback was given for the omission and commission errors.

Overall, the Go/No-Go Task included 412 test trials and 152 practice trials. Keys and order of the experimental conditions were fully counterbalanced.

2.6. Self-Reported Measures

For exploratory analyses and to identify sample characteristics, participants answered several questionnaires and additional questions.

2.6.1. Dutch Eating Behaviour Questionnaire

The Dutch Eating Behaviour Questionnaire (van Strien et al., 1986) included 33 items with subscales for restrained eating (e.g., "*Do you deliberately eat foods that are slimming?*"), emotional eating (e.g., "*Do you get the desire to eat when you are anxious, worried or tense*?") and external eating (e.g., "*If you see or smell something delicious, do you have a desire to eat it*?). Each item was rated on a scale from 1 (*never*) to 5 (*very often*). Cronbach's alpha for the questionnaire was (α =0.93), providing excellent reliability.

2.6.2. The Eating Motivation Survey (TEMS)

The Eating Motivation Survey (Renner et al., 2012) included liking (e.g., "*I eat what I eat… because I feel like eating it*"), health (e.g., "*... in order to fulfil my need for nutrients, vitamins, and minerals*"), pleasure (e.g., "*... in order to indulge myself*"), sociability (e.g., "*... so that I can spend time with other people*"), visual appeal (e.g.,"*…because it looks appealing*"), weight control (e.g.,"*...because it is low in fat*") and affect regulation (e.g., "*... because I am* *sad*") subscales (37 items), providing excellent reliability (α = 0.90). Participants rated each item on a scale from 1 (*never*) to 7 (*always*).

2.6.3. Difficulties in Emotion Regulation Survey (DERS)

The DERS included 36 items representing six subscales: non-acceptance of emotional responses (e.g., "*When I'm upset, I feel guilty for feeling that way*."), difficulties engaging in goal-directed behaviour (e.g., "*When I'm upset, I have difficulty focusing on other things*."), impulse control difficulties (e.g., "*When I'm upset, I have difficulty controlling my behaviors.*"), lack of emotional awareness (all reverse-coded items; e.g., "*When I'm upset, I acknowledge my emotions*."), limited access to emotion regulation strategies (e.g., "*When I'm upset, I believe that there is nothing I can do to make myself feel better*."), and lack of emotional clarity (e.g., "*I have difficulty making sense out of my feelings*.") (Gratz & Roemer, 2004). Participants answered each item on a scale from 1 (*almost always*) to 5 (*almost never*). This survey provided excellent reliability (α = 0.94).

2.6.4. The Emotion Regulation Questionnaire

The Emotion Regulation Questionnaire consisted of 10 items measuring reappraisal (e.g., "*When I want to feel less negative emotion, I change the way I'm thinking about the situation*.") and suppression (e.g., "*I keep my emotions to myself*.") (Gross and John, 2003). Each item was rated on a scale from 1 (strongly disagree) to 7 (strongly agree). Cronbach's alpha for reappraisal items was α = 0.89, providing good reliability, and for suppression items was α = 0.70, providing acceptable reliability.

2.6.5. Additional Measures

Participants rated their hunger levels on a scale from 1 (*not hungry at all*) to 7 (*very hungry*) before the tasks. Following the Go/No-Go Task and questionnaires, they reported their weight goals (*lose, maintain,* or *gain weight*) and answered 7-point Likert scales on their current emotional state (1= *very negative* to 7 = *very positive*), the importance (1 = *not important at all* to 7 = *very important*) and difficulty (1 = *not difficult at all* to 7 = *very difficult*) of eating healthily, weight concerns (1 = *not concerned at all* to 7= *very concerned*). Finally, they rated food items used in the inhibition task on a taste (1 = *not tasty at all* to 7 = *very tasty*) and health scale (1= *not healthy at all* to 7= *very healthy*).

2.7. Procedure

After confirming the written consent form, participants first answered questions on age, gender and hunger levels. Then, they practised the Go/No-Go Task as outlined in section 2.5. After this initial practice, they received the manipulation text on the mood effects of different foods as described in section 2.4. Once they answered all of the manipulation check questions correctly, they reported their current emotional state from 1 (*not negative at all*) to 7 (*extremely negative*). Following the first emotional state question, they were asked to rate the first block of affective images as described in section 2.3 and report their emotional state at the end as a measure of affect manipulation. Then, they proceeded with the first condition of the Go/No-Go Task. After completing the first condition of the Go/No-Go Task, they rated their emotional state, which was then followed by a second affect induction procedure where they rated the second block of the affective images. Following the last emotional state question, they received the second condition of the Go/No-Go Task. Eventually, they filled out the aforementioned surveys described in section 2.6.

Participants were debriefed at the end by stating the true nature of the study, including that the deceptive information they received on the mood effects of the food and negative affect induction procedure were necessary to test the hypothesis of the study. They were also given information on support services. All surveys and experiments were coded online using the PsyToolkit platform (Stoet, 2010, 2017).

2.8. Behavioural Analyses

The outcome measure for inhibitory control was computed by calculating the percentage of no-go trials with commission errors (i.e., when participants pressed when they were supposed to withhold) (Wessel, 2018). Reaction times on go trials were also included in the analysis (Batterink et al., 2010) as an indicator of approach tendencies; this means, decreased reaction times were expected to indicate an increased approach tendency. A decreased proportion of inhibitions reflected poorer inhibitory control.

2.9. Statistical Analysis

R Studio (version 4.3.2), JASP (Version 0.18.3), and IBM SPSS Statistics (Version 21.0) were used for computing outcome variables and inferential statistical analyses, preregistered at https://osf.io/wmv8k, with all data and analyses are available at: https://osf.io/y2pd6 (see Appendix D). Following the pre-registered criteria, first, participants who showed erroneous key presses that were three standard deviations (of the sample) away from the sample mean were excluded from the analyses (N=6). Then, inhibition scores with outlying omission rates were excluded from the analysis (7.43% of the individual values) as this reflects poor task engagement rather than better inhibition performance (Labonte and Nielsen, 2023). Finally, values exceeding three standard deviations from the mean were considered outliers for the proportion of inhibitions (2.47% of the individual values) and reaction times (1% of the individual values). All data and analyses are available at https://osf.io/y2pd6/.

Two-way repeated measures ANOVAs on reaction times and proportion of inhibitions were preregistered and conducted to test the hypotheses. The same analysis was performed on error rates for exploratory purposes. Bivariate correlations were also performed for exploratory analyses, and self-report measures of maladaptive eating and emotion regulation difficulties were used as covariates in ANCOVAs for exploratory purposes.

3. Results

Table 1. ***Descriptive Data: Self-Reported Measures***

Measure	Mean	SD	Min	Max
Hunger	3.15	1.8	1	7
BMI	24.48	3.88	18	40
Restrained Eating	2.43	0.85	1	5
Emotional Eating	2.24	0.88	1	4.46
External Eating	2.91	0.70	1.6	4.5
TEMS Liking	5.4	0.74	2.4	7
TEMS Health	4.64	1.05	1.8	7
TEMS Pleasure	4.42	0.97	2	7
TEMS Social	3.69	1.28	1	7
TEMS Visual Appeal	3.44	1.03	1	6.4

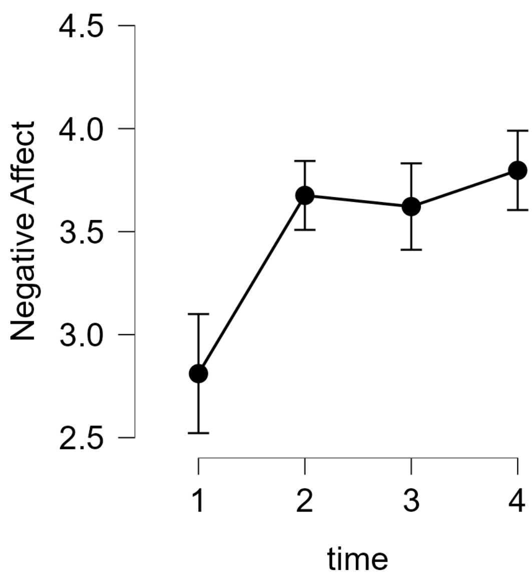
TEMS Weight Control	3.07	1.19	1	6.8
TEMS Affect Regulation	2.95	1.37	1	6.17
DERS Nonacceptance	3.36	0.78	1.67	5
DERS Goals	2.98	0.79	1.4	4.8
DERS Impulse	3.73	0.79	1.83	5
DERS Strategies	3.48	0.72	1.75	5
ERQ Reappraisal	5.02	0.96	2.67	7
ERQ Suppression	3.83	1.16	1.25	6
Weight Concern	3.76	1.80	1	7
Importance of Healthy Eating	5.42	1.36	1	7
Difficulty of Healthy Eating	3.80	1.70	1	7

Descriptive data for individual differences measures are presented in Table 1. Participants also reported their weight goals; 55.4% of them reported that they want to lose weight (*N*=41), 41.9% of them reported that they want to maintain their weight (*N*=31), and 2.7% of them reported that they want to gain weight (*N*=2).

3.1. Affect Manipulation Check

To test whether rating affective images efficiently resulted in increased negative affect, we performed a one-way repeated-measure ANOVA on affective state ratings with time (i.e. before and after rating the affective images) as a within-subjects effect. The degrees of freedom were corrected by using Greenhouse-Geisser correction (ε =.74) as the assumption of sphericity was violated (χ^2 (5) = 37.19, p <.001). The analysis showed that the negative affect has increased over time (F (2.23, 162.66) = 16.69, p<.001, η^2_p = .186). The negative affect measured before the affect induction procedure at Time 1 (*M*=2.8, *SD*=1.42) significantly increased compared to all following time points (see Figure 1); when participants rated the first block of the images at Time 2 (*M*=3.7, *SD*=1.45), (t (73)= - 5.56, p<.001, d= -0.55), after completing the first condition of inhibition task at Time 3 (*M*=3.6, *SD*=1.63), (t (73)= - 5.21, p<.001, d= -0.52) and after rating the second block of the images at Time 4 (*M*=3.8, *SD*=1.73), (t (73)= -6.34, p<.001, d= -0.63). There were no significant differences across Time 2, Time 3 and Time 4 (F (2, 146) = 1.06, p= .35, η^2_p = .014).

Figure 1. ***Negative affect across time***



Note. Bars reflect confidence intervals

3.2. Reaction Times on Go-Trials (Approach Tendencies)

Table 2. ***Descriptive Data: Reaction Times on Go-Trials***

Condition	Food Type	Max	Min	Mean	SD
Feel Better	Mood-enhancing	858.47	462.82	633.40	82.17
Feel Better	No mood-effects	908.97	451.38	660.41	99.15
Sustain Mood	Mood-enhancing	861.92	461.36	665.17	81.44
Sustain Mood	No mood-effects	839.15	378.00	650.68	83.90

Note. 2.7% of reaction time data points were omitted; n=3 data points were excluded due to being outliers, and n=5 data points were invalid values due to responses falling out of the valid time window.

