The Effect of Recent Meal Recall and Its Implications for Weight Loss

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It does not exceed the prescribed word limit for the Degree Committee (School of Biological Sciences).

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Abstract

The present thesis investigated the meal-recall effect, wherein remembering a recent meal reduces subsequent snack intake. A review of the literature suggested that the meal-recall effect might be driven by a temporary increase in interoceptive ability, which could then help individuals to perceive lingering satiety signals more strongly and to resolve ambiguous gastrointestinal signals (Chapter 2). A laboratory-based replication of the meal-recall effect was attempted, however, due to testing restrictions, data collection was prematurely ceased (Chapter 3). Instead, the effect was replicated online, with food photographs used as a proxy for intake (Chapter 4). The effect was not elicited in Experiment 1, potentially due to methodological issues, but changes to the design in Experiment 2 resulted in the meal-recall effect being successfully replicated. There was no evidence to support the idea that improved interoception was the mechanism underlying the meal-recall effect. Imagining a recent meal as bigger than in reality was shown to be an effective method of reducing biscuit intake, but visualising details of a previous meal disrupted the manifestation of the meal-recall effect (Chapter 5). Two weight loss interventions based on the meal-recall effect were tested for usability, by asking users for feedback (questionnaires and interviews) after using the interventions for a week (Chapter 6). Finally, the feasibility of a memory-based weight loss intervention was tested over a six-week period, and a number of potential improvements were identified (Chapter 7). The difference in weight loss between the intervention (1.81kg) and the control group (1.07kg) was not significant. The results suggest that a weight loss intervention based on the meal-recall effect has the potential to be feasible and acceptable to users, however more research is required to understand why the effect occurs and why it seems easily disrupted by contextual factors.

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Chapter 1
General Introduction

What motivates people to start and stop eating? Intuitively, we might say that hunger is what motivates people to eat, and fullness is what leads them to stop a meal. Although this is true to an extent, appetite regulation seems to be a much more complex issue. This is evident, as our society is currently facing a severe obesity crisis (World Health Organisation, 2021). Understanding how people gain weight is relatively simple; excess weight is gained when people have a positive energy balance, meaning they eat more calories than they burn (Dovey, 2010). However, understanding *why* some people consume excessive calories, and identifying *how* food intake can be reduced, is much more difficult.

It is being increasingly recognised that cognition has a considerable impact on regulating eating behaviour, sometimes even more so than physiological cues (Higgs & Spetter, 2018). Research suggests that episodic memory is especially critical in regulating future intake. In extreme cases, hippocampal damage, which leads to an inability to form long-term memories of recent eating, leads to excessive intake (Rozin et al., 1998). In neurotypical populations, disrupting the encoding of a meal-memory increases intake at a subsequent meal, and conversely, paying special attention to a meal can reduce subsequent intake in some cases (Robinson et al., 2013). It has also been shown that recalling a recently consumed meal decreases subsequent intake during a snacking session, a phenomenon which will henceforth be referred to as the meal-recall effect (Higgs, 2002; Higgs, Williamson, & Attwood, 2008; Szypula et al., 2020). Given the prevalence of obesity and the extent to which it affects both the individuals with excess weight and the society more generally (Hermawati & Lawson, 2014), it seems vital to understand and capitalise on methods which can help people to lose weight. There appears to be a particular need for weight loss methods which are seen as novel and appealing to potential users, as this can increase adherence and engagement with an effective intervention (Tang, Abraham, Stamp, & Greaves, 2015).

The aims of this thesis were to replicate the meal-recall effect (i.e. the finding that people tend to eat less after recalling a recently eaten meal, than after recalling a different event) and to identify factors which could further potentiate this intake-reducing effect. The results of these studies informed the design and development of a memory-based weight loss intervention. Two studies were conducted to assess the usability and feasibility of this novel tool.

1.1 A Short Overview of Appetite Regulation

In order for an organism to function properly, food intake must be balanced - both undereating and overeating can lead to malnutrition and suboptimal functioning of health (Department for International Development, 2012). As a result, the mechanisms which control food intake often contain redundancy, and tend to involve many different brain regions, organs, tissues, hormones, and neurotransmitters. Prompts to eat may be internally or externally generated; for instance, simply viewing images of food might provide an external cue which can motivate people to eat (Schüssler et al., 2012). Internally generated cues which encourage food intake include hormonal fluctuations. The gastrointestinal system releases ghrelin, which stimulates food consumption, in response to food deprivation, as well as in response to learned stimuli predictive of hunger, such as time of day (Cummings, 2006). Injecting healthy, neurotypical participants with ghrelin (intravenously) significantly increased their appetite and stimulated vivid images of favourite foods (Schmid et al., 2005).

But, ghrelin cannot be the only mechanism which motivates food intake, as gastric bypass patients still experience hunger and still eat regularly, despite ghrelin being almost absent from their bloodstream (Cummings et al., 2002). The liver also plays an important role in sensing and responding to glucose and lipid deprivation. Experiments on rabbits found that injecting a glucose inhibitor into the liver resulted in immediate eating, but cutting the vagus nerve (which connects the liver to the brain) suppressed this effect and further injections no longer motivated food intake (Novin et al., 1973). Similarly, inhibiting fatty acid metabolism in the liver stimulated food intake, but severing the vagus nerve disrupted this effect (Ritter & Taylor, 1990). These results suggest that the liver can sense lipid and glucose deprivation, and can communicate this information to the brain via the vagus nerve.

Once signals motivating food intake are processed and acted upon, the next step is for the meal to end at an appropriate time, once an adequate amount of energy has been ingested. Satiation is an umbrella term which refers to the process of terminating an eating episode (Forde, 2018). Meal size and duration can be influenced by caloric and macronutrient content, as well as by the sensory properties of the food being eaten (Forde, 2018). Stomach distention, caused by the stomach being filled up with food or drink, is an important mechanism which signals satiation (Wang et al., 2008). However, pure mechanical distension (i.e. stretching the stomach with a gastric balloon, without providing any nutritional content) only vaguely reduces feelings of hunger, and does not affect peptide or hormone production, suggesting nutritional content of meals also plays a role in regulating intake (Oesch et al., 2006). Processes such as sensory specific satiety (decline in enjoyment of a certain flavour after repeated exposure to it; Hetherington, 1996) and alimentary alliesthesia (decline in enjoyment of all flavours once physical fullness is reached; Cornil, 2017) also help to signal satiation had been reached.

As will be evident throughout this thesis, cognition can also have a profound impact on appetite regulation, sometimes even more so than physiological cues. For instance, people perceive foods labelled as 'healthy' or 'low fat' to be less filling than the same foods without such a label (Suher et al., 2016). As a result, participants serve themselves larger portions of food when it is labelled as 'healthy' (vs. 'tasty') and feel greater hunger after eating such food (Finkelstein & Fishbach, 2010). Thus, satiation can also be influenced by beliefs people hold about the food they are eating.

'Satiety' refers to a feeling of fullness, which suppresses desire for further eating (Forde, 2018). Insulin is secreted from the pancreas in anticipation of a meal (cephalic phase response) and then in response to increased blood glucose levels after a meal is terminated (Bellisle et al., 1983). Insulin promotes uptake of glucose into cells, where it is metabolised, used as required, and then converted into triglycerides for storage (Güemes et al., 2019). The brain does not require insulin to metabolise glucose, its primary source of energy, and yet it contains insulin receptors which monitor the blood (Woods & Porte, 1983). This suggests insulin helps to signal satiety. Indeed, infusing insulin into the hypothalamus of rats decreases food intake (Clegg et al., 2003), and intranasal administration of insulin after a meal in humans reduced intake of a palatable snack two hours later (Hallschmid et al., 2012).

Another important hormone in regulating consumption is leptin, which is secreted by adipose tissue (Van Harmelen et al., 1998). Unlike ghrelin or insulin, leptin is a long-term satiety factor which reduces intake, increases the metabolic rate, and therefore helps to keep a normal body weight (Klok et al., 2007). Levels of leptin circulating in the blood stream are positively correlated with increased BMI, greater fat cell size and more adipose tissue (Van Harmelen et al., 1998), which, in theory, suggests that people with obesity should be most affected by the intake-reducing effects of leptin. However, it has been suggested that those with obesity develop resistance to leptin, most likely as a result of overfeeding, overexposure to leptin and subsequent desensitization of the hypothalamus, which is normally responsive to fluctuations in leptin levels (Caro et al., 1996; Kolaczynski et al., 1996).

Many of these multiple signals of hunger and satiety ultimately act via interactions with the hypothalamus, which acquires information about the body's current energy status (Morita-Takemura & Wanaka, 2019). The arcuate nucleus, which is located at the base of the hypothalamus, is capable of sensing circulating hormones and nutrients in the blood, and this information is then processed to regulate feeding behaviour to maintain energy homeostasis (Dietrich & Horvath, 2013; Elmquist et al., 1999; Morita-Takemura & Wanaka, 2019). Neuronal populations in the hypothalamus stimulate or suppress appetite - neuropeptide Y (NPY), and agouti-related peptide (AgRP) increase appetite (i.e. they are orexigenic), whereas pro-opiomelanocortin (POMC) as well as cocaine- and amphetamine-regulated transcript (CART) act to decrease appetite (Morita-Takemura & Wanaka, 2019). Circulating hormones, such as leptin, ghrelin, and insulin, as well as nutrients such as glucose, can activate or suppress these orexigenic and anorexigenic neuronal populations, allowing the arcuate nucleus to rapidly respond to fluctuating states of the body. It was demonstrated that blocking glucose production (mimicking food deprivation) caused an increase in hypothalamic NPY concentration (Sindelar et al., 2004) and that release of ghrelin also stimulated the release of NPY (Van Den Top et al., 2004). The arcuate nucleus is positioned in a place where the blood-brain barrier (which controls which molecules can enter the brain from the bloodstream; Daneman, Zhou, Kebede, & Barres, 2010) is most permeable (i.e. in the median eminence), and this allows the nutrients and hormones to rapidly pass into the hypothalamus (Morita-Takemura & Wanaka, 2019). Therefore, the hypothalamus can quickly respond to changes in nutrient levels, by stimulating or suppressing appetite, to maintain energy homeostasis.

The arcuate nucleus acts via projections to the lateral hypothalamic area. When NPY is released by the arcuate nucleus, it binds to neurons in the lateral hypothalamic area, causing a cascade of processes which motivate an organism to search for and consume food (Elias et al., 1999). NPY is an extremely potent stimulator of food intake - rats injected with NPY consumed three times as much food as control rats (Clark et al., 1984), and long-term NPY injections produced sustained hyperphagia, leading to body weight increase and obesity (Zarjevski et al., 1993). Arcuate nucleus NPY neurons also project to the paraventricular nucleus (PVN), located in the hypothalamus, which acts to dictate when consumption should be terminated. Here they modulate the secretion of insulin (Bai et al., 1985) and AgRP, the balance of which ensures a meal lasts long enough to provide adequate energy intake, but not so long as to overload the digestive system (Wirth & Giraudo, 2000).

In sum, there are a variety of complex interactions and mechanisms through which appetite is increased or suppressed, and the hypothalamus seems to be one of the key brain regions responsible for regulating intake. However, it does not act in a vacuum, and instead responds to a complex input of signals from other brain areas and the peripheral body.

1.2 The Obesity Crisis

According to the World Health Organisation, a BMI greater than 25 kg/m^2 is considered overweight, and a BMI over 30 kg/m^2 meets criteria for obesity (World Health Organisation, 2020). For the past 40 years, the prevalence of overweight and obesity has steadily increased across the world (Finucane et al., 2011). In the US the prevalence of obesity between 2017-2018 was 42.4%, with 9.2% of adults having severe obesity (Hales et al., 2020). These rates were somewhat lower in the UK, with 28.7% of adults being obese, and a further 35.6% being overweight (Baker, 2019). Yet, these figures are alarming given the severe negative consequences of excess body weight. Adiposity is a risk factor for premature death due to coronary heart disease (Manson et al., 1990), stroke (Suk et al., 2003) and various types of cancer (Vucenik & Stains, 2012). There are direct consequences of obesity on the healthcare system. To illustrate this point, £6.1 billion was spent on obesity and obesity-related health conditions between 2014-2015 (Public Health England, 2017). But obesity also has indirect consequences for the wider society, caused by reduced productivity (e.g. due to absenteeism) and premature death (Hermawati & Lawson, 2014), as well as intangible costs associated with individuals with obesity suffering from mental health problems and reporting poorer quality of life (Hermawati & Lawson, 2014). It is therefore important to explore why obesity and overweight are so prevalent in today's world.

Pinpointing the exact reasons why our society is continuously becoming heavier is difficult, but a number of theories have been put forward. Given that eating in excess is an evolutionary adaptation, acting as a buffer against food shortages which were commonly experienced by our ancestors (Assanand et al., 1998), it is not surprising that a number of biological predispositions to weight gain have been identified over the years. For example, hundreds of genes which might contribute to obesity have been identified (Rohde et al., 2019), and body weight seems to be a highly heritable factor, with 45-75% of inter-individual variation in BMI attributable to genetics (Farooqi & O'Rahilly, 2007). Most adults display a relatively stable weight over the lifespan (Hao et al., 2016), and therefore many researchers have supported the notion of a homeostatic weight-control theory. This 'set-point theory' posits that each individual has a genetically predetermined weight and will find it difficult to maintain a weight outside of this narrow range (Keesey & Powley, 1975; Kennedy, 1953). Although this theory does not explain the sudden rise and continuous increase of obesity rates across the world, it helps to explain why people struggle to sustain weight loss (Rosenbaum et al., 2010). Other biological explanations for obesity include dysregulation of neurotransmitter production (Williams & Elmquist, 2012), defective appetitive signal interpretation (Miller, 2019) and alterations to the gut microbiome (Sanmiguel et al., 2015).

However, it's not possible to consider an issue as complex and multifaceted as obesity without also exploring environmental impacts, which can interact with and contribute to the aforementioned biological factors. After all, our genes have not changed substantially over the past few decades, but rates of obesity have, and therefore the environment must also play a significant role in the obesity crisis (Hall, 2018). Over time, our jobs are becoming more and more sedentary and less physically demanding, and our free time is increasingly being spent inactively, which means fewer calories are burned throughout the day, and it is more likely that excess weight will be gained (Hamilton et al., 2007). The way in which we access and consume food has also changed substantially over the years. Not only has food become abundant and more readily available, it is also being sold in ever increasing portions, which contribute to increased intake and weight gain (Hall, 2018). The nutritional content of food has also changed, as it is now common for excessive amounts of salt, sugar and fat to be added to processed foods (McGill, 2008). Given our innate preference for sweet and fatty foods (Saad & Gill, 2000), it is not surprising that this often leads to excessive consumption of these hypercaloric foods.

1.3 Determinants of Portion Size

It could be argued that the portion size of a food is more important than the product being consumed, when considering weight loss and weight-gain (Steenhuis & Poelman, 2017). Weight is gained because of a calorie surplus, not because of eating certain foods, so eating a small portion of a highly caloric food (e.g. chocolate) can still support weight loss goals, whereas eating a large amount of a food perceived to be low in calories (e.g. beans) can actually lead to weight gain. Unfortunately, there has been a steady increase in the standard serving sizes of many different foods over the past few decades (Church, 2008; Young & Nestle, 2002), and since people tend to consume more food if they are served a larger portion (i.e. the portion size effect; Zlatevska, Dubelaar, & Holden, 2014), this could partially explain why we are currently facing a severe obesity crisis. It is of great importance to understand the factors which can affect the size of a meal or snack, as this knowledge can be beneficial in designing a targeted weight loss intervention.

Portion size can be influenced by 'rational', conscious factors, such as liking a food and wanting to eat more of it (e.g. taking second helpings, despite not being hungry anymore), or knowing that a certain portion size should be eaten (Public Health England, 2018). Portion size can also be selected on the basis of standardised servings (e.g. one scoop, one packet, one can) or clearing one's plate, especially when it is not possible for individuals to select the portion size, for instance when buying food from a restaurant (Steenhuis & Vermeer, 2009). An individual may also consciously decide on their portion size so that it is consistent with their health-related goals (Elfhag & Rössner, 2005), for example by ensuring it has a certain number of calories.

However, research suggests that people are frequently unaware of the environmental and psychological cues which may impact their portion size selection on a day-to-day basis (Vartanian et al., 2008). To illustrate this point, seemingly trivial things such as light, warmth or the music playing in the background can influence the amount of food which is consumed (Stroebele & De Castro, 2004). Eating in the company of others, rather than eating alone, can increase energy intake by almost 20% (Hetherington et al., 2006). One study even demonstrated that participants will eat a smaller portion of food when in the presence of a confederate who ate very little, compared to a confederate who ate a normal-sized portion, despite having been food deprived for 24 hours (Goldman et al., 1991).

Importantly, portion size can also be influenced by cognitive factors. One notable example is sensory-specific satiety, which can exert influence on intake during a meal. Sensory-specific satiety refers to the fact people habituate to the food they are eating, and experience a diminishing sensation of appeal and pleasure from food as the meal progresses (Hetherington, 1996). In other words, the first few bites typically taste better than the last few bites, and so motivation to eat is higher at the beginning of a meal, and decreases over time. Reaching sensory-specific satiety helps us to end an eating episode at the right time (Epstein et al., 2009), even before other satiety signals (e.g. stomach distention, hormone secretion) have had time to manifest. Tasting a different flavour, for example tasting a sweet food after reaching sensory-specific satiety for salty food, leads to dishabituation and increased motivation to carry on eating (Sørensen et al., 2003). Therefore, greater variety of food available during a meal can increase overall energy intake (Brondel et al., 2009).

Interestingly, even imagined consumption of a certain food can induce sensory-specific satiety. Morewedge, Huh, and Vosgerau (2010) conducted a study in which participants were asked to repeatedly imagine eating a certain food (e.g. M&M's or cheese cubes) or to repeatedly imagine performing a non-food task which involved similar motor actions to eating sweets (e.g. putting a coin into a laundry machine). It was observed that imagined consumption of specific food items resulted in decreased desire for and decreased intake of that food at a later snack session (i.e. sensory-specific satiety was observed). Similar results were observed when participants were asked to imagine eating the sweets, or when they were asked to imagine placing the sweets in a bowl – visualising consumption led to lower intake of the real sweets, but imagined handling of the food did not (Morewedge et al., 2010). This study suggests that cognition, and specifically imagination, can have potent effects on regulating energy intake.

In a similar vein, portion size can also be influenced by expectation an individual holds about the food they have eaten or are about to eat. Expected satiety is the expectation one has about a particular food item's ability to induce feelings of fullness – the greater the expected satiety of a food item, the smaller the portion eaten (Brunstrom et al., 2008; Brunstrom & Rogers, 2009). For example, in one study, participants believed a 200kcal potion of pasta and an 894kcal portion of cashew nuts were equally satiating, because pasta was rated higher on expected satiety (Brunstrom et al., 2008). Expected satiety is learned, and generally increases as foods become more familiar (Brunstrom et al., 2010). Expected satiety can also be influenced by information received about a food item. Wooley (1972) asked participants to drink a milkshake, which was either labelled as 'low calorie' or 'high calorie'. In reality, the milkshake's energy content was reversed (milkshakes labelled 'low calorie' were actually high in calories and vice versa). The actual number of calories consumed had no impact on reported satiety and subsequent intake, but participants who believed they had consumed the 'high calorie' milkshake felt fuller and ate less at the next meal. Likewise, Brunstrom, Brown, Hinton, Rogers, and Fay (2011) reported that participants who were told that their smoothie contained a large portion of fruit felt less hungry and more full after drinking it, than participants who were told their smoothie contained a small portion of fruit. Crucially, even though all participants consumed an identical smoothie, hunger and fullness ratings were still significantly different between the two groups after three hours, suggesting the effects of expected satiety can have a long-lasting impact on appetite.

1.4 Memory as a Determinant of Portion Size

The evidence reviewed above suggests that many environmental and psychological cues can have a strong influence on energy intake. Research over the past few decades has also highlighted that another aspect of cognition, which can have an effect on how much a person eats, is memory (Higgs & Spetter, 2018). Of particular interest are the findings suggesting that episodic memory plays a crucial role in regulating intake. The following sections will review the evidence that the hippocampus, which supports episodic memory, plays a critical role in everyday appetitive behaviour, and that meal memories can be manipulated to directly influence intake.

1.4.1 Episodic Memory Definition

The notion that meal memories might regulate subsequent intake has gained momentum in recent years. Episodic memory refers to autobiographical experiences which can be retrieved and 're-visited' through 'mental time travel' (Tulving, 2002). It has been proposed that an episodic memory is distinct from other types of memories, because it binds contextual elements, commonly known as the 'what, where and when', into a memory which consequently has spatiotemporal relations (Clayton & Dickinson, 1998; Nyberg et al., 1996). In other words, an episodic memory not only contains the details of an event, but also embeds those details to a specific location and time, which results in an 'autonoetic' feeling (Tulving, 2002) as the individual is able to place themselves back in a past experience (Hassabis & Maguire, 2007). Conway (2009) proposed that there are nine main features of an episodic memory, one of which is that episodic memories are rapidly forgotten. Although the central details of an event are more resistant to forgetting, peripheral details are lost even after a relatively short period of time (Sekeres et al., 2016; Williams, Conway, & Baddeley, 2008). Yet, with some cueing and prompting, most 'forgotten' peripheral details can be reinstated, suggesting the forgetting of episodic details is a retrieval failure, rather than a permanent loss (Sekeres et al., 2016).

1.4.2 Evolutionary Basis

All living beings must acquire nutritional resources, and an organism's ability to maximise their energy intake, whilst decreasing the effort required, is a trait favoured by natural selection (Pyke et al., 1977). Some researchers have argued that episodic memory developed as a direct response to the need of remembering where food was found, to enable an organism to return to that location later (de Vries et al., 2020; New et al., 2007). Consistent with this idea, birds such as Scrub Jays are capable of remembering the exact location of a food they have hidden, and display episodic-like memories by being able to assess whether the food they cached has decomposed based on the type of food hidden and the amount of time passed (Clayton et al., 2001; Clayton & Dickinson, 1998). Similarly, rats are capable of remembering specific details about food they encountered in a maze (Roberts et al., 2008). In one experiment, rats were more likely to visit a maze arm when they expected to find chocolate there, but this preference dropped when chocolate was swapped for a grape (Babb & Crystal, 2006).

In humans, meal memories seem to be better recalled than other types of memories. Seitz, Blaisdell, and Tomiyama (2021) reported that participants made fewer errors when recalling how many pieces of candy they ate, compared to participants who recalled how many times they moved a bead into a container. Although both actions were similar in terms of motor movements, memories of eating seemed superior to non-food memories (Seitz et al., 2021). Furthermore, highly caloric foods seem to be remembered better than foods low in calories. In one experiment (de Vries et al., 2020), participants were asked to walk through a room where different high- and low-calorie foods were displayed in different locations. Significantly fewer location errors were made when remembering the position of high-calorie, as opposed to low-calorie foods, suggesting that, evolutionarily speaking, memories serve as an aid to locate and revisit sources of energy dense foods, which is an important survival adaptation (de Vries et al., 2020). Interestingly, this enhanced-memory effect was also observed when participants were only exposed to the smell of high- or low-calorie food items in different places (de Vries et al., 2020).

It has also been shown that this preference for remembering the spatiotemporal location of high-energy foods is especially pronounced in females, a potential adaptation leftover from ancestral labour division between males and females (New et al., 2007). Using a highly-ecologically valid task, New et al. (2007) demonstrated that females were more accurate when recalling locations of various food items on a farmer’s market, especially for energy-dense foods. These results were evident even after controlling for how much the participants liked each of the recalled food items and how often they ate these foods. In accordance with the findings outlined above, Allan and Allan (2013) found that better spatial memory for the location of high-calorie snacks predicted a higher BMI in females. In a similar vein, Leng et al. (2021) demonstrated that females with obesity had superior memory for food-related items, in comparison to lean females, but the females with obesity displayed memory deficits for non-food items. Taken together, there exists strong evidence to suggest that food-related memories are evolutionarily special, and that memory systems of both human and non-human animals are geared towards remembering food, especially that high in energy.

1.4.3 Episodic Memory and the Hippocampus

It is widely accepted that the hippocampus is one of the main neural structures which supports episodic memory (Eichenbaum & Cohen, 2001; Squire & Zola-Morgan, 1991). Interestingly, the structure of the hippocampus is tailored to receiving and interpreting food signals; it contains receptors for a vast number of neurotransmitters implicated in appetitive behaviour (Kanoski & Grill, 2017), such as leptin and insulin (Farr, Banks, & Morley, 2006; Zhao, Chen, Quon, & Alkon, 2004). The hippocampus is also well connected to the hypothalamus, which is one of the key areas controlling appetitive behaviour (Timper & Brüning, 2017). Taken together, the biological structure of the hippocampus and its connections to other brain regions imply that it is capable of supporting the link between episodic memory and eating behaviour.

1.4.4 The Hippocampus and Intake Regulation in Animals

Decades of research on rodents have shown that the hippocampus is critical for normal regulation of eating and eating behaviours. Schmelzeis and Mittleman (1996) noted that rats with lesioned hippocampi were more likely to show increased appetitive response to food after being fed to fullness. In subsequent studies, it was found that hippocampal lesions led to significantly greater food intake and weight gain (Davidson et al., 2009; Henderson et al., 2013). Temporarily inactivating the hippocampus after a meal decreased the time elapsed between the end of that meal and the beginning of another meal, suggesting the hippocampus is not only involved in meal size regulation, but also in meal frequency (Henderson et al., 2013). The same study also provided evidence that without a functioning hippocampus, meal size was not predictive of the length of delay between meals, implying it may also be required for normal processing of satiety signals.

Hannapel et al. (2019) found that optogenetically inhibiting hippocampal neurons after a meal led to faster initiation of the next meal, and increased amount of food eaten. The researchers also noted that disrupting hippocampal functioning five minutes after the meal was finished increased subsequent intake to a much greater extent, than disrupting hippocampal functioning as the meal was eaten. The implication put forward was that hippocampal neuronal activity after the meal is the critical period for food-inhibition signals to be generated, possibly because this is when the meal memory is consolidated (Hannapel et al., 2019). The importance of meal-memories in predicting future food requirements was highlighted by Davidson and Jarrard (1993). Their research showed that rats with selective lesions to the hippocampus struggled to discriminate interoceptive state stimuli, and to use them to engage in normal feeding behaviour. Rats with hippocampal lesions did not eat more than control rats, but approached the feeding hopper significantly more frequently. The authors suggested that this occurred because, without a functioning hippocampus, the rats found it difficult to anticipate the satiating consequences of feeding, without actually tasting the food.

It can be reasoned that since the hippocampus supports memory formation, and meal memories seem crucial for regulating subsequent intake, then consuming a meal should stimulate memory formation (Parent, 2016). Indeed, rats with hippocampal lesions which ate a sucrose meal exhibited greater synaptic plasticity (which is indicative of memory formation), than control rats which were handled but not fed (Henderson et al., 2016). This study adds to the convincing body of literature suggesting that hippocampal functioning in animals is tightly linked to intake regulation. It is also worth mentioning a potential link between hippocampal lesions and disinhibited behaviour. Some of the ways in which impulsive behaviour can manifest is disproportionate or inappropriate temporal discounting, or premature responding on a motor task (Dalley, Everitt, & Robbins, 2011). Studies have shown that disrupting hippocampal functioning is associated with both types of impulsive behaviour (Bannerman et al., 1999). Rats with hippocampal, but not orbitofrontal cortex, lesions are more impulsive in their behaviour (Mariano et al., 2009), and prefer immediate low rewards over delayed high rewards (McHugh, Campbell, Taylor, Rawlins, & Bannerman, 2008). These findings suggest that the hippocampus may be involved in temporal information processing (Mariano et al., 2009), and so hippocampal dysfunction might result in deficits in relative time estimation (Buhusi & Meck, 2005), potentially explaining the increase in disinhibited behaviour following damage to this brain region.

1.4.5 The Hippocampus and Intake Regulation in Humans

Perhaps the most striking demonstration of the role the hippocampus plays in the regulation of human consumption was a study conducted on amnesic patients (Rozin et al., 1998). Two densely amnesic patients with damage to their hippocampus were offered a substantial meal. Once they finished eating, they were offered another substantial meal soon after finishing the first one. The patients, having no memory of eating the recent meal, ate the second meal, and were even willing to eat a third portion too (but were not allowed to for safety reasons). On one occasion, an amnesic patient consumed an excess of 1000kcal in a single meal – as a comparison, control participants without hippocampal damage refused to eat any of the second meal, consuming less than 400kcal in total. Interestingly, the researchers did not observe a substantial pre- to post-meal drop in hunger ratings for the amnesic patients, and the patients still reported being somewhat hungry even after eating two consecutive meals.

This finding is reminiscent of patient H.M., who had a bilateral hippocampal lesion and dense amnesia. It was noted that H.M. rarely commented on his internal drives, such as hunger or thirst, and either persistently rated his hunger on mid-point of the scale, irrespective of when the rating was being made, or rated his hunger as higher immediately after a meal, than immediately before a meal (Hebben et al., 1985a). Higgs, Williamson, Rotshtein, and Humphreys (2008) reported that sensory-specific satiety was not impaired in amnesic patients who consumed multiple consecutive meals, which suggests that it is indeed the lack of an explicit meal-memory, and not other processes, which lead to overeating when the hippocampus is damaged. These studies suggest that memories of recent eating are a vital part of intake regulation in humans, and that without a functioning hippocampus, satiety signals are not properly processed, despite adequate, or even excessive amounts of food being eaten.

1.5 The Role of Meal-Memories in Regulating Consumption

Evidence presented so far supports the idea that a functioning hippocampus plays an important role in regulating subsequent consumption. The hippocampus not only supports long-term episodic memory formation (Eichenbaum & Cohen, 2001), but also many other functions such as spatial cognition (Moser et al., 2008; O'Keefe & Nadel, 1978). Therefore, studies on amnesic patients cannot definitely establish whether intake regulation is disrupted due to a lack of meal memories, or because of other cognitive processes. Thus, experiments which manipulate meal memories of neurotypical individuals, and then observe the effects these manipulations have on subsequent intake, are vital in establishing the importance of recent meal memories in regulating subsequent consumption. If meal memories have a suppressing effect on intake in humans, then disrupting them should result in a weaker meal memory and therefore increased consumption.

Indeed, it has been shown that disrupting the encoding of meal-memories in healthy individuals has a substantial impact on intake. It is known that distracting people while they are eating can divert their attention away from monitoring their intake and/or interfere with processing satiation cues (Stroebele & de Castro, 2006). It is therefore unsurprising that distraction during the meal, for instance watching TV, listening to music or listening to audiobooks, can result in an immediate increase in energy intake (Bellisle et al., 2004; Blass et al., 2006; Long et al., 2011; Stroebele & de Castro, 2006). In a meta-analysis of studies pertaining to the effects of attentive eating on intake, Robinson, Aveyard, et al. (2013) noted that while distraction increased immediate intake of food, it had a significantly greater effect on food consumed a few hours after the distracted meal. A study by Higgs and Woodward (2009) illustrates this point clearly, as participants who ate a fixed lunch at the laboratory whilst being distracted with a TV show subsequently ate more snacks, than when they were not distracted during their meal. Similar results were observed when participants were distracted during mealtimes by playing video games (Oldham-Cooper et al., 2011) or by eating 'on the go' (Ogden, Oikonomou, & Alemany, 2017).

Evidence to support the idea that distracting participants during a meal impairs the formation of a meal-memory comes from a study by Mittal, Stevenson, Oaten, and Miller (2011). In this study, participants were asked to consume snacks either whilst watching TV or whilst sitting quietly in a room. They were then asked to recall the amount of snacks they ate about an hour later. All participants underestimated the amount of food they ate, but those in the TV-watching group underestimated their intake significantly more than those in the control condition. This suggests that those who watched TV whilst snacking had a poorer memory of the eating episode. However, as noted by Francis, Stevenson, Oaten, Mahmut, and Yeomans (2017), this study was confounded because the distracted group ate more snacks than the control group, and therefore greater snack intake (rather than greater distraction) could have produced the observed results. Nevertheless, even when Oldham-Cooper et al. (2011) kept the portion of the to-be-recalled food constant, they still found that those who played a video-game whilst eating were significantly less accurate at recalling the serial-order of the food items consumed, than those who were not distracted. This suggests that distraction during a meal might increase subsequent meal size by impairing the formation of a meal-memory.

Morris, Vi, Obrist, Forster, and Yeomans (2020) demonstrated that not paying attention during eating can disrupt the processing of satiety-cues. In this study, participants consumed a low- or a high-calorie drink, whilst being engaged in a task which was either high or low in perceptual load. Participants who were not distracted (in the low-effort task) responded to the two types of drinks in a predictable way– they ate fewer snacks after consuming the high-calorie drink and more snacks after drinking the low-calorie version. However, those who engaged in a cognitively demanding task whilst eating did not adjust their subsequent snack intake in the same way. These participants ate a comparable amount of snacks irrespective of whether they consumed a low- or a high-calorie pre-load. This study shows that not paying attention to an eating episode disrupts processing of internal satiety cues, which help to inform subsequent consumption. There was no evidence to suggest that the perceptual load tasks affected memory for the sensory characteristics of the drinks (e.g. how creamy or sweet they were), and the study did not investigate how the cognitive tasks influenced episodic memory of the consumption (Morris et al., 2020).

Conversely, enhancing the encoding of meal-memories has been shown to reduce intake at the next meal. Eating a meal whilst focussing on the sensory characteristics of the food (e.g. taste, texture or colour) led to an immediate decrease in the amount of food eaten (Bellisle & Dalix, 2001; Long et al., 2011). In another study, it was found that paying more attention to the sensory experience of a meal had no effect on immediate intake, but influenced subsequent snacking behaviour (Higgs & Donohoe, 2011). In that study, participants were asked to eat a fixed lunch in the laboratory whilst engaging in one of three tasks: listening to an audio clip which encouraged them to focus on their meal, reading a neutral article about food, or eating without any additional stimuli. Participants returned two hours later, and were asked to complete a bogus taste test, in which they had an *ad-libitum* access to different biscuits. Participants who were encouraged to focus on their meal reported that their lunch memories were more vivid. These participants also ate fewer biscuits during the taste test, compared to participants who read an article about food or those who ate without any additional stimuli. It was noted that there was a marginally significant correlation between memory vividness and the amount of biscuits consumed (r= -0.37). The authors argued that those who paid attention to their lunch formed a stronger meal memory, which in turn helped to regulate their biscuit intake more effectively.

It is worth noting that a number of recent studies have questioned the effect of mindful eating on subsequent snacking. For example, Tapper and Seguias (2020) asked participants to pay attention to the sensory characteristics of their lunch whilst eating it, or to eat without these additional mindfulness instructions, but found no differences in immediate intake. Participants completed a taste test after their lunch, but no differences in snack intake were found between the focussed group and the control group. Participants were asked to remain mindful of their meals for the rest of the day and were then asked to report their half-day intake in a surprise food-recall test. Once again, no differences were observed in terms of the number of calories consumed throughout the day between the focussed group and the control group. A similar lack of an effect of mindful eating on subsequent intake was observed by other researchers (Whitelock et al., 2018; Whitelock, Gaglione, et al., 2019). However, it could be argued that instead of demonstrating that focussing on a meal during eating has no effect on intake, these studies may show that this effect is prone to disruption. It has been suggested this may be because meals are well remembered even when people are not consuming them mindfully, so differences in memory between focussed and control conditions are sometimes not sufficient to produce reliable effects on intake (Whitelock et al., 2018).

1.6 The Meal-Recall Effect

The studies discussed so far imply that manipulating the encoding of meal-memories can increase or decrease subsequent intake, providing strong support for the notion that memory for recent eating regulates consumption. It has also been shown that retrieving a meal-memory before eating can affect intake. In a between-subjects study conducted by Higgs (2002), female participants were given a fixed lunch (a slice of pizza) and asked to return for a bogus taste test two/three hours later. Immediately before the taste test, participants were either asked to spend five minutes recalling the lunch they ate at the laboratory a few hours earlier, or they were asked to think about anything they wanted. Then, participants were presented with three plates, each containing 15 biscuits. Participants were instructed to taste each type of biscuit, and to rate their taste. They were told that they would have 10 minutes to complete the task, and that they should taste as many biscuits as necessary for them to give accurate ratings. Participants were also told to help themselves to any leftover biscuits, and were left alone in the room. The taste test was actually a method to covertly assess snack intake, as the plates were weighed before and after the session. The results revealed a significant reduction in biscuit intake (-14.7g) after recalling a recent lunch, compared to recalling memories unrelated to the meal.

The study by Higgs (2002) was the first demonstration of, what will henceforth be referred to as, the meal-recall effect. Since then, the meal-recall effect has been replicated numerous times by many research groups (Collins & Stafford, 2015; Higgs et al., 2008; Stafford & Thompsett, 2019; Szypula et al., 2020; Vartanian et al., 2016; Yeomans et al., 2017). It has been shown that the meal-recall effect is only elicited by relatively recent meal-memories, as recalling more distant meals (e.g. lunch from the day before) does not seem to suppress snack intake (Higgs, 2002; Higgs et al., 2008). On the other hand, it has also been shown that recalling a meal-memory which is *very* recent (i.e. recalling a meal an hour after eating) does not produce the meal-recall effect (Higgs et al., 2008). Therefore it seems physiological satiety cues (e.g. stomach distention) must be given a chance to fade slightly, and some forgetting of the meal must occur, in order for the effects of meal-memory recall to be able to manifest (Higgs et al., 2008).

Dietary restraint, which is defined as an individual's tendency to purposefully limit their food intake (regardless of physiological hunger or satiety cues; Herman & Mack, 1975), was not shown to modulate the meal-recall effect (Higgs et al., 2008). It is unclear whether dietary disinhibition, which is the tendency for individuals to be hyperresponsive to palatable foods, and to overeat (Stunkard & Messick, 1988), exerts an effect on the strength of the meal-recall effect; Higgs et al., (2008) found that the meal-recall effect was only present in individuals with low disinhibition scores, whereas Szypula et al. (2020) noted that the strength of the meal-recall effect was not dependent on disinhibition scores. Another factor which does not seem to modulate the meal-recall effect is general episodic memory ability, as having a low or a high memory ability did not affect the magnitude of the meal-recall effect (Szypula et al., 2020).

Furthermore, it was also noted that inducing a positive mood in participants, which has been shown to impair performance on tasks which require substantial attentional resources (e.g. the Tower of London task; Phillips, Smith, & Gilhooly, 2002), can also disrupt the meal-recall effect (Collins & Stafford, 2015). In this study, either a neutral or a positive mood was induced in participants, who were then either asked to recall a recent lunch, or to think about whatever they wanted. The meal-recall effect was evident in the 'neutral-mood' group, but disappeared for the 'positive-mood' group. Szypula et al. (2020) reported that when a meal was recalled verbally during an interview with the experimenter (as opposed to being recalled in writing), the meal-recall effect was disrupted. Depletion in attention resources was put forward as an explanation as to why the meal-recall effect was not observed. Another finding from this study was that guiding participants through the meal-memory in detail (e.g. by asking them to recall the texture, flavour, and location of the meal) *increased* subsequent biscuit intake, relative to asking participants to recall the memory in less detail. It was speculated that this was because in the guided-recall condition, participants began thinking about food in general, which stimulated their appetite and led to an increase in intake. However, thinking about their meal in less detail led participants to recall the consumption episode, which suppressed intake.

These findings suggest that recalling a recent meal, immediately before another meal, suppresses subsequent intake, but that this effect can be easily disrupted by cognitive or contextual factors. Table 1 contains a review of experiments which observed the meal-recall effect, as well as the effect sizes of the results. Effect sizes were calculated based on *F* or *t* statistics reported in original publications, using formulas provided by Lakens (2013). Omega-squared (w^2) was reported instead of partial eta-squared, as it provides a more unbiased effect size measure, especially when sample sizes are small (Lakens, 2013). In general, recalling a recent meal leads to an average biscuit intake decrease of 17.6g (see Table 1) which translates into a meaningful decrement in the context of weight loss. The effect sizes also seem to be substantial, suggesting that the meal-recall effect is capable of modulating intake in meaningful ways.

1.7 Manipulating Meal Memories

Episodic memory is not a perfect recording of the experienced event – memories are prone to disruption and forgetting every time they are recalled (Schacter et al., 2011). Memories are especially prone to distortion when already-formed memories are retrieved and then updated with new information (Nader & Einarsson, 2010). There has been some evidence to suggest that exposure to new, incorrect information presented to participants after witnessing the initial event (e.g. being told that a car was blue after seeing a car which was actually green) can result in information 'blending' (e.g. participants reporting seeing a blue-green car; Loftus, 1977). Meal memories may be particularly prone to interference (Wixted, 2004) due to the habitual and repetitive nature of meal times (White & McDonald, 2002), which means individual eating episodes are rarely distinctive. As a result, there exist a number of demonstrations that details of meal-memories can be manipulated in a variety of ways.