A two-way repeated measures ANOVA with Condition (feel better vs stay in the same mood) and Food type (food with presumable mood effects vs no mood effects) was conducted to test whether emotion regulation goals (i.e., in the feel better condition) resulted in faster go-responses towards unhealthy food stimuli with presumed mood-improving effects. As expected, the analysis showed no significant within-subjects effects of Condition (F (1, 69) = 2.1, p=.15, η^2_p = .029) or Food type (F (1, 69) = 2.72, p=.10, η^2_p = .038). Importantly, we found the expected significant interaction between Condition and Food type (F (1, 69) = 18.75, p <.001, η^2_p = .214). Post-hoc analyses with Bonferroni corrections confirmed the hypothesis that participants showed faster go responses towards food with presumable mood-enhancing effects in the feel better condition (M=633.4, SD=82.17) than when in stay in the same mood condition (M=665.17, *SD*=81.44), (*t* (69) = -3.53, *p* =.004, *d* = -0.37), and compared to food without mood effects within the feel better condition (*M*=660.41, *SD*=99.15), (*t* (69) = -4.42, *p* <.001, *d* = -0.31). As expected, there were no significant differences in reaction times towards food with presumable mood-enhancing effects and food without no mood effects in the control (i.e. stay in the same mood) condition, and between feel better and control conditions towards food without mood effects (*p*s >.05). The results thus support our assumption that wanting to feel better emotion regulation goals resulted in an increased approach tendency towards unhealthy food that was introduced as enhancing mood. Descriptive data for reaction times in the go-trials are provided in Table 2.

3.3. Proportions of Inhibitions

Table 3. *Descriptive Data: Proportions of Inhibitions*

Condition	Food Type	Max	Min	Mean	SD
Feel Better	Mood-enhancing	1	.75	.94	.06
Feel Better	No mood-effects	1	.56	.94	.07
Sustain Mood	Mood-enhancing	1	.56	.96	.05
Sustain Mood	No mood-effects	1	.56	.95	.07

Note. 10% of single values were omitted; *n*=9 single values were excluded due to being outliers, and *n*=22 single values were excluded due to showing high omission rates.

We performed a two-way repeated measures ANOVA to test whether inducing emotion regulation goals to feel better resulted in impaired inhibition towards unhealthy food with presumable mood-enhancing effects. Condition (feel better vs stay in the same mood) and Food type (with presumable mood effects vs no mood effects) were included as within-subjects factors. As predicted, the analysis revealed no significant effect of Condition (F (1, 58) = 2.05, p=.16, η^2_p = .034), or Food type (F (1, 58) = 1.86, p=.18, η^2_p = .031). However, contrary to our hypothesis, there was no significant interaction between Condition and Food type (F (1, 58) = 0.97, p=.33, η^2_p = .016). Descriptive data for proportion of inhibitions are available at Table 3.

3.4. Exploratory Analyses on Proportions of Erroneous Responses

Table 4. *Descriptive Data: Proportions of Erroneous Responses*

Condition	Food Type	Max	Min	Mean	SD
Feel Better	Mood-enhancing	.42	0	.06	.08
Feel Better	No mood-effects	.80	0	.12	.19
Sustain Mood	Mood-enhancing	.67	0	.09	.12
Sustain Mood	No mood-effects	.63	0	.08	.12

Note. 3% of error rate data points were omitted; n=10 individual data points were excluded due to being outliers.

Descriptive data for error rates are provided in Table 4. To explore whether the proportion of erroneous key responses (i.e. accepting food that is not consistent with the task goal) has differed between feel better and stay in the same mood conditions across food types (i.e., with and without presumable mood effects), we performed two-way repeated measures of ANOVA with Condition and Food type as within-subjects factors. The analysis revealed that there was no significant effect of Condition (F (1, 64) = 0.23, p=.63, η^2_p = .004). This showed that task conditions did not differ in terms of difficulty. However, there was a significant effect of Food type (F (1, 64) = 5.8, p=.019, η^2_p = .083), and a significant interaction between food type and condition (F (1, 64) = 5.26, p=.025, η^2_p = .076).

We then performed post-hoc analysis with Bonferroni corrections. The proportion of erroneous key responses was increased towards food without presumable mood effects (M= .08, SD= .12) compared to food with presumable mood-enhancing effects (M= .07, SD= .098), (t (64) = -2.41, p =.019, d = -0.096), suggesting that participants struggled to learn that some unhealthy food may not help them to feel better. The difference between error rates for food types with different mood effects was not significant in the control condition (p>.05). In contrast, error rates were increased for the food without presumable mood effects (M= .089, SD= .134) compared to food with mood effects (M=.056, SD= .075), (t (64) = -3.09, p =.02, d = -0.29) in the condition where emotion regulation goals to feel better was induced. This may reflect that the feel better condition involved higher conflict, where participants found it difficult to “reject” the food items without mood effects, whereas they were able to apply the task rule more efficiently in the control condition.

3.5. Exploratory Analyses Using Weight Loss Goals

Restrained eaters are a particularly vulnerable population that may increase their food intake in response to negative affect (Evers et al., 2018; cf. Hagerman et al, 2021; Reichenberger et al., 2020; cf. Standen & Mann, 2021). Restrained eaters can show decreased inhibitory control towards unhealthy food (Liu et al., 2020; Zhang et al., 2017). It has been suggested that low and high-restrained eaters should be distinguished in research on disinhibited eating involving food go/no-go paradigms (Price et al., 2016). Importantly, more than half of the participants in our sample reported that their weight goal was to lose weight, indicating that restrained eating patterns could have influenced the analyses on inhibitions. To explore how restrained eating patterns could have influenced inhibition performance[1], we used weight goals as a between-subjects effects factor in a two-way repeated measures ANOVA on the proportion of inhibitions. To do so, we have created two groups of weight goals based on participants' answers: (i) participants who want to lose weight (i.e. diet goals) and (ii) others who want to maintain their weight and to gain weight (no diet). This resulted in roughly similar groups N_{Diet}= 41, $N_{No\text{-}diet}$= 33. Independent samples t-tests confirmed that participants in the diet group showed significantly higher restrained eating scores (t (72)= 2.36, p=.021, d=.55), higher weight control motivation (as measured by TEMS) (t (72)= 3.64, p<.001, d=.85), increased BMI (t (60)= 4.44, p<.001, d=1.13) and weight concern (t (72)= 7.91, p<.001, d=1.85) than the no-diet group (please see descriptives in Table 5). There were no other significant differences in self-reported measures, including emotion regulation difficulties, eating motivations, external and emotional eating scores and taste and health ratings of the presented stimuli across these two groups (all ps>.05).

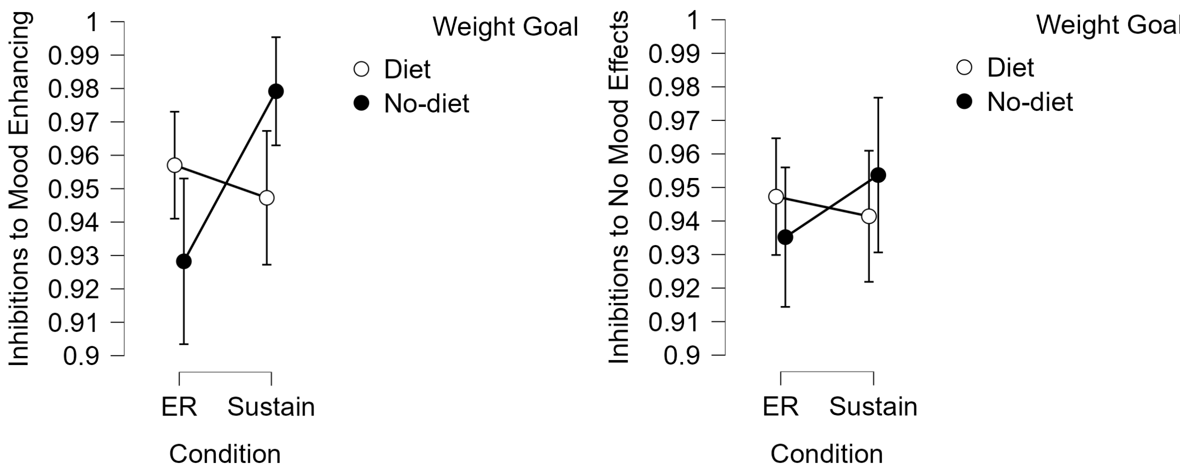
Table 5. ***Descriptive Data for Dieters and Non-Dieters***

	Group	Mean	SD
Restrained Eating	Diet	2.63	0.84

	No-diet	2.17	0.81
Weight Control	Diet	3.49	1.3
	No-diet	2.55	0.97
Weight Concern	Diet	4.85	1.24
	No-diet	2.39	1.44
BMI	Diet	26.39	3.74
	No-diet	22.57	3.01

A two-way repeated measures ANOVA with weight goals (diet vs no diet) as between-subjects factors, and Condition (feel better vs sustain) and Food type (food with presumable mood effects vs no mood effects) as within-subjects factors was performed on proportion of inhibitions (also see Footnote 1 for reaction times). There was no significant between-subjects effects of weight goal (F (1, 57) = .005, p=.94) and no within-subjects effects of Condition (F (1, 57) = 3.02, p=.087, η^2_p = .050) and Food type (F (1, 57) = 1.84, p=.18, η^2_p = .031) and no significant interaction between Food type and weight goals (F (1, 57) = .013, p=.91). However, there was a significant interaction between weight goals and Condition (F (1, 57) = 7.56, p=.008, η^2_p = .117).

Figure 2. Inhibition patterns across emotion regulation to feel better (ER) and sustain conditions for dieters and non-dieters for food types with different presumable mood effects



Note. Error bars represent 95% confidence intervals.

The post-hoc analyses with Bonferroni corrections revealed that participants without diet goals showed decreased proportion of inhibitions in the feel better condition (*M*= .93, *SD*= .07) than when they were asked to stay in the same mood (*M*=.97, *SD*= .06) (t (57) = -3.04, p =.021, d = -0.55). However, participants with diet goals did not show any significant differences in inhibitions across conditions (*p*s>.05). This reflected that non-dieters struggled to inhibit unhealthy food when emotion regulation goals to feel better were induced, while dieters have not shown such an effect.