One aspect of meal memories which can be influenced is remembered satiety. Brunstrom et al. (2012) showed people a bowl containing either 300ml or 500ml of soup. The participants then ate from this self-filling/self-draining bowl and either ingested the amount of soup they were presented with or ingested an amount different to the one witnessed (i.e. intake could be ‘congruent’ e.g. see 300ml, eat 300ml or ‘incongruent’ e.g. see 300ml, eat 500ml). The results showed that over the inter-meal interval, hunger increased to a lesser extent in those who saw a 500ml bowl of soup, irrespective of whether they actually consumed 300ml or 500ml. In other words, two hours after the meal, hunger was predicted by remembered consumption, rather than by actual consumption. These results highlight episodic memory likely plays a direct role in regulating consumption, but it also shows that details of meal-memories can be manipulated to alter energy intake.

Another experiment which investigated meal memory manipulations was conducted by Robinson, Blissett, and Higgs (2012). In this study, participants ate a small portion of a healthy vegetable quiche in the laboratory, and then rehearsed enjoyable aspects of the snack (or its neutral aspects, such as listing the ingredients). Participants were asked to return the next day and were asked to serve themselves food from a buffet, which contained the previously tasted quiche, as well as other foods. Those who listed enjoyable aspects of the vegetable quiche served themselves almost twice as much quiche as those in the control group, demonstrating that even brief manipulations of meal memories can have profound effects on subsequent intake. In a similar way, just recalling a past memory of eating vegetables (without listing enjoyable aspects of the food) increased the amount of vegetables participants served themselves at a buffet (Robinson et al., 2011). These results further strengthen the argument that meal memory manipulations can affect food intake.

Table 1

A review of studies investigating the meal-recall effect with standardised effect sizes

	Experiment Number	Participants	Study Design	Conditions	Meal-recall effect observed?	Intake	Decrease in intake	Effect size
Collins and Stafford (2015)	1	69 non-dieting females	Between -subjects	Lunch cue (think about recent meal) vs. no cue (think about anything)	Yes	Lunch cue: 41.00g (*SE*=1.82) No cue: 55.50g (*SE*=1.87)[1,]	14.64g (26.4%)	ω_p^2=0.61
Higgs (2002)	1	20 females scoring less than 2.2 on DEBQ restraint (van Strien et al., 1986)	Between -subjects	Lunch cue vs. no cue	Yes	Lunch cue: 54.7g (*SD*=5.3) No cue: 69.4g (*SD*=5.6)	14.7g (21.2%)	Cohen's d_s= 0.98 (large)
	2	23 females scoring less than 2.2 on DEBQ restraint (van Strien et al., 1986)	Between -subjects	Lunch today (think about recent lunch) vs. lunch yesterday (think about lunch eaten the previous day) vs. no cue (think about anything)	Yes	Lunch today: 24.2g (*SE*=2.9) Lunch yesterday: 47.6g (*SE*=6.0) No cue: 43.7g (*SE*=8.8)	23.4g (49.2%) 19.5g (44.6%)	ω_p^2=0.20
Higgs et al. (2008)	1	14 lean males (BMI between 19–25 kg/m^2)	Within-subjects	Lunch today vs. lunch yesterday	Yes	Lunch today: 11.26g (*SE*=2.1) Lunch yesterday: 15.45g (*SE*=2.8)[1]	4.19g (27.1%)	ω_p^2=0.27

[1] As intake data was not included in the original manuscript, these values were extracted from the corresponding figure using image analysis software (https://apps.automeris.io/wpd/).

	2	73 lean females (BMI between 19–25 kg/m^2)	Between -subjects	Lunch today vs. lunch yesterday	Yes (only in low-disinhibition participants)	Lunch today: 4.66g (*SE*= 1.2) Lunch yesterday: 6.94g (*SE*=1.2)[1]	2.28g (32.9%)	ω_p^2=0.06
	3	47 lean females (BMI between 19-25 kg/m^2)	Within-subjects	Lunch today vs lunch yesterday	Yes (only in participants who recalled meal from 3-hours ago; marginally significant)	Lunch today: 13.90g (*SE*=3.6) Lunch yesterday: 21.92 (*SE*=3.7)[1]	8.02g (36.6%)	ω_p^2=0.05
Stafford and Thompsett (2019)	1	16 students (14 males, 2 females)	Between -subjects	Lunch cue vs. no cue	Yes (marginally significant)	Lunch cue: 12.32 (*SD*=5.0) No cue: 26.55 (*SD*=5.2)[1]	14.23g (53.6%)	Cohen's *d*= 2.98 (large)
Szypula et al. (2020)	1	16 (4 males, 12 females)	Within-subjects	Lunch today vs. lunch yesterday	Yes	Lunch today: 53.8g (*SD*= 43.1) vs Lunch yesterday: 62.9g (*SD*= 46.3)	9.1g (14.5%)	ω_p^2=0.23
Vartanian et al. (2016)	1	63 unrestrained females (scored less than 15 on the dietary restraint scale; Herman & Polivy, 1980)	Between -subjects	Lunch today vs. non-food recall (describe journey into the laboratory)	Yes	Lunch today: 29.74g (*SE*=3.3) Non-food recall: 49.66g (*SE*=3.1)[1]	19.92g (40.1%)	Cohen's *d*= 1.07 (large)
Yeomans et al. (2017)	1	120 lean, unrestrained females (average score of 9.2 on TFEQ; Stunkard & Messick, 1985)	Between -subjects	Drink today (recall drink consumed recently) vs. drink yesterday (recall drink consumed the day before)	Yes	Drink today: 276.53g (*SE*=17.3) Drink yesterday: 359.62g (*SE*=20.5)[1]	83.09g (23.1%)	ω_p^2=0.13

1.8 A Vicious Cycle of Obesity

The ‘vicious cycle of obesity’ theory has been put forward to explain how excess food intake and body weight impair cognition, especially memory, and how this leads to further excessive intake, which results in additional memory impairments and maintenance of overweight and obesity (Kanoski & Davidson, 2011). As experiments on amnesic patients have shown, when the hippocampus is not functioning properly, meal-memories are disrupted, eating becomes excessive, and satiety-cue processing is impaired. Yet, hippocampal damage is not only evident in amnesic patients, but also in people who are obese. Having a higher BMI has been linked to decreased functional activity of brain areas which support episodic memory (Cheke et al., 2017). Many studies have also highlighted that obesity correlates with reduced volume of the hippocampus and other structures within the frontal and temporal lobes (Carnell et al., 2012; Fotuhi et al., 2012). In older adults (60-64 years old), a higher BMI significantly predicted lower hippocampal volumes, as well as greater hippocampal atrophy over an eight-year follow-up period (Cherbuin et al., 2015). Worryingly, such hippocampal deficits were also observed in children with obesity alongside a significantly reduced cognitive performance (Bauer et al., 2015). These obesity-related brain deficits have been associated with significant cognitive impairments, most notably in executive functioning and episodic memory (Cheke, Simons, & Clayton, 2016; Cournot et al., 2006; Elias, Elias, Sullivan, Wolf, & D’Agostino, 2003; Gunstad, Lhotsky, Wendell, Ferrucci, & Zonderman, 2010; Kanoski, 2012; Miller & Spencer, 2014). Importantly, weight loss seemed to reverse these memory impairments (Rochette et al., 2016; Siervo et al., 2011).

It has also been shown that diet can rapidly impair the functioning of the hippocampus. Experiments on rats showed that diets high in saturated fats (which are found in butter, fatty meats, and cheese, for example) led to poorer hippocampal-dependent learning and memory formation (Greenwood & Winocur, 1996). Similar results were observed if the rats were fed a diet high in sucrose or fructose (Jurdak et al., 2008; Mielke et al., 2005; Ross et al., 2009). These sugars are commonly found in products such as fizzy drinks, processed foods, fast foods, sweets, and dressings. Diet-induced impairments in rats were observed as quickly as three days after starting a high-fat, high-sugar diet (Kanoski & Davidson, 2010). McLean et al. (2018) demonstrated an even more rapid decline in hippocampal-dependent memory tasks, which was apparent after a single day of a high-fat diet. However, over 30 days of exposure to such a diet was required for deficits in non-hippocampal-dependent tasks to become apparent, suggesting the hippocampus is particularly susceptible to diet-induced disruption. This conclusion is also supported by findings of Beilharz, Maniam, and Morris (2016), who found that diet-induced cognitive impairments were equally severe in rats which were fed a high-fat/high-sugar diet and gained weight, and in rats which were fed the diet but did not gain weight.

In light of these findings, it is particularly concerning that a ‘Western diet’, which is characterised by high levels of saturated fats and refined sugars, is prevalent in today’s society and is rapidly spreading across the world (Kopp, 2019). Much like in experiments on rats, being exposed to a Western diet leads to significant cognitive deficits in humans. Consuming a Western diet has been identified as a significant risk factor for dementia (Kalmijn et al., 1997) and Alzheimer’s disease (Grant et al., 2002). Self-reported consumption of a Western-diet and predicted impaired performance on hippocampal-dependent tasks (Francis & Stevenson, 2011) and was associated with smaller hippocampal volume (Jacka et al., 2015). Attuquayefio et al. (2016) demonstrated that eating a high-fat/high-sugar breakfast for four days caused a significant decline in performance on a verbal learning task in young, lean, and healthy adults. These findings were later replicated by Stevenson et al. (2020).

Thus, it seems that having a higher BMI, and therefore more excess weight, is related to hippocampal-related deficits, both in terms of structural volume and performance on hippocampal-dependent tasks, and that consuming a high-fat/high-sugar diet leads to weight-gain, and also impairs hippocampal functioning. Consumption of a Western diet leads to excess body weight, which in turn also impairs hippocampal functioning, resulting in disruption of meal-memory formation and retrieval. It has been suggested that an inability to utilise meal-memories properly may lead to excess energy intake, which may in turn exacerbate weight-gain and perpetuate the cycle, although direct evidence for this claim is yet to be obtained (Kanoski & Davidson, 2011). Although it is difficult to point-out the factors which initially contribute to the formation of the vicious cycle, it seems clear that interrupting it at any stage may have a knock-on effect on this chain reaction. Therefore, manipulating meal-memories has the potential to break the vicious cycle, and could hypothetically help people to achieve weight loss.

1.9 What is mHealth?

Even relatively small reductions in body mass can lead to clinically significant improvements to general health (Donnelly et al., 2009; Wing et al., 2011). Given the steadily increasing rates of obesity, it is important to develop and test novel ways to help people lose weight (Besson et al., 2020). Existing weight loss methods vary in their invasiveness and effectiveness. For example, bariatric surgery can lead to around 26kg more weight loss than non-surgical treatment (Gloy et al., 2013), but is linked to adverse side effects such as bone loss (Stein & Silverberg, 2014) and permanent damage to the stomach or other organs (Elder & Wolfe, 2007). Pharmacological treatments can also be effective at inducing weight loss, through reducing appetite, reducing rates of fat uptake or increasing energy expenditure, but are associated with severe psychiatric side effects (Hsu et al., 2010). Although lifestyle interventions often result in more modest weight loss effects (Gloy et al., 2013), they don't typically produce significant side effects, and are not invasive.

Conventionally, weight loss intervention programmes were delivered face-to-face by specially trained providers on a designated site (Hurkmans et al., 2018; Orozco et al., 2008). This meant such programmes were labour intensive and costly (Norman et al., 2007; Radcliff et al., 2012), and generated problems such as drop-out and low adherence due to the distance a patient needed to travel to get to the intervention centre (Eberhardt et al., 2001; Radcliff et al., 2012). An alternative, which has firmly emerged in the past two decades, is delivering weight loss interventions over the internet, specifically in the form of mobile health technology (Azar et al., 2013). A variety of devices can be used to deliver Mobile health (mHealth) interventions, including smartphones, tablets and other wireless devices (Villinger et al., 2019). mHealth applications and programmes are designed to help users to improve their health by supporting them in a variety of contexts, such as care delivery, monitoring and support (Tomlinson et al., 2013). Research suggests that the effectiveness of weight loss programmes delivered remotely (via mHealth) is comparable to the effectiveness of programmes delivered in-person (Appel et al., 2011; Hurkmans et al., 2018), implying mHealth is a suitable alternative for conventional weight loss programmes. Given that the majority of the population are smartphone owners, and that most mHealth apps are free of charge, they seem to be easily accessible to most people (Azar et al., 2013).

1.10 mHealth for Weight Loss

Some of the first mHealth interventions utilised text messaging, paging and voice communication to help people improve their health (Villinger et al., 2019). However, as functionality of mobile devices improved, many mHealth interventions began to use applications (apps) instead (Ali et al., 2016), because they allowed interventions to become more interactive and personalised for a targeted audience (Servick, 2015; Villinger et al., 2019). Lyzwinski (2014) conducted a meta-analysis of studies which specifically focussed on weight loss as a result of using a mobile phone or other mobile devices, and interventions which employed smartphone-based features. The meta-analysis revealed that the majority of mHealth weight loss interventions led to a significant reduction in body mass, and a medium effect size was reported. It was also noted that mHealth interventions produced a greater weight loss effect than non-mobile interventions. However, the author also emphasises the substantial heterogeneity of findings, suggesting not all interventions are equally effective (Lyzwinski, 2014).

In addition, Villinger et al. (2019) conducted a meta-analysis which led the authors to conclude that mHealth interventions not only produce significant weight loss and lead to a BMI reduction, but also have a positive effect on blood pressure, blood lipids and frequency of engaging in healthy behaviours (such as eating fruits and vegetables). It has also been reported that self-monitoring, defined as registering food and drink intake, as well as portion sizes and physical activity, makes people more aware of their behaviour and can make people feel more accountable (Cavero-Redondo et al., 2020). A meta-analysis carried out by Cavero-Redondo et al. (2020) highlighted that mHealth interventions which focussed on self-monitoring were particularly effective at helping people to lose weight, and had higher adherence rates than paper-based interventions (e.g. food diaries). These findings suggest that mHealth interventions have the potential to effectively help people lose weight and that they are more likely to be successful than non-mobile interventions.

1.11 A Potential Memory-Based Intervention

In light of the finding that recent meal-recall can decrease subsequent intake, it is plausible to assume that recalling recent meals regularly could help individuals to eat less, and to therefore lose weight. There is potential for a memory-based weight loss intervention, which would utilise the meal-recall effect, to be an acceptable and efficient method of helping people to regulate their eating behaviour. It seems appropriate to deliver this intervention through a smartphone, as this will make the intervention more accessible to users, and is more likely to result in eating behaviour changes or weight loss.

A conceptually similar intervention was tested by Whitelock, Kersbergen, et al. (2019), in which participants were encouraged to eat more attentively. The intervention was delivered through an app designed specifically for that study. Participants were asked to photograph every meal they had throughout the day, and after taking a photograph, they were asked to provide a short description of the food they ate. They were then given the opportunity to consume their meal. Participants were asked to return to the app once they finished eating to provide information on whether they finished the entire meal and to rate how they felt after eating the meal. Next, users were asked to return to the app immediately before eating their next meal to review their past entries, and to access an audio clip which encouraged them to eat more attentively and to focus on the experience of eating their meal (listening to the clip was encouraged, but optional). In the control group, participants did not have access to the app and simply received dietary advice through text messages. The researchers reported no significant differences in terms of weight loss between the intervention (1.2kg loss) and the control group (1.1 kg loss), and no significant changes in eating behaviour scores (e.g. biscuit intake during a bogus taste test, reliance on hunger and satiety cues or food cravings).

Although this may be taken as evidence that encouraging people to think about their previous and current meals is not an effective method of helping people to improve their eating behaviours or to lose weight, it's important to first highlight a number of caveats of this study. Firstly, only 27 out of 53 participants were classified as regular users (approximately 51%), which shows intervention adherence was low. This could potentially be due to the complexity of the intervention and the amount of effort a user had to put in to use the app as intended (i.e. accessing the app three times for every meal eaten). As it has been shown that higher adherence to an intervention increases the likelihood of achieving weight loss (Acharya et al., 2009) it's important to find ways to increase regular usage, for example by making the intervention less complex and less demanding in terms of effort.

At the same time, it's also important to investigate whether decreasing the complexity of the intervention impacts its efficacy in terms of behaviour change and weight loss. It has been shown that even a very simple intervention can lead to significant weight loss (Lally et al., 2008). In this intervention, participants were just given a leaflet containing simple recommendations to help them lose weight (e.g. moving more and eating healthier), or were placed in a waiting-list control group. Participants in the intervention group lost an average of two kilograms in eight weeks, whereas those in the control group lost less than half a kilogram. Such results seem promising, as they may suggest a low-effort intervention might be a more effective weight loss tool, than a complex, high-effort intervention. These results also suggest that a potential reason why no significant weight loss differences were observed by Whitelock, Kersbergen, et al. (2019) between their intervention and control groups might be that their simple control group programme was as effective as the mindful eating app.

It seems that sustained usage of an intervention or a tool is the most important predictor of weight loss, and so securing intervention adherence should be the primary focus of any weight loss intervention (Mattila et al., 2013; Norman et al., 2007; Payne, Lister, West, & Bernhardt, 2015). An intervention which is simpler and requires less user effort might produce stronger results, than a more complex intervention - even if the latter, if followed, would be more powerful. Whitelock, Kersbergen, et al.'s (2019) study suffered from low engagement rates, potentially because of how effortful the intervention was, but users reported positive experiences of using the app, and said the app encouraged them to start making healthier food choices, to eat smaller portions and to pay more attention to hunger and satiety cues whilst eating (Whitelock et al., 2020). Thus, reminding people of recently eaten meals seems to be a beneficial strategy to help them improve their eating, but adherence rates must be improved so that users can fully benefit from the intervention. Such a low-effort, memory-based weight loss intervention could then be used to supplement other weight loss techniques, such as goal setting (Linde et al., 2005; Pearson, 2012) to maximise chances of successful weight loss.

1.12 Thesis Overview and Aims

The obesity pandemic our society is currently facing is damaging to people's health and expected lifespan, as well as to the economy. As a result, there is a strong need for new weight loss tools to be developed. A relatively understudied potential weight loss method is regulating intake by recalling recent eating episodes. It has been shown that thinking about a recent meal immediately before snacking can reduce subsequent energy intake (Higgs, 2002), especially if the meal-memory is a few hours old (Higgs et al., 2008). My MPhil research (Szypula et al., 2020) suggested that the meal-recall effect is vulnerable to disruption, but it also highlighted ways in which the meal-recall effect could potentially be amplified. Thus, the first aim of this thesis was to replicate the meal-recall effect. The second aim was to assess whether manipulating a recent meal memory with an imagination task could further strengthen the meal-recall effect, leading to even lower snack intake. The final aim of the thesis was to evaluate the usability and feasibility of a memory-based intervention for weight loss, which was based on the meal-recall effect.

Chapter 2 reviews potential mechanisms by which the meal-recall effect could suppress intake. Thus far, the exploration of a potential mechanism has been sparsely reported in the literature, but understanding the means through which recent meal-recall modulates eating could prove vital to harnessing the advantages of the meal-recall effect. Evidence is reviewed to highlight both the mechanisms which are likely to contribute to the effect, and those that are unlikely to underpin it. This chapter is theoretical due to constraints to in-person testing caused by the Covid-19 pandemic. Chapter 3 is a replication of one of the first studies which reported the existence of the meal-recall effect (Higgs, 2002). The laboratory-based experiment examined whether recalling a recent meal would lead to lower snack intake, compared to recalling a recent journey. Due to the Covid-19 pandemic, data collection for the replication study had to be terminated early. Thus Chapter 4 details two meal-recall replication studies carried out online. Intake behaviour was assessed by asking people to select a photograph of a portion size they would want to consume, following recall of a recent meal or a non-food recall.

Following these replication attempts, Chapter 5 examines whether manipulating episodic meal memories could modulate the strength of the meal-recall effect. A laboratory experiment tested the hypothesis that imagining a past meal as larger and more satiating than in reality would potentiate the meal-recall effect, and further suppress snack intake (compared to just recalling a recent meal). This is followed by a proof-of-concept study, for which data collection was interrupted due to Covid-19 restrictions. Chapter 6 focusses on developing a memory-based weight loss intervention, which is based on the meal-recall effect. The chapter outlines how a Facebook Messenger chatbot intervention was constructed, and presents an assessment of the chatbot's usability. Lastly, Chapter 7 explores the feasibility of the same Facebook Messenger chatbot, to evaluate whether an intervention based on the meal-recall effect is likely to be successful if launched on a larger scale.

Chapter 2
What Is the Mechanism of the Meal-Recall Effect?

Although the meal-recall effect was replicated a number of times (Collins & Stafford, 2015; Higgs, 2002; Higgs et al., 2008; Stafford & Thompsett, 2019; Szypula, Ahern, & Cheke, 2020; Vartanian, Chen, Reily, & Castel, 2016), the potential mechanism for the effect has only been explored briefly. For example, Higgs et al. (2008) discussed multiple speculative mechanisms of the effect, but highlighted that 'the results do not elucidate how recalling recent eating affects subsequent intake' (pg. 461). A recent review by Parent, Higgs, Cheke, and Kanoski (2021) explored a possible route through which the meal-recall effect might decrease intake, but the explanations were heavily focussed on rodent brain circuitry.

In this section, I will explore potential mechanisms of the meal-recall effect, and both human and animal literature will be considered. It is worth noting that the following list of potential mechanisms is not exhaustive, as only cognitive mechanisms are being considered, given that the meal-recall effect is elicited by cognitive processes. It is plausible to assume that other, purely physiological mechanisms, for example hormonal or neurotransmitter regulation, may be partly or fully responsible for intake suppression following recent meal-recall (for a detailed review of intake regulation mechanisms see Hopkins, Blundell, Halford, King, & Finlayson, 2016). However, since this thesis focusses on behaviour and cognition, such biological mechanisms will not be discussed. It is also worth noting that it's possible more than one mechanism might account for the effect of recalling a recent meal.

2.1 Unlikely Mechanisms

Before exploring candidate mechanisms, I will first briefly review mechanisms that have been suggested, but are unlikely to contribute to the meal-recall effect.

2.1.1 Demand Characteristics

It could be argued that the meal-recall effect is only produced because participants are displaying demand characteristics, which describe participants changing their behaviour in line with how they think the experimenter wants them to behave (the 'good-subject effect'; Nichols & Maner, 2008). However, there is evidence to suggest that the effect is unlikely to be induced due to demand characteristics (Higgs, 2002; Higgs et al., 2008; Szypula et al., 2020). The true aims of experiments pertaining to the meal-recall effect are concealed from participants, and the studies are advertised as investigations into food preferences. Also, Higgs (2002), Higgs et al. (2008), Szypula et al. (2020) and Vartanian et al. (2016) all reported that they verified whether or not participants had worked out the aim of the study – out of these studies, only one participant was aware of the experimental aims (in Szypula et al., 2020), but their data were removed from the analysis. Therefore, although it is important to always ensure that participants are not aware of the experimental aims when running a study pertaining to the meal-recall effect, demand characteristics are unlikely to be the driving factor behind it.

2.1.2 Priming of General Health Consciousness

It has been suggested that the meal-recall effect is unlikely to be influenced by health consciousness (Vartanian et al., 2016). Vartanian et al. (2016) tested the possibility that thinking about a recent meal activates a general health consciousness, which in turn motivates people to eat less. They reasoned that thinking about a recent exercise episode might prime similar health-consciousness attitudes, and should therefore also result in decreased snack intake. However, the researchers found that thinking about recent exercise did not decrease intake, relative to the control condition in which participants described an abstract shape. One caveat to this interpretation is that it is well established that thinking about exercise leads to increased food intake (e.g. Albarracin, Wang, & Leeper, 2009; Koenigstorfer, Groeppel-Klein, Kettenbaum, & Klicker, 2013; Werle, Wansink, & Payne, 2011) and therefore this manipulation may not have been a valid way to elicit health-consciousness. In fact, it has been reported that adding a few fitness-related words to a packaging of a trail mix led to an increased intake of the product, and made participants feel they were closer to their desired fitness levels, and less guilty after eating the trail mix (Koenigstorfer et al., 2013). Therefore, it could be argued that instead of priming a health-conscious attitude by asking participants to recall a recent exercise episode, Vartanian et al. (2016) actually led participants to reduce their monitoring of food intake (Wilcox et al., 2009). This claim is consistent with the fact that biscuit intake in Vartanian et al.'s study was approximately 29g after meal-recall (experiment 1), but it was approximately 54g after exercise-recall (experiment 2).

Nevertheless, other research findings also seem to suggest that the meal-recall effect is unlikely to be driven by health-oriented thinking. For instance, preliminary evidence provided from a study by Stafford & Thompsett (2019) indicates that even when the laboratory-meal given to participants (which was then recalled a few hours later) was healthy, the meal-recall effect was still evident. If recalling a recent meal activated general health consciousness, one would expect the healthiness of the reference meal to have an effect on the magnitude of the effect. However, the difference in intake between the lunch-cue and no-cue conditions was about the same (approximately 15g) irrespective of whether an ‘unhealthy’ (Higgs, 2002; exp. 1) or a ‘healthy’ (Stafford & Thompsett, 2019) lunch was consumed and recalled.

2.1.3 The Contrast Effect and Hedonic Valuations

Another mechanism which is unlikely to elicit the meal-recall effect is the contrast effect, as discussed by Higgs (2002). Higgs described that the contrast effect occurs when imagining or thinking about a highly palatable food leads to another food item being perceived as less palatable (Rogers & Hill, 1989). Because of this decreased palatability, subsequent intake is lower. This could explain the meal-recall effect, if it is assumed that the reference meal (which is recalled) is perceived as more palatable than the snacks offered. However, as reported by Higgs (2002), this explanation is not supported by the data, because irrespective of whether a lunch-cue or no-cue was given, biscuit liking was similar across groups. Similar results were observed by Higgs et al. (2008) and Szypula et al. (2020), who both note that biscuit liking was similar across all experimental groups.

On the other hand, Collins and Stafford (2015) suggested that contrast effects were indeed responsible for the meal-recall effect they observed. The researchers reported that food liking ratings were significantly lower after the lunch-cue, compared to the no-cue condition. They claimed that because in their study participants could make their own lunch choice (from a number of alternatives offered) their reference meal was likely ‘preferred’ over the snack they were given, resulting in lower intake in the meal-recall group. They also suggested the same results would have been observed in Higgs (2002), had the sample size been bigger. However, this claim is problematic, because the meal-recall effect was successfully elicited in other studies in which lunch (the reference meal) was not controlled (Higgs et al., 2008; Szypula et al., 2020; Vartanian et al., 2016). Unless it is assumed that every participant, in each one of these studies, ate a lunch which was significantly more palatable than the biscuits offered, this explanation does not seem plausible. Moreover, Stafford and Thompsett (2019) reported that snack liking was higher in the meal-recall condition, yet consumption was decreased. In a similar vein, Vartanian et al. (2016) found that the hedonic value (i.e. craving for and liking) of the test-food did not differ between meal-recall and non-meal-recall conditions. Since the meal-recall effect was elicited in this study, it seems that perceiving the test-food (in this case biscuits) in a more or less desirable way does not mediate the observed suppression in intake. In sum, it seems that the relationship between the meal-recall effect, reference meal-liking and snack-liking is complicated. Given that the magnitude of the meal-recall effect is relatively stable across experiments (around 10-20g reduction in biscuit intake), it seems unlikely that the contrast effect, or changes to hedonic valuations of the snack, are the primary driving factor.

2.2 Potential Mechanisms

Since episodic memory seems to be strongly related to intake regulation (Rozin et al., 1998), and this food-memory relationship appears to be an evolutionary adaptation (Seitz et al., 2021), the general mechanism of the meal-recall effect is likely to be similar in human and non-human animals. As previously outlined in Chapter 1, the hippocampus appears critical for food intake regulation in both humans and rats. In rats, the hippocampus can be divided into dorsal (dHC) and ventral (vHC) regions, and there is evidence to suggest the dHC is primarily responsible for mediating the relationship between food intake and memory (Parent et al., 2021). Inhibiting the activity of dHC neurons right after a meal is finished impairs meal-memory consolidation, and this results in faster initiation of the next meal and greater food intake (Hannapel et al., 2019; Henderson et al., 2013). It has also been reported that consuming a meal results in increased presence of biomarkers critical for synaptic plasticity, the process through which new memories are formed (Henderson et al., 2016, 2017; Parent et al., 2021). These findings suggest that memory of a recent meal acts to (at least partially) inhibit consumption, and that the dHC is critical for meal-memory consolidation. However, another question remains – how exactly does the hippocampus act to inhibit intake after a recent meal? The remainder of this chapter will explore the potential mechanisms which might mediate the meal-recall effect.

2.2.1 Improved Interoception

Interoception refers to being able to perceive internally generated bodily signals (Craig, 2003). Research suggests rats are capable of perceiving interoceptive cues, as they can be trained to differentiate between high (24 hours) and low (1 hour) food restriction levels, and can use these signals to learn to anticipate positive or negative reinforcement (Davidson & Jarrard, 1993; Hock & Bunsey, 1998; Parent et al., 2021). However, lesions to the hippocampus prevent rats from being able to learn this relationship (Davidson & Jarrard, 1993; Hock & Bunsey, 1998) and disrupt maintenance of this learned association if the hippocampus is lesioned after the learning takes place (Davidson et al., 2010). Parent et al. (2021) reviewed how endocrine ‘energy balance-relevant’ signals, such as ghrelin and leptin, interact with the rodent hippocampus. The authors noted that hippocampal processing of these signals modulates food-related behaviour, which might explain how meal-memories inhibit subsequent intake. They also highlighted that, in both humans and rats, damage to the hippocampus results in impaired ability to interpret hunger and satiety cues, which leads to excessive intake. Therefore, one explanation (or at least a partial explanation) for why recalling a recent meal suppresses intake might be that it produces changes to interoceptive-cue processing.

When people are less certain about how hungry/satiated they are, and about how much they should be eating, they often use external cues to make their decisions (Lewis et al., 2015). For example, they may rely on biscuit palatability as an external cue which encourages intake (Herman, Roth, & Polivy, 2003). A hypothetical momentary improvement in interoceptive awareness, due to recalling a recent meal, is likely to help individuals contextualise ambiguous internal signals they might be perceiving. There are a number of factors which may affect the magnitude of internal cue ambiguity: baseline interoceptive ability, contextual factors which impact interoceptive ability (e.g. self-monitoring) and contextual cues which can be internal (e.g. remembering a recent meal) or external (e.g. seeing food wrappers). Resolving this interoceptive ambiguity can help individuals to regulate their intake more effectively (e.g. eating when hungry, or not snacking when still feeling satiated from the last meal).

It has been reported that in humans, there are significant inter-individual differences in interoceptive ability, as well as in interoceptive accuracy, usually measured by heartbeat perception tasks (Herbert, Pollatos, Flor, Enck, & Schandry, 2010; Pollatos, Schandry, Auer, & Kaufmann, 2007). Whitehead and Drescher (1980) showed that gastric and cardiac signal awareness were highly correlated (r=.51), and Herbert, Muth, Pollatos, and Herbert (2012) suggested that participants with higher cardiac awareness scores felt fullness more intensely, as demonstrated by the fact they needed to ingest less water to feel the same level of fullness as participants who had lower cardiac awareness scores. Defects in interoception have been linked to a number of eating disorders, for example Anorexia Nervosa (Kaye et al., 2009) and Bulimia Nervosa (Khalsa & Lapidus, 2016), suggesting interoception is important for 'normal' food intake. Although traditionally, interoceptive awareness was described in terms of being a stable trait (Herbert et al., 2013), due to individual differences in interoceptive awareness and accuracy being potent (Blascovich et al., 1992; Cameron, 2001; Schandry & Bestler, 1995), and the test-retest reliability being good (Mussgay et al., 1999), some researchers argue that interoceptive awareness can also fluctuate in response to environmental cues and context

(Durlik, 2016). For example, Herbert et al. (2012) demonstrated that fasting for 24 hours significantly improved participants' interoceptive awareness, as measured by the heartbeat perception task. This increase in interoceptive accuracy correlated with the felt intensity of hunger, supporting the idea that interoceptive ability can fluctuate over short periods of time. The authors argued that improved interoceptive awareness was a result of internal bodily signals becoming stronger and more arousing, and therefore becoming easier to discriminate. In line with these conclusions, Higgs et al. (2008) suggested that recalling a recent meal 'facilitates the labelling of internal states associated with the consumption of food' (pg. 462) which can explain why snack intake is reduced.

One contextual factor which can modulate interoception awareness is self-focussed attention, or self-monitoring. Self-focussed attention is defined as increased attention to internally generated information and can act as a proxy for interoceptive awareness (Ingram, 1990). Weisz, Balazs, and Adam (1988) showed that increasing participants' self-attention (which was achieved by placing a mirror in front of them) led to better accuracy on the heartbeat discrimination task, in which they had to judge whether the rhythm of a tone was similar or dissimilar to the rhythm of their heart. Heartbeat tracking, which required participants to tap their finger after each heartbeat they felt, was not affected by the self-attention manipulation. However, Ainley, Tajadura-Jiménez, Fotopoulou, and Tsakiris (2012) demonstrated that increased self-attention could improve accuracy on the heartbeat tracking task, but only for participants who generally had lower interoceptive sensitivity. Therefore, baseline interoceptive accuracy may modulate fluctuations in interoceptive awareness, by momentarily improving perception in response to increased self-attention (Durlik, 2016).

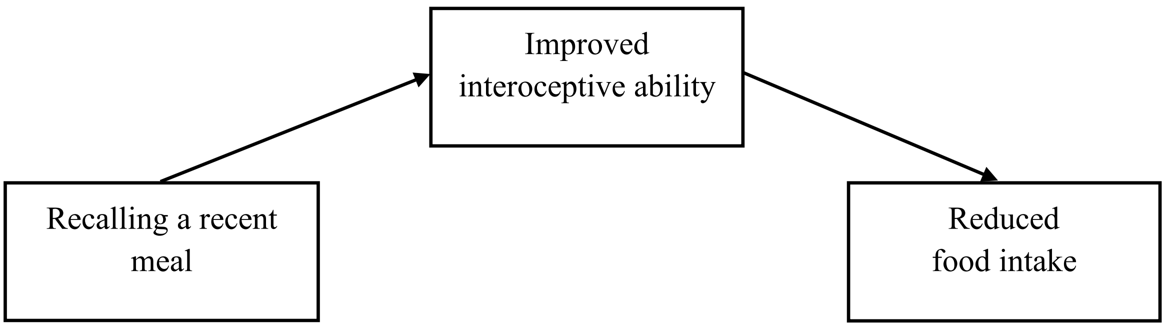
Bellack, Rozensky, and Schwartz (1974) conducted a weight loss study, in which participants were allocated to different programmes. In one of the programmes participants were asked to write down everything they were about to eat (pre-behaviour monitoring; P.M.), and in another to write down everything they ate immediately after finishing their meal (post-behavioural monitoring; Pt.M.). Both groups lost a significant amount of weight after 6 weeks, however the P.M. group lost twice as much weight as the Pt.M. group (albeit this difference was not significant). More importantly, the P.M. group kept losing weight over the next six weeks (after the official trial had ended), whereas the Pt.M. group did not. This suggests that increased self-monitoring may reflect increased interoceptive ability, which in turn helps to regulate intake.

In light of this evidence, it could be argued that recent meal recall decreases intake at a subsequent meal because recalling a meal increases attention paid to internal hunger and satiety signals (see Figure 1). Recalling a recent meal may help individuals to contextualise ambiguous internal states, leading to better consumption regulation and therefore lower intake. Furthermore, increased self-attention may act as a proxy for increased interoceptive awareness. However, one caveat of this potential mechanism is that self-focussed attention is difficult to operationalise. In fact, although self-monitoring is a firmly established concept in the literature, there exist few measures which assess the extent to which an individual is experiencing self-focussed attention.

Some researchers employ very specific measures of self-focussed attention, which are only relevant to the context of that study. For instance, (Woody, 1996) manipulated the extent to which participants experienced self-focussed attention to explore its role in exacerbating social phobia. In order to assess whether the manipulation affected participants' self-focussed attention, they were asked to complete the Focus of Attention Questionnaire (FAQ). This questionnaire was specifically tailored to monitoring of constructs related to social phobia, for example participants were asked if they focussed on what they were about to say or do next, or on the impression they were making on the other person. To the best of my knowledge, no studies have assessed how meal memories influence self-focussed attention, and literature on measuring gastric interoception using questionnaires is scarce.

Figure 1

Hypothesised mediation model to explain the mechanism of the meal-recall effect in terms of improved interoceptive ability



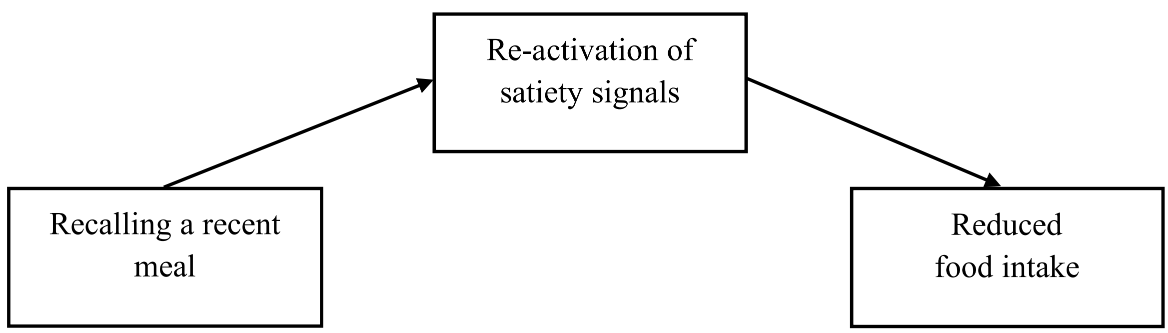
2.2.2 Changes in Hunger, Appetite or Satiation

Another potential mechanism which can account for meal-recall's inhibiting effect on intake is that recalling a recent meal re-activates satiety cues associated with that meal-memory, and this helps individuals to better regulate their intake (see Figure 2). Although no experiments have directly investigated how participants 're-live' or 're-experience' hunger and satiety signals through memory, evidence from separate lines of memory research suggests this is a plausible suggestion. For instance, it has been shown that brain regions associated with encoding an event are re-activated when remembering that event (Danker & Anderson, 2010). fMRI data suggests that activity in the visual association cortex which was present at encoding is reinstated at retrieval (Vaidya et al., 2002), and the auditory association cortex is activated when encoding and retrieving auditory information (Lars Nyberg, Habib, McIntosh, & Tulving, 2000).

Similar findings have been found for olfactory memories as well (Buckner & Wheeler, 2001). Smith, Henson, Dolan, and Rugg (2004) demonstrated that the overlap in brain activation between encoding and retrieval is also present for emotional stimuli, showing that encoding an image in the context of positive or negative valence subsequently activated brain regions typically involved in positive or negative affect processing at retrieval. These findings suggest that recalling an event generates similar brain activity as encoding an event. Therefore, it is plausible to assume that recalling a meal-memory could re-instate satiety signals which were originally associated with the eating episode; these signals could either be a 're-activated' version of the original satiety signals, or completely novel satiety signals generated in response to the meal-memory.

Figure 2

Hypothesised mediation model to explain the mechanism of the meal-recall effect in terms of re-activation of satiety signals



This explanation assumes that the hippocampus is critical for both detection and interpretation of interoceptive hunger/satiety cues. Parent et al. (2021) speculated that this explanation is unlikely to be true for rodents, because the hindbrain is sufficient to process feelings of satiation (Grill & Hayes, 2012) and previous research has attributed sensing current energy and nutrient levels to the hypothalamus (Timper & Brüning, 2017). However, conscious recall of a recent meal is not the same as not disrupting the encoding of a meal memory, which is the paradigm employed in rodent studies. Therefore, it's possible that in humans, being able to form and maintain meal memories inhibits subsequent intake, but conscious reactivation of such memories may further strengthen the effect by making hunger and satiety cues more potent. Despite this logic, no research to date has found any significant effects of meal-memories on self-reported levels of satiety and/or hunger (Collins & Stafford, 2015; Higgs, 2002; Higgs et al., 2008; Szypula et al., 2020; Vartanian et al., 2016).