There was no significant three-way interaction between weight goal, food type and condition (F (1, 57) = 2.004, p=.16, η^2_p = .034), showing that proportion of inhibitions did not differ across food types (i.e., mood-enhancing food and food with no given mood effects). However, in order to understand results better, we explored effects of food-type in post hoc analyses using Bonferroni corrections. Non-dieters showed the expected pattern, where they significantly decreased inhibition to food with presumable mood effects in the feel better condition (*M*=.93, *SD*= .07) than in the sustain condition (*M*=.98, *SD*= .04), (*t* (57)= -3.44, *p*=.023, *d*= -0.80). As expected, non-dieters did not show any significant differences in inhibitions across feel better (*M*=.94, *SD*= .07) and sustain condition (*M*=.95, *SD*= .07) for food without presumable mood effects (please see Figure 2), (*t* (57)= -1.25, *p*=1.00, *d*= -0.29) However, dieters did not show the expected pattern; proportion of inhibitions to food with presumable mood effects in feel better condition (*M*=.96, *SD*= .05) did not significantly differ in sustain condition (*M*=.95, *SD*= .06), (*t* (57)= .72, *p*=1.00, *d*= 0.15). As expected, dieters also did not show significant differences in inhibitions to food without presumable mood effects in feel better condition (*M*=.95, *SD*= .07) compared to sustain condition (*M*=.94, *SD*= .07), (*t* (57)= .43, *p*=1.00, *d*= 0.092). Descriptive data are provided in Table 6.

Table 6. ***Proportion of Inhibitions by Diet Goals***

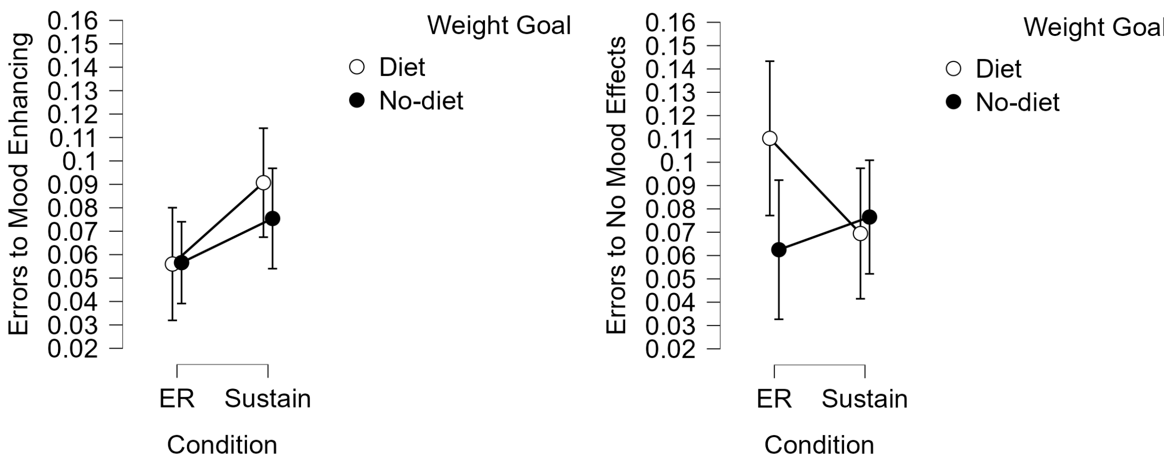
Condition	Food type	Weight Goal	N	Mean	SD
Feel Better	Mood-enhancing	Diet	32	.96	.05
		No-diet	27	.93	.07
	No mood-effects	Diet	32	.95	.07
		No-diet	27	.94	.07
Sustain Mood	Mood-enhancing	Diet	32	.95	.06
		No-diet	27	.98	.04
	No mood-effects	Diet	32	.94	.07

No-Diet	27	.95	.07

We further explored why non-dieters showed expected patterns on inhibition performance, whereas dieters did not. Therefore, we have conducted further analyses on error rates to reveal whether dieters efficiently learned and applied the task rule.

A two-way repeated measures of ANOVA with weight goals as a between-subjects factor and Condition and Food type as within-subjects factors was performed on error rates. The analyses revealed no significant effect of Condition (feel better vs sustain) and weight goals (dieters vs non-dieters) (*F*s <1). However, there was a significant effect of Food type (F (1, 63) = 5.1, p=.027, η^2_p = .075), and a significant two-way interaction between Food type and Condition (F (1, 63) = 4.5, p=.038, η^2_p = .067). This showed that effects on error rates reported in section 3.4. remained when weight goals were included as between-subjects factors. The three-way interaction between Food type, Condition and weight goals did not reach a statistically significant threshold (F (1, 63) = 3.48, p=.067, η^2_p = .052). However, we further explored whether the increased error rates to food without presumable mood effects in feel better condition differed across dieters and non-dieters. Bonferroni-corrected post-hoc tests revealed that dieters showed significantly higher errors towards food without mood effects in the feel better condition (*M*=.110, *SD*= .156) than to food with presumable mood effects (*M*=.056, *SD*= .071), (t (63) = -3.89, p =.005, d = -0.49). This suggest that dieters have “accepted” all unhealthy food items when they were asked to feel better whereas they efficiently applied the task rule in the stay in the same mood condition as reflected by post hoc tests (ps>.05 for error differences across food types for the sustain condition for dieters). In other words, they struggled to unlearn emotion regulation effects of the food and inhibited all unhealthy food similarly. All other post-hoc comparisons for the three-way interaction between weight goal, Condition and Food type were not significant (ps>.05) showing that error patterns in the initial analyses were potentially explained by dieter's erroneous responses (please see Figure 3).

Figure 3. Error rate patterns across emotion regulation to feel better (ER) and sustain conditions for dieters and non-dieters for food types with different presumable mood effects.



Note. Error bars represent 95% confidence intervals.

4. General Discussion

The current study investigated whether emotion regulation goals and beliefs about regulatory effects of food can cause difficulties avoiding and inhibiting these foods. We hypothesised that when participants are instructed to feel better by using unhealthy food, they would show increased approach tendencies to food with presumable mood-enhancing effects and difficulty inhibiting their responses to this food compared to when they were asked to sustain their mood. These were expected to result in faster reaction times on go-trials (i.e., approach tendency) and decreased proportion of inhibitions to food with presumable mood effects on no-go trials.

In line with our hypothesis, we found that participants showed increased tendency to approach food stimuli with presumable mood effects in the feel better condition as opposed to the control condition, and compared to food without mood effects. These approach responses to food with presumed mood effects were inhibited poorer in the feel better condition than in sustain condition by non-dieters. Interestingly, dieters struggled to learn that some unhealthy food may not help them to feel better goals as reflected by erroneous key responses. These results highlight that people approach unhealthy food and find it hard to avoid it under negative affect because they believe some food may function as a means to achieve their emotion regulation goals of relieving such negative emotional states. In addition, restrained eaters may show tendencies to believe that all unhealthy but tasty food helps them feel better. Therefore, we further support that alternative adaptive emotion regulation strategies can be efficient mechanisms to target in interventions on emotional eating patterns and disposition to affect-induced eating in restrained eaters, because when unhealthy food is perceived as the only available means to regulate emotions, people find it difficult to avoid and resist unhealthy food. In sum, we show how emotional eating may reflect an emotion regulation strategy.

With these findings, we extended evidence from Tice et al. (2001) showing how believing that food will not improve mood results in decreased unhealthy food consumption. In their studies, participants in control condition were not given any information on the mood effects of the food whereas the experimental group received information that food may not help them to feel better. As discussed previously, this may have led to possible demand effects, for instance, participants in the experimental condition might have decreased their food intake by guessing study's purpose whereas participants in control condition to follow their own beliefs about how eating may help them to feel better. In the current study, we were able to control for such demand effects and individual differences in food beliefs by using a within-subjects design where all participants were given mood effects of the food, rather than a separate control group not receiving any information. Participants, therefore, were directed to adapt the given information across the control and experimental conditions, rather than applying their own associations between food and mood effects. Although this has provided us with a more controlled design, we have not included a measure to test whether participants believed the given manipulation text on the mood effects of the food. However, we aimed to address that the experimental condition and control condition would simulate two opposite task goals that are congruent with two distinct stimulus types. We also aimed that participants would temporarily adopt the given rule by recalling times where they have felt better (or not) following consumption of the food provided as examples, also by including aspects of social conformity (Edelson et al., 2011; Higgs & Thomas, 2016). Future research could include food stimuli that are tailored to preference and associations made with mood effects for each participant, for instance, by a pre-test where participants can report what food they may use to feel better when they experience specific emotions (Altheimer et al., 2021). Despite this limitation, patterns in reaction times have shown that participants adapted the given information on functions of food efficiently during the task trials. Therefore, we were able to establish further causality that people may find it difficult to avoid unhealthy food when wanting to feel better because they believe that some foods provide them with an effective strategy to achieve emotion regulation goals. Importantly, we showed that activated goals to feel better can cause a tendency to approach unhealthy food, extending findings on how active indulgence goals can result in increased unhealthy food craving and intake (Kochs et al., 2022; Veit et al., 2020; Wethmann et al., 2016; but see Kochs et al., 2022). Therefore, moving beyond research using self-reported measures in the studies testing indulgence goals, we provide behavioural evidence on how active, momentary goals can influence automatic approach tendencies to unhealthy food.

Surprisingly, there were no differences in the proportions of inhibitions across conditions toward food with mood-enhancing effects and food with no mood effects. Given that the analysis on reaction times has reflected an effective goal and belief manipulation, this was unexpected. One possible explanation is that the increased trial number in the Go/No-Go Task, compared to what was used in the pilot study, might have resulted in the proportion of inhibitions being impacted by individual differences rather than state manipulation directly (Enkavi et al., 2018). In fact, while non-dieters have shown the expected patterns of decreased inhibition in the experimental condition (to feel better) compared to the control condition, dieters did not show any significant differences in inhibition towards any food type. This was surprising as previous work argued that restrained eaters are more vulnerable to affect-induced eating than non-restrained eaters (Evers et al., 2018; cf. Hagerman et al, 2021; Reichenberger et al., 2020; cf. Standen & Mann, 2021). Indeed, further exploratory analyses on error rates have revealed a potential explanation for why dieters did not show expected patterns, whereas non-dieters did. Specifically, when dieters were asked to feel better, they made significantly higher errors with food that was told not to have any regulatory effects than with food with presumable mood effects. This means they “accepted” all unhealthy food items to improve their mood; therefore, did not apply the task rule efficiently in the feel better condition and did not show the expected patterns in inhibition performance. Importantly, this may also mean, dieters might have struggled to unlearn that food may not help them to improve their affective states. These patterns further support the previous research that food may represent a regulatory strategy for restrained eaters (Evers et al., 2018; Reichenberger et al., 2020), although further studies are needed to directly test whether beliefs about the regulatory function of unhealthy food differ for restrained eaters compared to non-restrained eaters.