Nevertheless, it is possible that the traditional measures used to assess appetite are not sensitive enough to detect subtle differences, which recalling a recent meal might cause. Appetite is frequently assessed with a limited number of questions (e.g. please rate how hungry you are on a scale of 1-10), and this may not capture the multifaceted nature of hunger and satiety, which could explain why recalling a meal does not seem to affect subjective ratings of appetite. The concepts of hunger and satiety are closely related (Blundell, 1991; Green et al., 1997; Sørensen et al., 2003), but they are not polar opposites (Karalus, 2011). Despite it being a universal feeling, different people describe hunger in very different ways. Stunkard (1959) asked 200 participants with and without obesity to describe hunger, and found that most people associated it with stomach emptiness and a desire to eat. Yet, McCutcheon and Tennissen (1989) reported that people receiving most of their food intravenously do not report high levels of hunger, despite their stomachs being physically empty. Similarly, hunger is often described in terms of feeling 'hunger pangs' in the stomach, yet complete removal of the stomach does not prevent a person from feeling hungry (Wangensteen & Carlson, 1931). Furthermore, Monello, Seltzer, and Mayer (1965) and Harris and Wardle (1987) all reported that asking participants to describe the bodily sensations they associate with hunger did not yield a common set of sensations, which would be reported by every person. Only 60% of participants reported feeling stomach emptiness, and rumbling was reported by just over a third of respondents (Harris & Wardle, 1987). Eating did not seem to completely ease such sensations, as about a quarter of participants reported feeling that their stomach was empty, even after a meal (Harris & Wardle, 1987). It has also been reported that hunger ratings are not a strong predictor of actual intake (Mattes, 1990). In fact, eating in the absence of hunger is frequently reported, especially by adults with obesity (Goldschmidt et al., 2017). These findings suggest that hunger is a complex, multifaceted state, and is unlikely to be encompassed by a single descriptor.

Satiety refers to post-ingestive processes which inhibit eating, until the next meal is started (Forde, 2018). However, subjective satiety is not always a true reflection of previous energy intake and does not always accurately predict subsequent intake. For example, as described in Chapter 1, Brunstrom et al. (2012) conducted a study in which participants ate soup from a self-filling/self-draining bowl. Participants who saw a bigger portion of soup reported greater satiety two hours after eating, even though they physically consumed a smaller portion. This suggests feelings of satiety can be influenced by cognition, and are not fully reliant on actual consumption. In addition, research suggests that there is more than one 'type' of satiety. Jordan (1969) demonstrated that participants who consumed their meals intragastrically (i.e. had food pumped directly to their stomach, without having food in their mouth) were less satiated by the food, and reported a 'desire for something to chew, taste, or swallow' (pg. 500) after their intragastric meal. Similarly, Cecil, Francis, and Read (1999) found that when a high-fat or high-carbohydrate soup was pumped directly into the stomach, satiety ratings were about the same for both soup types. However, when the soups were eaten normally, the high-fat soup was significantly better at inducing fullness and led to lower intake of a subsequent test meal. Tournier and Louis-Sylvestre (1991) showed that participants consumed more food after ingesting a liquid-meal, than after ingesting a solid-meal, even though the hunger ratings were not different. Most importantly, Karalus and Vickers (2016) demonstrated that it's possible for people to report being physically satiated, despite feeling 'mental' hunger. In this study, the researchers offered people equal volumes of oatmeal or oranges for breakfast. Those who ate the oranges reported similarly low levels of hunger, as those who had the oatmeal, but they also reported feeling more 'mentally' hungry 10 minutes after they finished their meal. The researchers proposed that whereas physical hunger was related to sensations of the stomach, for example emptiness or hollowness, stomach pain, or stomach growling, 'mental' hunger described one's urge to eat or chew something, the need to refuel or preoccupation with food thoughts. This research suggests that both hunger and satiety can have 'physical' and 'mental' aspects to them.

In spite of this, researchers typically use a very narrow set of questions to assess appetite, such as those proposed by Blundell et al. (2010), which incorporate 'hunger', ‘fullness’ and ‘satiety’, as well as ‘desire to eat’, and ‘prospective consumption’ (how much do you think you could eat right now?). Indeed, these scales are most typically employed when investigating the meal-recall effect (Collins & Stafford, 2015; Higgs, 2002; Higgs et al., 2008; Szypula et al., 2020; Vartanian et al., 2016). Given how multifaceted and complex feelings of satiety and hunger can be, it does not seem surprising that no study has found evidence of significant changes to appetite ratings before and after recalling a recent meal, when these simple measures were employed. As noted by Karalus (2011), hunger and satiety can have both mental and physical aspects to them, so recalling a recent meal may affect only one ‘type’ of appetite, but this may not be reflected in traditional scales. Thus, the question as to whether recalling a meal memory influences hunger and/or satiety remains open.

2.3 Additional Factors

Given how complex human cognition is, it seems fair to suggest that a number of additional factors may influence the meal-recall effect. It’s implausible to assume these factors are the main explanation for the meal-recall effect, primarily because meal-memories seem vital to intake regulation in both humans and rodents, and the factors described below are assumed to be uniquely human. Nevertheless, it is worth considering these supplementary factors, as they might offer greater insight into the mechanism of the meal-recall effect.

2.3.1 Guilt

Guilt is characterised as an unpleasant emotion, which stems from a belief that one has done something wrong or inappropriate (Baumeister et al., 1994). Guilt is a form of cognitive tension between knowing what one should be doing and what one is actually doing (Freedman et al., 1967). As a result, feelings of guilt are frequently followed by efforts to compensate for one’s perceived wrongdoings, in order to alleviate these negative feelings (Burnett & Lunsford, 1994). Recalling a recent meal might suppress subsequent snack intake, because recalling a past meal might generate feelings of guilt. Polivy, Herman, Hackett, and Kuleshnyk (1986) gave participants some chocolates to eat, and asked one group to keep the food wrappers visible on the table, and another group to put the wrappers straight into the bin. Accumulating food wrappers made people more aware of their eating, which the researchers argued helped people to suppress ‘mindless’ overeating. It is possible that this mindless overeating was suppressed because participants felt guilty about eating chocolates, as the wrappers acted as a visual reminder of their intake. Research suggests that keeping a food-diary, where an individual records all the food they have eaten over a certain period of time, can lead to a decrease in food intake (Blundell, 2000; Goris et al., 2000), possibly because of increased awareness of intake and/or feelings of accountability (Atkinson Jr et al., 2004).

Support for this idea comes from a study by Piqueras-Fiszmanand Jaeger (2016), who found that participants recalling a past occasion of overeating reported higher feelings of guilt and shame, than those who recalled a positive meal or a routine evening meal. Even though guilt ratings in the overeating group (*M*=4.09) were significantly higher than those in the positive meal and routine meal conditions, the actual differences in guilt ratings were relatively small between the groups (*M*=2.68 after recalling a positive meal; *M*=3.54 after recalling an evening meal), suggesting that recalling any past meal can induce feelings of guilt. Similar results were obtained by Steenhuis (2009), who found that women experienced at least some guilt following any meal of the day, although guilt ratings were highest after eating sweets and ice-cream. Therefore, it is plausible to assume that recalling a recent meal might generate feelings of guilt, irrespective of the 'type' of meal being recalled. This notion is supported by preliminary findings reported by Stafford and Thompsett (2019). These researchers observed a substantial reduction in intake following recall of a recent meal (it is worth noting that this difference was not significant at p=.07, but this might have been due to a small sample size of 16 participants). More importantly, a significant increase in ratings of guilt after the lunch-cue, compared to no-cue, was also observed. Interestingly, these effects were evident even though the lunch the participants were served was healthier than that normally given to participants in meal-recall studies. Therefore, it seems that guilt may be at least partially responsible for suppressing intake after recent meal recall, irrespective of how healthy or unhealthy the reference meal was.

Why might guilt suppress intake? Guilt causes a cognitive frustration, which people seek to resolve (Miceli & Castelfranchi, 1998). Since it is argued that the guilty feelings arise from recalling a recent meal, people may seek to relieve their feelings of guilt by counterbalancing the (perceived) indulgence of their previous meal with decreased snacking (Lee-Wingate et al., 2014). This is especially true since guilt can trigger negative thoughts about food, because it reminds people about the culturally persistent strive for thinness (Macht & Dettmer, 2006), further discouraging participants from snacking.

2.3.2 Portion Appropriateness and Social Norms

In their paper, Higgs et al. (2008) note that 'it is possible that participants eat less when reminded of a recent meal because they consider it appropriate to eat less given the recent meal' (pg. 461). Vartanian et al. (2016) also propose that 'thinking about one's recent food intake (…) affects how much is perceived as appropriate to eat at a subsequent eating occasion' (pg. 35). Research suggests that beliefs about what an 'appropriate' portion of food looks like can influence subsequent intake (Herman et al., 2003; Roth, Herman, Polivy, & Pliner, 2001). For example, when participants were led to believe that other participants had eaten very little food, they also significantly decreased their biscuit intake (Robinson, Benwell, et al., 2013). Similarly, when participants were told that others had eaten a lot of food, they also ate a lot (Roth et al., 2001). The researchers argue this is because eating a lot became the social norm in the context of that study, and the participants simply adhered to the social norm when deciding how much to eat.

It could be that recalling a recent meal activates a social norm which pertains either to people knowing they have already eaten a meal and they don't need to eat anything else (most meal-recall studies took place 2-3 hours after lunch), or to people knowing that snacking between meals is often perceived negatively by others (Chaplin & Smith, 2011; Jacquier et al., 2017). If such a social norm is activated, participants may decrease their snack intake because they might believe this is the 'appropriate' thing to do.

Alternatively, increased awareness of social norms regarding the appropriate portion size may trigger a fear of negative evaluation. When writing down the contents of their previous meal, participants are aware that the experimenter will be able to read what they wrote. There are a number of negative stereotypes associated with perceiving someone as eating excessively (Vartanian et al., 2007). For example, women who eat larger portions are seen as less feminine (Chaiken & Pliner, 1987), less physically attractive (Bock & Kanarek, 1995) and less desirable as a target for social interaction (Basow & Kobrynowicz, 1993). Thus, people tend to (consciously or not) avoid situations which can lead others to think they are eating excessively (Herman et al., 2003). Perhaps participants in meal-recall studies experience such a fear of negative evaluation, which causes them to snack less on biscuits, as a compensatory behaviour to make them appear more favourably.

Recently, Arthur, Stevenson, and Francis (2021) tested this mechanism in an online study. These authors argued that recent meal-recall activates beliefs that people should not eat soon after finishing a meal, and that re-activation of such beliefs mobilises self-control to limit subsequent intake. The authors also suggested that recalling a recent meal acts in a way similar to dietary restraint, meaning that people consciously exert effort to limit their food intake after remembering a recent meal. However they noted that, in contrast to true dietary restraint, suppressed intake after recent meal-recall is not driven by a ‘dieting-motivation’ (pg. 6). In this study, participants were asked to recall either a recent meal, or a more distant meal eaten the previous day, and were then asked to view and rate pictures of palatable foods. The participants rated their desire to eat the pictured food, and assessed how much of a given food they would want to eat, if that food was available to them right that moment (prospective intake). The authors found that ratings of desire and prospective intake were significantly lower after recalling a recent meal, as opposed to recalling a more distant meal. Interestingly, it was revealed that in the control group, level of dietary restraint predicted desire/prospective intake (i.e. those who scored higher on dietary restraint reported lower desire and lower prospective intake), however in the experimental group, this correlation was no longer evident. The authors used this as evidence to suggest that when a recent meal is recalled, all participants behave as if they were restrained in their eating, which leads them to suppress snacking behaviour (or in this case, to suppress their desire to consume palatable foods). Arthur and colleagues did not include a measure of self-control motivation, which would have been useful in order to assess whether there is a direct link between recent meal-recall and increased motivation to consciously limit one’s food intake.

2.4 Summary of the Potential Mechanisms

Given that hippocampal lesions produce similar effects in both humans and rodents, it seems plausible to suggest that a common mechanism mediates the relationship between meal memories and subsequent intake. This common mechanism is likely to be the processing of interoceptive appetitive signals by the hippocampus. Meal memories help to resolve ambiguous internal signals (e.g. am I hungry or nauseous?), which help to regulate subsequent consumption. Consciously recalling a meal memory may simply potentiate this process, by momentarily improving interoceptive ability, which enables an individual to perceive any lingering satiety signals more strongly, which reduces snacking. This might also allow individuals to rely more on internal cues, rather than external cues, when deciding whether and how much to eat. In addition, recalling a recent meal may re-activate satiety signals associated with the meal memory, and this might also help an individual to regulate their intake. Higher-order cognitive factors, such as guilt, social norms, and fear of negative evaluation, may also contribute to the effects of recent meal recall on intake.

2.5 Testing the Potential Mechanisms

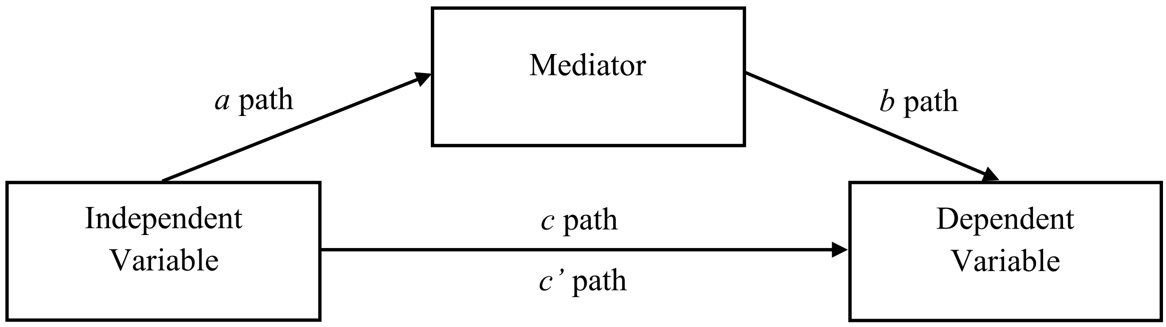
Due to the Covid-19 pandemic, it will not be possible to fully test the mechanisms of the meal-recall effect. For example, interoceptive awareness is usually measured with a heart-beat perception task (Herbert & Pollatos, 2014), or the water-load test (Van Dyck et al., 2016), but this requires an in-person visit to the laboratory. However, Chapter 4 explored whether there is evidence to support these theoretical assumptions, using questionnaire data to assess interoceptive awareness. Data was also collected to assess mental hunger and fullness, to explore whether a more sensitive scale would help establish whether recalling a recent meal affects appetite. Guilt, social norms, and fear of negative evaluation were also assessed with questionnaires, to help pinpoint what their role in the meal-recall effect might be. These measures were tested as potential mediators of the relationship between meal-recall and (prospective) biscuit intake.

In essence, a mediation analysis is a series of regressions, to test a hypothetical causal chain. A full mediation would occur when variable X, which normally predicts Y, no longer predicts Y when a mediator (M) is included in the model (Baron & Kenny, 1986). If the inclusion of a mediator only weakens the relationship between X and Y, but it does not eliminate it, it is assumed the variable is a partial mediator (Rucker et al., 2011). In a mediation model, the *a* path is the effect of the independent variable on the mediator, the *b* path is the effect of the mediator on the dependent variable, the *c* path represents the effect of the independent variable on the dependent variable, and the *c'* path is the effect of the independent variable on the dependent variable, when the mediator is included in the model (see Figure 3).

In the past, it was assumed that significant *a*, *b* and *c* paths were a prerequisite for a mediation analysis. However, more recent considerations of mediation encourage mediation models to be carried out, even when one or more paths are not significant (Zhao, Lynch, & Chen, 2010). This is especially relevant to situations where the effect of the independent variable on the dependent variable (*c* path) is not significant. This is because the indirect effect (*a* x *b* path) can still be significant in this situation.

Figure 3

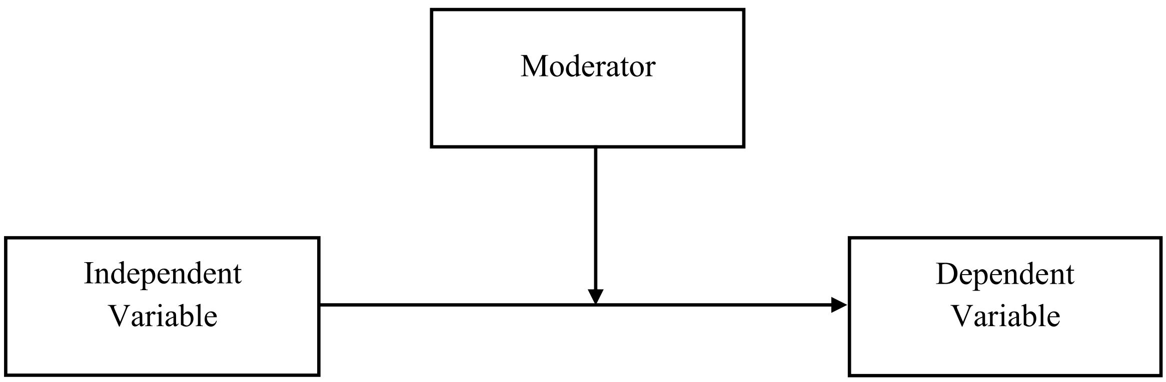
A theoretical model of mediation, with the mediation analysis pathways labelled



A moderation analysis, on the other hand, is a multiple regression model with an added interaction term, to assess whether a relationship between two variables is dependent upon a third variable (the moderator; Aguinis, 2004). Full mediation means that a third variable accounts for the relationship between two variables, whereas full moderation means that the relationship between two variables is differentially influenced by the various levels of the third variable (see Figure 4). Thus, although related, moderation and mediation are conceptually different. Both of these procedures will be used in Chapter 4 to examine the potential mechanism behind the meal-recall effect.

Figure 4

A theoretical model of moderation



2.6 Chapter Summary

This chapter outlined the potential mechanisms for the meal-recall effect and explored how likely each of the suggested mechanisms was. It was determined that recalling a recent meal immediately before eating the next meal might decrease subsequent intake by temporarily increasing interoceptive awareness, and this might help to resolve ambiguous internal signals. It was also hypothesised that recalling a recent meal may re-activate satiety signals associated with the meal-memory, and this may further help to regulate intake. Guilt, portion appropriateness and social norms were identified as factors which could also play a secondary role in driving the meal-recall effect. A number of questionnaires to help operationalise key variables were identified. Lastly, it was argued that both moderation and mediation analyses may be required to assess whether a potential variable is the acting mechanism for the meal-recall effect. The mechanism for the meal-recall effect was explored in more detail in Chapter 4.

Chapter 3

Laboratory-Based Replication of the Meal-Recall Effect

In Chapter 1, studies which showed that recalling a recently consumed meal has a strong influence on reducing subsequent food intake (i.e. the meal-recall effect) were reviewed. The first experiment in this thesis aimed to replicate and extend the results of Higgs (2002). The original experiment recruited unrestrained and non-dieting female undergraduate students who were randomly assigned to one of three groups: 'lunch today' in which they were asked to recall a meal they recently ate, 'lunch yesterday' in which they recalled the same meal, but eaten the previous day or a 'no cue' group, in which they were asked to think about anything they wanted. All participants spent 5 minutes on the recall task, and were then asked to take part in a biscuit 'taste test'. It was found that biscuit intake was significantly lower in the 'lunch today' group, than any other group. Participants in that group ate approximately 21g (46%) fewer biscuits than participants in the other two groups. This experiment had a relatively small sample size of 25 people, and a very large effect size was observed (approximately d=4.2).

In the present replication, a few changes were made to the methodology of the original study. Firstly, the original 'no cue' control condition was replaced with a 'journey recall' condition, in which participants were asked to think about their journey into the laboratory. This change was made because instructing participants to think about anything could have led them to think about food (e.g. a past or a future meal) and this would make the conditions less well controlled. The journey-recall control has been successfully employed by Vartanian et al. (2016). Another change which was made was that the 'lunch yesterday' condition was replaced with an 'imagination' condition, in which participants imagined that their previous meal was much bigger and satiating than in reality. This change was related to a proof-of-concept study explored in Chapter 5 and results for that particular condition will be reported there. It was hypothesised that the meal-recall effect would be replicated in the present study. In other words, it was predicted that biscuit intake would be significantly lower in the 'lunch cue' group, than in the 'journey cue' group. No pre- to post-recall changes to traditional appetite measures were predicted (as reported by Higgs, 2002).

3.1 Method

3.1.1 A Priori Power Analysis

In the original study (Higgs, 2002), the observed effect size was very large (approximately *d*=4.2). Other meal-recall effect experiments by Higgs and colleagues, as well as those conducted by other labs, also found large effect sizes. A sample size calculation was conducted in G*Power (Faul et al., 2007). It was revealed that in order to detect a large effect size (Cohen's f=0.4), with 80% power, using alpha level of .05, a total of 66 participants would be required (22 participants per group). However, in order to ensure the study would not be underpowered, the sample size required to detect a medium effect size (Cohen's f=0.25) was used instead. In this case, a sample size of 159 people (53 per group) would be required, with 80% power and an alpha level of .05. However, it was not possible to recruit the target number of participants, because data collection was interrupted by Covid-19 restrictions.

3.1.2 Participants

Only unrestrained, non-dieting females were recruited for the study. As in Higgs (2002), unrestrained eating was defined as scoring 2.2 or less on the DEBQ restraint scale (van Strien et al., 1986). Out of 88 participants who completed an online screening questionnaire, 54 were eligible to take part in the study, and 20 were tested before Covid-19 restrictions were introduced and testing was ceased.

3.1.3 Design

A between-subjects design was employed, with participants randomly allocated (using Excel) to either the 'lunch cue' (n=7), 'journey cue' (n=6) or 'imagination' (n=7) group.

3.1.4 Ethical Approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

3.1.5 Materials

3.1.5.1 DEBQ. In order to assess whether participants were eligible for the study, they were asked to complete the restraint facet of the DEBQ (van Strien et al., 1986; Appendix A), by filling out an online questionnaire which was sent to them over email. Restrained eating was measured with 10 questions presented on a 1-5 Likert scale anchored 'never' to 'very often'.

Two questions also had a 'not relevant' option. A mean of all responses was calculated to generate the restraint score.

3.1.5.2 Mood Questionnaire. Participants were asked to complete a mood questionnaire, which was used to help disguise the real aim of the study. Participants made their ratings on a 0-10 Likert scale anchored 'not at all' to 'very much' (see Appendix B). They were asked to rate how happy, sad, excited, scared, energised and tired they felt.

3.1.5.3 VAS Ratings. In order to assess whether participants' appetite sensations were affected by the recall task, participants were asked to complete four rating scales (based on Barkeling, Rossner, & Sjoberg, 1995; see Appendix C). The scales in this study were modelled on pen-and-paper Visual Analogue Scales (VAS), which were employed in the study by Higgs (2002). The questions and their anchor points were as follows: 'How strong is your desire to eat?' (Not strong at all – Very, very strong); 'How hungry do you feel?' (Not hungry at all – Very, very hungry); 'How full do you feel?' (Not full at all – Very, very full); 'How much food do you think you would be able to eat right now?' (No food at all – A very, very large amount of food). Participants were asked to place a mark on a 10cm line to reflect how they were feeling at a given moment. All of the VAS ratings were presented on a single, white, A4 piece of paper. A ruler was then used to calculate the distance (in cm) from the beginning (left side) of the line to the mark. Ratings were made at three time points: before and after the recall task, as well as after the biscuit taste test.

3.1.5.4 Recall Tasks. Participants were randomly allocated to one of three groups. In the 'lunch cue' group participants were instructed to 'please recall what you ate for your previous meal and write down your thoughts below'. In the 'journey cue' group participants were asked to 'please recall your journey into the laboratory and write down your thoughts below' and those in the 'imagination' group were told to 'please recall what you ate for your previous meal and imagine that your portion was bigger and more filling than in reality. Write down your thoughts below'. The tasks were designed in Qualtrics and participants could type their response into a textbox provided.

3.1.5.5 Biscuit Taste Test. Participants were asked to participate in a bogus taste test, where they rated three types of biscuits on ten different taste attributes (e.g. how crunchy, chocolatey, salty etc. they were). The biscuits used were Maryland Choc Chip Mini Cookies (499kcal/100g), Maryland Double Choc Chip Mini Cookies (499kcal/100g) and Mini Jammie Dodgers (435kcal/100g). Following Higgs's (2002) paradigm, 15 biscuits of each kind were placed in individual boxes labelled with a reference number 1, 2 or 3. Each biscuit weighed approximately 5g (approximately 75g of biscuits were presented in each box). Participants were asked to rate the taste of various biscuits in a fixed order (Choc Chip Cookies, Double Choc Chip Cookies, Jammie Dodgers). Ratings were made on a slider scale from 0 – 10, on an online questionnaire designed in Qualtrics. Lastly, the participants were asked to report whether there was anything that could have influenced the amount of biscuits they ate (e.g. illness, stress). These reasons were assessed at the end of data collection and none of them were deemed significant enough to justify exclusion from the analyses.

3.1.6 Procedure

Participants were recruited from the Cambridge SONA participant pool. The study advert claimed that the aim of the study was to assess the relationship between mood and taste preferences. Those who expressed interest in the study were emailed a pre-screening questionnaire, which included the DEBQ restraint questions, as well as questions which assessed whether the participant was currently dieting, their age, sex, weight and height. If a participant was eligible to participate, they were invited into the laboratory. Testing took place between 1pm and 5pm, and participants were instructed to eat a meal about 2 hours prior to their allotted time slot.

Upon arriving, participants were given the mood questionnaire. This was followed by completion of the four VAS ratings to assess hunger, fulness, desire to eat and disgust. Then, depending on the condition they were allocated to, participants were instructed either to think about their recent meal, their journey into the laboratory, or to their recent meal which was followed by imagining the meal was bigger and more filling than in reality. Participants were given five minutes to write their thoughts down, during which time the experimenter was not present in the room. When the experimenter returned, participants were asked to complete the VAS ratings again, and they were then given instructions on how to complete the biscuit taste test.

Three boxes of biscuits were put in front of the participants, and the experimenter told the participant they were to taste each biscuit in turn and to make ratings to assess various aspects of their taste. Participants were told it was important for them to give accurate ratings, so they should eat as few or as many biscuits as necessary to achieve such ratings. Participants were also informed that the biscuits would have to be disposed of at the end of the session for hygiene reasons, so they may help themselves to any leftover biscuits after they finish. The experimenter then answered any questions the participants might have had and left the room for 10 minutes. Upon returning to the room, participants were asked to complete the VAS ratings again, and were then asked to write down what they thought the true aims of the study were. No participant had second-guessed the true aims of the study. Participants were debriefed and paid £5 cash for their participation.

3.1.7 Analysis Plan

Total biscuit intake (in grams) was calculated by weighing the biscuit bowls before and after each taste test session and subtracting one score from the other. The present study was severely underpowered, and so a Bayesian statistical model was used. As Bayesian factor calculations do not depend on large sample sizes, the interpretation of results based on small samples is more informative when such an approach is applied (Van de Schoot & Depaoli, 2014). The results for the imagination cue group are not pertinent to the present replication, and they are instead reported in Chapter 5 (see section 5.4).

3.2 Results

3.2.1 Initial Analyses

3.2.1.1 Manipulation Check. A manipulation check confirmed that all participants followed the instructions correctly, and only reported the information they were asked to recall in each group.

3.2.1.2 Missing Data. One participant in the journey-recall group did not report their weight. Little's MCAR test was not significant, $X^2(12)=8.84$, $p=.716$, suggesting the missing data point was a random occurrence. A linear regression was performed, with height and age as the independent variables and weight as the dependent variable. The missing weight value was replaced with multiple imputation, with age and height as the predictor variables. Five imputations were generated. The average value imputed was 54.78 and this was rounded up to 55kg.

3.2.2 Demographics

Data from 13 participants were analysed. BMI scores less than 18.5 were classified as underweight, scores between 18.5 and 24.9 as normal weight and scores above 25.0 were considered overweight/obese (World Health Organisation, 2018). All but one participants had a BMI within the normal range and the two groups did not differ in terms of their baseline characteristics (see Table 2).

Table 2

Summary statistics of demographic variables in different experimental groups

	Lunch cue	Journey cue
N	7	6
Age	21.14 (3.85)	21.83 (4.07)
Age Range	18-29	19-30
BMI	20.86 (2.32)	21.58 (1.83)
Restrained Eating (DEBQ)	1.80 (0.19)	1.88 (0.33)
Baseline hunger	3.19 (1.97)	3.78 (2.33)
Baseline fullness	4.64 (1.52)	4.10 (2.00)
Baseline desire to eat	4.30 (1.35)	4.47 (2.22)

Note. Standard deviations are presented in parentheses. Restraint ratings made on a 1-5 scale; appetite ratings marked on a 10cm VAS scale. Higher ratings indicate greater endorsement.

3.2.3 Main Analyses

3.2.3.1 Biscuit Intake. The difference in intake between the lunch cue (M=32.57, SD=18.11) and the journey cue (M=46.33, SD=18.48) groups (see Figure 5) was assessed with a Bayesian statistical model. The analysis was conducted using JASP (JASP Team, 2020) following the guidelines outlined by van Doorn et al. (2021). Biscuit intake was normally distributed in both groups, as revealed by a non-significant Kolmogorov-Smirnov test (lunch cue: D[7]=.21, p=.200; journey cue: D[6]=.19, p=.200) and a non-significant Shapiro Wilk test (lunch cue: W[7]=.84, p=.106; journey cue: W[6]=.97, p=.882). A one-tailed (group 1 < group 2) Bayesian independent-samples t-test was carried out, with default priors (Cauchy scale). The analysis returned a BF_{10} of 1.36 (95% credible interval [-1.55, -0.03]), suggesting there was weak evidence in favour of the hypothesis that recalling a recent lunch reduced biscuit intake.

3.2.3.2 Effect of Cue on Appetite. Pre-to-post recall changes to hunger, fullness, and desire to eat ratings are shown in Table 3. None of the changes to these appetite ratings were substantial in the two groups.

Figure 5

Biscuit intake during the taste test, as a function of recall cue (error bars represent 95% CI)

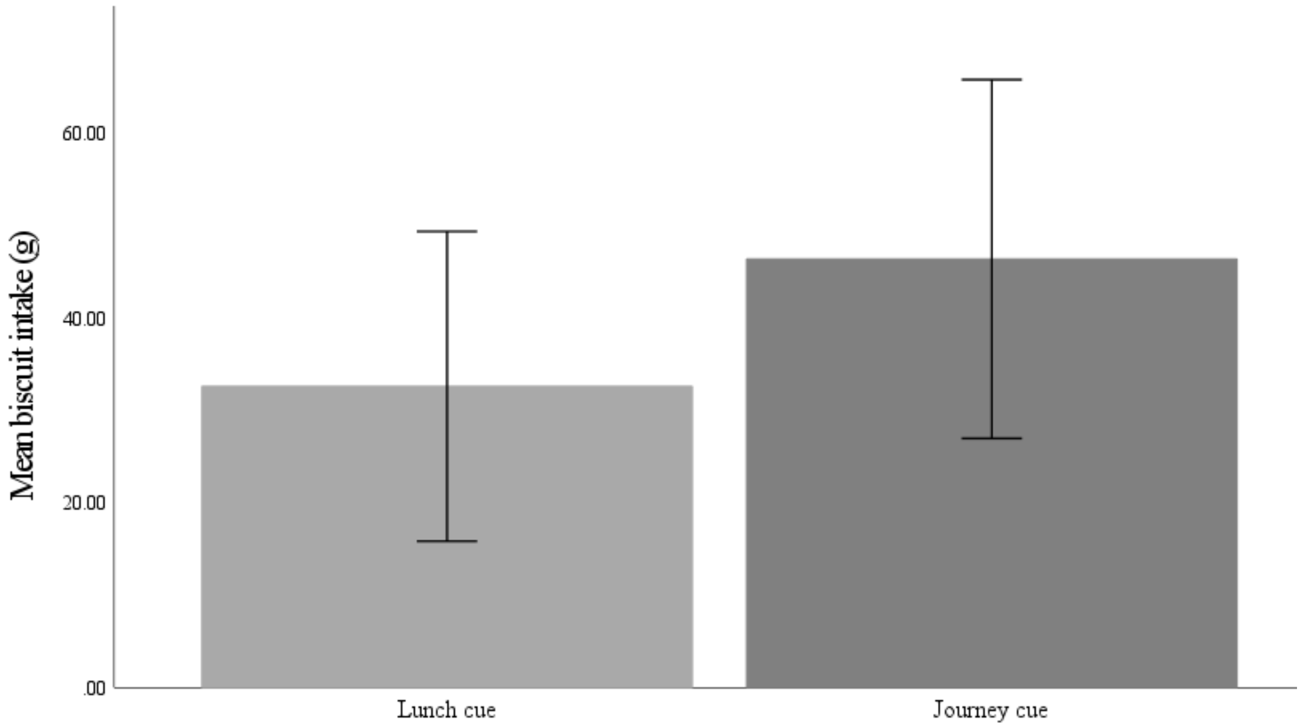


Table 3

Mean appetite ratings given before and after the recall task, as a function of recall cue

	Lunch cue		Journey cue	
	Pre-recall	Post-recall	Pre-recall	Post-recall
Hunger	3.19 (1.97)	3.59 (1.82)	3.78 (2.33)	3.95 (2.43)
Fullness	4.64 (1.52)	4.63 (1.29)	4.10 (2.00)	3.48 (2.31)
Desire to eat	4.30 (1.35)	3.71 (1.44)	4.47 (2.22)	4.68 (2.13)

Note. Standard deviations are presented in parentheses. Ratings marked on a 10cm VAS scale. Higher ratings indicate greater endorsement.

3.2.3.3 Effect of Biscuit Taste Test on Appetite. Participants filled out the appetite VAS ratings after completing the recall task, and then after completing the 10-minute biscuit taste test. Participants in both groups seemed to report higher levels of fullness after the snacking session, which is not surprising given they ate biscuits in-between making the two ratings. Hunger and desire to eat ratings remained relatively stable between the two time-points (see Table 4).

Table 4

Mean appetite ratings given after the recall task and after the biscuit taste test, as a function of recall cue

	Lunch cue		Journey cue	
	Post-recall	Post-snacking	Post-recall	Post-snacking
Hunger	3.59 (1.82)	2.80 (1.96)	3.95 (2.43)	3.13 (2.37)
Fullness	4.63 (1.29)	5.89 (1.44)	3.48 (2.31)	5.28 (2.88)
Desire to eat	3.71 (1.44)	3.11 (2.35)	4.68 (2.13)	3.17 (2.86)

Note. Standard deviations are presented in parentheses. Ratings marked on a 10cm VAS scale. Higher ratings indicate greater endorsement.

3.2.3.4 Biscuit Ratings. Average biscuit liking and ratings of how likely participants were to choose such biscuits for themselves were comparable across the two groups (see Table 5).

Table 5

Mean ratings of biscuit liking and choice, as a function of recall cue

	Lunch cue	Journey cue
Biscuit liking	5.24 (1.01)	5.89 (1.50)
Biscuit choice	4.81 (1.51)	4.44 (1.50)

Note. Standard deviations are presented in parentheses. Ratings made on a 0-10 scale. Higher ratings indicate greater endorsement.

3.3 Discussion

The aim of the present experiment was to replicate the meal-recall effect, previously reported by Higgs (2002). Data collection was prematurely terminated due to restrictions to in-person testing caused by the Covid-19 pandemic, and Bayesian statistics were used for the analysis. The evidence in favour of the alternative hypothesis was weak. However, the data trended in the hypothesised direction, as participants who recalled a recent lunch ate almost 14g fewer biscuits, than those who recalled a recent journey into the laboratory. This is consistent with findings previously reported by Higgs (2002) and Szypula et al. (2020). The observed effect size was very small (w^2=0.06), but comparable to that achieved by Higgs et al. (2008) with a larger sample size. As expected, traditional appetite measures did not seem to be affected by the recall task. Given restrictions to in-person testing, the replication was attempted again, this time using an online paradigm. This replication is the focus of the next chapter.

Chapter 4
Online Replication of the Meal-Recall Effect

A replication of the meal-recall effect was presented in the previous chapter, however due to Covid-19 restrictions, testing had to be terminated before a complete sample of participants was recruited. The meal-recall effect is usually investigated using laboratory-based methods, as the bogus taste test paradigm requires food intake to be physically measured (Robinson et al., 2018). Because of restrictions to in-person testing, it was necessary to devise a new, remote method of investigating the meal-recall effect. However, a method to investigate intake remotely is not only useful when laboratory testing restrictions are in place. The laboratory-based taste test is a laborious procedure, which requires a lot of time, as participants need to be tested individually (Bucher et al., 2012). Such a method is also frequently limited by practical issues, such as lack of facilities to prepare and store food, limited food choices, and high running costs, as well as food spoilage and waste (Bucher et al., 2012). These issues are even more prominent when it is considered that a large number of participants need to be tested, in order to minimise the likelihood of producing unreliable results (Button et al., 2013). Devising a valid and reliable method to measure food intake remotely would enable researchers to collect eating-behaviour data faster and more effortlessly, and would allow multiple foods to be tested in a single session, in a range of environments, where food preparation facilities are limited (e.g. hospitals; Wilkinson et al., 2012).

It has been shown that there is a strong relationship between hypothetical portion sizes and real food intake. Bucher et al. (2012) asked participants to serve themselves a meal from a fake food buffet (where the food items were plastic replicas) and to serve themselves a meal from a real food buffet. These sessions took place two weeks apart. The researchers found that the correlation between theoretical energy served in the fake food buffet, and actual energy served in the real food buffet was high (r=0.76), but also found that people served themselves approximately 32 fewer calories in the fake food buffet. Another way in which researchers can examine hypothetical portion sizes or hypothetical energy intake is by using virtual reality (VR). Ung, Menozzi, Hartmann, and Siegrist (2018) created a virtual food buffet and found that the amount of food people served themselves in such a virtual environment was highly correlated with the amount of food people served themselves in a fake food buffet (r=0.80). Persky, Goldring, Turner, Cohen, and Kistler (2018) further showed that the portion of pasta served from a virtual buffet correlated well with the portion of pasta served from a real buffet

(r=0.61), although the portion served from the virtual buffet was slightly smaller (the difference was about 89 calories). Cheah et al. (2020) reported similar findings, as they found a good correlation between total calorie selection from a virtual buffet and from a real food buffet, even after they controlled for BMI, hunger, age and sex (partial r=0.59). These findings suggest that hypothetical food selection is strongly related to real food selection, and therefore fake food buffets and virtual buffets are valid tools for measuring appetitive behaviour without serving real food.

However, using fake-food or virtual-food buffets requires elaborate set-ups and expensive materials (Ung et al., 2018), and so food photographs are most frequently used to assess (hypothetical) portion sizes (De Keyzer et al., 2011). Respondents are usually asked to recall a recently consumed food, and are required to match this recalled portion to that depicted on the photographs (Biro et al., 2002). In a study conducted by Nelson, Atkinson, and Darbyshire (1996) participants served themselves a portion of food, and were then asked to select a photograph which best resembled the portion of food they consumed. The researchers noted that in general, food photographs were a useful tool for estimating recalled portion size. Lean participants (with a BMI less than 25) showed a 5-10% overestimation for most food types, whereas participants with obesity (with a BMI over 30) showed a 2-5% portion underestimation. In most cases, energy intake estimated with a photograph correlated well with actual energy intake.

De Keyzer et al. (2011) also found food photographs to be a good method of estimating past intake, as the correlation between consumed and estimated portions was acceptable (r ranged from 0.48 to 0.75). However, in that study, the researchers only used bread, margarine, coffee and water as the test foods. Ovaskainen et al. (2008) presented participants with set portions of food, and then asked them to recall the size of each presented portion (which was not consumed by the participant). Approximately 50% of participants were able to estimate the portion size exactly, and there was no relationship between the estimation accuracy and the energy density of the food. Faggiano et al. (1992) found that the critical factor which determined whether or not a participant estimated their portion accurately, was the size of the minimum and maximum portions depicted in the photographs. The researchers found that if a participant ate a small portion of food, and the minimum portion of food shown in the photograph was similar (or even bigger) than the portion consumed, people overestimated their portion. On the other hand, if participants ate a big portion, and the photograph showing the biggest possible portion contained a similar amount of (or even less) food, participants tended to underestimate their intake. Portions were overestimated by as much as 90%, and underestimated by as much as 50%. However, if the amount actually consumed fell within the range of portion sizes shown, intake was estimated well.

The studies mentioned above all asked participants to either estimate a portion of food they have recently eaten, or a portion of food they were recently presented. However, perhaps surprisingly, there is a shortage of studies which used food photographs to estimate prospective intake. Bucher and Keller (2015) used a web-buffet to assess whether a portion of food participants selected online would correspond to the portion of food participants would eat in the laboratory. In that study, 32 participants were asked to first select a portion of food they would like to eat from a web-buffet, and were then invited to the laboratory to serve themselves a real-food lunch, composed of the same food items as presented in the web-buffet. A high correlation (r=0.63) was observed between hypothetical energy intake (from the web-buffet) and real-energy intake. Overall, there was a tendency for participants to underestimate the portion of food they would consume by about 11%, and the researchers suggested this may be because the food looked more appealing in real life, than in the photographs. Likewise, Wilkinson et al. (2012) found that digital portion size selection was strongly correlated with actual intake. This was true when participants were asked to select a portion size which would stop them from getting hungry until their next meal (expected satiety; r=0.66) and when participants were asked to select a portion size they would want to eat right this moment (ideal portion; r=0.52).