Alternatively, some studies argue that current diet goals can be activated when successful dieters are exposed to unhealthy food cues and when restrained eaters are reminded of situations where their unhealthy food restraint was effective (Meule et al., 2011; Papies et al., 2008; Stroebe et al., 2013). It can be argued that activated diet goals may have overridden the task rule to feel better for non-dieters in the current study. However, we did not have any measures of dietary success to conclude whether such cue-activated recall of diet goals could explain why dieters did not show the effects of emotion regulation goals. Therefore, further investigation is needed to directly test whether success in dietary restraint can predict whether restrained eaters use unhealthy food to relieve negative affect. For instance, the use of direct measures such as the Restraint Scale (Herman et al., 1978) and the Perceived Self-Regulatory Success in Dieting Scale (Fishbach et al., 2003) could be beneficial to understand how dietary success in restrained eating may help to inhibit existing tendencies to approach unhealthy food as a regulation strategy.

Overall, we have provided evidence that emotion regulation goals can result in an automatic approach tendency to unhealthy food, which may explain why affect-induced eating is not a universal experience and may be limited to those who struggle with emotion regulation (Altheimer et al., 2021; Brytek-Matera, 2021; Dalton, 2024). Specifically, we simulated a situation where a learnt response to unhealthy food would occur as a means to emotion regulation goals. This is in line with what has been argued, that only those who have previous experiences of relief after consuming unhealthy food might be the ones who are susceptible to affect-induced eating later on (Altheimer et al., 2021). In addition, when emotion regulation goals are activated and there is no other way of regulation is possible (or was proposed in the current design), an automatic approach to food may occur, which explains why those with limited adaptive regulation strategies may fail to resist unhealthy food. However, whether such automatic and dominant responses can be efficiently inhibited may depend on other active health goals, which is promising that current healthy diet goals can override the priority to feel better, for instance. By using direct measures of dietary success and beliefs about mood effects of food in maladaptive eating, future research can shed light into whether and when restrained eaters may struggle to resist unhealthy food when experiencing negative affect.

5. Conclusion

The present study experimentally tested whether emotion regulation goals to feel better and beliefs about regulatory effects of food can undermine the ability to inhibit and avoid unhealthy food. Our findings highlight how using unhealthy food as an emotion regulation strategy can heighten the approach tendency to food believed to relieve negative affect. Whether such dominant responses resulting from emotion regulation goals and beliefs about regulatory function of the food can be efficiently inhibited may depend on other active goals, such as current diet goals might override emotion regulation goals to feel better. Alternatively, some restrained eaters may find it difficult to unlearn the emotion regulation function of unhealthy food. Future research is needed to understand when dietary restraint leads to increased unhealthy food consumption in response to negative affect.

Ethical Statement

The study was approved by the Ethics Committee of the University of Reading and followed the Declaration of Helsinki [2023-042-EF].

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Declaration of competing interests

The authors declare no competing interests.

Appendix A. Stimuli Ratings

Table A.1. ***Stimuli ratings from pre-test survey (as reported in Chapter 2).***

	Health		Taste	
Items	Mean	SD	Mean	SD
Sweet Bakeries*	1.44	0.66	4.29	0.85
Pizza	2.00	0.90	4.03	1.01
Chocolate*	1.69	0.73	4.42	0.79
Doner Kebab	2.35	0.86	3.83	1.24
Gummy Candies	1.15	0.39	3.81	1.11
Ice cream (in a cup)	1.47	0.72	4.21	0.99

Lasagne	3.07	0.81	4.08	1.10
Burger*	2.16	0.91	4.14	1.07
Cake	1.34	0.56	3.66	1.24
Ice cream popsicles	1.65	0.69	3.77	1.10
French Fries*	1.61	0.68	4.39	0.89
Potato Chips	1.46	0.69	4.17	0.89

* selected items.

Table A.2. ***Ratings of presented stimuli***

		Mean	**SD**
Health	Sweet Items	1.735	0.827
	Savoury Items	2.507	1.020
Taste	Sweet Items	5.242	1.156
	Savoury Items	5.274	1.015

Appendix B. Normative ratings from two databases for emotional stimuli

Table B. ***Valence and Arousal Ratings for Emotional Stimuli***

	Valence		**Arousal**	
	NAPS	**OASIS**	**NAPS**	**OASIS**
Mean	3.261	2.254	4.015	4.205
Std. Deviation	0.465	0.452	0.663	0.582
Minimum	2.440	1.255	2.800	3.350
Maximum	4.304	2.971	4.980	5.455

Appendix C. Normative ratings of emotional stimuli in two separate blocks

Table C. ***Valence and arousal ratings across affect induction blocks***

	Valence		Arousal	
	1	**2**	**1**	**2**
Mean	2.833	2.638	4.226	4.002
Std. Deviation	0.705	0.658	0.597	0.640
Minimum	1.824	1.255	3.180	2.800
Maximum	4.304	4.043	5.455	5.287

Note. Valence and arousal did not significantly differ between two questionnaires used in affect induction procedures (ps > .05).

Appendix D. Data and Supplementary Analyses

All data and analyses can be accessed at: https://osf.io/y2pd6/

Footnotes

[1] The same analyses were performed on reaction times. Weight goals did not have a significant effect on reaction times and did not interact with within-subjects effects of Condition and Food-type, and there was no three way Weight goals x Condition x Food type interaction (all *ps*>.05). Importantly, when weight-goals were included as between-subject factors, effects on reaction times reported in section in 3.2. on the two-way interaction between Condition and Food type remained significant as well as post-hoc comparisons.

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CHAPTER 5

GENERAL DISCUSSION

General Discussion

This doctoral project tested whether emotional eating is caused by depleted cognitive resources to resist temptations or reflects a motivational shift from long-term health goals to short-term emotion regulation and indulgence goals. To test the ability to resist unhealthy food, we have used measures of "inhibitory control", which is a key cognitive mechanism involved in the control of eating.

Resource depletion accounts have argued that negative affect depletes cognitive resources to exert control, because people use these resources for regulating affect, and not enough resources are available for control. Hence, when negative affect is experienced, inhibitory control ability must be impaired (cf. Baumeister et al., 2024; Chester et al., 2016; but also see Macht, 2008, for a summary of other 'depletion' theories). Evidence so far from these approaches has been inconsistent, where the so-called "depletion" effect could not be replicated in many studies (e.g., Lin et al., 2020; Vohs et al., 2021) and studies using inhibitory control and other cognitive measures testing the detrimental impact of negative affect on cognitive resources lacked fully controlled experimental designs and showed inconsistent findings (e.g., Byrne et al., 2021; Liu et al., 2020). Importantly, a significant amount of counter-evidence showed that cognitive control ability can even be improved by negative affect (e.g., Storbeck et al., 2024; Yang & Pourtois, 2018) because negative affect can signal a need for behavioural adjustment (Botvinick, 2007; Dignath et al., 2020). Therefore, the first study (Chapter 2) tested whether experimentally induced negative affect causes depletion of cognitive resources necessary for inhibiting automatic responses to unhealthy food, by including proper control conditions of positive and neutral affective states, as well as both food and non-food stimuli. In a within-subjects counterbalanced design, positive, negative and neutral affective states were induced across food and non-food

Go/No-Go Tasks. Findings showed that induced negative or positive affect did not impair inhibitory control, neither in food nor in non-food contexts. Increased restrained eating and difficulties in emotion regulation were significantly correlated with decreased ability to inhibit unhealthy food only when negative affect was induced, indicating that impaired inhibition of unhealthy food reflects emotion regulation problems rather than resource depletion at either trait or state levels.

Motivational accounts have argued that people may indulge in temptations when they experience negative affect, not because their resources to suppress hedonic responses become depleted, but because their motivation and attention shift to feeling better or to reward themselves (Inzlicht & Schmeichel, 2012). Some studies have tested motivational explanations by inducing temporary motivational states to eat healthily or to indulge, mostly in between-subjects designs (e.g., Franssen et al., 2022; Werthmann et al., 2016; but also see Veit et al., 2020). Findings from these studies had been limited to self-reported measures of craving (Franssen et al., 2022) or laboratory food intake (Veit et al., 2020); with only one study measuring automatic cognitive responses to food (Werthmann et al., 2016). In two studies (Chapters 3 and 4), we have used within-subjects designs to test whether a motivational shift to indulge (Chapter 3) and inducing a motivation to feel better (Chapter 4) in response to induced negative affect can lead to difficulties resisting unhealthy food. In the second study (Chapter 3), we investigated whether shifting between temporary and malleable motivational states to eat healthily, as opposed to enjoying tasty food, can impact the ability to resist unhealthy food in different stages of stopping, extending recent theoretical explanations that motivational shifts can override automatic and learnt responses. Across Stop Signal Task and Go/No-Go Task trials, health oriented and indulgence motivational states were induced via task rules in a within-subjects design (cf. Golubickis et al., 2021). We showed how the motivational shift to indulge compared to eating healthily impaired the ability to resist automatic responses to unhealthy food when stopping occurred early (Go/No-Go Task), but not when stopping was required later (Stop Signal Task).

In the last study (Chapter 4), we combined methods of negative affect induction across inhibition trials from Chapter 2 and motivational state manipulation used in Chapter 3. We examined whether emotion regulation goals (i.e., motivational state to feel better) can impair the ability to inhibit unhealthy food responses when negative affect is induced and unhealthy food is presented as a means to achieve these emotion regulation goals to feel better. Across Go/No-Go Task trials, participants responded to food items with different presumable mood effects (i.e. food that makes them feel better vs food with no mood effects), following task rules to feel better or stay in the same mood. Wanting to feel better caused an increased tendency to approach unhealthy foods that were believed to improve affective states across all participants. Non-dieters showed difficulties inhibiting these approach responses when asked to feel better, whereas dieters showed difficulties learning that some unhealthy food may not help them to improve their affective states. This study provided novel causal evidence on how emotional eating reflects an emotion regulation strategy.

Across three studies, we have challenged the assumption that increased unhealthy food consumption in response to negative affect is caused by depleted cognitive resources and show how it reflects a motivational shift. Induced negative affect did not impair inhibitory control of food or non-food stimuli (in Chapter 2), and it has caused impaired inhibition and increased response tendency to unhealthy food only in restrained eating, for those with emotion regulation difficulties, or when participants were asked to regulate their negative affect (Chapter 4). A motivational shift induced by task goal to indulge resulted in impaired inhibition performance across all participants in Chapter 3, and this effect was also preeminent when negative affect and emotion regulation goals were induced in Chapter 4 for those with no active diet goals.

An overview of the empirical chapters with tested hypotheses, used methods and main findings is provided in Table 1. In this chapter, I will turn back to the themes raised in the general introduction, that is, to previously discussed research gaps and debates in the literature, to address how conducted studies answered the open questions and provided further evidence for (or against) the different models proposed to explain emotional eating. Following this, I will elaborate on the strengths and limitations of the methodology used in the empirical chapters and how open questions emerging from these limitations can be addressed in future research.

Table 1. Summary of Empirical Chapters: Tested Hypotheses, Methods and Findings

Chapters	Aims & Hypotheses	Affect / Motivation Manipulation	Cognitive Tasks	Findings
Chapter 2: Selective Depletion: Negative affect selectively impairs the inhibition of unhealthy food in disordered eating	Testing Resource Depletion accounts; if negative affect depletes resources, poorer inhibition should be observed in the negative condition regardless of stimulus type	Negative, Positive and Neutral Affect induced by personalised idiosyncratic words, presented in the task trials in a within-subjects design	Go/No-Go Task; Including non-food (i.e. household items) and food (both palatable and healthy) stimuli	Induced negative (or positive) affect did not impact the inhibition of food or non-food items. Only restrained eaters (s1) or those with emotion regulation difficulties (s2) struggled to inhibit unhealthy food when negative affect was induced.
Chapter 3:	Causal evidence	Motivational state	Go/No-Go Task	Shifts to

Shifting Priorities: Switching between health and indulgence motivational states impacts proactive inhibition towards unhealthy food	for motivational shift explanations: improved inhibition in the health-oriented motivational state condition than in the indulgence state condition (even when switching between them in the same experimental situation), whether different stages of inhibition might be differently impacted by higher-order goals	to eat healthily and to enjoy tasty food; applied as a secondary task rule in a within-subjects design	and Stop Signal Task as measures of early and late initiated inhibition. Both tasks included non-food (i.e. pictures of animals) and food (both palatable and healthy) stimuli	motivation to eat healthily as opposed to enjoying tasty food resulted in increased ability to resist unhealthy food, in the early stages of stopping (GNGT), but not when stopping occurs late (SST) (across studies 1 and 2).
Chapter 4: Testing the causal role of emotion regulation goals in inhibitory control and approach bias toward unhealthy food	Causal evidence for motivational shift explanations; whether emotion regulation goals under negative affect (motivational shift to feel better) result in difficulty resisting unhealthy food that is believed to improve mood; poorer inhibition in feel better condition to food with presumed mood-regulatory effect than in the stay in the same mood (i.e., control) condition	1- Motivational state to feel better as opposed to sustain the current affective state; applied as a primary task rule in a within-subjects design 2- Beliefs about regulatory function of food (can help to feel better vs no mood effects) manipulated by a deception text and applied as a primary task rule in a within-subjects design 3- Negative affect induced by affective images from NAPS & OASIS	Go/No-Go Task, including high-calorie palatable food items as stimuli and negative affective images for affect induction	Induced emotion regulation goals to feel better resulted in increased tendency to approach unhealthy food that was believed to improve mood, and for non-dieters, difficulty inhibiting these responses to unhealthy food. Dieters may find it difficult to unlearn mood enhancing effects of unhealthy food.

1. Stopping yourself *on time*: Motivational shift to control enhances inhibitory control before taking an action

Inhibitory control is a key cognitive mechanism involved in the control of eating, referring to the effortful suppression of a certain behaviour (Verbruggen & Logan, 2008). Previous research has shown that decreased inhibitory control is associated with higher calorie consumption, increased BMI, and unsuccessful dieting (Guerrieri et al., 2007; Houben et al., 2012; Meule et al., 2011, 2014a, 2014b; Nederkoorn et al., 2009; Price et al., 2016; Tsegaye et al., 2022), whereas improved inhibitory control is associated with reduced portion size, greater weight loss, increased healthy and decreased unhealthy food intake (Adams et al., 2017, 2021; Houben & Jansen, 2015; Lawrence et al., 2015). Therefore, across three studies, it provided us with a reliable measure of the ability to resist automatic responses to unhealthy food.

The different task paradigms of inhibitory control can map onto different inhibition processes. For instance, in the Stop Signal Task, participants initiate a response in every trial and are asked to stop an ongoing response when the stop signal is presented. In contrast, in the Go/No-Go Task, they do not initiate responses in every trial; instead, they withhold or respond to different stimuli in separate trials. In fact, some studies showed evidence that inhibition measured in the Stop Signal Task was associated with food intake and cravings (e.g., Guerrieri et al., 2007; Houben et al., 2012; Nederkoorn et al., 2009; Meule et al., 2014b). Other studies found that inhibition performance in the Go/No-Go Task (e.g., Meule et al., 2011, 2014a; Price et al., 2016; Tsegaye et al., 2022), but not in the Stop Signal Task (e.g., Kelly et al., 2020), predicted food intake. Some argued that the inhibition processes represented in these two tasks may reflect different real-life eating behaviours. For example, in the Go/No-Go Task, inhibition occurs before an action is taken, which may be comparable to situations where a person may refrain from making an unhealthy food decision altogether. In the Stop Signal Task, ongoing action is required to be inhibited, which may reflect the resisting behaviour when people restrict their further food intake after starting to eat (Meule et al., 2011).

These different stages of stopping have been conceptualised in several ways, such as response cancellation and response restraint, or early and late inhibition or proactive and reactive inhibition (Braver, 2012; Meyer & Bucci, 2016; Stuphorn & Emeric, 2012; Svaldi et al., 2014, 2015; Van Belle et al., 2014) and such different stages of stopping may involve top-down or bottom-up processes differently. For instance, proactive inhibition (i.e. response restraint or early inhibition) is argued to be goal-driven and involve top-down processes, whereas reactive inhibition (i.e. response cancellation or late inhibition) is suggested to rely on cue-driven bottom-up processes (Braver, 2012; Meyer & Bucci, 2016; Stuphorn & Emeric, 2012; Van Belle et al., 2014).

In Chapter 3, we have provided some insights into this debate. As we have induced indulgence and health-oriented motivational states, we were able to further investigate the impact of active higher-order goals (i.e. top-down processes) on early (i.e., Go/No-Go Task) and late (i.e., Stop Signal Task) initiated inhibition. Early-initiated inhibition was impacted by this shift in motivation, whereas late-initiated inhibition was not influenced across the two studies. We argue that when an action has not been taken, active goals (or a shift in motivation) can impact the ability to resist unhealthy food, further supporting that proactive inhibition (i.e., early) involves top-down processes dominantly, whereas reactive inhibition may rely more on bottom-up processes, and therefore was not impacted by induced motivational states. However, future studies are needed to replicate these findings, for instance, with more comparable task designs of early and late-initiated inhibition measures to further distinguish between distinct inhibitory processes. Differences across the used inhibition task designs are discussed further in section 7.2.

In fact, previous research has evaluated control of eating dominantly as a cue-activated process without much distinction between different stages of stopping. For instance, it was argued that rewarding aspects of the food stimuli can cause a higher desire to eat (Meule et al., 2014b; Ouwehand & Papies, 2010; Papies et al., 2008) and stimulus-activated responses can be unlearned by stop-signal training (e.g., Lawrence et al., 2015). Here, we also acknowledge the cue-activated responses to tasty but unhealthy stimuli and the involved bottom-up processes. For instance, in Chapter 3, we show that participants significantly better inhibited non-food items compared to food items. This reflects that reward cues of food stimuli may challenge inhibitory control. However, importantly, we further show that activated goals can also override such automatic cue-response associations that impact food responses, as the induced health-oriented motivational state facilitated inhibitions to unhealthy food compared to the indulgence state.

This distinction between reactive and proactive control extends beyond differences in top-down and bottom-up cognitive processes to contemporary arguments in the self-control literature. The process model of self-control (i.e., one of the motivational explanations) has identified four stages of resisting temptations (Duckworth et al., 2016; Napolitano et al., 2024). The first stage, similar to proactive inhibition, includes situational strategies, for instance, avoiding walking into a bakery. For instance, people who are good at self-control proactively avoid situations where inhibiting such dominant cue-activated responses would be necessary (Hofmann et al., 2012; Inzlicht & Roberts, 2024). The second stage involves shifting attention to cues other than temptation, for example, to calorie content or harmful ingredients of tasty food. Then, the appraisal stage includes reminding themselves of the consequences of engaging in temptation; for instance, thinking of the guilt or weight gain one may experience. The last stage includes stopping an ongoing response, for example, ordering a salad once already having walked into the bakery. It was argued that this very last stage is the least promising, and "last resort" stage in terms of the ability to resist the temptation to consume food that is not in line with one's health goals. Our findings further support this process of successful self-control as we show that a motivational state to eat healthily improved inhibition when stopping occurred before initiating responses (Go/No-Go Task), whereas shifting between indulgence and health states did not influence inhibition performance in the later stages of stopping (Stop Signal Task). Therefore, while active health goals could help inhibit the most basic automatic approach responses, it might be most effective if an action towards temptation has not been taken.

2. Eating your emotions, *you cannot change them otherwise*: Emotional eating reflects problems with emotion regulation

Many discussions evolved around whether distinct negative emotions can differentially impact eating (Bongers & Jansen, 2016; Macht, 2008). Recent meta-analyses analysing large datasets argued that emotional eating behaviour might occur only for those with emotion regulation difficulties, as use of food would comfort and relieve negative affect, compensating for the other failed attempts to cope (Altheimer & Urry, 2019; Brytek-Matera, 2021; Evers et al., 2018; Kopetz et al., 2018; Nolan et al., 2025; Taut et al., 2012). From this perspective, there might not be a uniform effect between specific emotions and increased eating; it is rather that any discomfort that is attempted to be soothed by food can result in difficulty resisting unhealthy food.

In Chapter 2, we have provided further experimental evidence that emotion regulation difficulties are associated with difficulty resisting unhealthy food. Specifically, as restrained eating increased (Study 1) and access to emotion regulation strategies decreased (Study 2), the proportion of inhibitions to unhealthy food decreased when negative affect was induced, compared to healthy food and non-food stimuli. This was particularly important and novel because most evidence on emotion regulation arguments thus far has been based on correlational designs with self-report measures of uncontrolled eating (e.g., Nolan et al., 2012), studies testing whether adaptive regulation strategies can lead to healthier food decisions (e.g., Taut, 2012; Langley et al., 2023), or data that did not involve behavioural measures of inhibition (e.g., Evers et al., 2018). However, future studies are still needed to replicate and explore these effects further, as predictors of impaired inhibition to unhealthy food in negative affect differed across the two samples. Potential reasons for these discrepancies are further discussed in section 7.3, with open questions pertaining to whether restrained eating patterns may also reflect emotion regulation difficulties.