It has also been shown that digital portion size selection, where photographs are used as a proxy for intake, is sensitive to experimental manipulations. For instance, digital portion sizes selected by participants who underwent bariatric surgery decreased significantly after the operation, and the selected portion sizes predicted weight loss three months later (Hamm et al., 2020). Cheon and Hong (2017) conducted a study investigating how feelings of low socioeconomic status can stimulate appetite. In the first version of their experiment, they manipulated perceived economic status of their participants, and then asked them to estimate how much they would like to eat based on photographs of food. In a subsequent iteration of this experiment, socioeconomic status was again manipulated, but this time participants were asked to eat real food, and their intake was covertly measured. In both cases, those who were in the low-status condition selected/ate a larger portion of food than those in the high-status condition, showing that hypothetical portion selection can respond to experimental manipulation in the same way as real-food portion selection.

The present study examined whether it would be possible to replicate the meal-recall effect using a digital portion selection task, instead of the physical taste test. One reason for this was because of testing restrictions caused by the Covid-19 pandemic. Additionally, one of the main aims of this thesis was to assess whether the meal-recall effect could be used for weight management, if it was converted into a digital intervention. Thus, it was also important to demonstrate that the meal-recall effect can be elicited away from a laboratory setting, without the presence of an experimenter. In order to assess prospective intake remotely, a digital portion selection task was devised, based on the work of Wilkinson et al. (2012) and Bucher and Keller (2015). In line with the original meal-recall effect, it was hypothesised that those who recalled a recent meal would select a photograph showing a smaller portion of popcorn, than those who recalled the non-food event.

A further aim of this study was to explore whether a potential mechanism of the meal-recall effect could be identified. Based on findings presented in Chapter 2, it was hypothesised that recalling a recent meal may temporarily heighten people's interoceptive awareness. This was based on the finding that hippocampal damage disrupts processing of hunger and satiety cues, which normally help to regulate intake (Rozin et al., 1998). Improved interoceptive awareness could then make any lingering satiety signals more prominent, and suppress prospective intake. Thus, a number of interoceptive awareness and appetite measures were administered to participants before and after the experimental manipulation.

4.1 Experiment 1: Method

4.1.1 A Priori Power Analysis

The power analysis was conducted in G*Power (Faul et al., 2007). Szypula et al. (2020) found that that the effect-size of the meal-recall effect was d_z=0.62. However, given the novel testing paradigm, the sample size was based on a third of that effect size (d=0.20). To detect an effect of this size, with 95% power, at least 328 participants would be required. Overall, data from 571 participants was collected and data from 540 participants was used for the statistical analysis.

4.1.2 Participants and Design

The sample for this study was recruited through Prolific and the experiment was presented in Qualtrics. The entire experiment was completed remotely. The inclusion criteria were that participants had to be between 18-40 years old, be currently residing in the UK, and have no current or past diagnoses of an eating disorder. The study design was between-subjects, with two conditions: recalling a recently eaten meal or recalling a recent episode of tidying a room or house. Participants were randomly allocated to one of these conditions.

4.1.3 Ethical Approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

4.1.4 Questionnaires

4.1.4.1 Overview. One of the aims of the present study was to investigate the potential mechanism for the meal-recall effect (candidate mechanisms were discussed in Chapter 2). A number of questionnaires were employed to help assess the likelihood of each mechanism being involved in the effect. In order to explore whether recalling a recent meal decreased intake by temporarily heightening an individual's interoceptive awareness, three questionnaires were employed: the Self-Monitoring Questionnaire, the Six-Item Gastric Interoception Scale, and the Body Perception Questionnaire (BPQ). It was necessary to employ more than one questionnaire to measure interoceptive awareness, as there are no established methods of measuring state interoception using questionnaires, particularly for experiments completed entirely remotely.

The Self-Monitoring Questionnaire was not validated, and was designed especially for the present experiment, the Six-Item Gastric scale has previously been used in unpublished work only, and the BPQ was validated as a trait measure of interoceptive awareness, but its wording was adjusted so that questions referred to perception of interoception at the time the questionnaire was being completed (to generate a state measure of interoception). All three questionnaires attempted to assess the degree to which participants were aware of their internally generated signals, especially those relating to gastric sensations, and all three questionnaires had a slightly different focus (Self-Monitoring Questionnaire: current sensations, body perception; Six-Item Gastric Scale: sensations arising from the stomach, extent to which these sensations affect food decisions; BPQ: whole-body focus). It was also predicted that baseline (trait) interoceptive awareness would modulate the relationship between meal recall and prospective intake, and so the MAIA questionnaire was also administered.

Another candidate mechanism was increased sensitivity to lingering satiety cues. To this end, traditional appetite measures were employed (hunger, fullness, desire to eat and amount of food could eat), as well as the Five Factor Satiety Questionnaire, a validated measure which is more sensitive to subtle appetite fluctuations. This questionnaire also included a measure of "mental hunger", which might manifest when the stomach is full, but the meal was not satisfying (e.g. mental hunger might be felt after eating high-volume, low-energy food [e.g. watermelon] when very hungry). Aside from these two primary candidate mechanisms, it was also hypothesised that other aspects of cognition might also play a role in the relationship between meal recall and subsequent intake. It was thought that recalling a recent meal might elicit feelings of guilt, which could in turn modulate (prospective) intake. To this end, a measure of guilty feelings was administered before and after the meal recall task. Another idea this experiment tested was that when recalling a recent meal, people adjust their perception of what constitutes an "appropriate" size for a snack. Thus, a questionnaire to measure the extent to which people believed their selected snack portion was of an appropriate size was created (but not validated). Similarly, it could be that rather than adjusting their perception of what an appropriate snack size is, participants could have experienced state fear of negative evaluation by others. To measure this, the Fear of Negative Evaluation questionnaire was administered (this measure was validated), but the wording of the items was adjusted to reflect state rather than trait perceptions. As it was also predicted that the extent to which fear of negative evaluation influenced prospective intake would be modulated by baseline motivation to manage impressions (i.e. those who are generally more wary of how they are perceived by others would be more prone to experiencing fear of negative evaluation), a validated questionnaire to measure this trait was also administered.

For increased clarity, it is worth noting that the PANAS-X, DEBQ and Dieting Status selection were only used for characterising the sample. Measures of BMI, MAIA, Fear of Covid-19, and pre-recall appetite were used for both sample characterisation and statistical analyses (as covariates in the main ANOVA, apart from the appetite ratings), and the remaining questionnaires were only used for hypothesis testing. Details of all questionnaires employed in the study are given below.

4.1.4.2 Traditional Appetite Scales. Participants' hunger, fullness, desire to eat and the amount of food they could eat were measured with a slider scale designed in Qualtrics. The scales were modelled on pen-and-paper Visual Analogue Scales (VAS), which were used in Chapter 3 (see section 3.1.4.3 for further details). The scales were presented as horizontal lines, with values ranging between 0 and 100 (see Appendix D).

4.1.4.3 Five Factor Satiety Questionnaire (FFSQ). The Five Factor Satiety Questionnaire (FFSQ; Karalus, 2011) measured appetite with greater sensitivity than traditional hunger/fullness scales. The questionnaire comprised 37 questions which measured different facets of appetite: mental hunger, physical hunger, mental fullness, physical fullness and food liking sensations. Ratings for all facets (except for liking) were given on a 7-point scale, with anchor points ‘none/not at all’ and ‘strongest/greatest imaginable sensation’. The food liking facet was rated on an 11-point scale with anchors ‘greatest imaginable disliking/liking’ (see Appendix E). Scores were calculated by averaging across all items in a given subscale.

4.1.4.4 MAIA. Participants were given the Multidimensional Assessment of Interoceptive Awareness version 2 (Mehling, Acree, Stewart, Silas, & Jones, 2018), which measured generalised interoceptive ability (see Appendix F). The questionnaire comprised 37 items, which were measured on a 0-5 scale (anchors ‘never’ and ‘always’). Due to a technical error, questions 27-37 were not displayed to the participants. Five facets of interoception (out of eight described in the original paper) were calculated by averaging corresponding items (see Mehling et al., 2018).

4.1.4.5 Six-Item Gastric Interoception Scale. The Six-Item Gastric Interoception Scale was developed by the Cheke laboratory (unpublished) and was based on the Toronto Alexithymia Scale (Taylor et al., 1985). The six questions assessed participants’ ability to perceive internally generated gastric signals (e.g. using satiety cues to decide when to stop eating, recognising hunger signals etc.; see Appendix G). The questionnaire items were rated on a 1-5 scale (anchors ‘strongly disagree’ and ‘strongly agree’). Whilst participants completed the questionnaire, they were asked to think about how they were feeling right now, at that very moment. Higher scores indicated greater gastric interoceptive awareness.

4.1.4.6 Body Perception Questionnaire Very Short Form (BPQ-VSF). General bodily state awareness was measured with a 12-item version of the Body Perception Questionnaire (BPQ; Cabrera et al., 2018). Statements (e.g. ‘I am aware how hard my heart is beating’) were rated on a 1-5 Likert scale anchored ‘strongly disagree’ to ‘strongly agree’ (see Appendix H). All responses were summed into a single score, with 12 being the minimum and 60 being the maximum score. It was emphasised that participants should make their ratings based on how they were feeling at that very moment.

4.1.4.7 PANAS-X. In order to measure participants' positive and negative affect, the Positive and Negative Affect Schedule - Expanded (Watson & Clark, 1994) was used. Participants were asked to indicate the extent to which they felt particular emotions right at that very moment. Different words and phrases which reflected emotions and feelings were rated on a 1-5 scale (anchors 'very slightly to not at all' and 'extremely'; see Appendix I). Items corresponding to each dimension were averaged, and higher scores indicated a given affect was experienced more strongly. This questionnaire was administered to control for baseline positive and negative affect.

4.1.4.8 Appropriate Size. This seven-item scale measured whether participants thought the popcorn portion size depicted in the photograph they selected was appropriate in terms of its size. Two of the items were taken from Ueland, Cardello, Merrill, and Lesher's (2009) paper, and the rest were constructed based on previous literature findings (see Appendix J). The statements were rated on a 1-5 Likert scale anchored 'strongly disagree' to 'strongly agree'. All responses were averaged to get a single 'portion appropriateness' score. The scale had a high internal consistency score ($\alpha=0.85$).

4.1.4.9 Fear of Negative Evaluation – Straightforwardly-Worded Items. The fear of negative evaluation questionnaire was based on a scale constructed by Rodebaugh et al. (2004). In the original questionnaire, items assess general tendency for people to experience fear of negative evaluation, and so items were re-worded (and in places shortened) so that they would be written in the present-continuous tense (e.g. a statement which started with 'I usually worry' was replaced with 'I am worried'). One statement ('I often worry that I will say or do the wrong things') was removed, as it did not seem appropriate to include it given the experimental context and the present-tense wording of the items. Statements were rated on a 1-5 Likert scale with anchors 'strongly disagree' and 'strongly agree'. Participants were asked to think about how they were feeling right that moment, when rating the statements (see Appendix K). The items had high internal consistency ($\alpha=0.96$).

4.1.4.10 Motivation to Manage Impressions Scale. The motivation to manage impressions scale was constructed by Lee-Wingate et al. (2014). The scale measured general tendency to manage impressions, and to change behaviour in order to please others. Eight statements were rated on a scale of 1-5 with anchors 'strongly disagree' and 'strongly agree' (see Appendix L). Internal consistency was slightly low when all items were included ($\alpha=0.68$), and so the last item was removed from the scale which increased the alpha value to a satisfactory score (α=0.70).

4.1.4.11 Fear of Covid-19 Scale. Given that the experiment was conducted only a few months after the first Covid-19 lockdown was announced, Covid-related stress levels were measured (Ahorsu et al., 2020). The questionnaire consisted of seven statements which were rated on a 1-5 scale ranging from 'strongly disagree' to 'strongly agree' (see Appendix M). The score for each item was summed to get a single fear of Covid-19 score.

4.1.4.12 Self-Monitoring Questionnaire. A novel 7-item scale was developed to measure the extent to which participants were monitoring the effects food had on their body. The items were based on previous literature describing self-monitoring related to food intake. The questions were worded so that participants reflected on their state at the moment they were completing the questionnaire, helping to capture their state in real-time. Responses were given on a 0-100 VAS scale (the slider was draggable), and the anchors were 'strongly disagree' and 'strongly agree' (see Appendix N). The scale had an acceptable internal consistency score (α=0.78).

4.1.4.13 Dutch Eating Behaviour Questionnaire (DEBQ). Participants completed a full version of the Dutch Eating Behavior Questionnaire (van Strien et al., 1986). The DEBQ measured restrained eating, emotional eating and external eating, and consisted of 33 items. Responses were given on a 1-5 Likert scale, anchored between 'never' and 'very often'. Twelve of the items also had the option of 'not relevant' available (see Appendix A). This questionnaire was used to assess baseline eating behaviour tendencies.

4.1.5 Tasks

4.1.5.1 Recall Tasks. The critical manipulation of the experiment was asking participants to recall and describe their previous meal, or the last time they cleaned their room and/or house. Participants typed their response into a textbox displayed on the screen and could spend as long as they wanted on the task.

4.1.5.2 Popcorn Portion Size. Instead of measuring physical food intake, participants' eating behaviour was assessed with a digital portion selection task. Participants were instructed to imagine they decided to eat some popcorn right then, at that very moment, and were asked to pick a popcorn portion size they would like to eat. There were 21 photographs, each depicting a two-litre, glass bowl with some popped popcorn inside. The smallest possible portion size was 0g popped corn (empty bowl) and subsequent portion sizes increased by 5g increments of popped popcorn, up until the maximum portion of 100g (see Figure 6). The portion selection task was presented as a slider on a screen, which the participants could move between the 21 possible choices – the bigger the number on the scale selected, the bigger the portion size displayed on the photograph (see Figure 7)[2]. The instructions emphasised that participants should select a portion size they would actually want to eat in real life, and they were told to assume that they could not keep any popcorn for later or share it with anyone.

4.1.6 Procedure

Testing was conducted between 3-5pm to maximise the likelihood participants would have eaten lunch about 2-3 hours earlier. Participants firstly completed traditional appetite scales and the mental hunger subscale of the FFSQ. They were also asked to rate their current feelings of guilt on a 0-100 VAS. Then, participants were either asked to describe their most recently eaten meal or the most recent time they tidied their room or house. They then completed the appetite scales, the mental hunger subscale and the guilt ratings again. This was followed by the popcorn portion selection task.

[2] Special thanks to Mr. Nami Sunami (nsunami@pm.me) for his help in programming this feature.

Figure 6

Images used in the popcorn portion selection task

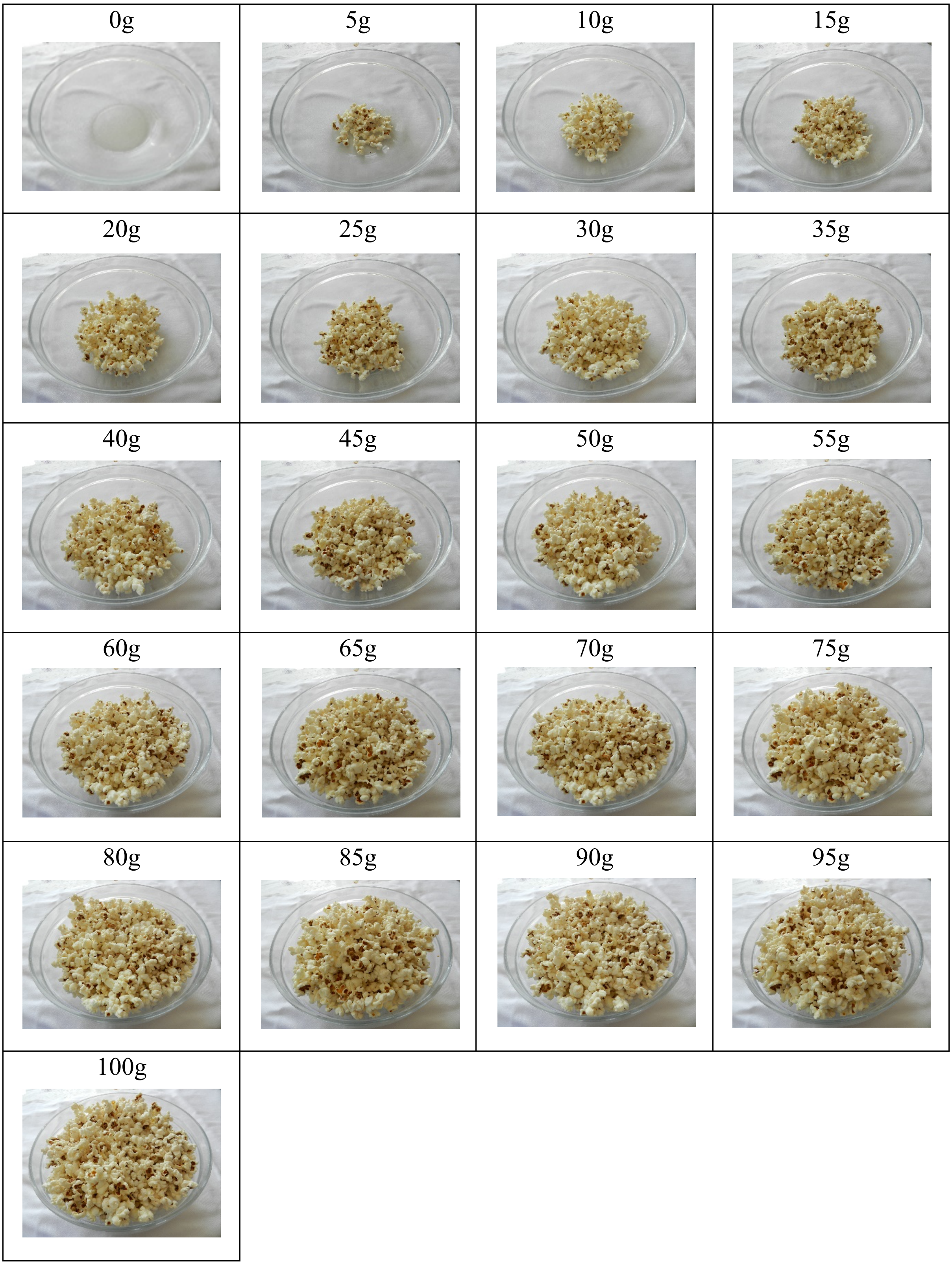


Figure 7

The slider used for the portion selection size. Each point on the slider corresponded to a different image of a specific portion size. The photographs were presented in an ascending order (+5g each time the slider was moved one point from left to right)

Next, the remaining subscales of the FFSQ were presented to participants, along with all the other questionnaires described above. The order of presentation of these questionnaires was randomised. Three attention check questions were included within these questionnaires, which instructed participants to select a specific rating to show they were reading the content. Then, participants were asked to answer questions about their demographics (age, sex, weight and height), and about their most recent meal. Participants were asked to specify how many hours ago they had their most recent meal, how healthy they thought their last meal was (1-10 scale from 'not at all healthy' to 'very healthy'), how usual their recent meal was (1-10 scale from 'very unusual' to 'very usual') and how energy dense it was (1-10 scale from 'very low in energy/calories' to 'very high in energy/calories'). The final questionnaire presented was the

Fear of Covid-19 scale and this was followed by a debrief. Participants were paid £1.42 for their participation.

4.1.7 Analysis Details

Statistical analyses were carried out in SPSS v.27. Baseline differences in demographic variables between the two groups were explored with ANOVA, or Chi-squared tests if the variables were categorical. The effect of recall group on popcorn portion size selection was assessed in a number of ways. Firstly, an ANOVA including all data was conducted, with popcorn portion size as the dependent variable and the recall group as the independent variable. Next, scores for the five facets of MAIA were included separately as covariates, in order to assess whether baseline differences in interoception affected the relationship between meal-recall and popcorn portion selection. Conceptual replications of Higgs et al. (2008), and of Szypula et al. (2020) were also conducted by performing an ANOVA using data only from a select group of participants which reflected the characteristics of the samples recruited in these studies. Additional ANOVAs using the entire dataset were conducted to control for the effect of covariates (baseline interoceptive awareness, sex, Covid-19 stress). Post-recall differences between the two recall groups in terms of popcorn preference, affect, characteristics of most recently eaten meal and FFSQ appetite facets were compared using ANOVAs. Pre- to post-recall differences in appetite ratings (traditional scales and FFSQ mental hunger facet) were assessed with a repeated-measures ANOVA, and significant interactions were assessed with post-hoc paired *t*-tests. Potential moderators (state interoceptive awareness and social norms) and mediators (appetite changes and guilt) were assessed using the PROCESS macro (Hayes, 2017).

4.2 Experiment 1: Results

4.2.1 Initial Analyses

4.2.1.1 Manipulation Check. In order to verify that participants followed the recall instructions, the responses were reviewed and assessed for content. Five participants in the control group mentioned food in their response (e.g. talked about cleaning up after lunch they ate a few hours earlier). These participants were excluded from further analyses. All participants in the meal-recall group described food. None of the post-experimental comments left by participants suggested that they had second-guessed the purpose of the study.

4.2.1.2 Eligibility Check. One of the eligibility criteria for the study was that participants had to be aged between 18-40. Even though a filter was applied to the study settings to screen out participants outside of this age range, one participant reported being 60 years old and another reported being 46 years old – both were excluded from further analyses.

4.2.1.3 Participant Exclusion. It was pre-specified that participants would be removed from the analysis if their selected portion size had a *z*-score of more than 3.29 or less than -3.29, failed two or more attention check questions, or if they reported extreme BMI. Extreme was defined as having a BMI lower than 17.5 (Rø et al., 2004) or higher than 40 (World Health Organisation, 2020). No participants had a *z*-score of more than 3.29 or less than -3.29 for their popcorn portion size selection. Thirty participants reported an extreme BMI, and seven participants failed at least two out of three attention check questions, and so were removed from the analysis. Four participants mentioned that they were suffering from a condition or an illness which prevented them from eating normally or eating popcorn in general (e.g. pregnancy, digestive disorder, severe depression). A post-hoc decision was made to remove these participants from the analysis. Altogether, 41 participants were excluded from the analysis. In total, data from 530 participants was used for the analysis (meal-recall N=267; control N=263).

4.2.1.4 Statistical Assumptions. The skewness value of popcorn portion size (across both groups) was 0.04 (*SE*=0.106), and the kurtosis value was -0.82 (*SE*=.212). A visual inspection of the frequency distribution revealed a multimodal distribution, with peaks at 45g, 70g and 95g (most likely caused by a response bias; Simonson, 1989; Simonson & Tversky, 1992). Neither a logarithmic transformation nor a square-root transformation reduced the kurtosis score, or eliminated multimodality. However, given a relatively low skew value and the fact that an ANOVA is robust enough to withstand normality assumption violations (Blanca et al., 2017), no further action was taken. This decision was also based on the fact that the homogeneity of variance assumption was not violated, as indicated by a non-significant Levene's test (F[1,528]=0.003, p=.959).

4.2.2 Demographics

The two groups were generally similar in terms of baseline characteristics (see Table 6). However, it was revealed that participants in the two groups differed significantly on three facets of general interoceptive ability (MAIA). It was also revealed that the distribution of females/males in the two groups was unequal. In order to account for this difference, additional

ANCOVAs were conducted to assess whether MAIA scores or sex are significant covariates when assessing portion size differences between the two groups.

Table 6

Summary statistics of demographic variables in different experimental groups

	Meal-Recall	Control	
N	267	263	
Sex (M/F/O)	137/128/2	160/103/0	χ^2 (2)=6.46, p=.040*
Age	28.16 (6.09)	27.54 (6.33)	F(528)=1.34, p=.247
Age range (min-max)	18-40	18-40	
BMI (kg/m^2)	24.71 (4.74)	24.04 (4.59)	F(528)=2.76, p=.097
Restrained Eating (DEBQ)	2.78 (0.94)	2.70 (0.99)	F(528)=0.96, p=.327
External Eating (DEBQ)	3.29 (0.56)	3.28 (0.52)	F(528)=0.05, p=.832
Emotional Eating (DEBQ)	2.55 (1.01)	2.65 (0.97)	F(528)=1.19, p=.276
MAIA noticing	3.26 (0.85)	3.07 (0.89)	F(528)=6.80, p=.009**
MAIA not-distracting	2.11 (0.95)	2.22 (0.90)	F(528)=1.82, p=.178
MAIA not-worrying	2.44 (0.90)	2.38 (0.87)	F(528)=0.66, p=.418
MAIA attention regulation	2.78 (0.90)	2.62 (0.81)	F(528)=4.56, p=.033*
MAIA emotional awareness	3.08 (0.99)	2.89 (0.96)	F(528)=5.17, p=.023*
Dieting Status (never/trier/ex-dieter/sometimes/often/always)	68/53/17/ 88/26/15	73/47/14/ 80/32/17	χ^2 (5)=1.92, p=.860

COVID stress score	14.96 (6.32)	14.93 (5.71)	$F(528)<0.01$, $p=.959$

Note. Standard Deviations are presented in parentheses. See Methods for details on scales used. Higher ratings indicate greater endorsement.
*significant at $p<.05$; **significant at $p<.01$

4.2.3 Pre-Recall Appetite Ratings

The two groups did not differ significantly in terms of their appetite ratings, before they performed the recall task (see Table 7).

Table 7

Mean pre-recall appetite ratings between the two experimental groups

	Meal-Recall	Control	
Pre-recall hunger	36.45 (25.78)	34.88 (23.39)	$F(528)=0.54$, $p=.463$
Pre-recall fullness	49.23 (25.16)	49.37 (25.01)	$F(528)<0.01$, $p=.951$
Pre-recall desire to eat	39.06 (26.20)	37.52 (25.04)	$F(528)=0.48$, $p=.489$
Pre-recall amount able to eat	43.82 (22.40)	41.70 (21.75)	$F(528)=1.22$, $p=.270$
Pre-recall mental hunger (FFSQ)	39.74 (18.77)	40.30 (17.84)	$F(528)=0.13$, $p=.723$

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

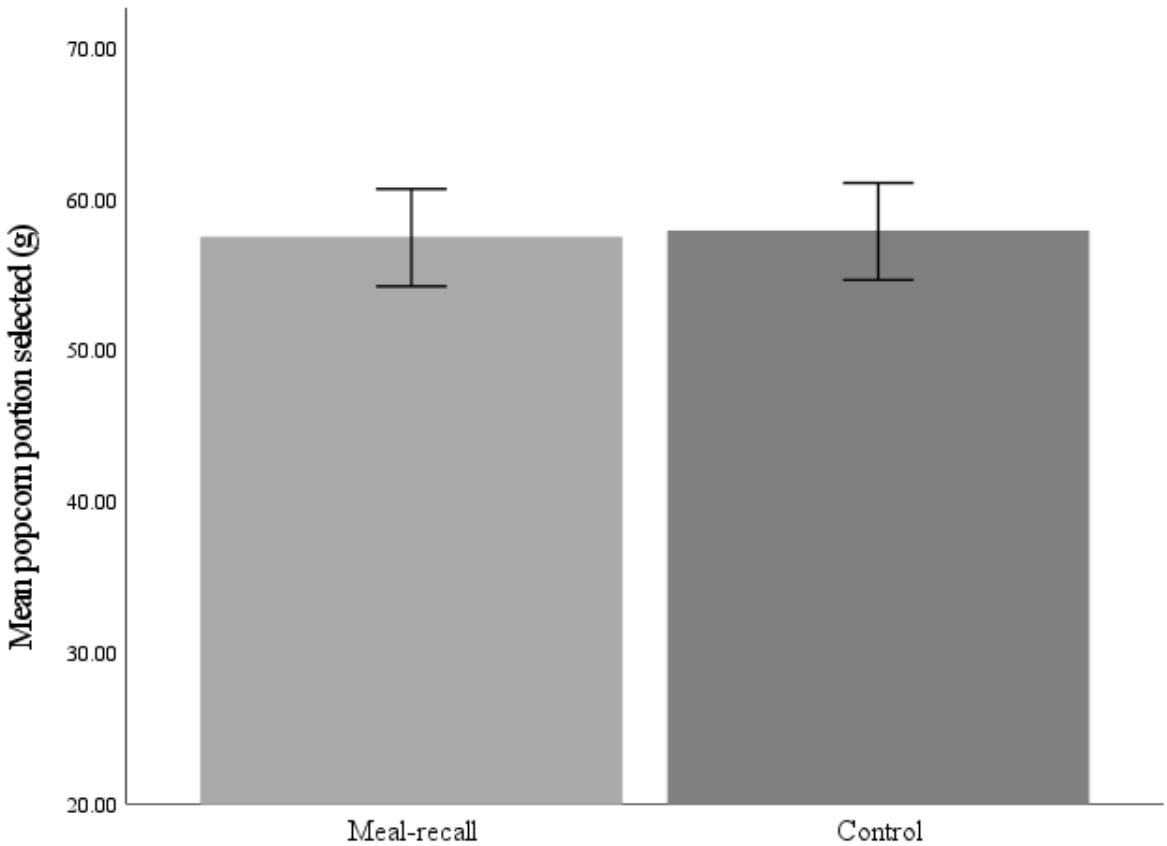
4.2.4 Main Analyses

4.2.4.1 Popcorn Portion Size Selection. An ANOVA revealed that the size of the popcorn portion selected by participants did not significantly differ between the meal-recall ($M=57.43$, $SD=26.70$) and control ($M=57.85$, $SD=26.40$) conditions, $F(1,528)=0.03$, $p=.857$ (see Figure 8). Sex, MAIA noticing, MAIA attention regulation and MAIA emotional awareness were added as a covariate into separate analyses of recall cue on prospective intake, but none of them were significant (all $p>.30$).

4.2.4.2 Higgs, Williamson and Attwood (2008) Replication. In order to explore whether the meal-recall effect can be replicated online, when the experimental context is similar to that employed by Higgs et al. (2008; experiment 3), an ANOVA was conducted, which only included females, with a BMI between 19-25, who ate their previous meal between two and three hours earlier (meal-recall n=44; control n=62). The ANOVA revealed no significant main effect of condition on popcorn portion size (meal-recall *M*=52.84, *SD*=27.56; control *M*=57.58, *SD*=26.19), $F(1,104)=0.81$, $p=.371$.

Figure 8

Average prospective intake ratings (g), as a function of recall cue (error bars represent 95% CI)



4.2.4.3 Szypula, Ahern and Cheke (2020) Replication. Szypula et al. (2020) were able to elicit the meal-recall effect in a more diverse sample than Higgs et al. (2008), and so the next attempt at a replication of the meal-recall effect in an online environment only incuded participants who ate their meal two/three hours ago (meal-recall n=134; control n=144). An ANOVA revealed no significant differences in popcorn portion size selection between the two groups (meal-recall M=57.13, SD=27.31; control M=56.81, SD=27.70), $F(1,276)=0.01$, $p=.923$.

4.2.4.4 Controlling for Covid-19 Stress. As the data were collected during a pandemic, there existed the possibility that pandemic-related stress and anxiety might have altered the results. Therefore, an additional ANCOVA was conducted, with Covid-19 stress score as a covariate. The covariate was not significant, $F(1,527)=0.14$, $p=.704$, and the model remained non-significant, $F(2,527)=0.09$, $p=.915$.

4.2.5 Post-Recall Popcorn Preference

A series of ANOVAs did not reveal significant differences between the meal-recall and control groups (see Table 8) in terms of post-recall popcorn liking, likelihood of choosing popcorn as a snack, or in terms of popcorn craving.

Table 8

Mean ratings of popcorn liking, choice and craving, in the two experimental groups

	Meal-recall	Control	
Popcorn liking	57.60 (29.44)	59.15 (29.13)	$F(1,528)=0.37$, $p=.542$
Popcorn choice	35.84 (31.72)	36.91 (30.08)	$F(1,528)=0.16$, $p=.692$
Popcorn craving	22.98 (26.48)	22.92 (25.45)	$F(1,528)<0.01$, $p=.980$

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

4.2.6 Post-Recall Affect

There were no significant differences between the two recall groups in terms of post-recall negative affect ratings, $F(1,528)=0.01$, $p=.907$, or post-recall positive affect ratings, $F(1,528)=0.26$, $p=.609$.

4.2.7 Recent Meal Assessments

At the end of the experiment, all participants were asked to rate their most recent meal on several aspects. There were no significant differences between the two groups in terms of characteristics of most recently consumed meals (see Table 9).

Table 9

Mean ratings of recent meal characteristics in the two experimental groups

	Meal-Recall	Control	
Number of hours since last meal	3.53 (3.54)	3.40 (3.39)	$F(1,528)=0.16, p=.687$
Previous meal healthy	6.15 (2.55)	5.85 (2.53)	$F(1,528)=1.92, p=.167$
Previous meal calorific	6.27 (2.00)	6.22 (1.93)	$F(1,528)=0.10, p=.756$
Previous meal usual	6.90 (2.36)	7.00 (2.23)	$F(1,528)=0.30, p=.586$

Note. Standard Deviations are presented in parentheses. All ratings made on a 1-10 scale. Higher ratings indicate greater endorsement.

4.2.8 Pre- to Post-Recall Changes in Appetite

Repeated-measures ANOVAs assessed whether there were pre- to post-recall differences in various appetite ratings (see Table 10). Statistical tests revealed that there were no significant pre- to post-recall differences in hunger ratings, $F(1,528)=0.03$, $p=.857$, and the interaction term between hunger scores and group was not significant, $F(1,528)=0.47$, $p=.496$. Desire to eat scores decreased significantly pre- to post-recall, $F(1,528)=7.53$, $p=.006$, $\eta_p^2=.01$ but the interaction terms failed to reach statistical significance, $F(1,528)=3.63$, $p=.057$. Given the interaction term was approaching significance, it may be noteworthy that, in terms of absolute values, desire to eat ratings decreased more in the control condition, than in the experimental condition. Reported fullness also decreased significantly after the recall, $F(1,528)=17.46$, $p<.001$, $\eta_p^2=.03$, but the interaction term was not significant, $F(1,528)=0.04$, $p=.845$. Similarly, judgments reflecting how much a participant could eat decreased significantly pre- to post-recall, $F(1,528)=17.21$, $p<.001$, $\eta_p^2=.03$, but the interaction between the ratings and the group did not reach statistical significance, $F(1,528)=0.19$, $p=.661$. Lastly, mental hunger scores significantly decreased after the recall task, $F(1,528)=49.83$, $p<.001$, $\eta_p^2=.09$, and the interaction term was significant, $F(1,528)=8.16$, $p=.004$, $\eta_p^2=.02$. Post-hoc simple effects repeated-measures ANOVA revealed that mental hunger decreased post-recall in both groups, however this decrease was significantly greater in the control condition (meal-recall: $F[1,266]=8.12$, $p=.005$, $\eta_p^2=.03$; control: $F[1,262]=54.05$, $p<.001$, $\eta_p^2=.17$).

Table 10

Mean pre- and post-recall appetite ratings in the two experimental groups

	Meal-Recall		Control	
	Pre-recall	Post-recall	Pre-recall	Post-recall
Hunger	36.45 (25.78)	36.76 (26.46)	34.88 (23.39)	34.34 (23.86)
Desire to eat	39.06 (26.20)	38.49 (26.00)	37.52 (25.04)	34.37 (23.48)
Fullness	49.23 (25.16)	46.02 (26.20)	49.37 (25.01)	45.84 (25.61)
Amount could eat	43.82 (22.40)	41.58 (23.75)	41.70 (21.75)	38.94 (21.97)
Mental hunger	39.74 (18.77)	38.34 (20.39)	40.30 (17.84)	37.01 (18.86)

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

4.2.9 Post-Recall Appetite Differences

An ANOVA compared ratings on the remaining FFSQ items (see Table 11), which were only completed post-recall. Mental fullness was significantly higher in the meal-recall group, than in the control group. However, there were no significant differences between reported physical hunger scores, and no differences between the groups in terms of reported physical fullness. Previous meal liking scores were also comparable between the two groups.

Table 11

Mean post-recall ratings on FFSQ items in the two experimental groups

	Meal-recall	Control	
FFSQ mental fullness	61.00 (17.52)	55.44 (17.40)	$F(1,528)=13.40$, $p<.001$**, $\eta_p^2=.03$
FFSQ physical hunger	14.51 (14.63)	14.38 (14.02)	$F(1,528)=0.01$, $p=.911$
FFSQ physical fullness	19.91 (17.68)	19.96 (17.39)	$F(1,528)<0.01$, $p=.976$
FFSQ previous meal liking	70.77 (15.26)	68.49 (13.85)	$F(1,528)=3.22$, $p=.073$

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.
**significant at $p<.01$.

4.2.10 Testing the Mechanism: Improved Interoception

It was hypothesised that recalling a recent meal might lead to decreased subsequent intake, because recalling a recent meal might temporarily increase interoceptive awareness. Given that there are no established methods of assessing gastric interoceptive awareness, especially given the online set-up of the experiment, a number of measures were used. They were all tested in separate models. As interoceptive ratings were only given once, after the popcorn selection task, a moderation analysis was used to explore how these variables modulated the relationship between recall cue and prospective intake. The PROCESS Macro for SPSS (Hayes, 2017) was used.

Firstly, self-monitoring scores were included in the model. The overall model was not significant, $F(3,526)=1.07$, $p=.361$. Recall cue did not predict popcorn portion size, $b=-16.72$, $t(526)=-1.69$, $p=.092$, and self-monitoring scores did not moderate the relationship, $b=0.26$, $t(526)=1.78$, $p=.076$, 95% CI[-0.03, 0.55].

Next, gastric interoceptive awareness scores were assessed. The overall model did not reach statistical significance, $F(3,526)=0.71$, $p=.546$. Popcorn portion size was not predicted by group, $b=-22.47$, $t(526)=-1.41$, $p=.160$, and this relationship was not moderated by gastric interoception scores, $b=7.41$, $t(526)=1.45$, $p=.148$, 95% CI[-2.65, 17.47].

Lastly, BPQ scores were explored as a potential moderator. The overall model was not significant, $F(3,526)=0.69$, $p=.558$. Group did not predict popcorn portion size, $b=1.24$, $t(526)=0.17$, $p=.867$, and BPQ scores were not a significant moderator, $b=-0.11$, $t(526)=-0.10$, $p=.921$, 95% CI [-0.41, 0.37].

4.2.11 Appetite Changes as Potential Mediators

Chapter 2 explored the possibility that recalling a recent meal might re-activate satiety signals associated with the memory, and this might help individuals to regulate their subsequent intake. As appetite is a multifaceted concept, a number of hunger and satiety scales were employed (taken pre- and post-recall) and were then assessed as potential mediators of the relationship between meal-recall and popcorn portion size.

First, pre- to post-recall changes in hunger ratings were considered. The *a* path was not significant, $b=-0.85$, $t(528)=-0.68$, $p=.496$, and neither was the *b* path, $b=-0.01$, $t(527)=-0.18$, $p=.858$. The indirect effect was not significant, 95% CI [-0.20, 0.36]. Next, potential mediating effects of pre- to post-recall changes in desire to eat were assessed. Neither the *a* path, nor the *b* path were significant, *b*=-2.58, *t*(528)=-1.90, *p*=.057, and *b*=0.09, *t*(527)=1.25, *p*=.213, respectively. The indirect effect was not significant, 95% CI [-0.75, 0.17]. Change in pre- to post-recall ratings of fullness were not predicted by group (*a* path), *b*=-0.32, *t*(528)=-0.20, *p*=.845, and neither did the change in ratings predict popcorn portion size, *b*=-0.02, *t*(527)=-0.38, *p*=.707 (*b* path). The indirect effect was not significant, 95% CI[-0.20, 0.28]. In terms of pre- to post-recall changes to ratings of amount which could be eaten, the *a* path was not significant, *b*=-0.53, *t*(528)=-0.44, *p*=.661. However, the magnitude of pre- to post-recall change in ratings significantly predicted the popcorn portion size selected, *b*=0.17, *t*(527)=2.07, *p*=.039. Yet, the indirect effect was not significant, 95% CI[-0.68, 0.32]. Lastly, pre- to post-recall mental hunger was assessed. The *a* path was significant, *b*=-1.90, *t*(528)=-2.86, *p*=.005, but the *b* path was not, *b*=-0.11, *t*(527)=-0.75, *p*=.453. The indirect effect did not reach statistical significance, 95% CI[-0.34, 0.90].

The remaining facets of FFSQ were only measured post-recall, and so they were assessed as potential moderators instead. The effect of recall cue on popcorn portion size remained non-significant, *b*=-0.99, *t*(526)=-0.12, *p*=.902, and mental fullness scores did not moderate the relationship, *b*=0.02, *t*(526)=0.12, *p*=.903, 95% CI[-0.24, 0.28]. Physical hunger scores did not moderate the relationship either, as neither the effect of recall cue, *b*=-2.38, *t*(526)=-0.73, *p*=.468, nor the interaction term, *b*=0.19, *t*(526)=1.20, *p*=.230, 95% CI[-0.12, 0.51], were significant. Similarly, when physical fulness scores were added to the model, the effect of recall cue remained non-significant, *b*=2.12, *t*(526)=0.60, *p*=.546. The interaction term was not significant, *b*=-0.09, *t*(526)=-0.65, *p*=.518, 95% CI[-0.34, 0.17]. Lastly, previous meal liking was not a significant moderator. The effect of recall cue was not significant, *b*=-9.58, *t*(526)=-0.85, *p*=.398, and neither was the interaction term, *b*=0.14, *t*(526)=0.89, *p*=.376, 95% CI[-0.17, 0.45].

4.2.12 Partial Mechanism: Guilt

It was hypothesised that recalling a recent meal might elicit feelings of guilt, and these may in turn lead individuals to eat less. Therefore, it was predicted guilt may be a partial mediator of the relationship. There were no significant group differences in pre- to post-recall guilt ratings, *b*=-2.20, *t*(528)=-1.75, *p*=.080 (the *a* path). It is worth highlighting that, in terms of absolute values, guilt ratings decreased more in the control group, than in the meal-recall group. Change in guilt ratings did not predict popcorn portion size, *b*=-0.04, *t*(527)=-0.44, *p*=.661 (*b* path), and the indirect effect was not significant, CI 95%[-0.28, 0.53].

4.2.13 Partial Mechanism: Social Norms

Recalling a recent meal might decrease subsequent intake, in part because social norm concepts related to appropriate portion sizes are activated. Portion appropriateness scores were tested as a potential moderator of the relationship between recall cue and prospective popcorn portion size. The main effect remained non-significant, $t(526)=0.21$, $p=.936$, and portion appropriateness scores did not moderate the relationship, $t(526)=-0.18$, $p=.856$.

In a similar way, it was hypothesised meal-recall may increase participants' fear of negative evaluation, which might motivate them to select a smaller portion of popcorn. The analysis revealed that the relationship between recall cue and popcorn portion remained non-significant, $t(526)=-0.77$, $p=.444$, and negative evaluation scores did not moderate the relationship, $t(526)=0.83$, $p=.407$. The analysis was conducted again with baseline motivation to manage impression scores as a covariate, however the results remained unchanged. The model remained non-significant, $t(525)=-0.75$, $p=.454$, fear of negative evaluation was not a significant moderator, $t(525)=-0.19$, $p=.847$, and motivation to manage impression scores were not a significant covariate in the model, $t(525)=1.16$, $p=.246$.

4.3 Experiment 1: Discussion

The primary aim of the present experiment was to assess whether it would be possible to replicate the meal-recall effect using an online questionnaire. No differences were observed in terms of the portion size selected between the meal-recall group and the control group. A secondary aim of this experiment was to explore whether a potential mechanism of the meal-recall effect could be elucidated. To this end, a series of moderation and mediation analyses were conducted, with interoceptive awareness, appetite changes, guilt and social norms as the variables of interest, however none of the analyses revealed any significant effects.

One of the reasons why the manipulation may not have produced the expected results is that food photograph selection might not be an appropriate method to assess subtle differences in intake. However, given that a number of studies were able to demonstrate a good correlation between digital and real portion sizes, it seems unlikely that a lack of effect was because prospective intake cannot be estimated through photographs. Instead, it's more likely that the lack of an effect might be attributed to a flawed experimental design.

Popcorn was chosen as the snack food to be photographed, because the meal-recall effect has previously been replicated in the laboratory using popcorn as the taste test food

(Higgs et al., 2008) and because popcorn portion size increments are clearly visible in photographs (i.e. it is easy to see an increase from e.g. 10g to 15g of popcorn). However, once a certain threshold had been passed, the additional popcorn added to the photographs was no longer clearly visible, and it was difficult to differentiate between larger portion sizes (e.g. the visual difference between photographs of 75g and 80g of popcorn was minimal). This means that at some point, participants were likely no longer seeing the difference between portion sizes, and were therefore potentially not selecting a photograph which appropriately reflected their intended portion size. This suggestion is supported by the fact that a response bias was seen in the data, with almost 46% of participants selecting one of three photographs (out of the available 21 photographs). Such a response bias also decreased the variability within data, making the analysis hard to interpret.

Popcorn was chosen as the snack food because it is an amorphous food (i.e. its portion is not usually assessed in terms of pieces), which minimised the probability that participants' portion size selections would be restricted by conscious counting of snack items. However, it has been noted that foods high in volume but light in weight tend to be estimated less accurately than other foods (Gittelsohn et al., 1994), which could have affected the results. The number of photographs participants could choose from when deciding on their popcorn portion size was also problematic - previous studies exploring the link between digital portion size selection and actual intake asked participants to choose from eight (Bucher & Keller, 2015) or 51 (Wilkinson et al., 2012) portion size photographs. Although it has been shown that presenting participants with eight photographs, rather than four, resulted in better estimation accuracy (Nelson & Haraldsdóttir, 1998), it is not clear whether more photographs always help participants to make better estimations. Wilkinson et al. (2012) showed participants 51 photographs of food portion sizes, however in their study, depressing a key caused the photographs to change rapidly, creating the illusion that the portion size was 'animated'. Bucher and Keller (2015) presented their eight portion size photographs all at once, on a single display, and therefore photographs could be compared side by side to assess portion size change. In the present study, only one photograph was presented at a time, but the images did not load rapidly and therefore no 'animation' effect could be achieved. As only one photograph was shown at a time, it made comparing previous photographs with each other difficult, especially given the challenge of discriminating between larger portion sizes from the photographs. Therefore, showing participants 21 photographs could have interfered with their ability to accurately assess the portion size presented, especially because of the amorphous nature of the food.

Not only were the photographs used problematic, but also the recall task might not have been optimally designed and implemented. In previous laboratory-based studies, the meal-recall effect was successfully elicited irrespective of whether or not participants were required to spend a fixed amount of time recalling their recent meal (5 mins in Higgs, 2002) vs. as long as required in (Szypula et al., 2020). In the present study participants were not restricted in terms of the amount of time they had to spend on the recall task, however, it might be that participants need to engage with experimental manipulations carried out online for longer, in order for them to be effective.

Usually, in laboratory-based studies examining the meal-recall effect, participants in the control condition are asked to think about a meal from the day before, anything they want, or about their journey into the laboratory. However, as the present data was collected during the Covid-19 pandemic when lockdowns were in place, it was not appropriate to ask participants about recent journeys. Asking participants to think about anything they wanted was vague, and could have biased the results if people started to think about food, and given that the employed paradigm was novel, it was unclear whether thinking about a distant meal memory could obscure potential effects. Instead, participants in the control condition were asked to recall the last time they cleaned their house. Unexpectedly, the cleaning-recall condition seemed to affect appetite ratings, in some cases to an even greater extent than the experimental condition (e.g. mental hunger). To the best of my knowledge, no studies have examined how recalling an instance of cleaning one's room/house affects appetite. However, it is well established that priming of cleanliness concepts can affect the severity of moral judgements, and can influence physical sensations (e.g. alleviate feelings of disgust; Schnall, Benton, & Harvey, 2008; Tang et al., 2017; Zhong & Liljenquist, 2006). Thus, it seems that recalling a recent memory of cleaning one's house may not be as neutral as previously thought, and it may have interfered with the observed results.

There are a number of improvements which could be made to the experimental design, including changing the test food used, using fewer photographs, employing a different control condition, and requiring participants to engage with the recall task for a fixed period of time. These changes were implemented in the second version of the experiment.

4.4 Experiment 2: Introduction

Whilst Experiment 2 was being designed, Arthur et al. (2021) published an article, in which they reported successfully replicating the meal-recall effect using an online questionnaire. The authors used a single photograph of a palatable food, and asked participants to rate (on a 0-7 scale) the extent to which they would want to eat the food depicted in the photograph (desire), and how much of it they would want to consume at that moment in time (prospective intake). Such ratings were obtained for 10 different foods. The authors found that both desire and prospective intake ratings were significantly lower after recalling a recent meal, compared to recalling a meal from the previous day. In the first online replication experiment I conducted, a non-food event was chosen as the control condition, as there was a possibility a distant meal memory (i.e. lunch from the day before) could obscure any true effects of recalling a recent meal. However, given that Arthur et al. (2021) replicated the effect successfully using this control condition, it was also used in the present experiment.

Another article, which was also published whilst Experiment 2 was being designed, informed the design of the prospective intake task. Pink and Cheon (2021) tested the validity of two simplified portion selection tasks, and assessed how scores obtained on these tasks compared with scores obtained on a standard portion selection task used in a laboratory setting. Laboratory-based portion selection tasks require a large number of portion photographs (approximately 50) to be presented on a computer screen. Because the photographs are presented offline, they load rapidly and holding down the arrow keys creates an ‘animation’ of the portion size increasing or decreasing. As a result, such a portion selection task has good ecological validity, as even small changes in portion size can be detected (Wilkinson et al., 2012). However, this approach cannot easily be embedded into commonly used online experiment platforms, such as Qualtrics, and variable internet connection speeds would interfere with smooth viewing of such photographs (Pink & Cheon, 2021). To mitigate these issues, Pink and Cheon (2021) developed a simplified version of the portion selection task, in which five portion photographs were presented simultaneously in an ascending order, on a horizontal or vertical VAS rating scale (which ranged from 0-100). The authors found that most results which were obtained using a standard portion size task could be replicated with the simplified tasks, and there was good agreement between the sizes of prospective portion sizes selected on the three different tasks. Thus, a simplified portion selection task, based on the work of Pink and Cheon (2021), was used in the present experiment. The horizontal-line version was chosen to ensure entire photographs would be presented simultaneously on a single screen, without the need for scrolling.

Even though the primary aim of this experiment, to replicate the meal-recall effect online, has already been achieved by Arthur et al. (2021), it was important to conduct the present study. This is not only because the field of psychology is currently facing a replicability crisis (Pashler & Wagenmakers, 2012), but also because it was worth testing how robust the effect is when a slightly different methodology is used. Another reason why the present study was conducted is that there is still a significant lack of data to suggest what the mechanism driving the meal-recall effect might be. Arthur et al. (2021) proposed that the meal-recall effect was caused by increased self-consciousness, triggered by a reminder of a recent meal, which caused participants to deliberately limit their desire for palatable foods and their prospective intake. To test their hypothesis, the authors conducted an ANCOVA with their prospective intake measure as the dependent variable, group ('lunch today' vs. 'lunch yesterday') as the independent variable, and with dietary restraint as the covariate. They found a significant interaction between group and restraint. The results of that experiment suggested that, in the 'lunch yesterday' group, dietary restraint score predicted prospective intake, but this relationship was not observed in the 'lunch today' group. The authors interpreted this as evidence that recalling a recent meal makes people behave in a way consistent with scoring highly on dietary restraint, irrespective of their actual level of restraint. In other words, they suggested that participants who recall a recent meal eat less at a subsequent snacking session, because they consciously restrict their intake, and that this is the mechanism behind the meal-recall effect. However, the authors did not include any measure of explicit cognitive processes they suspected might underlie the effect, making their interpretation of the data speculative. The present experiment improved upon Arthur et al.'s method by including measures to assess the extent to which participants thought their selected portion size was appropriate, the extent to which they were experiencing fear of negative evaluation and the extent to which they felt guilty. A replication of the ANCOVA these researchers conducted was also attempted in the present study.

4.5 Experiment 2: Method

4.5.1 A Priori Power Analysis

The power analysis was conducted in G*Power (Faul et al., 2007). Cohen's f effect size statistic was calculated based on the partial eta-squared value of 0.02 reported by Arthur et al., (2021). The analysis revealed that 640 participants would be required to detect an effect of this size, with 95% power. However, based on the results of Experiment 1 and those reported by Arthur et al., it was expected that a large number of participants may need to be excluded from the analysis (e.g. because of not following the instructions properly, reporting an eating-related illness, reporting an extreme number of hours since last meal etc.). Thus, the required sample size was increased by 25%, and 798 participants were recruited.

4.5.2 Participants and Design

The sample for this study was recruited through Prolific and the experiment was presented in Qualtrics. The entire experiment was completed remotely. The inclusion criteria were that participants had to be between 18-40 years old, be currently residing in the UK and have no current or past diagnoses of an eating disorder. The study design was between-subjects, with two conditions: recalling a recently eaten lunch or recalling lunch eaten the previous day. Participants were randomly allocated to one of these conditions.

4.5.3 Ethical Approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

4.5.4 Materials

4.5.4.1 Questionnaires. Most of the questionnaires used in the present experiment were also used in Experiment 1. These included traditional appetite scales, the FFSQ, MAIA, Six-Item Gastric Interoception Scale, BPQ, PANAS-X (positive and negative affect), appropriate size (α=.79), fear of negative evaluation (α=.94), motivation to manage impressions (last item removed, α=.68) and DEBQ restraint (see Experiment 1 for details). The questions on the self-monitoring scale were slightly altered, so that greater focus would be placed on identifying and measuring state interoceptive awareness (α=.86; see Appendix O). The scale used remained the same. Fear of Covid-19 scale was not included in the present experiment, as the experiment was conducted almost a year and a half after the first lockdown was announced. Instead, participants were asked to specify whether they currently suffered from a loss of taste or smell (which is a frequent symptom of Covid-19), as this could have impacted their prospective intake.

4.5.5 Tasks

4.5.5.1 Recall Tasks. Participants were allocated to one of two conditions, which differed in terms of the event participants were asked to recall and describe. One group was asked to recall their most recent meal ('lunch today') and the other group was asked to recall their lunch from the previous day ('lunch yesterday'). Participants typed their response into a textbox displayed on the screen. They had to spend at least three minutes on the writing task, but they could spend more time on it if they wanted to.

4.5.5.2 Biscuit Portion Size. Participants' prospective intake was measured with photographs of various portion sizes of biscuits. Participants were shown six images which were collated into a single horizontal strip, with a slider underneath the photographs (see Figure 9). The first picture depicted an empty white plate, and the subsequent five photographs showed increasing portions of broken up biscuits. The biscuits were broken up to prevent participants from counting the number of biscuits and using external cues to decide how many biscuits to select. Three types of biscuits were photographed (see Figure 10): Maryland Mini Choc Chip Cookies, Maryland Double Choc Chip Mini Cookies and Mini Jammie Dodgers. The portion size increased in 20g increments (maximum portion size shown was 100g). The slider was positioned in a way that the value selected on the slider corresponded with the weight of the biscuit portion size depicted on the photograph (e.g. placing slider at scale point 20 corresponded to a 20g portion of biscuits).[3] The slider scale point was not displayed to the participant.

[3] Special thanks to Mr. Thomas Gibbons (tom@tgibbons.com) for his help in programming this feature.

Figure 9

The biscuit portion size selection task, as displayed to the participants in Qualtrics

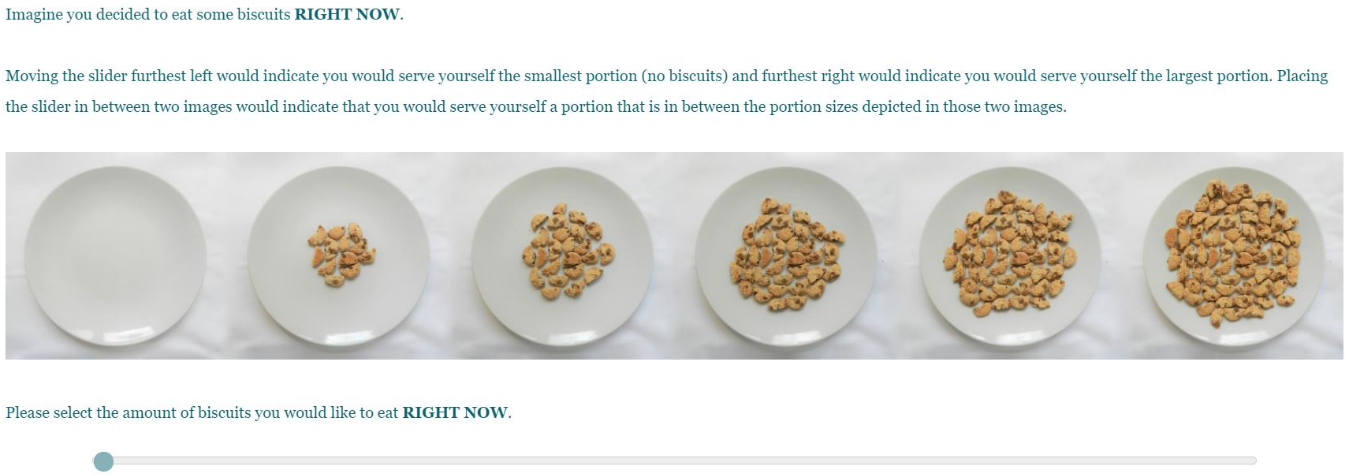


Figure 10

The three types of biscuit photographed for the portion selection task

4.5.6 Procedure

Participants were screened for eligibility by Prolific. Participants who signed up for the study were first presented with the information sheet and were asked to sign a digital consent form. Next, demographic information was collected (age, sex, weight and height) and participants completed the DEBQ restraint and the MAIA. Participants were then asked to think about how they were feeling at right that moment, and were asked to complete the traditional appetite scales (hunger, fullness, desire to eat), the mental hunger scale (from FFSQ), and a rating of guilt. This was followed by the recall task, which involved describing a recent or a distant meal depending on group allocation. Once the writing task was completed, participants completed the traditional appetite scale, mental hunger scale, and guilt ratings once again. After making these ratings, participants completed the prospective intake task. Participants were instructed to consider the amount of biscuits they would want to eat at that moment, if they were available for them to eat. Following the guidance of Pink and Cheon (2021), participants were given the following instructions: 'imagine you decided to eat some biscuits right now. Moving the slider furthest left would indicate you would serve yourself the smallest portion (no biscuits) and furthest right would indicate you would serve yourself the largest portion. Placing the slider in between two images would indicate that you would serve yourself a portion that is in between the portion sizes depicted in those two images'. Ratings were made for three different types of biscuits (the order of these was randomised). Participants were told that they should select a portion of biscuits they would want to eat in real life, and they should assume they cannot keep any biscuits for later or share them with anyone.

This task was followed by questionnaires presented in a randomised order: self-monitoring, impression management, fear of negative evaluation, appropriate size, PANAS, BPQ, six-item gastric interoception scale, the physical hunger and physical fullness facets of the FFSQ, and the biscuit liking scale. Three attention check questions were included alongside the questionnaire items, which instructed participants to select a specific rating to show they were reading the content. Food liking and mental fullness facets of the FFSQ were presented last, as these questions asked the respondent to rate their most recently consumed meal on a number of aspects. Participants then gave details about their previous meal, which included the number of hours since they last ate, and ratings of how healthy, usual and calorific their most recent meal was. Participants also confirmed whether they had any past or current diagnoses of an eating disorder, stated whether they were suffering from a loss of taste or smell, and were asked to guess the aim of the study, to verify whether anyone had second-guessed the true aims. A debrief was then presented.

4.5.7 Analysis Details

The analysis plan was mostly the same as in Experiment 1. As the effect was successfully replicated in the experiment, conceptual replications of Higgs et al. (2008) and Szypula et al. (2020) were not conducted. As in the previous experiment, both moderation and mediation analyses were conducted to assess the potential mechanisms. Significance of the *a*, *b* and *c* paths was not a requirement for a mediation analysis to be carried out (Hayes &

Rockwood, 2017; Meule, 2019; Zhao et al., 2010). Additionally, an ANCOVA with recall cue as the predictor, biscuit portion as the dependent variable and dietary restraint score as a covariate was carried out in an attempt to replicate results reported by Arthur et al. (2021).

4.6 Experiment 2: Results

4.6.1 Initial Analyses

4.6.1.1 Manipulation Check. Participants were asked to describe a meal they either ate recently, or one they ate the previous day, but not everyone followed these instructions. Ten participants did not recall a recent meal, and nine participants did not recall a meal from the day before. In addition, seven participants did not recall a meal at all (e.g. they described what they usually eat). These 26 participants were excluded from the analysis.

4.6.1.2 Missing Data. A number of participants' reported heights were deemed to be highly unlikely (e.g. 0.98m or 3.12m) and they were treated as missing data. Multiple imputation was used to replace nine values lower than 1.4m and higher than 2.3m, and weight and sex were used as predictors. Participants also reported some improbable body weights (e.g. 30kg), and so scores lower than 40kg and higher than 210kg were replaced with imputed data, with height and sex used as predictors (this was a post-hoc decision). Each score was imputed five times, and an average of these scores (rounded up to the nearest integer) was used as a replacement value.

4.6.1.3 Attention Checks. Thirty-seven participants failed two or three attention check questions and their submissions was rejected and replaced with new participants.

4.6.1.4 Participant Exclusion. The same pre-specified exclusion criteria were applied to the present study, as in Experiment 1 (prospective intake *z*-score more than 3.29 or less than -3.29, extreme BMI reported – see 4.2.1.3 for further details). Additionally, for the present experiment it was pre-specified that any participant who mentions suffering from any disease which would impact normal intake would be removed from the analysis.

Participants were excluded from the analysis for the following reasons: three participants reported suffering from a condition which affects normal eating (e.g. irritable bowel syndrome), and thirty participants reported an extreme BMI. No participants had a *z*-score of more than 3.29 or less than -3.29 for their average biscuit portion size selection.

Some participants reported they ate their most recent meal a very long time ago, and sixteen extreme values, defined as having a z-score higher than 3.29, were identified (all of these corresponded to reports of not having eaten for more than 14 hours). A post-hoc decision was made to remove these participants from further analyses. Altogether, 49 participants were excluded from the analysis. In total, data from 723 participants was used in the analysis ('lunch today' N=363; 'lunch yesterday' N=360).

4.6.1.5 Statistical Assumptions. The skewness value of the average biscuit portion size (across both groups) was 0.34 (SE=.09) and the kurtosis value was -0.58 (SE=0.18). The homogeneity of variance assumption was not violated, as indicated by a non-significant Levene's test ($F[1,721]=0.22$, $p=.640$).

4.6.2 Demographics

The groups were broadly similar in terms of their baseline characteristics (see Table 12). However, the groups unexpectedly differed on average MAIA attention regulation scores. As MAIA scores were included in a moderation analysis (see 4.6.15) no further action was taken.

4.6.3 Pre-Recall Appetite Ratings

The two groups did not differ significantly on any of the pre-recall appetite ratings (see Table 13).

Table 12

Summary statistics of demographic variables in different experimental groups

	Lunch today	Lunch yesterday	
N	363	360	
Sex (M/F)	163/200	161/199	$\chi^2(1)<0.01$, $p=.961$
Age	24.70 (5.23)	24.57 (5.22)	$F(1,721)=0.12$, $p=.727$
Age range (min-max)	18-40	18-40	
BMI (kg/m^2)	24.70 (4.94)	24.81 (4.92)	$F(1,721)=0.10$, $p=.757$
Restrained Eating (DEBQ)	2.61 (0.84)	2.52 (0.90)	$F(1,721)=2.04$, $p=.154$

MAIA noticing	3.18 (0.91)	3.26 (0.87)	$F(1,721)=1.28$, $p=.258$
MAIA not-distracting	2.27 (0.92)	2.18 (0.93)	$F(1,721)=1.52$, $p=.218$
MAIA not-worrying	2.18 (0.86)	2.26 (0.84)	$F(1,721)=1.76$, $p=.185$
MAIA attention regulation	2.57 (0.88)	2.73 (0.86)	$F(1,721)=6.04$, $p=.014$*
MAIA emotional awareness	3.27 (1.03)	3.36 (1.02)	$F(1,721)=1.37$, $p=.243$
Smell loss (none/partial/total)	346/15/2	341/17/2	$\chi^2(2)=0.15$, $p=.928$

Note. Standard Deviations are presented in parentheses. See section 4.5.3 for details on scales used. Higher ratings indicate greater endorsement.
*significant at $p<.05$.

Table 13

Mean pre-recall appetite ratings between the two experimental groups

	Lunch today	Lunch yesterday	
Pre-recall hunger	33.80 (28.23)	37.93 (29.92)	$F(1,721)=3.65$, $p=.057$
Pre-recall fullness	52.09 (28.52)	48.82 (28.74)	$F(1,721)=2.36$, $p=.125$
Pre-recall desire to eat	40.52 (29.46)	42.20 (30.19)	$F(1,721)=0.57$, $p=.450$
Pre-recall amount able to eat	44.05 (25.16)	46.77 (26.30)	$F(1,721)=2.02$, $p=.156$
Pre-recall mental hunger (FFSQ)	40.47 (21.48)	41.98 (21.74)	$F(1,721)=0.88$, $p=.350$

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

4.6.4 Main Analyses

4.6.4.1 Biscuit Portion Size Selection. An ANOVA revealed that a significantly smaller portion of biscuits was selected after recalling a recent meal (*M*=41.74, *SD*=25.10), compared to recalling a meal eaten the previous day (*M*=46.21, *SD*=25.35), $F(1,721)=5.68$, $p=.017$, $\eta_p^2=.008$ (see Figure 11).

4.6.4.2 Sex as a Moderator. It has previously been reported (Whitelock, Gaglione, et al., 2019) that males may react differently to females to some eating-related manipulations. Thus, an exploratory ANCOVA was conducted to assess the effect of sex on intake in the two conditions. Sex was a significant covariate, $F(1,720)=14.94$, $p<.001$, $\eta_p^2=.020$, and the model remained significant, $F(1,720)=5.82$, $p=.016$, $\eta_p^2=.008$. However, the interaction between group and sex was not significant, $F(1,719)=0.08$, $p=.782$, suggesting sex was not a moderator of the relationship between meal-recall and prospective intake.

4.6.4.3 Controlling for the Impact of Covid-19. Loss of taste and smell is a common symptom associated with a Covid-19 infection, and can lead to altered patterns of eating behaviour (Walker et al., 2020). Thirty-two participants reported suffering from partial loss of taste and smell, and four participants reported total anosmia. Excluding these participants from the analysis did not change the results of the main analysis, as the effect of recall cue was still significant, $F(1,685)=5.72$, $p=.017$, $\eta_p^2=.008$.

4.6.4.4 Controlling for Altered Eating Behaviour. Ninety-three participants declared that their eating was disrupted in some way on the day they completed the study. Excluding these participants from the main analysis did not affect the main conclusions drawn, as the effect of recall cue was still significant, $F(1,680)=4.39$, $p=.037$, $\eta_p^2=.007$.

4.6.5 Post-Recall Biscuit Preference

There were no differences between the two groups (see Table 14) in terms of biscuit liking, likelihood of choosing biscuits as a snack, and in terms of biscuit craving.

Figure 11

Mean prospective biscuit intake, as a function of recall cue (error bars represent 95% CI)

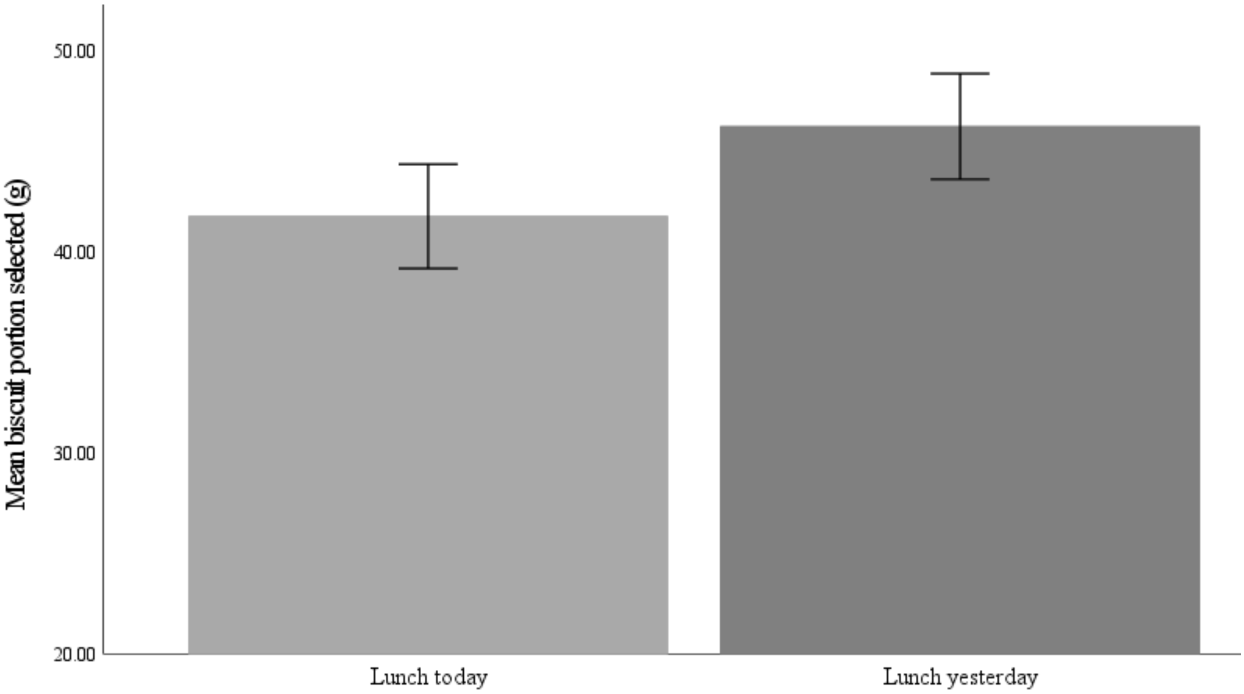


Table 14

Mean ratings of biscuit liking, likelihood of choosing biscuits as a snack and craving for biscuits in the two experimental groups

	Lunch today	Lunch yesterday	
Biscuit liking	57.44 (30.71)	60.59 (28.77)	$F(1,721)=2.02, p=.156$
Biscuit choice	41.45 (31.93)	45.89 (30.61)	$F(1,721)=3.64, p=.057$
Biscuit craving	26.17 (27.50)	29.25 (28.47)	$F(1,721)=2.18, p=.140$

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

4.6.6 Post-Recall Affect

Participants in the 'lunch today' group reported significantly higher negative affect (M=1.79, SD=0.77), than those in the 'lunch yesterday' group (M=1.67, SD=0.67), $F(1,721)=5.04$, $p=.025$, $\eta_p^2=.007$. Those in the 'lunch today' group also reported a significantly lower positive affect (M=2.78, SD=0.91), than those in the 'lunch yesterday' group (M=2.92, SD=0.89), $F(1,721)=4.09$, $p=.043$, $\eta_p^2=.006$.

4.6.7 Recent Meal Assessments

At the end of the experiment, all participants were asked to rate their most recent meal on several aspects. There were no significant differences between the two groups in terms of characteristics of most recently consumed meals (see Table 15).

Table 15

Mean ratings of recent meal characteristics in the two experimental groups

	Lunch today	Lunch yesterday	
Number of hours since last meal	2.99 (2.17)	2.94 (2.13)	$F(1,721)=0.11$, $p=.741$
Previous meal healthy	5.67 (2.56)	5.75 (2.58)	$F(1,721)=0.17$, $p=.684$
Previous meal calorific	6.70 (2.00)	6.68 (2.09)	$F(1,721)=0.01$, $p=.914$
Previous meal usual	6.66 (2.26)	6.59 (2.56)	$F(1,721)=0.12$, $p=.733$

Note. Standard Deviations are presented in parentheses. All ratings made on a 1-10 scale. Higher ratings indicate greater endorsement.

4.6.8 Pre- to Post-Recall Changes in Appetite

Repeated-measures ANOVAs assessed whether there were pre- to post-recall differences in various appetite ratings (see Table 16). As expected, hunger ratings did not change pre- to post-recall, $F(1,721)=0.49$, $p=.486$, and interaction between the groups was not significant, $F(1,721)=0.21$, $p=.650$. Contrastingly, mental fullness scores decreased after the recall task, $F(1,721)=18.20$, $p<.001$, $\eta_p^2=.025$, however the interaction term was not significant, $F(1,721)=1.62$, $p=.203$. Desire to eat scores were not affected by the recall task, $F(1,721)=0.40$, $p=.526$, and there were no differences between the groups, $F(1,721)=0.48$, $p=.487$. Reported fullness significantly decreased after the recall task, $F(1,721)=11.50$, $p=.001$, $\eta_p^2=.016$, but the interaction term was not significant, $F(1,721)=0.01$, $p=.922$. Ratings of how much participants were be able to eat decreased after the recall task, $F(1,721)=8.33$, $p=.004$, $\eta_p^2=.011$, but the interaction between the groups was not significant, $F(1,721)=0.64$, $p=.424$.

Table 16

Mean pre- and post-recall appetite ratings in the two experimental groups

	Lunch today		Lunch yesterday	
	Pre-recall	Post-recall	Pre-recall	Post-recall
Hunger	33.80 (28.23)	34.56 (28.72)	37.93 (29.92)	38.09 (29.22)
Mental hunger	40.47 (21.48)	38.28 (22.52)	41.98 (21.74)	40.79 (23.16)
Desire to eat	40.52 (29.46)	39.49 (28.86)	42.20 (30.19)	42.25 (30.07)
Fullness	52.09 (28.52)	49.38 (29.35)	48.82 (28.74)	46.26 (28.85)
Amount could eat	44.05 (25.16)	41.53 (27.32)	46.77 (26.30)	45.34 (27.65)

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

4.6.9 Post-Recall Appetite Differences

The remaining facets of the FFSQ were completed only after the recall task, and the ratings were compared between groups with an ANOVA (see Table 17). None of the remaining FFSQ facets were significantly different between the two groups.

Table 17

Mean post-recall ratings on FFSQ items in the two experimental groups

	Lunch today	Lunch yesterday	
FFSQ mental fullness	65.46 (16.28)	65.40 (16.31)	$F(1,721)<.01$, $p=.961$
FFSQ physical hunger	19.37 (17.10)	21.33 (19.17)	$F(1,721)=2.10$, $p=.147$
FFSQ physical fullness	27.95 (22.44)	25.12 (20.20)	$F(1,721)=3.18$, $p=.075$
FFSQ previous meal liking	70.98 (14.91)	70.89 (14.91)	$F(1,721)<.01$, $p=.932$

Note. Standard Deviations are presented in parentheses. All ratings made on a 0-100 scale. Higher ratings indicate greater endorsement.

4.6.10 Improved Interoception as a Mechanism

One hypothesis of the present study was that recalling a recent meal would temporarily increase interoceptive awareness, and that this change would moderate the relationship between recall cue and biscuit portion size selection. Interoceptive awareness was measured in three ways: the self-monitoring questionnaire, the six-item gastric interoception scale and the BPQ, which were all administered post-recall.

In the first analysis, it was assessed whether post-recall self-monitoring scores moderated the relationship between recall cue and average biscuit portion size. The effect of recall cue on prospective intake became non-significant, $t(719)=1.72$, $p=.086$, and self-monitoring scores were not a significant moderator of the relationship, $t(719)=-1.09$, $p=.276$.

Next, the gastric interoception scores were examined. The relationship between the recall condition and prospective intake became non-significant, $t(719)=-1.89$, $p=.428$, and gastric interoception scores did not moderate this relationship, $t(719)=-0.38$, $p=.706$.

Lastly, BPQ scores were assessed as a potential moderator. As before, the relationship between the recall cue and the portion size became non-significant, $t(719)=-0.13$, $p=.897$, and BPQ scores were not a significant moderator of the relationship, $t(719)=0.71$, $p=.475$.

4.6.11 Appetite as a Potential Mediator

Participants completed a number of appetite measures both pre- and post-recall. It was assessed whether any of these pre- to post-recall differences could act as a mediator for the relationship between recall cue and biscuit portion size.

Firstly, pre- to post-recall hunger scores were examined. As in the previous mediation models, the *c* path was significant ($b=4.47$, $t[721]=2.38$, $p=.017$). Changes in hunger scores were not predicted by the recall cue, $b=-0.60$, $t(721)=-0.45$, $p=.650$ (*a* path), and hunger score differences did not predict biscuit portion size, $b=0.001$, $t(720)=0.02$, $p=.988$ (*b* path). The indirect effect was not significant, 95% CI[-0.24, 0.15]. In a similar way, changes in fullness scores were not predicted by the recall cue, $b=0.15$, $t(721)=0.10$, $p=.922$ (*a* path), and fulness score differences did not predict biscuit portion size, $b=0.06$, $t(720)=1.35$, $p=.177$ (*b* path). The indirect effect was not significant, 95% CI[-0.23, 0.27].

Next, changes in ratings of desire to eat were examined. Recall cue did not predict changes in desire, $b=1.01$, $t(721)=0.70$, $p=.487$ (*a* path), and the change in ratings did not predict biscuit portion size, $b=0.05$, $t(720)=1.16$, $p=.246$ (*b* path). The indirect effect was not significant, 95% CI[-0.13, 0.36]. Likewise, pre- to post-recall changes in the amount participants could eat were not predicted by cue type, $b=1.10$, $t(721)=0.80$, $p=.424$ (*a* path), but the change in scores predicted the size of the selected biscuit portion, $b=0.22$, $t(720)=4.46$, $p<.001$. The indirect effect was not significant, 95% CI[-0.35, 0.89].

The difference in mental hunger scores was not predicted by the recall cue, b=1.01, $t(721)$=1.27, p=.203. Change in mental hunger predicted biscuit portion size, b=0.36, $t(720)$=4.08, p<.001. The indirect effect was not significant, 95% CI[-0.19, 0.94].

The remaining FFSQ facets were only measured post-recall, and so a moderation analysis was performed instead. Including physical hunger scores as a moderator caused the relationship between recall cue and prospective intake to become non-significant, $t(719)$=1.90, p=.059, and the moderation was not significant, $t(719)$=-0.79, p=.431. Likewise, when physical fulness scores were included in the model, the effect of recall cue became non-significant, $t(719)$=1.38, p=.167, and the moderation was not significant, $t(719)$=-0.55, p=.582. Mental fullness scores were not a moderator either, $t(719)$=-0.17, p=.868, and their inclusion caused the model to become non-significant, $t(719)$=1.14, p=.253. Lastly, when previous meal liking was added to the model, neither the model remained significant, $t(719)$=-0.58, p=.565, nor was the moderation significant, $t(719)$=1.09, p=.277.

4.6.12 Partial Mechanism: Guilt

Pre- to post-recall differences in guilt ratings were not significantly different between the two recall groups, b=0.89, $t(721)$=0.73, p=.467 (*a* path). Differences in guilt ratings predicted biscuit portion size, b=0.14, $t(720)$=2.52, p=.012 (*b* path), but the indirect effect was not significant, 95% CI[-0.25, 0.53].

4.6.13 Partial Mechanism: Social Norms

A moderation analysis was conducted to assess whether appropriate portion size scores modulated the relationship between recall cue and prospective intake. The analysis revealed that the effect of condition on biscuit portion size was no longer significant, $t(719)$=0.12, p=.906, and that portion appropriateness scores did not moderate the relationship, $t(719)$=0.34, p=.733.

Similarly, when negative evaluation scores were included in the model, the relationship between recall cue and prospective intake became non-significant, $t(719)$=0.25, p=.801. Negative evaluation scores did not moderate the relationship, $t(719)$=-0.87, p=.384. Adding baseline motivation to manage impression scores as a covariate did not change the conclusions of the moderation analysis. The relationship between recall condition and biscuit portion size became non-significant, $t(719)$=0.27, p=.789, motivation to manage impressions scores were not a significant covariate, $t(719)=-1.36$, $p=.174$, and the relationship was still not moderated by fear of negative evaluation scores, $t(719)=0.62$, $p=.538$.

4.6.14 Controlling for Baseline Interoception

There existed a strong possibility that individual differences in interoceptive ability could have impacted how participants reacted to the meal-recall effect. Specifically, it was thought that recalling a recent meal would decrease subsequent (prospective) intake to a greater extent in people with poor baseline interoceptive awareness. To test this idea, a moderation analysis with MAIA scores was conducted using PROCESS (Hayes, 2017). To minimise the number of comparisons made, scores for individual facets were averaged to create a single composite score for baseline interoceptive awareness. The overall model was significant, $F(3,719)=6.68$, $p<.001$, $R^2=0.03\%$, but the interaction between recall cue and MAIA scores was not, $t(719)=0.13$, $p=.895$.