The findings in Chapter 2 directed us to ask the question whether this effect between emotion regulation difficulties and unhealthy food disinhibition reflected a strategic emotion regulation choice. In other words, we asked whether people who have limited strategies to regulate their negative affect struggle to inhibit unhealthy food because they strategically choose unhealthy food to feel better (cf. Kopetz et al., 2018; Moors et al., 2017). Therefore, Chapter 4 directly instructed participants to use some unhealthy food to regulate the induced negative affect. We found that using food to regulate affect led to increased approach (i.e. response) tendency to unhealthy food across all participants, specifically to food that was believed to improve negative affect, but not to other unhealthy food items that were not described to have any regulatory effects. This further showed how emotional eating reflects problems with emotion regulation, as difficulties avoiding and resisting unhealthy food can be caused by believing that some food functions as only available means to feel better.

Across Chapters 2 and 4, the presented studies involved a range of different emotions (e.g., anxiety, sadness, anger), which are different facets of negative affect that are experienced sometimes in combination with one another in everyday life (Larsen & McGraw, 2011). In line with Altheimer et al. (2021), our findings further highlight how strategically choosing food to feel better could impact food responses, going beyond links established between distinct emotions and unhealthy food decisions, which have been proposed to be universal effects (cf. Macht, 2008). Nevertheless, we did not systematically vary the negative emotions across the studies to conclude that there were no differences between how distinct negative emotions can lead to different responses to unhealthy food. Therefore, future studies can further investigate whether people choose to regulate some emotions with unhealthy food more often than others, for instance, due to different outcome expectations on whether certain emotions can be regulated by consuming tasty food while others cannot be easily changed (cf. Hennegan et al., 2013).

In sum, across Chapters 2 and 4, we provide experimental evidence on *whether, when, why and for whom* negative affect may lead to increased unhealthy food consumption: those who eat to feel better might struggle to resist unhealthy food when experiencing negative affect because unhealthy food consumption can be a strategic and maybe most effective or only available choice to regulate affect for them (Altheimer et al., 2021).

3. Resource depletion, *not so depleted*: Negative affect may not compromise the ability to resist

The resource depletion accounts were one of the two competing explanations of emotional eating that we aimed to test and challenge in the current project (Baumeister et al., 2024; Chester et al., 2016; Ding et al., 2020; but also see Macht, 2008, for other accounts). Experimental evidence showing whether negative affect can cause depletion of resources to resist has remained limited to inhibition of non-food stimuli (Chester et al., 2016; Ding et al., 2020; Patterson et al., 2016) or relied on self-reported measures of negative affect rather than experimental affect induction (Byrne et al., 2021). Importantly, experimental research with food stimuli has not included proper controls, for instance, by not including positive affect inductions or non-food stimuli (Liu et al., 2020). Interestingly, a large amount of counterevidence from the affective signalling hypothesis has shown that negative affect could improve cognitive control (Botvinick, 2007; Dignath et al., 2020; Pourtois, 2020) and inhibitory control of non-food stimuli (Storbeck et al., 2024). It was therefore important to address these discrepancies in a fully controlled experimental design by including proper control conditions for arousal and different stimulus types to test whether negative affect could cause depletion of cognitive resources to resist. For instance, if negative affect depletes cognitive resources due to the same resources being devoted to affect regulation, then inhibition performance is expected to be impaired both in food and non-food contexts when compared to neutral or positive affective states. However, previous evidence lacked proper experimental designs to draw such conclusions.

In Chapter 2, we have challenged the assumption that negative affect compromises the ability to inhibit by using a fully controlled and balanced within-subjects experimental design where negative, positive and neutral affect were induced in both food and non-food tasks. Across two studies, we have shown that induced negative affect did not impair inhibitory control performance, neither in food nor in non-food contexts. Instead, we have found that increased restrained eating significantly correlated with decreased inhibition to unhealthy food compared to other types of stimuli when negative affect was induced.

Based on the limited resources model, Macht (2008) argued that negative affect can cause disinhibited eating in restrained eaters because they constantly attempt to resist their food urges, which leads to almost trait-level depletion in their cognitive resources (also see Boon et al., 2002). We challenge this assumption in two ways. Firstly, in Chapter 2, we show that impaired inhibition in restrained eating was selectively evident for unhealthy food when negative affect was induced, but not for healthy food or non-food stimuli. This means, depleted resources due to constantly controlling eating in restrained eaters may be not what caused them to struggle with inhibiting, as they did not show any difficulties inhibiting other types of stimuli. Secondly, in Chapter 4, we show that dieters and non-dieters did not show any differences in inhibiting their unhealthy food responses when negative affect was induced. If anything, non-dieters showed decreased inhibition when asked to feel better. Therefore, such constant use of control resources to restrict food intake may not explain why restrained eaters may fail to resist unhealthy food when they experience negative affect.

Although we did not include affect manipulation check questions in Chapter 2, we employed an affect induction procedure previously used in comparable studies (Langley et al., 2023; O'leary et al., 2023). However, it is possible that the used procedure may not have been strong enough to observe depletion effects on cognitive resources. In fact, a recent meta-analysis study on different affect induction procedures indicated that happiness and sadness may be most efficiently induced with emotional pictures, whereas anger and anxiety should be induced with autobiographical recall (Joseph et al., 2020). These were both affect induction procedures that we used across Chapters 2 and 4, but we did not tailor these procedures to different emotions separately. In addition, the strength of procedures (e.g., video clips, music, feedback) may differ depending on sample demographics such as gender, cultural differences or clinical symptomatology (Joseph et al., 2020). Therefore, future studies may want to employ stronger affect induction procedures that are tailored to sample characteristics and to specific emotions to replicate these findings.

4. Overrated willpower: Motivational shifts can impact automatic responses

Our first study (Chapter 2) suggested that negative affect does not cause depleted resources that are lacking for inhibition. In Chapter 3, we therefore tested whether a motivational shift can explain why people find it difficult to resist unhealthy food in certain situations, such as when experiencing negative affect (Inzlicht & Schmeichel, 2012).

The motivational explanations have argued that failures to resist temptations are not caused by depleted resources, but by a shift in motivation to indulge and attention to rewarding/hedonic cues (Inzlicht & Schmeichel, 2012). Evidence so far has tested whether activating indulgence and health goals (i.e. shifting motivation to temptations or to control) impacted food cravings (Franssen et al., 2022), the amount of food intake (Veit et al., 2020), and, importantly and most comparable to our study, attentional bias as a measure of automatic responses. Attentional bias was increased to unhealthy food for those induced with an indulgence motivational state than for the others in the health-oriented motivational state condition (Werthmann et al., 2016). However, this effect was limited to participants high in dietary restraint. Participants with higher dietary restraint were argued to have higher conflicts about food decisions, being more susceptible to motivational changes. Importantly, the study used a between-subjects design that does not allow for testing whether people can shift between motivational states.

In Chapter 3, by using a within-subjects design, we were able to directly test whether such a motivational shift is possible from one moment to another. The design also allowed us to control for individual differences to a great extent. We have extended these experimental findings by employing a measure of automatic tendencies (i.e., inhibitory control), which was impacted by the motivational states oriented to health as opposed to indulgence across all participants. We showed that a health-oriented motivational state facilitated resisting ability to dominant responses to unhealthy food as opposed to an indulgence-oriented motivational state. This allowed us to show how such automatic responses can be influenced by shifted motivation, therefore, allowing us to apply a similar method of motivation manipulation in Chapter 4 to test “feel better” goals. In Chapter 4, we showed that a motivational state to feel better resulted in an increased tendency to approach unhealthy food and impaired inhibition of such dominant responses. Overall, we supported the motivational accounts of self-control by showing that action towards temptations does not reflect compromised ability but can be caused by a temporary shift in motivation.

It is important to note that employed goal manipulations were designed for the presented proof-of-principle studies and to be applied to all participants. Therefore, they might have stronger effects on automatic behaviours than the way motivational changes impact eating behaviours in daily life. Future studies, therefore, would be helpful to investigate whether naturalistic manipulations yield similar effects in real-life behaviours. In a related vein, interventions targeting motivational processes may need to be tailored to individuals’ active goals and triggers of unhealthy food consumption (cf. Wiers et al., 2020). For instance, in the contexts where people are motivated to indulge (e.g., social contexts such as being in a restaurant), reminding health goals might be a less efficient way to promote healthy choices. Instead, pairing indulgence cues with healthy food options may be more efficient to implement behavioural changes (Turnwald & Crum, 2019).

5. Need to regulate: Emotional eating is a regulation strategy

Experiencing negative affect may activate emotion regulation goals to feel better (Evers et al., 2010; Gross, 2015). As Chapter 2 has shown that disinhibition of unhealthy food was associated with difficulties in emotion regulation, and Chapter 3 indicated that a motivational shift to indulge could influence automatic food responses, we tested whether shifts in motivation to feel better when experiencing negative affect could cause difficulties avoiding and inhibiting unhealthy food in Chapter 4.

Previous studies have indirectly shown that people may use tasty but often unhealthy food to achieve emotion regulation goals to feel better. For instance, people report eating to overcome an upsetting event or to relieve stress (e.g., Cleobury et al., 2014; Snuggs et al., 2025). Most evidence on whether emotional eating reflects a regulation strategy dominantly came from between-subjects experimental designs testing the effects of different regulatory strategies on food choices (e.g., Langley et al., 2023; Maier et al., 2015), or correlational designs assessing the relationship between self-reported measures of maladaptive emotion regulation strategies and unhealthy food choices (e.g., Dalton et al., 2024; O'Leary et al., 2023). Only one study so far has experimentally tested whether people eat unhealthy food because they believe that these foods will help them achieve their emotion regulation goals (Tice, 2001). This study was limited to a between-subjects design lacking a proper control condition. Specifically, the experimental group received information that food will not change how they feel; it may even prolong their current negative or positive affect. In contrast, the control group did not receive any information. Although participants in the experimental condition ate fewer snacks than others in the control condition, it was not clear whether this was caused by demand effects, such as participants in the experimental condition paying more attention to their eating, for instance, by understanding the study's hypothesis or due to attentional bias. Therefore, in Chapter 4, we included a fully counterbalanced within-subjects experimental design to test whether emotional eating reflects a regulatory strategy, establishing a causal link between beliefs about the regulatory effects of food and emotional eating. Specifically, all participants received information on how sweet (or savoury food) can help them feel better (or not) and were asked to respond to these food items in the Go/No-Go Task. Across the task trials, they were instructed to feel better in the emotion regulation goals condition and to stay in the same mood in the control condition by responding to these food types, while emotional pictures were presented to induce negative affect.