4.6.15 Arthur et al. (2021) Mechanism Replication

Arthur et al. (2021) reported that they found a significant interaction between dietary restraint and prospective intake, and showed that restraint predicted intake only in the 'lunch yesterday' group, and not in the 'lunch today' group. However, this finding was not replicated in the present experiment. A conceptually identical ANOVA was conducted, with prospective biscuit intake as the dependent variable, group as the independent variable, and restraint as the covariate. The overall model was significant, $F(3,719)=4.19$, $p=.006$, $\eta_p^2=.017$, but group no longer predicted biscuit portion size, $F(1,719)=0.06$, $p=.803$. The interaction between group and restraint was not significant, $F(1,719)=1.06$, $p=.304$.

4.7 Experiment 2: Discussion

The primary aim of the present experiment was to replicate the finding that people tend to eat fewer snacks after recalling a recent meal, as opposed to recalling a different event, using an online paradigm. The results suggested that the replication was successful, as those who recalled a recent meal selected a smaller biscuit portion size, than those who recalled a meal from the day before. The effect size observed in the present experiment ($\omega_p^2=0.01$) was substantially smaller than those observed in previous laboratory-based experiments ($\omega_p^2=0.05$-0.61; see Chapter 1) and in the online replication ($\omega_p^2=0.02$) conducted by Arthur et al. (2021). In the present experiment, those who recalled a recent meal selected a biscuit portion size which was on average almost 4.5g smaller than the portion selected by participants who recalled a meal from the day before.

This finding could be interpreted in two ways: the obtained effect size might be small because meal-recall manipulations delivered online may generally produce small effect sizes, or because the method of assessing prospective intake was not sensitive enough. Both interpretations have considerable merit, and are not mutually exclusive. Researchers wishing to utilise an online paradigm to investigate the meal-recall effect in the future should take this into account, by recruiting very large sample sizes for their studies. It may also be beneficial to focus most research efforts on laboratory-based designs, in order to better understand the meal-recall effect.

Consistent with previously reported findings (Higgs, 2002; Higgs et al., 2008; Szypula et al., 2020), no pre- to post-recall changes in hunger were observed in the present experiment. A mental hunger scale was included in addition to the traditional appetite scales because it has been shown it can reflect appetite more accurately than standard measures alone (Karalus & Vickers, 2016). As predicted, a more sensitive measure was able to pick up changes in the urge to eat (which may not necessarily correlate with actual energy states), as scores significantly decreased post-recall. This could suggest that some changes to specific elements of appetite may underlie the meal-recall effect. However, despite a sample-wide decrease in mental hunger, no group differences in Experiment 2 were observed. This could simply be due to the online set up of the experiment, which seemed to weaken the observed effect. However, given that other measures of appetite, including fullness and amount able to eat also significantly decreased post-recall, with no group differences observed, it seems likely that these findings reflect a tendency for participants to give lower appetite ratings on consecutive attempts. It would be beneficial if future laboratory-based studies included the mental fullness scale to further assess its role in the meal-recall effect.

The present experiment also explored potential mechanisms of the meal-recall effect. Based on the evidence reviewed in Chapter 2, it was hypothesised that recalling a recent meal could temporarily increase interoceptive awareness, which could help individuals identify any lingering satiety signals from the previous meal, which could then lead to a decrease in intake. This hypothesis was not supported by the results of the present experiment, as none of the three interoceptive awareness measures significantly moderated the relationship between recall cue and prospective intake. Contrary to the initial hypotheses, self-monitoring scores were significantly *lower* after recent meal-recall, and there were no group differences for the BPQ and gastric interoception scores. This could be because the three questionnaires focussed on different aspects of interoception - both the self-monitoring questionnaire and the BPQ included questions related to whole-body interoceptive awareness (e.g. *I am focussing on what my body feels like*, or *I am aware how hard my heart is beating*), whereas the gastric interoception questionnaire focussed on interoception related to appetite (e.g. *I am aware of how hungry I am right now*). It is not obvious how these differences could have contributed to the observed effect, but this would be worth investigating in future experiments. Additionally, it is possible that no group differences in BPQ and gastric interoception scores were observed because the measures were completed once, after the meal-recall manipulation. Perhaps administering the questionnaire before and after the manipulation would reveal some differences which are otherwise obscured by between-subjects variance.

Interoceptive awareness has not previously been tested as a potential mechanism underlying the meal-recall effect, and so these suggestions should be treated with caution. Testing changes to interoceptive awareness following the meal-recall manipulation, using established laboratory-based methods, should be prioritised. For example, the two-step water load test (Van Dyck et al., 2016) could be a valuable method to employ. Briefly, the WLT-II involves drinking water until perceived satiation, and then until maximum fullness. A study in a non-clinical sample showed that higher interoceptive awareness was negatively correlated with amount of water required to reach perceived satiation and maximum fullness. It would be interesting to test whether the results of the WLT-II would vary as a function of recall cue, and whether these results would mediate the meal-recall effect.

An interesting exploratory analysis was carried out in the present experiment, to assess whether the effect of recalling a recent meal would be especially potent at decreasing subsequent snacking for those people who have poor baseline interoceptive awareness. The results revealed that baseline interoceptive awareness scores were not a significant moderator of the meal-recall effect. Given the inconsistent results related to interoception acting as a mechanism of the meal-recall effect, it is difficult to interpret this finding. One possible explanation may be that very few participants had low baseline interoception, which could have obscured a potential moderation. This is illustrated by the fact that only about 2% of the sample had scores in the bottom 30% of the score range (i.e. had a score of 1.5/5 or less). There are no established benchmarks to categorise a MAIA score as high or low, however future studies should try to actively recruit participants with very low baseline interoceptive ability (in the bottom 30% of the score range), in order to assess whether it predisposes individuals to experience the meal-recall effect more strongly.

Unexpectedly, positive affect was significantly lower, and negative affect was significantly higher, in the ‘lunch today’ group. It is not clear why recalling a distant meal would induce a positive affect in participants. But, higher negative affect after recalling a recent meal could be explained by the fact that it is strongly linked to, and can act as a proxy for, feelings of guilt. As discussed in Chapter 2, recalling a recent meal might elicit feelings of guilt, even when the reference meal is relatively ‘healthy’ (Stafford & Thompsett, 2019). In support of this idea, there was a strong correlation between negative affect and post-recall guilt (r[721]=.45, p<.001). However, there were no group differences in post-recall guilt scores, and in pre- to post-recall changes in guilt. The negative affect scale included questions about feeling guilty, ashamed, and angry with self, and so it may be that recalling a recent meal does not just affect guilt, but rather negative affect in general. Future studies could investigate whether mood plays a role in the manifestation of the meal-recall effect.

A final finding of this experiment was that the observed results did not support the idea of a potential mechanism of the effect put forward by Arthur et al. (2021). These researchers hypothesised that remembering a recent meal might activate thoughts and beliefs which would consciously limit the amount of food a person decides to eat. In support of this idea, they reported results of an ANCOVA, with prospective intake scores as the dependent variable, recall cue as the independent variable, and dietary restraint as a covariate. The researchers reported a significant interaction between group and restraint, and interpreted this as evidence that after recalling a recent meal, people become restrained in terms of their eating, but this is not driven by a dieting mindset. In the present experiment, dietary restraint was a significant covariate, but it was not a moderator of the relationship between recall cue and prospective intake. Additionally, unlike in Arthur et al. (2021) experiment, beliefs about the appropriateness of the selected portion size, fear of negative evaluation, motivation to manage impressions and guilt were all measured in the present study. Although some of these variables were associated with the amount of biscuits participants wanted to eat, scores were not significantly different between the two recall groups. Therefore, at present, there is no evidence to suggest that recalling a recent meal causes participants to consciously restrict their intake. This could indicate that the meal-recall effect operates on a subconscious level, and is not driven by any explicit thoughts, beliefs, or restrictions. Further research, especially that conducted in-person, is required to elucidate the mechanism underlying the meal-recall effect.

One important issue to address is the fact that a large number of statistical analyses were conducted to interpret the data of the present experiment, and some of them were exploratory. The main aim of the experiment was to replicate the meal-recall effect, and the study was adequately powered to detect this. Subsequent analyses, especially those relating to the potential mechanism, were conducted to try and understand which variables were related to the meal-recall effect, and how they interacted with each other. It is worth noting that conducting these analyses could have produced a problem of multiple comparisons. However, research on the mechanism of the meal-recall effect has been neglected in the literature, and so it was important to conduct these analyses to help inform future hypotheses and experimental designs, even at the cost of an increased likelihood of observing a Type I error. The purpose of the findings presented is to stimulate further research on this topic, rather than to deliver concrete answers. The reader should bear these issues in mind when interpreting the results of the present experiment.

Chapter 5
Manipulating Recent Meal Memories

Previous chapters have explored and outlined how recalling a recent meal leads to decreased intake at a subsequent snacking session. The present study investigated whether manipulating details of a recent meal memory could produce an effect which would be more potent at suppressing eating, over and above simply recalling a recent meal. Experiments have demonstrated that mental visualisations of food are able to affect eating behaviour (Morewedge et al., 2010), thus it was plausible to expect mental manipulations of a recent meal memory to have an effect on intake.

It is important that an organism's food intake is balanced. Both over- and undereating can lead to serious health consequences and can result in suboptimal functioning. One mechanism which helps people to regulate their eating is energy compensation. In short, energy compensation occurs when energy intake from one meal (preload) causes adjustment to energy intake at the next meal (Blundell et al., 2010). Studies have shown that if the interval between the preload and the next meal is less than 30 minutes long, energy intake is mostly compensated for (or even overcompensated for; Almiron-Roig et al., 2013). However, this compensation becomes more imprecise as the interval between the preload and the next meal increases, and this usually leads to under-compensation (Almiron-Roig et al., 2013). It has been suggested that the effects of preloads are influenced more by the volume of food consumed than by their energy. This was well illustrated by a study which served participants different volumes of a milkshake with exactly the same overall energy. Despite the number of calories ingested remaining constant, those who consumed a 600ml preload (vs. a 300ml preload) consumed 12-18% less as the next meal (Rolls et al., 1998, 2000). Those who consumed a larger preload volume also felt more sated, than those who consumed the smaller portion. The authors suggested that greater satiety ratings in the larger-preload group were caused jointly by visual, cognitive, and physiological cues; the participants *saw* more food, they *realised* they were ingesting a lot of the milkshake and then *felt* greater stomach distension. Subsequent studies have shown that in many respects, visual and cognitive cues are more effective at inducing satiation than physiological cues.

Generally, people struggle to accurately estimate their food intake (Rolls et al., 2002) and the actual amount of food consumed frequently bears little relation to subsequent satiety and intake regulation (Wansink et al., 2005). For example, when participants ate from a self-filling bowl, they ate over 70% more soup than those who ate from a normal bowl, but their satiety ratings after the meal were no different to the control group (Wansink et al., 2005). Despite physically eating more food, the portion appeared to be regular and participant's satiety after a meal matched what they saw, not what they ate (Wansink et al., 2005)[4]. In another interesting study, participants ate biscuits whilst wearing a virtual reality headset (Narumi et al., 2012). The researchers modified the size of the biscuits the participants were holding and eating, so that they appeared smaller or larger than in reality. It was found that increasing the apparent size of the biscuits decreased intake, despite the actual size of the food being held constant. This shows that intake is regulated by cognitive factors, perhaps even more so than physiological cues in response to actual consumption. Believing one ate more is likely to reduce subsequent consumption, independently of actual energy intake. These findings support the idea that imagining eating a bigger portion of food than in reality could suppress subsequent intake via cognitive (and not necessarily physiological) cues.

Mental simulation of events, or visualisation, can act as a substitute for experience (Kappes & Morewedge, 2016). This can sometimes have the same consequences, as experiencing the imagined occurrence. For instance, mental visualisation of physical practice (e.g. playing the piano) can increase subsequent performance (Driskell et al., 1994). Imagining a team's perfect performance on an obstacle course led to increased confidence that the team was capable of performing well (Shearer et al., 2007). Mentally simulating events, such as donating blood, increased participants' intentions to actually partake in the imagined experience (Anderson, 1983). In a similar way, repeatedly imagining eating sweets decreased actual sweets intake (Morewedge et al., 2010). The authors interpreted this finding as evidence that mental simulation can elicit real effects on behaviour or cognition, in this case in the form of sensory-specific satiety. Therefore, there is evidence to suggest that mental simulation of consumption can have downstream consequences on actual intake.

Engaging in mental simulation of events can have profound effects on what is remembered. For example, in one experiment (Weinstein & Shanks, 2010) participants were shown photographs which were either in colour or in black and white. Then, they were shown the names of the items in the photographs they just saw, and were asked to recall whether a particular item was presented in colour or in black and white. Unbeknownst to the participants,

[4] Brian Wansink's work has been called into question by some researchers and some of his papers have been retracted (https://statements.cornell.edu/2018/20180920-statement-provost-michael-kotlikoff.cfm). The reason given for the retractions is that original data was not available to be assessed for integrity and therefore the research findings cannot be validated. As such, Wansink's findings might still be relevant, but readers should be cautious about potential problems with the researcher's integrity.

a number of previously unseen items were included. If the participant did not remember seeing a photograph of an item, they were instructed to imagine what it could have looked like. Then, at the final test, participants were shown the old photographs they initially memorised, as well as photographs of items they were asked to imagine. The results revealed that participants falsely recalled seeing the imagined items 29% of the time, suggesting that merely visualising an event can produce false memories.

Studies have shown that memories are highly malleable and prone to distortion (Loftus, 1979; Loftus et al., 1978; Loftus & Palmer, 1974), especially once already-formed memories are retrieved and then updated with new information (Nader & Einarsson, 2010). There has been some evidence to suggest that exposure to new, incorrect information presented to participants after exposure to the initial event (e.g. being told that a car was blue after seeing a car which was actually green) can result in information 'blending' (e.g. participants reporting seeing a blue-green car; Loftus, 1977). Such memory distortion can also occur for meal-memories, as illustrated by Brunstrom et al. (2012) in their study involving a self-filling/self-draining soup bowl (discussed in detail in Chapter 1).

Taken together, these findings suggest that simply thinking one ate more can decrease subsequent intake, mental simulation can affect overt behaviour, and that imagining events can deform original memories. The present experiment investigated whether asking people to recall a previous meal and then to visualise it as bigger than in reality would decrease the amount of biscuits subsequently eaten. It was investigated whether imagining a recent meal as bigger and more satiating than in reality would suppress snack intake over and above the meal-recall effect. The study also explored how this mental simulation task would affect the original memory of the meal.

An experimental paradigm similar to that used by Higgs and colleagues (2008) was employed. Participants were first given a fixed meal in the laboratory and were then asked to fast over the next three hours. Upon their return, participants completed one of five imagination exercises, which required mental visualisation of different scenarios. The five imagination exercises were:

'Recall + Enlargement' – participants were firstly asked to recall their lunch, and then imagined that the lunch they ate was twice as big. Special emphasis was placed on visualising what it would feel like to eat a lunch twice as big (in terms of physically chewing and swallowing the food as well as the resulting satiation).

‘Recall + Rumination’ – participants first recalled their lunch and then remembered the consumption episode in detail. Special emphasis was placed on remembering what it felt like to eat the lunch (in terms of physically chewing and swallowing the food as well as the resulting satiation).

‘Recall + Handling’ (control) – participants were firstly asked to recall the meal they consumed in the laboratory three hours earlier. They then imagined moving their lunch food around the plate.

‘Food Picture + Handling’ (control) – participants were not asked to think about their recently consumed lunch. Instead, they examined a photograph showing a meal they did not eat (spaghetti in tomato sauce), and then imagined moving this previously unseen meal around the plate.

‘Non-Food Picture + Handling’ (control) – once again, participants were not asked to recall their lunch, but instead viewed a photograph of paperclips and rubber bands arranged on a plate. They then imagined moving the stationary around the plate.

All of these visualisation tasks were followed by a bogus taste test, during which participants’ biscuit intake was covertly measured.

One aim of the present experiment was to explore whether the meal-recall effect could be replicated by asking participants to perform a mental visualisation exercise, in which they are guided through remembering specific details about their recent consumption episode. Szypula et al. (2020) found that when participants were guided in their meal-recall, by being asked to recall episodic details about the meal they recently ate (e.g. where were you, who were you with), biscuit intake *increased*, relative to intake preceded by an unguided meal-recall (i.e. simply being asked to recall a recent meal without further prompts). It was speculated that being guided through the meal memory could have led participants to think about food in general, rather than about details of the recent consumption episode. It is therefore possible that, depending on the focus of the meal-recall, snack intake might increase or decrease. The ‘Recall + Rumination’ imagination exercise in the present study was geared towards vividly remembering the physical sensations associated with the eating episode, rather than with thinking about the individual food items consumed. It was hypothesised that this would result in the eating episode being recalled more vividly and therefore it would strengthen the meal-recall effect (i.e. would decrease biscuit consumption, relative to the control groups).

The next aim of the present study was to investigate whether recalling a recent meal, and then imagining it was larger than in reality, would lead to decreased biscuit intake. It was hypothesised that this exercise could decrease biscuit intake over and above the decrease in intake usually observed after simple recall of a recent meal (i.e. the meal-recall effect). It was therefore expected that biscuit intake would be lowest after the 'Recall + Enlargement' exercise. Lastly, it was predicted that imagining a recent meal as bigger and more satiating than in reality could affect the original memory of the meal. Specifically, it was thought that the imagination task could induce some 'blending' between the memories of the original and imagined lunch size. It was thus hypothesised that participants who were asked to imagine their recent meal was larger than in reality would overestimate the true size of their meal, in a portion estimation task.

5.1 Method

5.1.1 A Priori Power Analysis

Szypula et al. (2020) found a large meal-recall effect size (Cohen's d_z=0.62) when a within-subjects design was employed. However, to account for the fact that part of the present study investigated a novel idea, and for the fact that the design of this study was between-subjects, the power analysis was set to detect a medium effect size instead (Cohen's f=0.30). The power analysis was conducted in G*Power (Faul et al., 2007). In order to achieve 80% power to detect a medium effect size, a total of 140 participants was required (n=28 for each of the five experimental groups). Overall, 156 participants were recruited.

5.1.2 Participants

156 participants were recruited for the experiment from the University of Cambridge participant pool and newsletter announcements. The inclusion criteria were: 18-65 years old, willing to eat the food provided by the laboratory, willing to fast for three hours between sessions 1 and 2, no history of eating disorders and fluent English speakers. Participants were also excluded if they were allergic to any of the foods provided.

5.1.3 Ethical Approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

5.1.4 Design

A between-subject design was used, with the imagination exercise type as the independent variable ('Recall + Handling' vs. 'Recall + Rumination' vs. 'Recall + Enlargement' vs. 'Food Picture + Handling' vs. 'Non-Food Picture + Handling') and total biscuit intake (g) as the dependent variable. Participants were randomly allocated to one of the five conditions (Table 18).

Table 18

Summary of the different tasks participants completed in each of the five groups

Condition	Pre-imagination task	Imagination exercise contents
Recall + Handling	Recall recent lunch	Imagine moving recent lunch around the plate
Recall + Rumination	Recall recent lunch	Recall eating recent lunch in detail
Recall + Enlargement	Recall recent lunch	Imagine recent lunch was twice as big
Food Picture + Handling	Describe a new meal shown on a photograph	Imagine moving a new meal around the plate
Non-Food Picture + Handling	Describe stationary shown on a photograph	Imagine moving stationary around the plate

5.1.5 Meal-Recall and Imagination Exercises

Participants in all of the 'Recall +' conditions were instructed to remember what they ate for the laboratory-based lunch and were asked to type their recollection into a textbox presented on a computer screen. The instructions reminded participants to be specific about the ingredients and their amounts when describing their lunch. Participants in the remaining two conditions were not asked to remember their lunch at all. Instead, they were shown a photograph depicting either 400g of Heinz spaghetti in tomato sauce ('Food Picture + Handling', see Figure 12a), or a handful of paperclips and rubber bands ('Non-Food Picture + Handling', see Figure 12b) arranged on a plate. Participants were instructed to examine the photograph carefully for as long as they wanted, and they were then asked to write a short description of the contents of the photograph they had seen.

Figure 12

Photographs shown to participants in the a) 'Food Picture + Handling' and b) 'Non-Food Picture + Handling' conditions

a)

b)

Next, all of the participants listened to a guided imagination exercise over headphones, which was different in each condition (see Table 18). The imagination exercises were matched as closely as possible on their duration and the number of words they contained ('Recall + Handling': 189 words, 1:55 min; 'Recall + Rumination': 188 words, 1:51 min; 'Recall + Enlargement': 185 words, 1:58 min; 'Food Picture + Handling': 194 words, 1:44 min; 'Non-Food Picture + Handling': 194 words, 1:52min; see Appendix P). The average exercise length was 1:52 min. Each imagination exercise contained five breaks which were seven seconds long and one 15-second break, during which participants could perform the mental manipulations. The voice used to record the imagination exercises belonged to an adult female (not the experimenter).

5.1.6 Materials

5.1.6.1 Overview. The following questionnaires and tasks were administered to characterise the sample: Source Memory Task, DEBQ, Subjective Imagination Ability, Subjective Memory Ability, and Portion Size Adequacy. The remaining questionnaires were used for hypothesis testing.

5.1.6.2 Source Memory Task. Participants' episodic memory ability was tested with a source memory task designed in Qualtrics. Participants were shown six words which appeared sequentially on the screen for 200ms and were asked to memorise the words. Unbeknownst to the participants, they would then not only be tested on the word, but also the colour of the font in which the word was written. The colour each word was presented in was randomised (it could either be blue, green, yellow, purple or red). There was a 60 second filler period between the study and the test phase, during which participants were asked to find differences between two images. Once the time was up the page progressed automatically to the test phase. The participants were asked to select the colour in which the word was written when it was shown to them in the study phase, or to indicate that they do not remember seeing the word. Four novel words were presented in the test phase, and the order of the questions presented was randomised. The participant scored one point for correctly indicating the colour that the word was written in (minimum score: 0, maximum score: 6).

5.1.6.3 Mood Questionnaire. Participants were asked to rate their mood using a questionnaire presented in Qualtrics. The questionnaire was administered four times throughout the experiment (before eating lunch, after eating lunch, before the imagination task and after the imagination task). Participants' mood was rated on ten different aspects (e.g. happiness, calmness, excitement, thirst etc.) on a slider scale which ranged from 0 (not at all) to 10 (extremely). The questionnaire was used as a way of measuring hunger levels, without indicating to the participants that this variable was of a particular interest to the experimenter. The mood questionnaire also served to strengthen the plausibility of the ostensible aim of the experiment (understanding how mood affects taste; see Appendix Q).

5.1.6.4 The Lunch Meal. Participants were served a 300g pot of Uncle Ben's Rice Time Sweet and Sour (338kcal per portion; 113kcal per 100g). The meal was heated in a microwave for 90 seconds and then served on a single-use plastic plate with a plastic fork. The rice was put in the middle of the plate and the sauce was poured on top of it (see Figure 13). A 250ml cup of water was also provided.

5.1.6.5 Questionnaires. Participants completed the restraint and emotional eating questions of the DEBQ (van Strien et al., 1986) and the disinhibition facet of the Three Factor Eating Questionnaire (Stunkard & Messick, 1985). TFEQ disinhibition was measured with 13 true or false questions, and three additional questions which were rated on a scale of 1-4 (see

Appendix A for anchors). Both questionnaires were presented using Qualtrics and completed on a computer.

Figure 13

A photograph of the fixed lunch participants were served in the first session of the experiment

5.1.6.6 Biscuit Taste Test. The bogus taste test was mostly similar to that employed in Chapter 3 (see 3.1.4.4). Participants rated three types of biscuits on ten different taste attributes (e.g. how crunchy, chocolatey, salty etc. they were). Ratings were made on a slider scale from 0 – 100, on an online questionnaire designed in Qualtrics. Three types of biscuits were tasted: Cadbury Fingers (517kcal/100g), McVities Digestives (483kcal/100g), and Maryland Cookies (492kcal/100g). The biscuits were broken into smaller pieces to prevent participants from consciously counting the number of biscuits they consumed (as in Higgs et al., 2008; see Figure 14). The ratings were made for one type of biscuits at a time in a fixed order (Cadbury Fingers, McVities Digestives, Maryland Cookies). Participants were asked to report if anything could have influenced their biscuit intake (e.g. illness, stress), but no report was deemed significant enough to warrant exclusion from the analysis.

5.1.6.7 Subjective Imagination Ability. A number of questions assessed how the participants rated their perceived imagination ability (see Appendix R). They were asked to rate three statements using a 5-point Likert scale ranging from 'extremely bad' to 'extremely good'. Internal consistency between these items was α=.85 and so the average score was calculated, and a new variable called 'subjective imagination ability' was created.

Figure 14

The set-up of the three biscuit boxes used for the taste test

5.1.6.8 Subjective Memory Ability. Participants' subjective memory ability was assessed by asking them to rate six statements (see Appendix S). Ratings were made on a 5-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. Internal consistency between these items was α=.83 and so the average score was calculated, and a new variable called 'subjective memory ability' was created.

5.1.6.9 Portion Size Adequacy. After eating their meal, participants were asked to judge the size of the portion they received. There were five responses to pick from: 'far below average', 'moderately below average', 'just right/average', 'moderately above average', 'far above average'. Because few people chose the extreme option at either end, the two 'below average' and 'above average' options were collapsed, creating a new three-group variable (portion size was below average, average, or above average).

5.1.6.10 Picture Portion Estimation. Participants were asked to look at five photographs depicting different-sized portions of the lunch they had consumed earlier and were asked to select which one they thought was an accurate representation of the portion they received (see Figure 15). The accurate portion showed 300g of rice and sauce on a single-use plastic plate. Two photographs showed a smaller portion (200g and 100g) and two photographs showed a bigger portion (400g and 500g). The food in the photographs was exactly the same as what the participants ate, but for practical reasons the rice and the sauce were not mixed in the photographs. All photographs were simultaneously presented on a computer screen in a grid-format, in a randomised order.

5.1.6.11 Physical Portion Estimation. In addition to retrospectively estimating their portion size by selecting a photographic representation, participants were also asked to physically recreate the portion of food they received. They were given two containers, one with 500g of rice and one with 500g of sweet and sour sauce. They were also provided with a clean plate and a clean bowl and were asked to put the amount of food they remembered having onto the plate and into the bowl (see Figure 16). Participants were asked to put the rice and the sauce into separate containers when performing the size estimation. This was done for practical reasons, as unmixed food could have been re-used by other participants which minimised food waste.

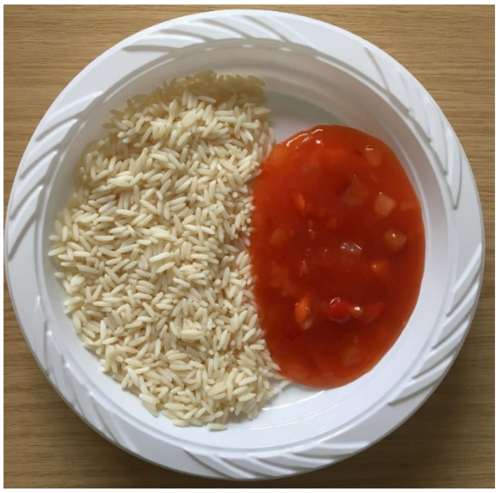
5.1.7 Procedure

Before coming to the experimental session, participants were asked to fast for at least one and a half hours, to ensure they would be able to eat the lunch provided. Participants were asked to confirm that they were not allergic to any of the ingredients and were asked how many hours ago they last ate. Participants completed the demographics questionnaire, then completed the source memory task, and then a mood questionnaire. They were then given their lunch. Participants were asked to try and eat the whole portion if they could, but to not force themselves or make themselves feel uncomfortable. The experimenter then left the room and waited for the participant to call her back once they finished eating, by ringing a wireless doorbell. After they ate, participants were asked to rate how similar the fixed lunch was to what they would normally eat, how satisfied they were with the size of the portion they received and how much they enjoyed eating the meal. All of these ratings were made on a 5-point Likert scale with responses ranging from ‘Completely Disagree’ to ‘Completely Agree’. They also judged the portion they received, in terms of whether it was below average, above average or average in size. Another mood questionnaire was completed, along with TFEQ and DEBQ. Completion of these questionnaires marked the end of the first session and participants were asked to come back three hours later. They were also reminded to refrain from eating or drinking anything with calories in it over this period of time.

Figure 15

Photographs used in the picture portion estimation task

100g



200g

300g

400g

500g

Figure 16

Set up for the physical portion estimation task

The second session began with a mood questionnaire. Then, depending on the condition they were in, participants completed the pre-imagination task (see Table 18). They were then instructed to close their eyes and listened to an imagination exercise through headphones. Next, participants were asked to complete the mood questionnaire and to rate how immersive, real, detailed and believable the events imagined during the listening tasks were, and how easy it was to imagine them. They were then asked to rate their subjective imagination ability and their subjective memory ability. Afterwards, participants completed the biscuit taste test.

Three boxes containing approximately 100g of biscuits were put in front of the participant. The biscuits were presented in a fixed spatial arrangement of Milk Chocolate Fingers (Cadbury, 516 kcal per 100g), Digestives (McVities, 495 kcal per 100g) and Chocolate Chip Cookies (Maryland, 487 kcal per 100g). A 250ml cup of water was also provided. The taste-rating task was explained to the participants, who were also informed that they were free to eat as many biscuits as they wished, since the biscuits would have to be disposed of at the end of the session for hygiene reasons. The experimenter then answered any questions the participants might have had and left the room for 10 minutes. Once the time was up, the experimenter returned to the room and asked the participants to complete the picture portion estimation (where they selected a picture of the portion that most accurately resembled the portion of lunch they received in the first session). They were then asked to rate how frequently they ate biscuits like the ones they were given during the taste test. Participants were then asked to perform a physical portion estimation, during which they re-created the portion of food they received with real food. Lastly, they were asked to write down what they thought the aims of the study were, whether they found anything odd and whether they changed their behaviour in any way throughout the experiment. Participants were then fully debriefed and given the chance to ask any questions. They were paid £10 for their participation.

5.1.8 Analysis Details

A one-way ANOVA was conducted to explore whether recalling a recent meal reduced the weight of biscuits subsequently consumed. Then, it was explored whether recalling the recent meal in detail, or imagining it as bigger, reduced snacking more than simply recalling the meal and imagining moving it around the plate. It was then compared which imagination exercise was more effective at reducing biscuit intake. Physical portion size estimations were compared to the original portion size with a one-sample *t*-test, and the frequency of selecting a particular portion-size photograph was investigated with a Chi-squared test. A number of covariates were then added to the original ANOVA model.

5.2 Results

5.2.1 Initial Analyses

5.2.1.1 Participant Exclusion. Altogether, 156 participants were recruited for the study. Data from five participants were excluded. A manipulation check revealed that when asked to recall their lunch (rice and sauce), three participants failed to follow instructions and recalled different food items. This also suggests they did not refrain from eating between the two sessions, and so these cases were removed from the analysis. One participant guessed the aim of the study, as she previously took part in a biscuit taste test in a different experiment, and so was removed from the analysis. One participant made it clear that he would attempt to eat all of the biscuits provided, and so his data was also excluded.

5.2.1.2 Checking Statistical Assumptions. Firstly, it was assessed whether the total weight of biscuits consumed was normally distributed. The skewness value (across all conditions) was 1.14 (*SE*=.197) and kurtosis was 1.56 (*SE*=.392), revealing a positive skew of the data. The variable was square-root transformed, and this reduced the skewness value to

0.40 (*SE*=.197) and kurtosis to 0.18 (*SE*=.392). The homogeneity of variance assumption was met, as shown by a non-significant Levene's test, $F(4,146)=0.74$, $p=.565$.

5.2.1.3 Participant Demographics. Data from 151 participants was used in the analysis (104 female, 68.9%). Participants' ages ranged from 18 to 57 (*M*=25.07, *SD*=7.78). BMI scores ranged from 17.16 to 35.83 (*M*=22.39, *SD*=3.30). BMI scores less than 18.5 were classified as underweight, scores between 18.5 and 24.9 as normal weight and scores above 25.0 were considered overweight/obese (World Health Organisation, 2018). Most participants had normal weight (77%) followed by participants with overweight/obesity (17%) and underweight participants (6%). The five experimental groups were mostly similar on their baseline characteristic (see Table 19).

Table 19

Comparison of baseline characteristics between conditions

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
N	30	30	31	30	30	
Sex (M/F)	7/23	11/19	8/23	8/22	13/17	$\chi^2(4)=4.05$, $p=.399$
Age	25.43 (6.65)	25.30 (9.78)	23.35 (4.69)	26.97 (10.15)	24.37 (6.34)	$F(4,146)=0.90$, $p=.464$
Age range	19-52	18-57	18-38	18-57	18-51	
BMI	22.23 (2.99)	22.93 (4.87)	23.01 (2.91)	22.41 (2.97)	21.32 (2.05)	$F(4,146)=1.29$, $p=.318$
Restraint (DEBQ)	2.45 (0.93)	2.59 (0.92)	2.07 (0.81)	2.31 (1.07)	2.45 (0.84)	$F(4,146)=1.40$, $p=.239$
Disinhibition (TFEQ)	7.53 (3.54)	7.47 (3.44)	6.68 (3.20)	6.93 (3.56)	6.83 (3.59)	$F(4,146)=0.38$, $p=.825$
Source memory score	2.07 (1.46)	2.93 (1.72)	2.65 (1.64)	2.63 (1.65)	2.10 (1.27)	$F(1,146)=1.77$, $p=.138$
Subjective memory ability	3.14 (0.80)	3.33 (0.85)	3.50 (0.75)	3.54 (0.88)	3.52 (0.70)	$F(1,146)=1.39$, $p=.240$

Subjective imagination ability	3.91 (0.68)	3.81 (0.79)	3.96 (0.86)	3.79 (0.91)	3.89 (0.76)	F(1,146)=0.23, p=.921

Note. Standard Deviations are presented in parentheses. See section 5.1.5 for details on scales used. Higher ratings indicate greater endorsement.

5.2.2 Post-Meal

As expected, a repeated-measures ANOVA revealed that pre-lunch hunger ratings significantly decreased post-lunch, $F(1,146)=515.81$, $p<.001$, $\eta_p^2=.779$. There were no significant differences between the groups, $F(4,146)=1.29$, $p=.279$. The lunch served in the laboratory was rated as relatively enjoyable and satisfying, although ratings of portion size adequacy and similarity to meals usually consumed were on average below the mid-point of the scale. Group differences were not significant (see Table 20). Although participants were instructed to finish the entire meal, 19.9% (n=30) of the sample did not eat the whole portion provided. On average, 17.62g of lunch was left (SD=39.96). The proportion of participants who did not eat the entire meal, and the weight of the leftover food, did not differ between the groups (see Table 20). Excluding participants who did not finish their lunch did not change the results of the main analysis (see Appendix T).

Table 20

Mean pre- and post-lunch hunger ratings, along with ratings of the lunch portion received and details related to leftover food

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
Pre-meal hunger	5.27 (2.64)	6.43 (2.22)	6.35 (1.56)	5.70 (2.74)	5.30 (1.78)	F(4,146)=1.90, p=.114
Post-meal hunger	1.20 (1.40)	1.70 (2.10)	1.97 (1.80)	1.50 (1.72)	1.66 (0.57)	F(4,146)=0.89, p=.470
Enjoyed Lunch	3.30 (1.34)	3.27 (1.08)	3.29 (1.19)	3.80 (1.03)	3.57 (1.10)	F(4,146)=1.23, p=.302
Lunch Satisfying	4.27 (0.87)	4.03 (1.16)	4.10 (1.11)	4.17 (1.05)	3.97 (0.89)	F(4,146)=0.39, p=.816
Lunch portion size adequate	2.83 (0.65)	2.90 (0.61)	2.81 (0.83)	2.80 (0.71)	2.77 (0.68)	F(4,146)=0.15, p=.962

Lunch similar to usual meals	1.80 (0.61)	1.80 (0.96)	2.00 (0.89)	2.37 (1.16)	2.30 (1.21)	F(4,146)=2.23, p=.069
Average weight of leftover food	16.40 (39.51)	20.17 (40.09)	14.23 (35.76)	12.17 (32.41)	25.23 (51.03)	F(4,146)=0.50, p=.737
Number of participants who did not finish meal	n=6	n=8	n=5	n=4	n=7	X^2(4)=2.17, p=.704

Note. Standard Deviations are presented in parentheses. See section 5.1.5 for details on scales used. Higher ratings indicate greater endorsement.

5.2.3 Imagination Exercises

A repeated-measures ANOVA assessing pre- to post-imagination task changes in hunger indicated that there were no significant differences, $F(1,146)=0.13$, $p=.721$. However, the interaction term with group was significant, $F(4,146)=5.55$, $p<.001$, $\eta_p^2=.132$. Post-hoc paired-samples t-tests revealed that there was a significant pre- to post-visualisation task decrease in hunger levels in the 'Recall + Enlargement' group, $t(30)=3.55$, $p=.001$, Cohen's $d_z=0.64$. No other comparisons were significant (all $p>.05$). The 'Recall + Enlargement' exercise was rated as least immersive, real or detailed, as well as most difficult to visualise, however one-way ANOVAs revealed that differences in ratings were not significant between groups (see Table 21).

Table 21

Mean pre- and post-imagination task hunger ratings, and mean ratings of the extent to which the different imagination tasks were immersive, real, detailed, believable, and easy to imagine

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
Pre-imagination hunger	4.10 (2.47)	4.57 (2.54)	5.55 (2.06)	4.40 (2.47)	4.20 (2.48)	F(1,146)=1.78, p=.137
Post-imagination hunger	4.07 (2.74)	5.03 (2.94)	4.58 (2.01)	4.87 (2.54)	4.07 (2.43)	F(4,146)=0.92, p=.454
Imagined events were immersive	4.07 (0.78)	3.70 (0.79)	3.45 (0.77)	3.80 (0.76)	3.73 (0.87)	F(4,146)=2.34, p=.058

Imagined events seemed real	3.87 (0.86)	3.40 (1.07)	3.26 (0.73)	3.70 (0.95)	3.67 (0.96)	F(4,146)=2.16, p=.077
Imagined events were detailed	4.00 (0.95)	3.77 (0.97)	3.65 (0.88)	3.93 (0.91)	3.67 (0.84)	F(4,146)=0.92, p=.455
Imagined events were believable	4.00 (0.74)	3.63 (1.19)	3.55 (0.96)	3.37 (1.25)	4.00 (0.83)	F(4,146)=2.33, p=.058
Events were easy to imagine	4.50 (0.68)	4.10 (0.99)	3.97 (0.75)	4.27 (0.87)	4.27 (0.83)	F(4,146)=1.77, p=.138

Note. Standard Deviations are presented in parentheses. Hunger ratings made on a 1-10 scale. All other ratings made on a 1-5 scale. Higher ratings indicate greater endorsement.

5.2.4 Effect of Visualisation on Biscuit Consumption

A one-way ANOVA was conducted, with total biscuit intake (transformed) as the dependent variable and the experimental group as the independent variable. Overall, the model was significant, suggesting that biscuit intake varied depending on the imagination exercise, $F(4,146)=2.88$, $p=.025$, $\eta_p^2=.073$ (see Table 22 and Figure 17). Next, eight planned comparisons were performed.

Table 22

Mean biscuit intake, liking and frequency of consumption in the five groups

	Recall + Handling	Recall + Rumination	Recall + Enlargement	Food Picture + Handling	Non-Food Picture + Handling	
Biscuit intake (g)	72.03 (36.69)	70.03 (39.10)	51.10 (24.55)	75.87 (39.81)	75.53 (34.50)	F(4,146)=2.88, p=.025*
Average biscuit liking	56.33 (15.35)	66.13 (13.39)	61.62 (16.24)	62.91 (16.09)	57.70 (16.03)	F(1,146)=1.98, p=.101
Frequency of biscuit consumption	3.10 (0.66)	2.93 (0.87)	3.06 (0.96)	3.13 (1.04)	2.93 (0.91)	F(4,146)=0.33, p=.858

Note. Standard Deviations are presented in parentheses. See section 5.1.5 for details on scales used. Higher ratings indicate greater endorsement.

The first comparison explored whether the meal-recall effect was elicited in the meal-recall groups (‘Recall + Handling’, ‘Recall + Rumination’ and ‘Recall + Enlargement’) relative to the control ‘Non-Food Picture + Handling’ group. It was found that only the ‘Recall + Enlargement’ group ate significantly fewer biscuits than the ‘Non-Food Picture + Handling’ group, $t(146)=-2.90$, $p=.004$, Cohen’s $d=0.82$ (large). Neither the ‘Recall + Handling’ group, nor the ‘Recall + Rumination’ group, differed significantly from the ‘Non-Food Picture + Handling’ group in terms of total biscuits eaten, $t(146)=-0.40$, $p=.690$ and $t(146)=-0.74$, $p=.463$, respectively.

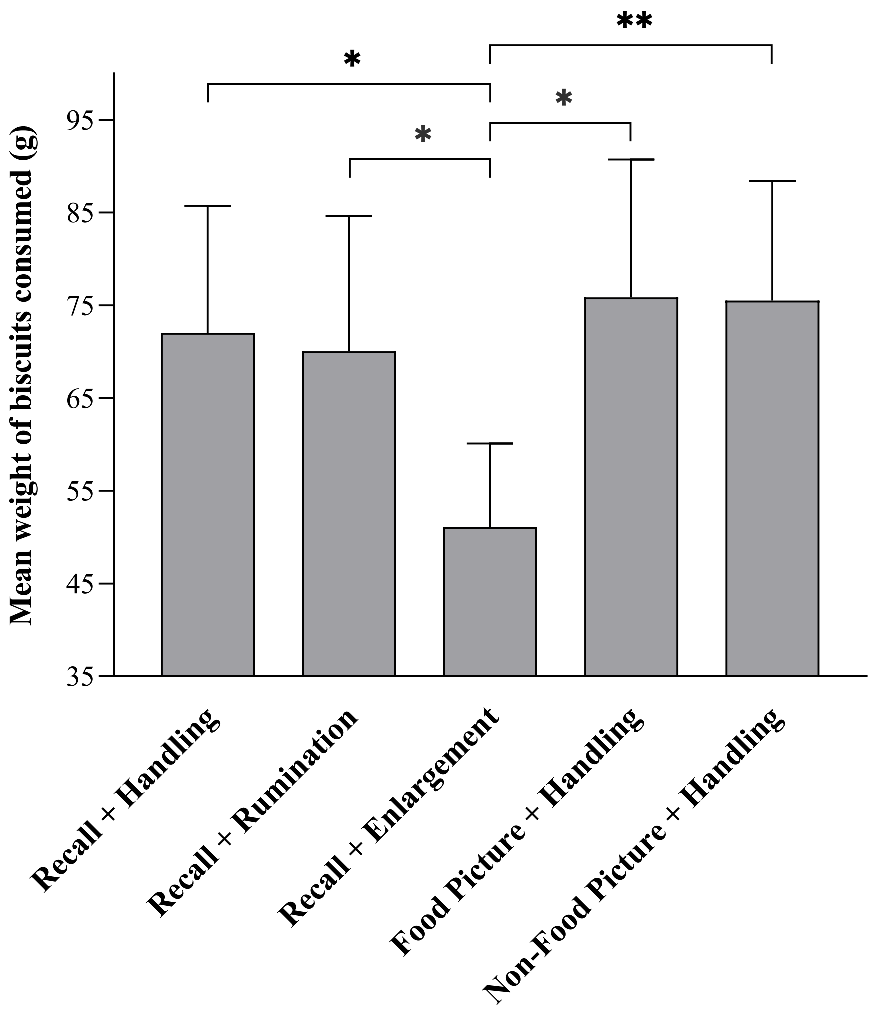
The next set of comparisons explored how ‘Recall + Enlargement’ influenced snacking behaviour, relative to other manipulations following recent meal recall. Imagining the portion as bigger in the ‘Recall + Enlargement’ condition decreased the amount of biscuits consumed, relative to imagining moving the food around the plate in the ‘Recall + Handling’ condition, $t(146)=-1.31$, $p=.014$, Cohen’s $d=0.67$ (medium). The ‘Recall + Enlargement’ group also ate fewer biscuits than those in the ‘Recall + Rumination’ condition, $t(146)=-2.16$, $p=.033$, Cohen’s $d=0.58$ (medium). However, the difference between the ‘Recall + Rumination’ and ‘Recall + Handling’ conditions in the total amount of biscuits eaten was not significant, $t(146)=0.34$, $p=.737$.

It was also investigated how thinking about food in general (rather than about a specific consumption episode) influenced snacking behaviour. To this end, the ‘Food Picture + Handling’ and the ‘Non-Food Picture + Handling’ conditions were compared in terms of the amount of biscuits consumed. No significant differences between these conditions in the amount of biscuits eaten were observed, $t(146)=-.08$, $p=.936$. It was also assessed whether imagined handling of a new meal in the ‘Food Picture + Handling’ group would increase snacking, relative to imagined handling of a recent meal in the ‘Recall + Handling’ group, but no significant differences were found, $t(146)=-0.32$, $p=.750$.

No hypotheses were put forward for the remaining comparisons, and so they were conducted *post-hoc* using Tukey’s HSD test. The difference between the amount of biscuits consumed between the ‘Recall + Enlargement’ and ‘Food Picture + Handling’ groups was significant ($p=.043$, Cohen’s $d=0.15$ [small]). However, the difference in consumption between the ‘Recall + Rumination’ group and the Food Picture + Handling’ group did not reach statistical significance ($p=.965$).

Figure 17

Mean biscuit intake across the five experimental groups (error bars represent 95% CI)



Note. * = p<.05; **= p<.01

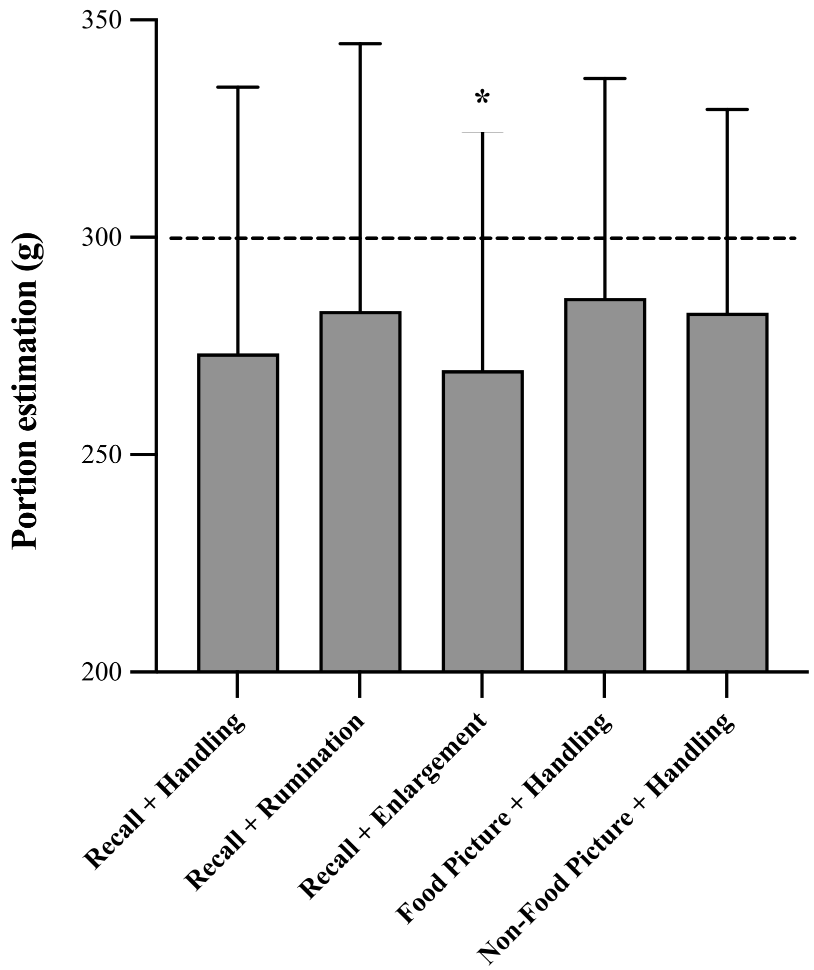
5.2.5 Portion Size Estimation

It was hypothesised that the different imagination tasks may influence subsequent perception of the lunch portion received. A one-sample *t*-test was conducted in order to test whether physical portion estimates in each group were significantly different from the true portion size (300g). All groups underestimated the portion they had received, but to different degrees (see Figure 18). Portion estimates were significantly smaller than the test value of 300g only in the 'Recall + Enlargement' condition (M=269.42g, SD=55.12), $t(30)$=-3.09, p=.004, Cohen's d=-0.55 (medium). No other group reached statistical significance ('Recall + Handling': M=277.30, SD=67.85, $t(29)$=-1.83, p=.077; 'Recall + Rumination': M=282.73, *SD*=61.80, *t*(29)=-1.53, *p*=.137; 'Food Picture + Handling': *M*=286.03, *SD*=50.59, *t*(29)=-1.51, *p*=.141; 'Non-Food + Handling': *M*=282.73, *SD*=46.64, *t*(29)=-2.03, *p*=.052).

Physical portion estimations were not significantly different across all groups, *F*(4,146)=0.40, *p*=.807. The estimated portion size was not correlated with the total weight of biscuits consumed across all groups, *r*=-0.06, *p*=.465. No relationship between these variables was also observed when each condition was investigated separately (recall + handling: *r*=-0.26, *p*=.171; recall + rumination: *r*=-0.20, *p*=.283; recall + enlargement: *r*=0.15, *p*=431; food picture + handling: *r*=.01, *p*.954; non-food picture + handling: *r*=-0.05, *p*=.778).

Figure 18

Mean weight of food portions produced in the physical portion estimation task (error bars represent 95% CI). Reference line denotes true portion size eaten.



Note. * = *p*<.05

Remembered portion size was also evaluated by asking people to select a photograph which most accurately represented the size of the meal they received for lunch. The results are shown in Table 23. A Chi-square test revealed that overall, the observed frequencies were not significantly different from each other across the different conditions, $\chi^2(8)=6.19$, $p=.626$. A further Chi-square suggested that the response frequency across the three portion sizes was not equally distributed, $\chi^2(2)=22.27$, $p<.001$. This suggests that across all of the conditions, participants were most likely to select a picture which either showed an underestimated portion or the correct portion, but very few people selected a portion size which was bigger than in reality (see Figure 19). The picture of the portion size selected did not predict biscuit intake, $F(2,148)=0.87$, $p=.422$.

Figure 19

Pie charts showing the percentage of participants who selected a photograph which showed either an underestimated, overestimated or a correct portion size in the different experimental conditions

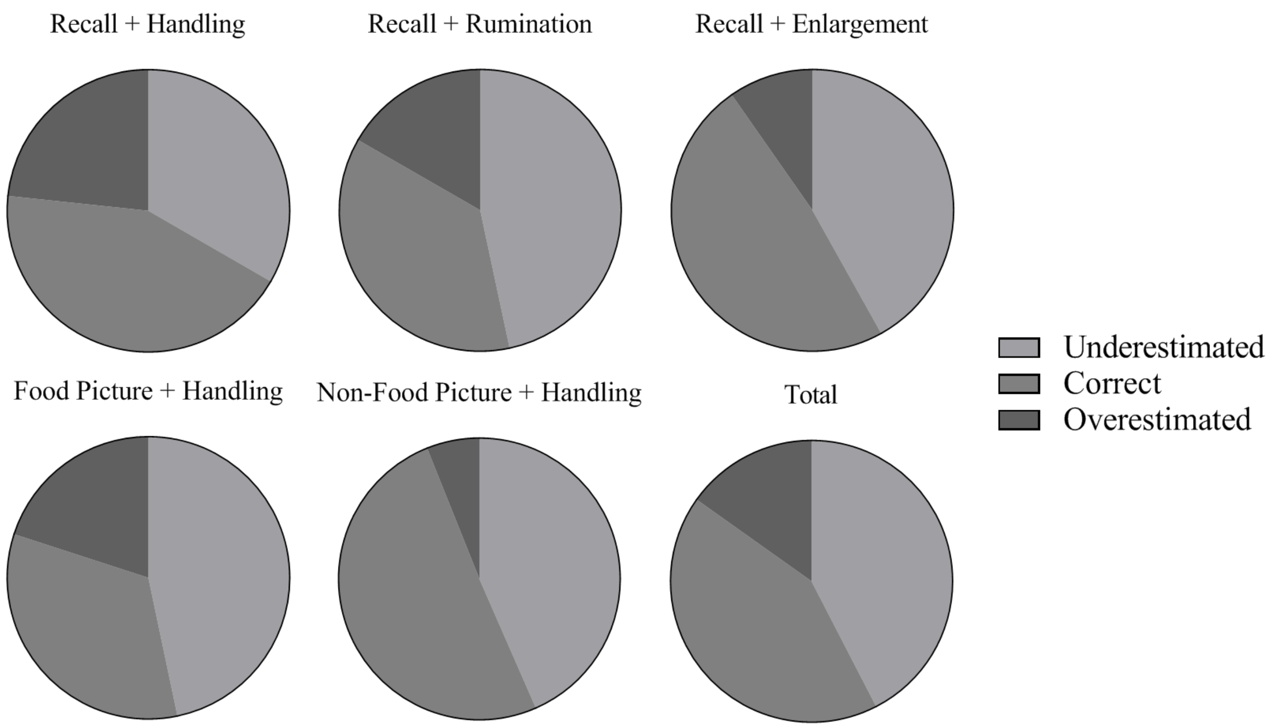


Table 23

Percentage of participants who underestimated, overestimated or correctly estimated the size of their lunch portion, by condition

	Recall + handling	Recall + rumination	Recall + enlargement	Food picture + handling	Non-food picture + handling	Total
Underestimated	33.3%	46.7%	41.9%	46.7%	43.3%	42.4%
Correct	43.3%	36.7%	48.4%	33.3%	50.0%	42.4%
Overestimated	23.3%	16.7%	9.7%	20.0%	6.7%	15.2%

5.3 Discussion

The present experiment aimed to investigate how recalling a recent meal, and then mentally visualising it in different ways, influenced snacking behaviour. In particular, it was investigated how recalling a recent meal and then i) vividly re-living what it felt like to eat the meal or ii) imagining that it was bigger and more satiating than in reality affected biscuit intake. It was hypothesised that recalling a meal and then remembering what it felt like to eat it ('Recall + Rumination') would decrease snacking behaviour (in line with the meal-recall effect). It was also predicted that imagining that the meal was bigger and more satiating than in reality ('Recall + Enlargement') would decrease snacking behaviour to a greater degree than the 'Recall + Rumination' condition. Snacking rates in these conditions were compared to three control conditions: in one group participants recalled a recent meal and then imagined moving it around the plate ('Recall + Handling'). In the other two conditions participants did not recall the recent meal at all. Instead, they either viewed a picture of a meal they had not eaten ('Food Picture + Handling') or a picture of some stationary on a plate ('Non-Food Picture + Handling') and then imagined moving the new meal or the stationary around the plate. It was hypothesised that snacking rates would be highest in the conditions with no recent meal recall.

The hypotheses were partially supported by the data. Firstly, the meal-recall effect (i.e. eating fewer biscuits after recalling a recent meal), was only elicited in the 'Recall + Enlargement' group, even though it was hypothesised the effect would be elicited in the 'Recall + Rumination' and 'Recall + Handling' conditions as well. Imaging the meal as bigger and more satiating in the 'Recall + Enlargement' group was a successful strategy to reduce biscuit intake, with participants consuming around 24g fewer biscuits, than those in the 'Non-Food Picture + Handling' group. In fact, significantly fewer biscuits were consumed in the 'Recall

+ Enlargement' than in all of the other conditions, highlighting how effective this imagination task was at decreasing intake.

Contrary to predictions, detailed visualisation of a recent meal in the 'Recall + Rumination' group did not affect biscuit intake. This seems to suggest that the meal-recall effect is easily disrupted by contextual factors and might not be reliably observed if additional cognitive tasks are also performed soon after recalling a recent meal. This is reminiscent of the findings previously observed in another study (Szypula et al., 2020) where simply changing the mode of recall (written vs. verbal), or depth of recall (unguided vs. guided) had profound effects on the way in which the meal-recall effect manifested. The results also seem to suggest that the most reliable way of eliciting the meal-recall effect seems to be by giving participants simple recall instructions, as opposed to instructions encouraging production of detailed recalls.

Recalling a recent meal and then imagining that it was bigger and more filling than in reality in the 'Recall + Enlargement' group was a very effective method of reducing biscuit intake. Participants in this group consumed over 32% fewer biscuits, which translated to about 122 fewer calories being consumed – a meaningful reduction for those wishing to lose weight. Our previous results suggested that recalling a recent meal reduces intake by about 14% (Szypula et al., 2020) and so this additional imagination task seems to have a beneficial effect on reducing consumption, over and above the meal-recall effect.

But why was the imagination task so effective at reducing intake? Although people are not very accurate when estimating their food intake (Rolls et al., 2002), the amount of food consumed is at least partially modulated in response to ingesting food before a meal (Almiron-Roig et al., 2013). The more food is consumed as a preload (i.e. before a meal) in terms of volume, the less food is subsequently ingested, irrespective of the caloric content of the preload (Rolls et al., 1998). Visual portion cues are frequently more powerful at reducing intake, than the actual energy content of the food consumed, and sometimes even more powerful than internal satiety signals e.g. from stomach distention (Wansink et al., 2005). In light of this evidence, it is possible that imagining feeling very full reduced subjective hunger, which in turn led to reduced biscuit intake. Indeed, the results seem to support this hypothesis, as hunger significantly decreased following the 'Recall + Enlargement' imagination task.

An alternative explanation as to why the imagination task decreased subsequent biscuit intake is that imagining eating so much food and feeling very satiated induced feelings of disgust in participants. A few participants mentioned that imagining the portion as bigger and more filling than in reality made them feel sick or disgusted, but this was mentioned in passing, as they were leaving the laboratory and was therefore not meticulously recorded. Disgust has an adaptive function in humans, as it discourages contact with things which may carry disease-inducing pathogens (Neuberg et al., 2011). Disgust not only motivates individuals to avoid the specific items which elicited the aversive response, but to also avoid contact with neutral or even positive items which were near the disgusting item (Morales & Fitzsimons, 2007; Randler et al., 2016). Thus, it may be that imagining an enlarged meal size either made the participants feel disgusted, which directly reduced subsequent biscuit intake, or it made the participants perceive the lunch portion as disgusting, and this feeling was then transferred onto the biscuits, which indirectly reduced intake.

It was hypothesised that imagining a recent meal as larger and more filling than in reality might change participants' original meal-memories, so that they end up believing the portion was bigger than it was. This was tested by asking participants to estimate the size of the lunch portion they received earlier in two ways: by physically recreating the size of the portion received and by selecting a portion photograph. It was anticipated that those asked to imagine their lunch as bigger would then overestimate the amount of food they were served. Somewhat surprisingly, this was not the case, as on average, all of the groups underestimated the lunch portion, although not all of them did so to a similar extent.

With the physical portion estimation task, only the 'Recall + Enlargement' group's estimates were significantly different from the true portion size. In terms of the photograph-selection task, 42% of all participants selected a photograph depicting an underestimated portion size. It is not clear why participants underestimated their remembered portion size in all groups. In the 'Recall + Enlargement' group, significant portion-size underestimation could have been caused by a contrast effect. Imagining a much bigger portion motivated participants to over-compensate their estimations, ultimately leading to an underestimation. However, this explanation is not consistent with the fact that other groups also underestimated their portions, even though they did not imagine their portion as bigger. Another potential explanation is that people are simply not accurate when estimating portions. Some research suggests that portion under or overestimations can be inconsistent (Hernández et al., 2006; Lucas et al., 1995), especially for amorphous foods, such as rice (Venter et al., 2000). Other research suggests that such amorphous foods tend to be underestimated in general (Faggiano et al., 1992). Additionally, some of the estimation error could have also been due to memory inaccuracy, as the consumption episode and the estimation task were separated by three hours. In other words, participants could have underestimated their portion size because of general inaccuracy associated with that type of task, because the food served was amorphous, or because the memory of the meal was already starting to fade. At present, it is not apparent how underestimating a portion size could have contributed to the meal-recall effect, given that underestimation was observed in all groups, even when participants were not asked to recall a recently consumed meal.

These findings demonstrate that the reduction in intake is unlikely to be a result of a change in the explicit memory for the size of the portion consumed. Contrary to the initial hypotheses, imagining the lunch portion as bigger and more filling does not seem to reduce intake through compensation for (imagined) greater intake (i.e. 'I had more to eat at lunch, so I will eat fewer biscuits now'). Although hunger ratings significantly decreased pre- to post-imagination task in the 'Recall + Enlargement' group, it is unlikely this was the primary mechanism which resulted in a reduced biscuit intake. Previous studies on the meal-recall effect found that recalling a recent meal does not affect hunger ratings in any meaningful ways, so it seems the change in hunger ratings can be attributed specifically to the imagination component of the study. Perhaps this could explain why just recalling a recent meal led to a 45kcal (-14.5%) reduction in biscuit intake, but recalling a meal and imagining it as bigger reduced intake by 122kcal (-32%).

The results of the present experiment suggest that asking participants to recall a recent meal and to then imagine it was larger than in reality, can significantly reduce biscuit intake. It was also found that elaborating on meal-memory recalls can disrupt the meal-recall effect, as also shown by our previous study (Szypula et al., 2020). These findings are relevant, as the focus of the subsequent chapters was developing a memory-based weight loss intervention. Given how strong the reduction in biscuit intake was in the present experiment, it was thought that developing a version of the intervention which would include the imagination task could be worthwhile. However, this required further testing, as in the present study the imagination task was presented as an audio clip, but it would have to be presented in a written format for the weight loss intervention. Therefore, a study was conducted in order to test whether a written-version of the imagination task could decrease biscuit intake as well as the auditory-version. The study also assessed whether the effect of the imagination task might be partially driven by increased levels of disgust.

5.4 Proof-of-Concept

An attempt was made to replicate the findings of the experiment described above, with written instructions instead of an audio exercise, and without a fixed lunch being served in the laboratory. This was done to assess whether such a manipulation would be a feasible exercise for a weight loss chatbot. The full replication study involved participants coming into the laboratory and either recalling a recent meal or recalling a recent journey. They then had *ad libitum* access to biscuits for 10 minutes. The results of this replication study are reported in Chapter 3, however, the study also involved an additional condition, the results of which will be discussed below. It is also important to note participants in the replication study were asked to rate their appetite and level of disgust, before and after the recall task, as well as after the biscuit taste test. In the imagination study described at the beginning of this chapter, some participants mentioned they felt disgusted by imagining their meal was bigger and more filling than in reality. Thus, disgust was included in the replication study in response to these reports, and results pertaining to this measure are described below.

Due to testing restrictions caused by the Covid-19 pandemic, the replication study had to be terminated prematurely, and only seven participants were allocated to the imagination condition. Although the study was underpowered, it still offers some interesting insight into the effect of imagining that a previous meal was larger than in reality.

5.4.1 Results

5.4.1.1 Demographics. All participants in the imagination group had a BMI within the normal weight range. The three groups seemed similar in terms of their baseline characteristics (see Table 24).

Table 24

Summary statistics of demographic variables in different experimental groups

	Lunch cue	Journey cue	Imagination cue
N	7	6	7
Age	21.14 (3.85)	21.83 (4.07)	22.86 (3.44)
Age Range	18-29	19-30	20-29
BMI	20.86 (2.32)	21.58 (1.83)	21.21 (2.11)
Restrained Eating (DEBQ)	1.80 (0.19)	1.88 (0.33)	1.64 (0.32)

Baseline hunger	3.19 (1.97)	3.78 (2.33)	4.94 (1.90)
Baseline fullness	4.64 (1.52)	4.10 (2.00)	3.90 (2.18)
Baseline desire to eat	4.30 (1.35)	4.47 (2.22)	4.53 (1.64)

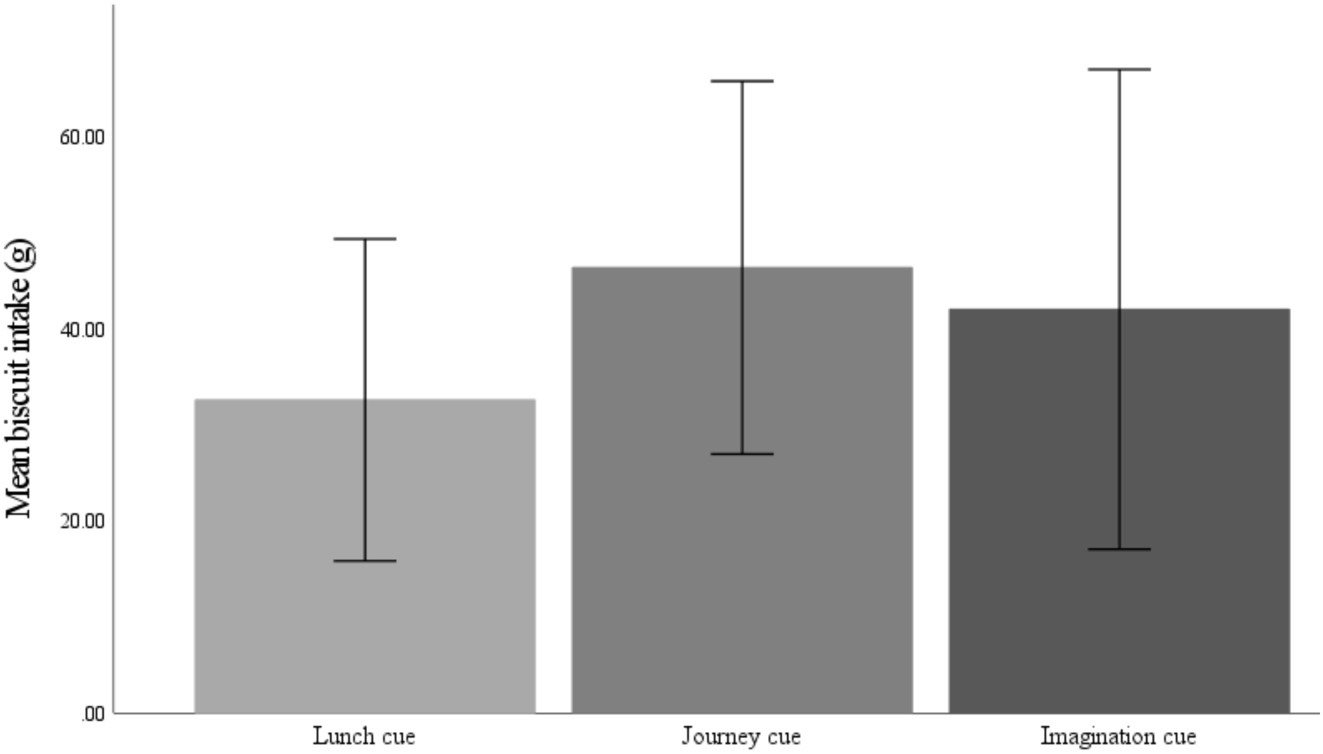
Note. Standard Deviations are presented in parentheses. Restraint ratings made on a 1-5 scale, appetite ratings marked on a 10cm VAS. Higher ratings indicate greater endorsement.

5.4.1.2 Biscuit Intake. The difference in intake between the lunch cue (*M*=32.57, *SD*=18.11), journey cue (*M*=46.33, *SD*=18.48), and 'imagination cue' (*M*=42.00, *SD*=26.98) groups (see Figure 20) was assessed with a Bayesian ANOVA. The analysis was conducted using JASP (JASP Team, 2020) following the guidelines outlined by (van Doorn et al., 2021). Biscuit intake was normally distributed in all groups, as revealed by a non-significant Kolmogorov-Smirnov test (lunch cue: *D*[7]=.21, *p*=.200; journey cue: *D*[6]=.19, *p*=.200; imagination cue: *D*[7]=.24, *p*=.200) and a non-significant Shapiro Wilk test (lunch cue: *W*[7]=.84, *p*=.106; journey cue: *W*[6]=.97, *p*=.882; imagination cue: *D*[7]=.85, *p*=.126). A one-way Bayesian ANOVA was carried out, with default priors (Cauchy scale). The analysis returned a BF_{10} of 0.40 for cue type, suggesting there was weak evidence in favour of the null hypothesis.

5.4.1.3 Effect of Cue on Appetite. The pre-post recall differences for the imagination cue group in terms of hunger ratings (*M*=-0.97, *SD*=2.05) and fullness ratings (*M*=0.80, *SD*=3.21) were similar to those observed for the lunch cue and journey cue groups (see Chapter 3). There was a small pre-to-post recall drop in desire to eat ratings (*M*=-0.96, *SD*=1.83) for the imagination cue group, which was comparable to the results observed in the other two groups (see Chapter 3).

Figure 20

Biscuit intake during the taste test, as a function of recall cue (error bars represent 95% CI)



5.4.1.4 Effect of Cue on Disgust. Disgust ratings were given before and after the recall task (see Table 25 and Figure 21). A noticeable pre- to post-recall increase in disgust was recorded in the imagination cue group.

Table 25

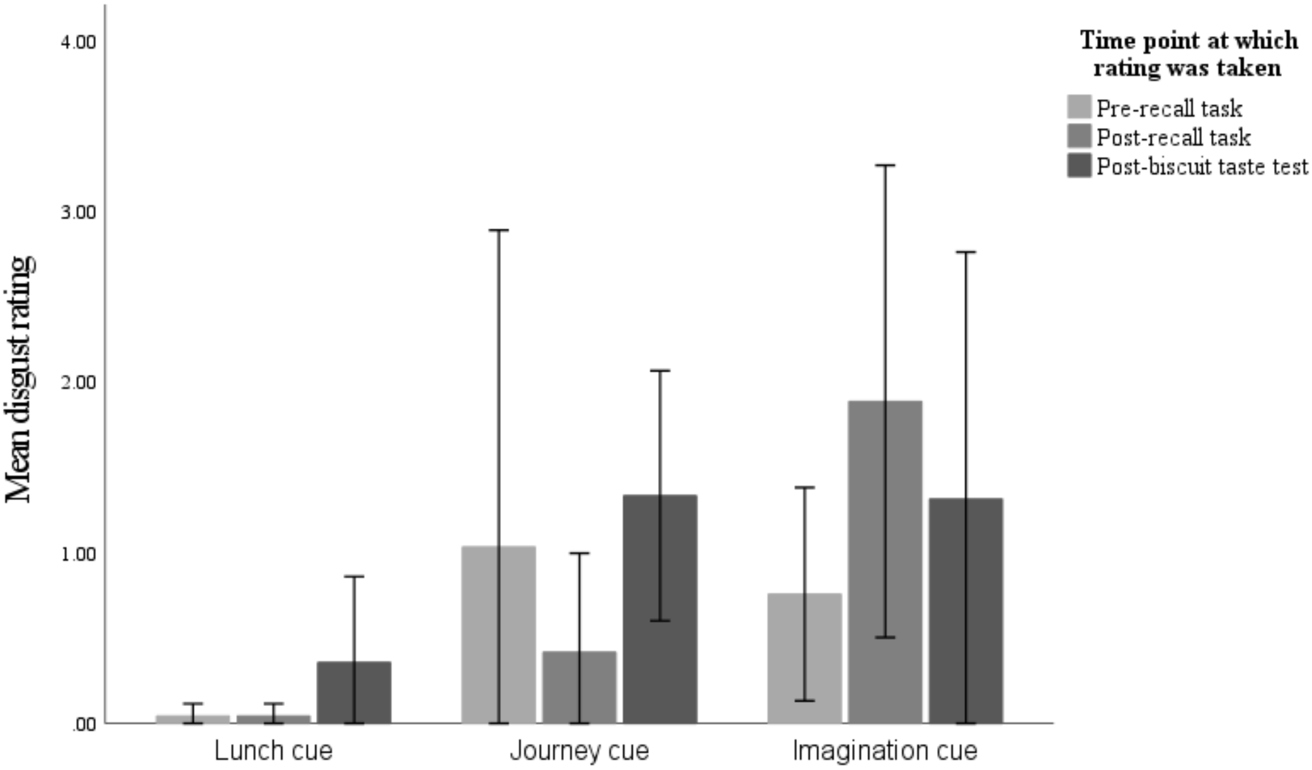
Change in ratings of disgust, as a function of recall cue. Ratings were made on a 10cm VAS scale at three time-points: before and after the recall task, and after the biscuit taste test

	Lunch cue	Journey cue	Imagination cue
Pre- to post-recall change in disgust	0.00 (0.12)	-0.62 (1.25)	1.13 (1.76)
Post-recall to post-taste test change in disgust	0.31 (0.47)	0.92 (0.64)	-0.57 (1.65)

Note. Standard deviations are given in parentheses. Negative values indicate a decrease from rating 1 to rating 2.

Figure 21

Disgust ratings taken at three different time points, as a function of recall cue (error bars represent 95% CI)



5.4.1.5 Effect of Biscuit Taste Test on Appetite. As expected, fullness ratings increased after the biscuit taste test was completed in all groups. However hunger ratings and desire to eat ratings given after the recall task and after the biscuit taste test were similar at both time-points across the conditions.

5.4.1.6 Biscuit Ratings. Biscuit liking ratings (*M*=5.00, *SD*=1.12), and biscuit choice ratings (*M*=4.29, *SD*=1.24) of participants in the imagination cue group were similar to those given by participants in the other two groups.

5.4.2 Discussion

Although this concept-of-proof study was not sufficiently powered for empirical statistical tests to be conducted, a number of interesting observations can be made from the reported results. Firstly, it seems that biscuit intake was lower after both the lunch cue and the imagination cue, than after the journey cue, which is a trend similar to that observed in the main study reported in this chapter. This provides some preliminary evidence that the imagination exercise might reduce intake irrespective of whether it is presented as an auditory visualisation task, or as a written instruction. However, a Bayesian ANOVA revealed weak evidence in favour of the null hypothesis, suggesting the differences between the groups were small.

As in previously reported studies, the recall task did not seem to affect appetite ratings, but an interesting pattern of results emerged for disgust ratings. As predicted, participants rated their level of disgust as substantially higher after the imagination task, and this trend was not observed in the other two conditions. This might suggest that, as mentioned by participants in the main study reported in this chapter, the imagination task might suppress snack intake via increased disgust. Disgust ratings were still elevated in the imagination cue group, even after the biscuit taste test was completed, suggesting the effects of the imagination task might persist some time after the task is performed (in this case about 10 minutes). One interesting finding to note is that, in the journey-recall group, disgust levels increased substantially from before the taste test (i.e. post-recall task) to after the taste test. This is most likely to be explained by the fact that, on average, participants in the journey-recall group ate the most biscuits, and perhaps this is reflected by the elevated post-snack disgust ratings. Post-taste test disgust ratings were comparable between the journey cue (M=1.33, SD=0.70) and imagination cue (M=1.31, SD=1.56) groups, suggesting that both eating a large portion of biscuits, and imagining a recent meal as bigger, makes people feel similarly disgusted. Thus, it could be argued that imagining a recent meal as bigger might elicit similar reactions as actually eating a large portion of sweet snacks.

The findings of the present experiment suggest that both recalling a recent meal, and imagining it was bigger and more filling than in reality, can suppress subsequent snack intake. In the main study of this chapter participants were guided through the imagination task by an audio recording. In the proof-of-concept experiment, the effects of the imagination task seemed to manifest even when the instructions were given in a written format. This implies presenting the imagination task in a written format is likely to be an effective way of suppressing subsequent intake. However, it is worth bearing in mind that this experiment was ended prematurely due to Covid-19 restrictions, and the study was underpowered for statistical analyses to determine whether the manipulations yielded significant findings. Given that the imagination task was a successful manipulation in the main study reported in this chapter, it was decided that two versions of the weight loss intervention would be developed: a simple meal-recall version and a meal-recall + imagination version. In order to further assess whether disgust played a role, it was decided that participants would be interviewed and asked to comment on whether using the intervention affected their appetite or physical state. The next two chapters investigated the usability and feasibility of these weight loss interventions.

Chapter 6

Assessing the Usability of the Chatbot Intervention

Experiments in Chapters 3, 4 and 5 investigated the meal-recall effect, which is characterised by a reduction in energy intake following recall of a recently consumed meal. Although these experiments helped to understand the meal-recall effect better, and highlighted some factors which made it stronger, they cannot tell us whether the effect could potentially be used as a weight-management or a weight loss intervention. The meal-recall effect has previously been included as part of a weight loss app (Robinson, Higgs, et al., 2013; Whitelock, Kersbergen, et al., 2019), however other features were also included in that app and therefore it is not clear whether just eliciting the meal-recall effect on its own (without additional measures such as issuing dietary advice or promoting mindful eating) would make a suitable weight-management intervention. This is an important question to consider, as it seems simpler weight loss interventions can be more effective than complex ones (Lally et al., 2008; O'Neil & Brown, 2005). The present and subsequent chapters investigate the usability, acceptability and feasibility of a novel, memory-based weight loss intervention.

In order to explore whether the meal-recall effect could be used as a weight loss intervention, it was first necessary to select a platform on which this novel intervention could be hosted. It was decided that a chatbot operating on Facebook Messenger would be the best choice for several reasons. Firstly, having the intervention online means that it is accessible from anywhere around the world, and almost any internet-connected device can be used to access the intervention. In 2018, 78% of adults in the UK (Ofcom, 2018), and 81% of adults in the US (Pew Research Centre, 2019) owned and used a smartphone. Given the need for weight loss interventions which are cheap, accessible and effective, it seems prudent to focus research efforts on developing smartphone-based programmes (Schnall et al., 2016; Whitelock, Kersbergen, et al., 2019). Secondly, developing a new app is a technologically complex and costly process, which requires specialist knowledge. But, it has been shown that 25% of apps which are downloaded are never used again (Dredge, 2011), so it might be easier and cheaper to build on already existing apps. In addition, Merchant et al. (2017) reported that participants were frustrated by using a study-designed app, because it was not as good as commercially-developed apps. Thus, integrating the intervention with an app which is already widely used increases the likelihood the chatbot will be used regularly (Ahtinen, 2009; Whitelock et al., 2020). There are 1.3 billion Facebook Messenger users globally, and it is the second most popular communication app (Statista, 2020), thus it seemed to be a good candidate for an accessible and familiar hosting platform.

Usability is the primary goal of user-centred design (Vredenburg et al., 2002). User-centred design was a concept popularised by Donald Norman (Norman, 1988), which stipulates that things should be designed in an intuitive and simple way, prioritising the needs of end-users. The user should be at the forefront of each step of the design process, and their usual characteristics, environments, behaviours, habits and prior knowledge should be considered (Chammas et al., 2015). User-centred design crucially involves real-world testing of designs to ensure that what the designer had in mind matches what the user thinks and does with the product (McCurdie et al., 2012).

There is evidence to suggest that apps which fail (i.e. are not downloaded and/or used) frequently suffer from usability problems and offer a poor user experience (Bhuiyan et al., 2014; Morey et al., 2017; Torous et al., 2018). On the other hand, it has been shown that apps which employ user-centred design are more useful (Mao et al., 2005), engaging and effective (McCurdie et al., 2012). Nielsen (Nielsen, 1994a, 1994b) proposed that there are ten usability heuristics which should be considered when designing a new product, to ensure user satisfaction and engagement. These heuristics were closely examined when designing the chatbot (see Table 26).

The aim of the present study was to assess the usability of a novel weight loss intervention, which is based on the meal-recall effect. Participants were asked to use one of two versions of a chatbot for one-week; the meal-recall version, which asked participants to recall their most recent meal immediately before their next meal, or the imagination version, which additionally asked participants to imagine that their previous meal was larger and more filling than in reality. Usability was assessed by asking participants to give pre- and post-trial ratings on aspects such as ease of use and effectiveness, as well as by asking them to rate different aspects of the chatbot's functionality. Moreover, individual semi-structured interviews were also conducted, and a thematic analysis was carried out, to investigate what participants thought of the intervention and to identify potential problems.

It was predicted that the overall usability of the chatbot would be good, and that participants would enjoy using the chatbot and would find it accessible and simple to operate. It was also hypothesised that using the chatbot would improve people's relationship with food, for example by encouraging more mindful eating and increased reliance on internal satiety cues when deciding how much to eat. However, significant changes to body weight, or to eating behaviour scores were not expected after just one week of engaging with the intervention. Additionally, there was a small risk that repeatedly recalling previous meals could have triggered participants to experience more frequent or more intensive food cravings, and it could have potentially decreased their overall affect and increased emotional guilt. This possibility was explored, but it was predicted that no such changes would be observed.

6.1 Method

6.1.1 Sample Size Justification

There are no standardised methods for determining a suitable sample size for a qualitative study, but one proposed strategy is saturation (Vasileiou et al., 2018). Saturation is reached when additional data no longer produce novel or insightful findings, which in the context of qualitative data can be interpreted as finishing data collection when reviewing additional interview transcripts does not generate new codes or nodes (Saunders et al., 2018; Strauss et al., 1998)

In light of this advice, eight interviews were initially conducted (four for the meal-recall condition and four for imagination). These interviews were then coded, and it became apparent that new codes were still being generated and that saturation was not yet reached. After conducting two more interviews, data started to become redundant, and therefore only two additional interviews were conducted after that, in order to confirm that the point of saturation has been reached. In total, 12 interviews were conducted (meal-recall n=6; imagination n=6).