As outlined previously, wanting to feel better increased the tendency to approach unhealthy food with presumed mood effects across all participants. This showed that people may eat emotionally because they believe that some foods can help them to achieve goals to feel better. While non-dieters showed poorer inhibition to food with presumable mood effects when asked to feel better, dieters did not show any difference in inhibition performance across conditions and to food with different supposed mood effects. It could be argued that current diet goals might have been activated by unhealthy food cues if dieters in our sample were successful restrained eaters (Stroebe et al., 2013). However, error rates reflected that when dieters were asked to feel better, they "accepted" the unhealthy food items that were described as not having any mood effects. This suggests that dieters struggled to unlearn the mood effects of the unhealthy food. These findings are in line with the previous studies arguing that restrained eaters might be more prone to emotional eating (Evers et al., 2018; Hagerman et al, 2021; Liu et al., 2020; Reichenberger et al., 2020; cf. Standen & Mann, 2021; Zhang et al., 2017), while we open new avenues for future research to test whether this is caused by restrained eaters having stronger food-feel better associations. However, as these findings were exploratory, selected samples of restrained and unrestrained eaters would be necessary in future research to test whether emotional eating patterns for restrained eaters are caused by such food beliefs.

6. Summary of Addressed Research Gaps and Future Directions

Across the empirical chapters, we provided novel experimental evidence for the competing motivational and resource depletion accounts of emotional eating and self-control. Conclusions and future directions discussed in Chapters 2, 3 and 4 are provided in Table 2.

Overall, we show that shifts in motivation explain difficulties resisting unhealthy food and negative affect does not cause compromised ability to control. Decreased inhibition of unhealthy food in response to negative affect only reflects emotion regulation difficulties and this occurs because people may perceive some unhealthy food as instrumental to achieving emotion regulation goals. Going beyond this debate, we provide further insight for previous discussions on early and late initiated stopping, effects of different emotions on food responses, restrained eating and its relation to emotional eating patterns. In Chapter 3, we show how early (proactive) inhibition involves top-down processes. Across Chapters 2 and 4, we claim that emotional eating may not be explained by uniform effects of emotions, which were previously argued to initiate different food responses due to valence and arousal (Macht, 2008). Instead, we further support that emotional eating occurs when any discomfort is aimed to be regulated by unhealthy food (Altheimer et al., 2021). In addition, we show that restrained eaters do not show depleted trait ability to control. Instead, they may struggle to regulate their emotions and believe that unhealthy food can help them to feel better. Of course, there is much to be explored in future studies, for instance, what strategies can help to resist unhealthy food when stopping later, what are the underlying reasons for emotion regulation difficulties for restrained eaters, whether and why they might be more prone to have food-feel better associations than non-restrained eaters. Future directions building on these findings will be further discussed in section 7 with methodological considerations.

Table 2. ***Summary of Discussions***

Chapters	Summary	Conclusions	Future Directions
Chapter 2: Selective Depletion: Negative affect selectively impairs the inhibition of unhealthy food in disordered eating	Induced negative (or positive) affect did not impact inhibition of food or non-food items in a within-subjects Go/No-Go Task. Only restrained eaters (s1) or those with emotion regulation difficulties (s2) struggled to inhibit unhealthy food when negative affect was induced.	Resource depletion models are challenged: negative affect does not compromise inhibition.	- Replication is needed, for instance using stronger affect manipulations - It should be assessed when dietary restraint is maladaptive and subsequently poses emotion regulation difficulties. E.g., can success or failure in dietary restraint explain why restrained eaters struggle to resist unhealthy food when experiencing negative affect?
Chapter 3: Shifting Priorities: Switching between health and indulgence motivational states impacts proactive inhibition towards unhealthy food	Shifts to motivation to eat healthily as opposed to enjoying tasty food resulted in increased ability to resist unhealthy food, in the early stages of stopping (GNGT), but not when stopping occurs late (SST).	Additional evidence for the motivational explanations of self-control. Not only do higher-order goals impact automatic responses, but it is also possible for people to shift between motivational states.	- More comparable task paradigms of early and late inhibition should be employed in future studies to understand whether proactive and reactive inhibition are differently impacted by motivational shift. - Naturalistic motivation manipulations and behavioural measures can be employed in future studies to further assess whether our findings on inhibition ability translates to real life eating behaviours
Chapter 4: Testing the	Induced emotion regulation goals	Causal evidence emotional	Future studies should assess why dieters may find it

causal role of emotion regulation goals in inhibitory control and approach bias toward unhealthy food	resulted in increased approach tendency towards unhealthy food with presumed mood-regulatory effects, and for non-dieters, difficulty inhibiting these responses to unhealthy food. Dieters struggled to unlearn that some unhealthy food may not help them feel better	eating reflect an emotion regulatory strategy rather than negative affect consistently resulting in depletion	difficult to learn that some unhealthy food may not help them feel better; and when existing health goals may override emotion regulation goals to feel better.

7. Methodological Considerations & Future Directions

In this section, I will detail several important methodological considerations and open questions to be explored further in future research. Firstly, all studies used measures of inhibitory control towards healthy and unhealthy food and non-food stimuli. However, we have made some adjustments to the task designs, in terms of the number of trials used, the variety of stimuli involved, or the type of inhibition task we have employed. These have provided some strengths but also limitations that can be addressed by future research. In addition, cognitive task paradigms may not always reflect how people solve self-control conflicts in daily life. Therefore, in section 7.1., I will also discuss to what extent observed effects can help to understand real life eating behaviours and how future studies can employ other measures to extend the presented findings. Secondly, exploratory findings on restrained eating in Chapters 2 and 4 were addressed only by using the Dutch Eating Behavior Questionnaire (DEBQ, Van Strien et al.,1986). However, there is more to be explored than what DEBQ measures, that is, maladaptive dietary restriction. Other aspects of restrained eating, such as perceived success in dietary restraint, guilt involved in failure to resist, or the relation of these aspects with emotional eating, should be explored further by including different measures and selected samples, which will be detailed in section 7.2. Thirdly, in section 7.3., I will evaluate the affect induction procedures used in the presented studies in line with the integral and incidental affect framework, raising new questions for future research to clarify when negative affect can also improve the ability to control. Finally, it is important to note that poorer task engagement (e.g., high omission rates reflecting overestimated inhibition performance) has led to exclusions in the presented studies, especially when experiments were conducted online. Therefore, future studies may include larger samples in a controlled lab environment to replicate observed effects efficiently.

7.1. Food Stimuli

We have started with a pre-test survey study where we established estimates for perceived healthiness and tastiness of the food stimuli in our population (Labonte & Nielsen, 2023). These stimuli were selected from a commonly used database (Blechert et al., 2019) and used across three studies, including samples from a comparable population to the survey sample. Each study has included participants' ratings in terms of perceived healthiness and tastiness of the food stimuli used in the inhibition tasks, and these measures were used in exploratory analyses to control for their effects on dependent variables. Across all studies, perceived tastiness or the healthiness of the used stimuli did not correlate with any measures. Although such personal preferences were controlled for, similar to the affect induction procedure employed in Chapter 2, personalising food stimuli could be beneficial in future studies to strengthen goal and affect manipulations. For instance, by using a pre-test, the associations that each person reports having with specific emotions and certain unhealthy food items can be taken into account (cf. Altheimer et al., 2021), or unhealthy food that each person likes and chooses to indulge in can be used when inducing indulgence goals.

It is also important to note that some criticism evolved around describing food as “healthy” or “unhealthy”, as such categories may not be helpful for implementing health behaviours (Schröder, 2003). Although we do not encourage such polarised descriptions of food, we evaluate these categories in line with the description of self-control conflict; food that serves short-term enjoyment goals or temptations, that has long-term negative health consequences if not balanced (Fujita, 2011; Milyavskaya et al., 2021). Besides, we do not only base these descriptions on the provided ratings available in the database but also on our pre-test survey, and use these categories for fully balanced and controlled experimental designs. Future studies may include more stimuli to assess, for instance, health and taste perceptions that may differ in cross-cultural and social contexts, which may influence whether people may justify unhealthy food choices when wanting to indulge or feel better (Higgs, 2015; Higgs & Thomas, 2016).

7.2. Inhibition tasks

Including increased trial numbers in inhibition tasks is conventionally considered to provide increased statistical power (Von Gunten & Barthalow, 2021); however, this comes with confounding effects, such as training effects or not allowing state manipulations to be studied efficiently due to tasks tapping into trait-level differences (Enkavi et al., 2019).

Modified versions of the Go/No-Go Task have been used across all presented studies in the current project. In Chapter 2, we have included 80 trials per block in the main study and 40 trials per block in the replication study. In Chapter 3, we used 40 trials per block, and in Chapter 4, we included 160 trials per condition.

In the first study, through two different pilot studies (*N*=22, *N*=20), we have tested 80 trials per block design for the Go/No-Go Task. By performing descriptive statistics, we have not found any differences between patterns for each condition when 80 trials were split into two parts. An increased number of trials would provide more reliable estimates when comparing performance in the less frequent no-go trials; therefore, we kept the 80-trial structure in the main study. However, error rates were relatively lower, possibly due to practice effects. Therefore, in the replication study, we have performed a pilot (*N*=12) with 40 trials per block and observed increased error rates that reflected more efficient involvement of dominant responses. Consistently, Chapter 3 also included 40 trials per condition.

On the other hand, Chapter 4 included 160 trials per condition with an increased number of different unhealthy food pictures. This adjustment in trial number was made for two reasons. First, the Go/No-Go Task design was more complex than the other two studies due to involving two task rules at once. Participants were expected to follow the deception information and reverse their responses under negative affect, whereas in Chapter 2, they only applied a go/no-go rule, and in Chapter 3, they used the categorisation rule based on their own perception of the food items (i.e., healthy vs not healthy; tasty vs not tasty). Second, there were only two experimental blocks in this study; hence, an increase in trial number per condition would provide a comparable task design to previous studies where affect and goal manipulations were used separately. However, this increase in trial number has resulted in individual differences to confound the effects of goal manipulation, reflected by, for instance, a three-way interaction with the restrained eating measure that could not be assessed further with exploratory analyses. As the impact of motivational states on inhibitory control has not been previously tested by previous research, it remains unclear whether such state manipulations can be efficiently studied in shorter task paradigms without compromising statistical power.

The Stop Signal Task in Chapter 3 was modified from a comparable study testing effects of reward contexts on inhibitory control (Houben et al., 2012). As Chapter 3 also included a Go/No-Go Task, including a higher number of trials in the Stop Signal Task was not plausible due to the lengthy procedure to result in possible fatigue and boredom. However, this resulted in unreliable estimates when the integration method was applied to calculate the Stop Signal Reaction Time. We, therefore, have replicated the SST with 150 trials per condition by including four more different pictures to avoid habituation to the presented stimuli. However, as we have not included the Go/No-Go Task within the replication study, we could not further explore differences in task performance, although we were able to produce more reliable estimates of SSRT in the longer design.

Future studies are still needed to understand the exact differences in the inhibitory processes in early and later stages; for instance, by using directly comparable task rules that are implemented across all trials in both tasks. In the presented studies in Chapter 3, motivational state manipulation was applied in separate trials in the Go/No-Go Task whereas it was applied in all trials of the Stop Signal Task. This procedure was followed in line with the conventionally used designs of both task paradigms. In future studies, by including a task design similar to Chapter 4 with different key responses during go-trials, the effects on the Go/No-Go Task can be more consistently compared to the Stop Signal Task.

Of course, the effects of negative affect and motivational states on inhibitory control can be further assessed with different methods than used cognitive task paradigms. For instance, neurophysiological measures could further shed light on whether different affective and motivational states impact the inhibitory activity (e.g., N2 and P3 amplitudes, frontal alpha asymmetry) in response to unhealthy food as opposed to healthy food and non-food items. Similarly, non-invasive brain stimulation techniques can be employed to assess further causality between motivational and emotional states and difficulties resisting unhealthy food. For instance, Transcranial Magnetic Stimulation can be used to temporarily disrupt the neural activity in the motivation-related brain areas (e.g., dorsolateral prefrontal cortex) and inhibition responses to unhealthy food can be observed accordingly. Alternatively, Transcranial Direct Stimulation may be useful to enhance inhibitory activity by targeting the prefrontal cortex to further assess bottom-up and top-down processes in different stages of stopping (Akil et al., 2024).

Although providing robust experimental effects, it is also important to note that inhibition tasks might not be the best measures of individual differences due to low between-subject variability, even when applied as lengthy procedures with many trials (Enkavi et al., 2019; Hedge et al., 2017). Therefore, exploratory findings in Chapter 2 and Chapter 4 should be replicated with selected samples or tested further with behavioural measures. In a related vein, cognitive task paradigms may not completely reflect real-life self-control behaviours. For instance, there is often one action to be taken to address the control demands in inhibition tasks, that is, to respond with associated keys to go trials or withhold this response (cf. Becker et al., 2024). However, strategies to pursue higher-order goals (e.g., health goals) extend beyond inhibiting impulses in everyday life (Becker et al., 2024; Fujita, 2011; Lopez et al., 2021). Therefore, behavioural measures are necessary to understand whether observed effects of negative affect and motivational shift on inhibition translate to real-life food choices and eating behaviours, where inhibition is only one of many strategies to follow long-term health goals. For instance, by using Ecological Momentary Assessments, whether control of eating in different contexts (e.g., before people start to eat as opposed to making a food choice) is impacted by motivational fluctuations between healthy eating and indulgence in daily life can be understood. Cognitive task paradigms of inhibitory control can still be included in such longitudinal designs to shed light on the extent to which they can explain overcoming temptations to unhealthy food in daily life.

7.3. Restrained Eating

Several studies reported that restrained eating is associated with difficulties resisting unhealthy food in response to negative affect (Evers et al., 2018; cf. Hagerman et al, 2021; Liu et al., 2020; Reichenberger et al., 2020; cf. Standen & Mann, 2021; Zhang et al., 2017). While Macht's (2008) model argued that this occurs due to rigid diet goals depleting control resources, some other explanations were proposed for why restrained eaters may fail to resist unhealthy food. For instance, Herman and Polivy (1980) suggested that restrained eaters may give up on their diet goals easily due to "what the hell effect", referring to abandoning the diet goal altogether because of believing that the goal is already violated by a momentary indulgence. This effect is also known as the "snowball effect", referring to situations where initial self-control failure leads to many other failures afterwards (Heatherton & Wagner, 2011).

Across Chapters 2 and 4, interesting but opposite patterns in individual differences of restrained eating have emerged in relation to inhibitory control of unhealthy food under negative affect. In Chapter 2, restrained eating was associated with poorer inhibition of unhealthy food under negative affect. In Chapter 4, dieters did not show impaired inhibition to unhealthy food when they were induced with emotion regulation goals compared to non-dieters. Although we showed that poorer inhibition ability is not underlined by depleted capacity to resist, as discussed in section 3 above, it remains unclear whether, why and when restrained eating patterns come together with enhanced or impaired inhibition.

In Chapter 4, we have used diet goals as a proxy of restrained eating as it was measured in the Dutch Eating Behavior Questionnaire (Van Strien et al.,1986), including questions on dietary behaviours (e.g., "*Do you try to eat less at mealtimes than you would like to eat?*", "*How often do you refuse food or drink offered because you are concerned about your weight?*", "*Do you watch exactly what you eat?*", "*How often do you try not to eat between meals because you are watching your weight*?"). However, it is still debated what determines such dietary restriction behaviours and intentions to be considered as "maladaptive" restrained eating patterns, which may come with emotion regulation difficulties (Polivy et al., 2020).

In fact, in our studies, restrained eating significantly correlated with emotional eating. However, this relationship had opposite directions in different samples. In Chapter 2, emotional eating and restrained eating were inversely correlated in the replication sample but showed a positive trend in the main study. In Chapter 4, there was a significant positive relationship between them. In this sample, restrained eaters found it difficult to learn that some unhealthy foods may not help them to feel better, reflecting underlying beliefs about regulatory effects of unhealthy food. As discussed in these chapters earlier, these relationships can indicate differences in success in dietary restraint. While a positive relationship between emotional and restrained eating can reflect unsuccessful restraint, an inverse relationship indicates success in dietary restraint (cf. Kong et al., 2015). Success in dietary restraint matters because it is argued that unsuccessful restrained eaters are more susceptible to increasing their unhealthy food consumption when experiencing negative affect (Meule et al., 2014; Liu et al., 2020). However, the presented studies did not have any measures of dietary success to address whether success in dietary restraint or other aspects (e.g., rigid diet goals) of restrained eating explains emotional eating patterns in restrained eaters. Therefore, future studies can use measures of perceived success in dietary restraint to further explore whether it is only unsuccessful restrained eaters who struggle to resist unhealthy food when they experience negative affect. Importantly, measures of emotional eating could be tailored differently for restrained eaters to better understand why and when negative affect can cause them to fail to resist unhealthy food. Future studies are also needed to test whether unsuccessful stopping in earlier trials of inhibition tasks may result in abandoning the task rule in later trials for restrained eaters, to further understand whether the observed effects can be explained by "what the hell" effect. In addition, scales such as the responses to failure scale (Zemack-Rugar et al., 2012) can be used to measure tendencies to abandon diet goals.

It is important to note that our findings on restrained eating were exploratory in the presented studies. Future studies should use selected samples of restrained and unrestrained eaters, or dieters with and without trait-level restrained eating patterns to further addressed observed effects. This would help to distinguish when current diet goals may efficiently override emotion regulation goals to feel better and when emotion regulation difficulties make it difficult for people to restrict their unhealthy food intake.

7.4. Affect Induction Procedures: Integral or Incidental?

It has been argued that incidental negative affect (i.e. affect arising in a preceding and separate situation to self-control conflict) and integral negative affect (i.e. affect arising from the conflict itself) may have different impacts on control ability (Schmeichel & Inzlicht, 2013; Inzlicht et al, 2015). While incidental affect may result in impaired control due to motivational and attentional shift to indulgence, integral affect may improve control ability by signalling the organisms to adapt the behaviour (Botvinick, 2007; Dignath et al., 2020). In the present studies in Chapters 2 and 4, we aimed to test the detrimental effects of negative affect on control ability. To enhance the affect manipulation, negative affect was induced as part of the task trials. It is important to address how our findings may relate to this important framework on how affect may impact control ability and the questions that can be addressed in future research.

In Chapter 2, there was a substantial increase in inhibitions in the negative affect condition compared to the control and positive affect conditions. The words from participants reported life events included words such as "*failed*", "*incompetent*", "*incapable*"; it is therefore possible that participants may have perceived these as negative feedback emerging from the task performance. This may explain the trend for an increase in inhibitions, as negative affect might have been perceived as integral to the control conflict (i.e., responses resulting in negative feedback, which signals for behavioural adjustment). In contrast, in Chapter 4, emotional pictures were presented during the task trials. In this study, these pictures may not have been perceived as integral to the control conflict because, in contrast to the words that could be perceived as reflecting task performance, they included scenes such as sad people, burnt fields, and car accidents that are irrelevant to the task. Therefore, instead of representing an affect arising from task conflict, emotional pictures likely created an incidental affective state that participants might have needed to regulate by responding to food items. Importantly, even if the negative affect emerging from emotional pictures could have functioned as integral to the task conflict, we have already aimed for participants to adjust their responses to negative affect. Hence, a possible integral affect did not pose a limitation to this study, given that the task rule already encouraged participants to take an action to adjust their responses accordingly in both conditions by responding to different items, in line with the described framework that the integral affect should act as an alarm to adapt responses.

Future studies may build on these findings, for instance, to further clarify whether concepts of integral and incidental affect can also involve a temporal aspect where affect occurs at the same time as the control conflict, which may not necessarily have a cause-and-effect link, such as in Chapter 4. Importantly, it is also possible that different emotions arising from the conflict can differentially impact the behaviour. For instance, guilt or shame as a consequence of failed no-go responses to unhealthy food may explain why restrained eaters may have shown disinhibition in some contexts, although being integral to conflict, still resulting in loss of control due to complete abandonment of diet goals (Polivy et al., 2020). Finally, as discussed in section 4, observed effects can be further tested with other affect induction procedures by systematically varying different emotions to further investigate when negative affect may lead to depleted or enhanced control ability (Joseph et al., 2020).

8. Conclusion

Across three sets of experimental studies, this doctoral project highlights how emotional eating may not be caused by depleted cognitive resources to resist temptations towards unhealthy food, but rather may reflect an emotion regulation strategy and a motivational shift to indulge. While restrained eating and difficulties in emotion regulation predicted impaired inhibition of unhealthy food under negative affect, motivational shifts to indulge and to feel better caused difficulties resisting unhealthy food, especially when these foods are believed to relieve negative affect. Importantly, a motivational shift to eat healthily improved the ability to resist unhealthy food in the early stages of stopping. These findings open new avenues for future research. Firstly, future studies are needed to explain why restrained eaters may be more prone to emotional eating, for instance, whether they hold beliefs about all unhealthy foods having mood-regulatory effects. Second, by using different affect induction procedures, these findings can be extended to further understand when negative affect can improve or impair inhibitory processes. Future studies may also want to employ more comparable task paradigms to further assess how late and early stages of stopping can be impacted by top-down processes. Finally, behavioural measures in future studies are needed to test whether our findings on inhibitory control can extend to real-life eating behaviours, which could inform the development of intervention strategies for health behaviour change.

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