6.1.2 Ethical Approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

6.1.3 Participants

Twelve participants were recruited from Prolific, an online recruitment platform with the following inclusion criteria: between 18-40 years old, regularly eat at least three meals a day, no current or past diagnoses of an eating disorder, no involvement in any structured weight loss programmes (e.g. Weight Watchers or Slimming World), not following any diets designed for weight loss, willing to lose weight, have Facebook Messenger, willing to use the chatbot on Facebook Messenger for one week and to then participate in the interview. These inclusion criteria were communicated to participants in the study description, and the first few items on the questionnaire confirmed that participants were eligible to take part.

6.1.4 Design

Participants were randomly allocated into a group where they had to recall their previous meal immediately before their next meal (meal-recall condition) or into a group in which thinking about their most recently consumed meal was followed by imagining that the food they ate was bigger and more satiating than in reality (imagination condition). In both conditions, participants had to write down what they ate for their most recent meal and to send this information to the chatbot. Participants in the imagination group were not asked to record details of the imagination task they performed.

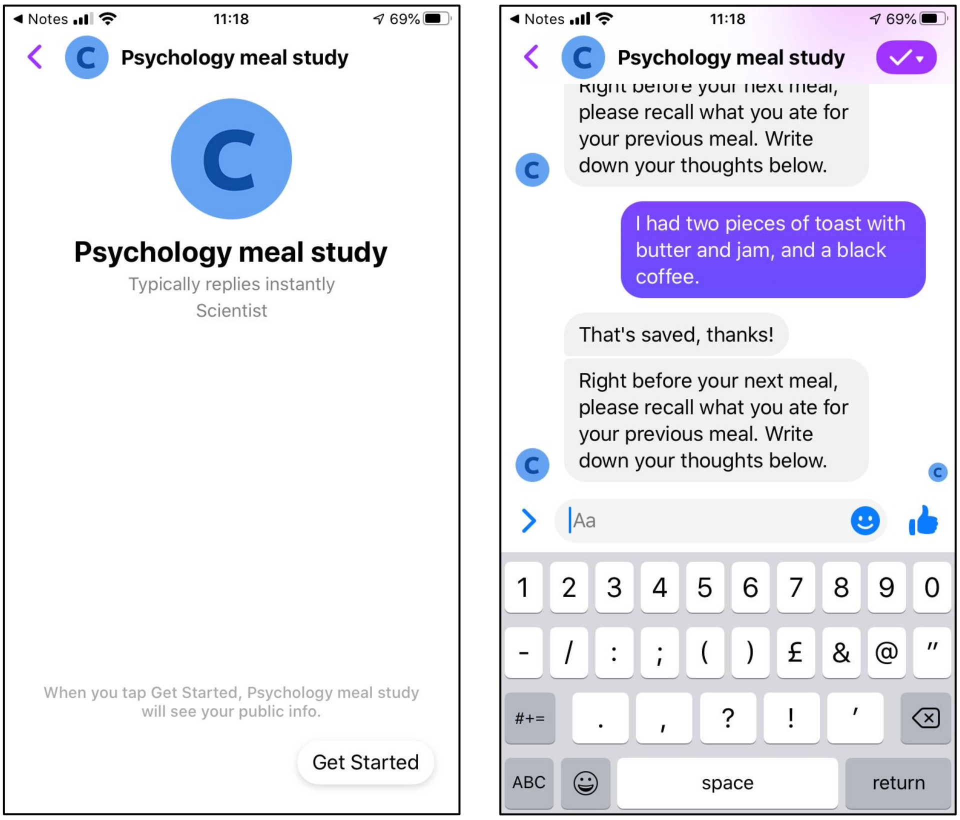
6.1.5 Materials

6.1.5.1 The Chatbot. Facebook Messenger was used as the platform for the chatbot, and a website called Chatfuel (www.chatfuel.com) was used to program the bot (see Figure 22). Participants clicked a link, which redirected them to the appropriate version of the chatbot. Once they pressed the 'get started' button, the chatbot sent the user instructions, which said 'right before your next meal, please recall what you ate for your previous meal. Write down your thoughts below'. In the imagination condition, these instructions were followed by an additional sentence: 'then, imagine that your meal was bigger and more filling than in reality'. After sending the chatbot a message, participants received an instant automated message saying: 'That's saved, thanks!' and this was followed by the same instructional message as they received at the beginning. Shirazi et al. (2014) reported that users may find frequent notifications to be distracting and annoying, but it was also reported that in certain situations, event reminders were useful. Therefore, for the present study, it was decided that if a participant did not spontaneously interact with the chatbot for 23 hours, then the chatbot automatically sent them a reminder saying 'you haven't logged any meals in a while. Please remember to recall a previous meal (and imagine it was bigger and more filling than in reality [imagination group only]), right before you eat your next one'.

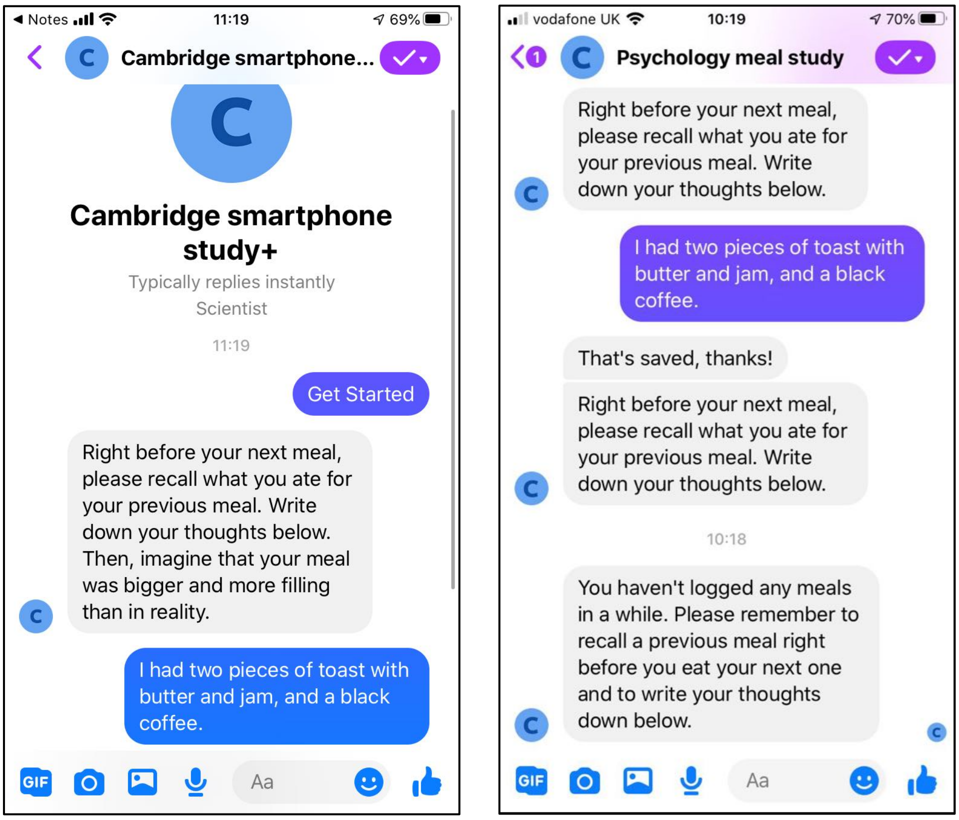
Figure 22

Screenshots showing the set-up and layout of the chatbot, as well as the responses and reminders the chatbot would send to the user. Two versions of the chatbot were tested: meal-recall only (screenshots a) and meal-recall + imagination (screenshots b)

a)



b)



In order to increase the likelihood that the chatbot would be perceived as having good usability, Nielsen's (Nielsen, 1994a, 1994b) usability heuristics were adhered to, and ways in which the intervention's design meets these principles are outlined in Table 26.

Table 26

Nielsen's (1994a, 1994b) usability heuristics and ways in which the chatbot's design addressed them

Heuristic	Definition	Application
Visibility of system status	User should be aware of what is happening at all times and should receive immediate feedback after performing an action.	Automatic message is sent immediately after a user logs a meal, confirming the message has been saved.
Match between system and real world	Language used should be simple and familiar, and functions should have predictable outcomes.	The language used in the automatic messages is straightforward. Chatbot capitalises on users' prior interface knowledge.
User control and freedom	Users should be able to undo unwanted actions and stop a significant command before it is executed.	Not relevant to current design (the only action which can be performed is sending a message).
Consistency and standards	New designs should follow established conventions, and be consistent with prior user knowledge and expectations.	Users are familiar with Facebook Messenger, using chatbot is consistent with using other instant messaging platforms.
Error prevention	Steps should be taken to prevent users from making errors. If an error occurs, error messages should clearly describe what the problem is and how to fix it.	Users could make an error of logging the wrong meal, logging at the wrong time, or forgetting to log. An automatic message is sent after every meal-log, reminding participants to return to the chatbot right before eating their next meal, and to recall their previous meal. A reminder is sent if the user does not engage with the chatbot for a considerable period of time.

Recognition rather than recall	Minimise the amount of information the user needs to remember to engage with the product.	Instructions on how and when to use the chatbot sent automatically after every meal log – visible when user returns for next meal log.
Flexibility and efficiency of use	Include shortcuts and multiple ways of achieving the same goal, to allow users to decide which option is best for their needs.	Facebook Messenger is available across various devices and operating systems, and switching between them is easy.
Aesthetic and minimalist design	Interfaces should be focussed around essential information, and all elements should facilitate achieving the primary function of the product.	The chatbot's design is very simple. The only function available is sending a message, and this is the primary goal of the intervention.
Help users recognize, diagnose, and recover from errors	Help users to recognise they made an error, describe what the error is and how to recover from it.	The chatbot cannot recognise if a user logged at the wrong time. A reminder is sent if the user does not log for a long time, and instructions on what to do are included in the automatic message.
Help and documentation	Any information users may need to use the product should be easily accessible and concise.	Instructions are presented before users start using the chatbot, a condensed version of the instructions is sent to the user after every meal log, and the participants can easily contact the experimenter in case of any questions or problems.

6.1.5.2 Questionnaires. Participants were asked to complete a number of questionnaires before and after the one-week trial, to assess potential changes to eating behaviour and eating-related cognition after using the chatbot. All questionnaires were designed and presented in Qualtrics.

Participants completed the Multidimensional Assessment of Interoceptive Awareness (Mehling et al., 2018), which measured generalised interoceptive ability, and the dietary restraint facet of the Dutch Eating Behaviour Questionnaire (van Strien et al., 1986). These two questionnaires were given to participants only once, before the trial began, and were used to characterise the sample. All of the other questionnaires mentioned below were given to participants twice – once before and once after the intervention, and participants were instructed to think about the previous seven days when giving their responses.

Participants also completed the Six-Item Gastric Interoception Scale, and the PANAS-X (Watson & Clark, 1994) which measured their positive and negative affect, as well as their feelings of guilt. Participants rated their tendency to eat mindfully using the Mindful Eating Behaviour Scale (Winkens et al., 2018), which consisted of 20 items rated on a 1-5 scale (anchors 'never' and 'very often'; see Appendix U). The questionnaire measured four facets of mindful eating: eating while focussing on food, eating while paying attention to hunger and satiety cues, being aware of eating and eating while not being distracted. The Food Acceptance and Awareness Questionnaire (Juarascio, Forman, Timko, Butryn, & Goodwin, 2011), assessed the extent to which people are willing to accept their cravings and urges to eat, which can help to control impulsive eating. It comprised 10 items, each rated on a seven-point scale (anchors 'never true' and 'always true'; see Appendix V). Additionally, the thoughts and guilt subscales of the Food Cravings Questionnaire (Cepeda-Benito, Gleaves, Williams, & Erath, 2000) were merged to form a single measure of trait food cravings (Meule, Lutz, Vögele, & Kübler, 2012). The 10 items were presented on a 1-5 Likert scale (anchors 'strongly disagree' and 'strongly agree'; see Appendix W). Another questionnaire given to participants was the Loss of Control over Eating – Brief (Latner, Mond, Kelly, Haynes, & Hay, 2014). The seven-item scale measured the extent to which an individual exhibits problematic food behaviours or cognitions. Responses were given on a 1-5 Likert scale (anchors 'never' to 'always'; see Appendix X).

Additionally, participants were asked to share their initial impressions of the chatbot (how appealing it was, how different it seemed from alternative methods, how likely it is to be effective) using a 1-5 Likert scale (see Appendix Y). At the end of the trial, participants were also asked to rate various aspects of the chatbot's usability on a 1-5 Likert scale. These included ease and convenience of use, fitting well into daily routine and effects on eating-related behaviour and cognition (see Appendix Z).

6.1.6 Procedure

Participants first answered a number of questions to confirm that they were eligible for the study. Then, they were presented with a short description of what the study would involve, the full information sheet and a consent form, which participants signed before proceeding. Next, participants provided demographic information (age, sex, occupation, height and weight) and completed the following questionnaires in a randomised order: MAIA, DEBQ (dietary restraint), Six-Item Gastric Interoception Scale, MEBS, FAAQ, FCQ-T, LOCES, and PANAS-X. Participants were reminded that the study would involve using a chatbot on Facebook Messenger, and were asked to share their Facebook username, so that the experimenter would be able to track their adherence to the intervention. Participants were reminded that this information would be deleted as soon as data collection was completed.

Then, participants viewed one of two instructional videos (meal-recall or imagination version), which explained how the chatbot should be used. The videos can be viewed at https://youtu.be/V9zA7vNZV1k (meal-recall version) and https://youtu.be/V9zA7vNZV1k (imagination version). Briefly, the clips were about three minutes long and described that the intervention would involve recalling the most recent meal immediately before eating the next meal, and sending this information to the chatbot as an instant message. Participants in the imagination group were also asked to write down what they ate for their most recent meal, but were then additionally asked to imagine that their portion of food was bigger and more satiating than in reality. They were not asked to write down their thoughts or feelings related to the imagination task, and therefore both groups recorded the same information in the chatbot (their most recent meal), but the imagination group performed an additional mental task afterwards. Participants in both groups were encouraged to use the chatbot before every meal, snack or drink, and to recall their most recently consumed item (which could have been a meal, a snack or a drink). This advice was based on the evidence showing that recalling a recent meal can influence snack intake (Higgs, 2002, 2008; Szypula et al., 2020), and that recalling a recent drink can influence intake of a main meal (Yeomans et al., 2017).

After watching the video, participants confirmed that they were able to view the clip, and they were asked three multiple-choice questions to test their understanding of the instructions. Participants could only proceed if all of these questions were answered correctly (but the questions could have been attempted an unlimited number of times). Then, participants rated their initial impressions of the chatbot. Lastly, participants were reminded that the interview would take place 8 days later, and were asked to select a suitable interview time. After selecting an interview time, a link to the chatbot was displayed and participants were instructed to begin using the chatbot right away.

After using the chatbot for one week, participants were sent another survey, in which they were asked to record their current weight, and to answer the same questionnaires again as in the first survey (with the exception of DEBQ and MAIA), to observe potential pre- to post-intervention changes. Participants were then asked to rate a number of statements on a 1-5 scale, pertaining to the chatbot's usability e.g. the extent to which they found it easy and convenient to use.

In the last step of the study, participants took part in individual, semi-structured, online interviews. The interviews lasted approximately 15-30 minutes, and the questions pertained to the ease of accessing and using the chatbot, understanding of how to use the chatbot, remembering to use the chatbot, and participants' opinions of logging/imagining their previous meals and cognitive, as well as emotional effects of using the chatbot (for a full list of interview questions, see Appendix AA). Only the participants' voices were recorded (webcams were off). At the end of the interview participants were fully debriefed and thanked for their participation. They were paid £1.50 for completing the initial survey and were issued a bonus of £13.50 for using the chatbot for seven days, completing the post-intervention survey and for taking part in the interview (£15 in total).

6.1.7 Analysis Details

An ANOVA was conducted to explore baseline differences between the two chatbot groups (meal-recall vs. imagination). Group differences in pre- and post-trial ratings of chatbot's usability were also compared using an ANOVA. Differences between perceived and actual chatbot usability in the two groups were assessed with repeated-measures ANOVAs, and any significant interactions were followed by paired-samples *t*-tests. Usability ratings which were given only after the one-week trial (and not before) were compared between groups using an ANOVA. Weight change and pre- to post-trial differences in cognition were all assessed with repeated-measures ANOVAs, and any significant interactions were followed by paired-samples *t*-tests. Given a noticeable (albeit non-significant) difference in mean BMI between the two groups, all analyses were re-run with BMI as a covariate.

The semi-structured interviews were recorded and transcribed, and then coded in NVivo (version 12). A thematic analysis following the steps of Braun and Clarke (2006), and supplemented by guidance from Castleberry and Nolen (2018), was conducted. Firstly, all transcripts were coded using a process of inductive analysis (i.e. codes were not forced into pre-existing frames or themes). Then, parts of the transcript were labelled with working versions of theme categories, and the transcripts were then re-read, and re-coded where necessary, to make the labels more consistent and coherent. These overarching themes were then split into smaller, more refined sub-sections of a theme, and quotes from participants were provided to demonstrate legitimacy of identified themes.

6.2 Results

6.2.1 Participant Demographics

Data from all 12 participants was used in the analysis. All of the participants were female, and were 28.08 years old on average (*SD*=3.78). The meal-recall group and the imagination group did not differ significantly in terms of age, dietary restraint, baseline interoceptive awareness or BMI, although it was noted that on average, participants in the meal-recall group had a normal BMI, whereas those in the imagination group had a BMI in the overweight range (see Table 27). This difference could potentially be explained by the fact that two participants in the imagination group had a BMI over 30.

Table 27

Summary statistics of demographic variables in the two chatbot groups

	Meal-recall	Imagination	
Sex (F/M)	6/0	6/0	
Age	29.5 (3.83)	26.67 (3.44)	$F(1,10)=1.81$, $p=.208$
Dietary restraint	2.58 (0.77)	3.13 (0.73)	$F(1,10)=1.58$, $p=.238$
Baseline Interoceptive Awareness (MAIA)	2.90 (0.81)	2.54 (0.47)	$F(1,10)=0.92$, $p=.361$
BMI	23.38 (3.25)	29.93 (8.34)	$F(1,10)=3.21$, $p=.103$
Normal weight (BMI≥18.5 and <25)	n=4 (66.7%)	n=2 (33.3%)	
Overweight (BMI≥25 and <30)	n=2 (33.3%)	n=2 (33.3%)	
Obese (BMI≥30)	n=0 (0.0%)	n=2 (33.3%)	
Occupation: Employed	n=2 (33.3%)	n=4 (66.7%)	
Occupation: Homemaker	n=2 (33.3%)	n=0 (0.0%)	
Occupation: Student	n=1 (16.7%)	n=1 (16.7%)	

Occupation: Unemployed	n=1 (16.7%)	n=1 (16.7%)

Note. Standard deviations presented in parentheses. Dietary restraint measured on a 1-5 scale; MAIA measured on a 0-5 scale. Higher ratings indicate greater endorsement.

Quantitative results

6.2.2 Effect of BMI

Although the difference in mean BMI between the meal-recall and the imagination groups was not statistically significant, those in the imagination group were more likely to be classified as having overweight or obesity. Thus, all analyses outlined below were re-run with BMI as a covariate (see Appendix BB). Overall, including BMI as a covariate did not affect the conclusions drawn from results reported below. BMI was only a significant covariate in a model assessing pre- to post-intervention differences in struggling to remember to use the chatbot, suggesting that higher BMI predicted a greater decrease between expected and actual struggle to remember to use the chatbot regularly.

6.2.3 Pre-Trial Impressions

Both versions of the chatbot seemed to be acceptable and quite appealing to participants, but the interventions were not considered to be particularly different to other available weight loss methods. Participants also seemed to be optimistic about the chatbot's effectiveness in terms of weight loss, but as the ratings were not near the maximum score, it appears they were not fully convinced. There were no significant differences in terms of ratings between the two groups (see Table 28).

6.2.4 Chatbot Usage

All participants used the chatbot at least once per day on all seven test days. The mean number of messages sent to the chatbot was 25.67 (SD=4.72) in the meal-recall group and 20.33 (SD=2.25) in the imagination group, and this difference was significant, $F(1,10)=6.24$, $p=.032$, $\eta_p^2=.384$. The users submitted an average of 3.67 (SD=0.67) logs per day in the meal-recall group, and 2.90 (SD=0.32) logs per day in the imagination group. These numbers were mostly consistent with the expectation that the chatbot would be used three times a day over the seven-day period. It was not possible to verify the number of meals which were logged at the correct time (i.e. right before eating the next meal).

Table 28

Mean ratings of how appealing, different, and effective the chatbot seemed to participants, before the trial commenced

	Meal-recall	Imagination	
Intervention appealing	3.17 (0.75)	3.50 (1.05)	$F(1,10)=0.40$, $p=.541$
Intervention different to others	2.83 (1.47)	2.67 (0.82)	$F(1,10)=0.60$, $p=.813$
Intervention will lead to weight loss	3.00 (0.63)	2.67 (0.82)	$F(1,10)=0.63$, $p=.448$

Note. Standard deviations presented in parentheses. All ratings made on a 1-5 scale. Higher scores indicate greater endorsement.

6.2.5 Pre- to Post-Trial Changes in Perceived/Actual Usability

Participants were asked to rate the chatbot on a variety of aspects before and after the trial, and ratings from these two time points were compared (see Table 29). A repeated-measures ANOVA revealed no significant pre- to post-trial differences in how enjoyable participants perceived the chatbot to be, $F(1, 10)=0.17$, $p=.687$. The interaction between enjoyability ratings and group was not significant, $F(1,10)=4.31$, $p=.065$. Perceived struggle to remember to use the chatbot regularly was significantly different before and after the intervention, $F(1, 10)=27.77$, $p<.001$, $\eta_p^2=.74$. The interaction between the ratings and group was significant, $F(1,10)=9.31$, $p=.012$, $\eta_p^2=.48$. Post-hoc comparisons revealed that only participants in the imagination group rated their struggle to use the chatbot regularly as significantly higher after the intervention, $t(5)=-5.00$, $p=.004$, $d=1.22$. Those in the meal-recall group had comparable ratings before and after the intervention, $t(5)=-2.00$, $p=.102$. Lastly, participants rated the chatbot's perceived and actual ability to improve eating habits as similar at both time points, $F(1,10)=1.80$, $p=.209$, and there were no differences between the two groups, $F(1,10)=0.20$, $p=.664$. These results suggest that participants' expectations about the chatbot correlated well with their actual experience, however it seems participants did not expect they would struggle to remember to use the chatbot as much as they actually did.

Table 29

Mean pre- and post-trial ratings of how enjoyable, difficult to remember to use regularly and effective the two chatbots were

	Meal-recall		Imagination	
	Pre-trial	Post-trial	Pre-trial	Post-trial
Intervention enjoyable	3.50 (0.55)	4.00 (0.63)	3.67 (1.03)	3.33 (0.82)
Struggle to remember to use	1.50 (0.84)	2.17 (0.98)	1.83 (0.75)	4.33 (0.52)
Intervention improves eating habits	3.33 (1.21)	3.00 (1.10)	3.17 (0.98)	3.00 (0.63)

Note. Standard deviations presented in parentheses. All ratings made on a 1-5 scale. Higher scores indicate greater endorsement.

6.2.6 Post-Trial Impressions of Chatbot Usability

Participants were asked to make ratings to reflect the chatbot's usability after participating in the intervention for one week. The imagination version of the chatbot was rated as significantly less convenient to use and significantly less able to fit into the user's daily routine. There were no significant differences in ratings of other aspects, however it's worth noting that participants also found the imagination chatbot more awkward to use. Perhaps surprisingly, participants in both groups were equally willing to use the chatbot long-term (see Table 30).

Table 30

Mean acceptability and effectiveness ratings of the two chatbot versions

	Meal-recall	Imagination	
Ease of use	4.50 (0.55)	4.17 (0.41)	$F(1,10)=1.43$, $p=.260$
Convenient to use	4.17 (0.75)	2.67 (0.82)	$F(1,10)=10.95$, $p=.008$, $\eta_p^2=.523$
Awkward to use	1.67 (0.82)	3.33 (1.03)	$F(1,10)=9.62$, $p=.011$, $\eta_p^2=.490$
Fits well into daily routine	3.83 (0.41)	2.67 (0.52)	$F(1,10)=18.85$, $p=.001$, $\eta_p^2=.653$
Improved memory for recent meals	3.50 (1.05)	3.50 (1.05)	$F(1,10)=0.00$, $p=1.000$

Pay more attention to meal	3.50 (1.22)	3.83 (0.98)	*F*(1,10)=0.27, *p*=.614
Willingness to use long-term	3.67 (1.03)	3.67 (1.03)	*F*(1,10)=0.00, *p*=1.000

Note. Standard deviations presented in parentheses. All ratings made on a 1-5 scale. Higher scores indicate greater endorsement.

6.2.7 Weight Change

Using the chatbot for a week did not lead to significant weight loss, *F*(1,10)=0.20, *p*=.668. On average, participants lost 1kg (*SD*=1.10) in the meal-recall group, and gained 0.58kg (*SD*=2.04) in the imagination group, but this difference was not statistically significant, *F*(1,10)=2.82, *p*=.124. In the meal-recall group, one participant lost 3kg, three participants lost 1.5kg and two participants' weight remained the same. In the imagination group, one participant lost 1.5kg, three participants neither lost nor gained weight, one participant gained 0.5kg and one participant gained 4.5kg. Since a gain of 4.5kg (1.92 standard deviations from the mean) seemed extreme given the length of the trial, an additional analysis which excluded this score was conducted. When the 4.5kg data point was removed from the analysis, mean weight loss in the imagination group was 0.20kg (*SD*=0.76). Overall weight loss over the trial period remained non-significant, *F*(1,9)=4.26, *p*=.069, and so did the difference between the groups, *F*(1,9)=1.89, *p*=.202.

6.2.8 Pre- to Post-Trial Differences in Cognition

Participants were asked to complete a number of measures to assess pre- to post-trial differences in cognition related to eating behaviour (see Table 31).

Table 31

Pre- to post-trial changes in eating related cognitions, in the two chatbot groups

	Meal-Recall		Imagination	
	Pre-trial	Post-trial	Pre-trial	Post-trial
Six-Item Gastric Interoception Scale	3.78 (0.67)	3.53 (0.66)	2.92 (0.49)	2.72 (0.57)
MEBS facet:				
Eating while focussing on food	4.33 (0.87)	4.10 (0.63)	4.13 (0.58)	3.90 (0.63)
Eating while paying attention to hunger and satiety cues	3.92 (0.86)	3.69 (0.34)	2.92 (0.64)	2.78 (0.60)
Being aware of eating	4.05 (0.57)	4.28 (0.85)	3.00 (0.76)	2.39 (0.49)
Eating while not being distracted	3.28 (1.16)	3.47 (0.87)	2.44 (0.20)	2.25 (0.60)

FAAQ scores	42.50 (5.01)	43.00 (3.29)	40.33 (7.31)	41.00 (6.07)
Trait Food Cravings (FCQ-T)	2.95 (1.22)	1.93 (0.68)	3.57 (0.54)	3.26 (0.72)
LOCES	1.79 (0.79)	1.64 (0.87)	3.10 (1.07)	2.93 (0.98)
PANAS Negative affect	2.05 (0.90)	1.58 (0.56)	2.58 (0.92)	1.97 (0.53)
PANAS Positive affect	3.03 (0.55)	2.60 (0.85)	3.02 (0.91)	2.52 (0.70)
PANAS Guilt	1.72 (0.99)	1.39 (0.33)	2.44 (1.07)	2.36 (0.69)

Note. Standard deviations presented in parentheses. See section 6.1.4.2 for details on scales used. Higher scores indicate greater endorsement.

6.2.8.1 Gastric Interoception. A repeated-measures ANOVA suggested that there were no significant pre- to post-trial differences in gastric interoceptive awareness, $F(1,10)=2.72$, $p=.130$. Differences between groups were non-significant $F(1,10)=0.04$, $p=.841$ (see Table 31).

6.2.8.2 Tendency to Eat Mindfully. Changes to mindful eating tendencies were assessed with the four facets of the Mindful Eating Behaviour Scale (MEBS; see Table 31). Pre- to post-trial ratings were not significant for eating while focussed ($F[1,10]=4.58$, $p=.058$; interaction: $F[1,10]<0.01$, $p>.999$), eating while paying attention to internal cues ($F[1,10]=0.93$, $p=.359$; interaction: $F[1,10]=0.05$, $p=.829$) and eating while not being distracted ($F[1,10]<0.01$, $p>.999$; interaction: $F[1,10]=2.00$, $p=.188$). Although the overall model for being aware of eating scores was not significant, ($F[1,10]=1.35$, $p=.272$), the interaction between the scores and the group was significant, $F(1,10)=6.22$, $p=.032$. Post-hoc comparisons revealed that eating awareness scores significantly decreased in the imagination group, $t(5)=3.05$, $p=.028$, $d=0.49$, but were not significantly different in the meal-recall group, $t(5)=-0.83$, $p=.444$.

6.2.8.3 Control Over Impulsive Eating. There were no pre- to post-trial changes in Food Acceptance and Awareness scores, $F(1,10)=0.17$, $p=.689$, and no group differences were observed, $F(1,10)<0.01$, $p=.954$ (see Table 31).

6.2.8.4 Food Cravings and Loss of Control Over Eating. There were no significant changes to food cravings score, $F(1,10)=3.90$, $p=.076$, and there seemed to be no significant differences between the two groups, $F(1,10)=1.13$, $p=.313$ (see Table 31). Similarly, loss of control over eating scores seemed similar before and after the intervention, $F(1,10)=1.99$, $p=.189$, and no interaction between the scores and group was found, $F(1,10)=0.01$, $p=.916$ (see Table 31).

6.2.8.5 Affect. The analysis showed that using the chatbot for a week significantly decreased negative affect scores, $F(1,10)=15.43$, $p=.003$, and this was observed to a similar extent in both groups as the interaction term was not significant, $F(1,10)=0.30$, $p=.598$. Positive affect scores significantly decreased after using the chatbot, $F(1,10)=4.96$, $p=.050$, $\eta_p^2=.33$, but there were no differences between the two groups, $F(1,10)=0.03$, $p=.877$. Guilt ratings were very similar pre- to post-trial, $F(1,10)=1.03$, $p=.333$, and no group differences were noted, $F(1,10)=0.37$, $p=.556$ (see Table 31).

Qualitative Analysis

6.2.9 Theme 1: Acceptability

Most people began the one-week trial feeling positive towards the idea of the chatbot. Some participants emphasised that they were motivated to use the chatbot, because of its novelty, for example one participant said 'it was very interesting, I haven't heard of anything like it before' (P1) and another added 'I liked the idea of using technology, it was something quite different (…) and people like technology nowadays' (P12). Only one participant specifically said that she found the premise of the imagination task 'quite interesting' and novel (P5). Users found the potential effects the chatbot, for example being mindful of the food they ate, were appealing, and this motivated them to want to use the chatbot regularly.

The chatbot was also compared to other weight loss apps by some participants, and it was noted that whereas other food trackers are predominantly focussed on calorie counting, the chatbot only required users to log what they ate, which was 'a wee bit more enjoyable for people than feeling very bogged down by the numbers' (P8). Another participant said that even though there are people who enjoy going to in-person weight loss classes, she found an online intervention more appealing (P12). It was also evident that some participants found the concept of the chatbot 'weird', because they would not usually think about what they have eaten (P11) and they would not write down what they ate (Participant 9). Others were confused by the fact that they had to recall a meal they ate previously, just before they ate the next meal (P11 and P12).

Three participants said that initially, they did not find the chatbot too appealing. One participant said this was because she would prefer more interaction from the chatbot (P6), another said she wasn't sure how it would work, so had to give it a go before forming an opinion (P8) and the third participant said she was having a stressful time and did not want to track her food on top of everything, but she said she gave the chatbot a try anyway because she likes trying new things (P10). Out of these three participants, only participant 6 said she did not quite enjoy using the chatbot by the end of the trial. The remaining two participants were initially excited about the chatbot, but ended up not liking it. One participant said: ‘It seemed quite a good idea (…) I was quite excited for it, it seemed pretty good’ but then said she actually ‘found it a little bit tedious, a little bit sort of boring to use, because it’s automated messages, it’s the same thing coming back every time, so it’s not very exciting to use’ (P7). The other participant explained that she thought the chatbot would reply with more personalised messages, and she found the chatbot harder to use than she anticipated (P11).

6.2.10 Theme 2: Design

6.2.10.1 Accessibility. All users thought that the design of the chatbot was simple, intuitive and that it was easy to access. Only one participant (P6) initially struggled to access the chatbot, because she thought the chatbot would initiate the conversation with her, but this was quickly resolved. The instructions provided were clear and informative. A number of participants supplemented their initial understanding of the instructions with the instructional video. As one participant described ‘I had some doubts after reading, but then watching the video confirmed that I had understood it correctly’ (P6). Another participant also added that ‘it was very well explained. It did make sense. I could see the understanding behind it’ (P12).

6.2.10.2 Platform. Almost everyone agreed that Facebook Messenger was a good platform to use for the intervention. Users believed that most people have Facebook Messenger anyway and use it regularly, so it’s a familiar and convenient place for them to interact with the chatbot. Participants also appreciated that ‘it was on Messenger app, which is something that I use anyway, so it wasn’t a new app that I had to download onto my phone’ (P9). Some users also believed that the chatbot was simple enough to be used by anyone, ‘I would say like across generations, you know, it’s very easy for anyone to pick up and use’ (P1). The chatbot was described as being ‘user-friendly’ (P4) and ‘very simple to use’ (P8). Although some users believed that having the intervention online was an advantage, ‘mostly because wifi is everywhere’ (P11), it was also evident that usability was reduced when users did not have steady access to their phone or to the internet. One user explained: ‘I didn’t write (the meal log) in the chatbot, either because I didn’t have my phone on me, or because I had no internet signal. I was away camping’ (P11). One participant said she did not have the Messenger app on her phone, because she didn’t use it that often, and so she struggled to use the chatbot regularly (P4). She was also the only person who would have preferred the chatbot to be a separate app, because she said ‘when I download it as an app (…) it’s in my head, so I always use it (…) but on Messenger (…) it’s not always going to be in my head’ (P4).

6.2.10.3 Interaction. A lot of participants said that they treated the chatbot as a task which had to be completed. One participant thought that ‘it didn’t feel like a chore to use’ (P2), another said it ‘became routine’ (P8) and although one user noted that she ‘wouldn’t call it ‘fun’ like a video game or something’ (P5), for most users it was not unpleasant to use the chatbot regularly. It was also mentioned that the chatbot did not interfere with people’s lives too much. Participants praised the chatbot because ‘it didn’t pop-up constantly’ (P2) and the messages participants received were delivered instantly: ‘by the time that you actually put it in, you press ‘enter’, you didn’t have all these notifications coming in delayed’ (P6). It seems that the users believed there is a fine line between receiving an acceptable number of notifications from the chatbot and receiving too many notifications. One participant said: ‘I’ve used some chatbots before and it’s like you’re getting messages sort of constantly every hour (…) it was incessant and you think ‘oh God, I’m just going to uninstall it because it’s too much’’ (P2).

The automatic messages a participant would receive after logging each meal were well received, and participants used them to remind themselves what they had to do. Although these messages made it clear what the participants were supposed to do, some thought they were boring because ‘it’s the same thing coming back every time, so it’s not very exciting to use’ (P7). Some users said that they would appreciate having ‘a wee bit of variety in the things it’s asking’ (P8). In fact, a number of participants remarked that the chatbot felt impersonal, and that they were ‘conscious that you were chatting to a chatbot’ (P6). It was clear that some users would prefer the chatbot to be more personalised and more human. For example, one participant said: ‘it’s a robot, you’re not getting a lot of support, you’re not getting someone who says: ‘you’re allowed to have a main and a dessert at a pub quiz’, you know? I didn’t have that kind of personalised feeling’ (P6).

6.2.10.4 Engagement. The automatic message sent out by the chatbot asked participants to recall their most recent meal and to write their thoughts down. The majority of participants simply listed the contents of their meal, without mentioning the portion size, and a minority of users added details such as the number of items they ate (e.g. ‘two sausages’ P9) or vaguely described the portion size (e.g. ‘a small portion’ or ‘a medium portion’ P10). Most users noted that not having to list the portion size was a big advantage of the chatbot. One participant tried to list the portion size for each meal, but she ‘got a bit lazy and I couldn’t be bothered’ (P6). Another mentioned that she ‘didn’t get bogged down on like the actual amount’ (P8), and listing the portion size was seen as unnecessary, as one participant said: ‘I don’t like going into so much detail when it’s about food (…) I know what I had’ (P10).

Listing the portion size was seen as cumbersome, with one user saying: ‘I think that would have made it a lot more difficult if I was doing it sort of like to the tee’ (P9), and another remarking that she liked the chatbot specifically because she didn’t have to ‘put the calories in or anything like that’ (P11). There was also a strong sense of participants not wanting to track their calories, as the chatbot was compared to other weight loss apps. One participant called calorie counting ‘dangerous for some people’ (P5) and another said that ‘it’s a wee bit more enjoyable’ (P8) to log meals, rather than to log calories. Thinking about a most recent meal was called a ‘bit more of a peaceful method’ (P8) and it was noted that using other interventions which require the user to log their portion size or the calories within their meal ‘took far longer’ (P5) and were ‘quite confusing sometimes’ (P12). However, one participant also added that although listing the portion size would make the task more difficult, people might stop and think twice before eating something unhealthy if they know they will have to record the food and the portion size (P12).

6.2.11 Theme 3: Usability

6.2.11.1 Adherence. One of the most commonly identified problems with the chatbot was lack of regular reminders to log a previous meal. The chatbot was set to send a reminder after 23 hours, in order to avoid overwhelming the user with notifications. However, this did not seem to work as well as anticipated. Almost every participant said they struggled to remember to log their meal at the correct time or that they have forgotten to log at some point. One participant said: ‘I always had to make sure I was aware and reminded myself to use it’ (P1) and another commented that remembering to log the meals was ‘the only thing I found difficult’ (P12). All but one participants agreed that more frequent reminders, especially around mealtimes, would be beneficial. The one participant who disagreed said that she doesn’t use Messenger on her phone (she used a laptop instead), so a reminder in the form of a phone notification would not work for her (P4).

It was noted that reminders would work especially well on days when the participants’ day was unstructured (e.g. over the weekend [P11]), or when they were very busy. One participant said: ‘I don’t have a routine for eating during the day. My work is very unpredictable, and I will eat at different times (…) without a trigger, I find it very difficult to remind myself' (P8) and others agreed that being 'preoccupied with something' (P12) makes it more difficult to remember to log the meals in the chatbot. Some participants spontaneously formed a strategy of using meal prepping as a 'sort of reminder, a prompt' (P7) to use the chatbot, and this seemed to be quite effective (P8). Four participants directly mentioned that remembering to log their meals became easier for them over time.

6.2.11.2 Functionality Requests. It was also quite common for participants to report wanting more encouragement from the chatbot. One participant said: 'diets can be tricky for people at times, and there are times when you just want to give up, so words of encouragement may be beneficial' (P1) and another added she'd like it if 'someone could pat me on the back and say 'you're doing a really good job'' (P6). Other participants also noted that they would appreciate receiving some nutritional advice or facts throughout the trial, 'something that makes you think of the impact of eating healthy directly on you' (P6). One participant wondered: 'maybe it could offer suggestions or something about the meals you should be eating' (P12).

6.2.11.3 Enjoyment. When asked directly whether or not they enjoyed using the chatbot, all but one participants agreed. For most users, the experience of using the chatbot was neutral (6 participants), neutral to positive (1 participant), or positive (3 participants). Two participants said that logging some meals was a positive experience, whereas logging other meals was a somewhat negative experience. One participant said 'I always feel more negative about my meals in the evenings (…) but more positive in the mornings' (P8), whereas another one said that logging her lunch was 'a bit of a negative one', but she 'enjoyed putting dinner in' (P11). No participant said they found the experience of using the chatbot completely negative. Participants in both groups seemed to equally enjoy using the chatbot.

It is also important to note that none of the participants felt embarrassed or awkward because they were worried about using the chatbot in front of other people. One participant said: 'I would always do it on my own, so I never felt embarrassed or anything like that' (P6), and another said that even though there were a couple of times she completed the meal logging (and the imagination task) in front of other people she 'didn't really feel weird, because it just felt like something I was just entering really quickly and then going back to what I was doing' (P11). However, users acknowledged that even though logging in front of others in a 'familiar setting' (P11) was not problematic, 'it might seem a bit rude to pull out my phone and to start logging things' (P7). Therefore, using the chatbot might be socially awkward in some situations, but in day-to-day situations users seem to be able to integrate the chatbot well into their social lives.

6.2.11.4 Imagination Task. Somewhat surprisingly, participants either had a neutral opinion about the imagination task, or a negative opinion about it. One participant said that the imagination task was 'very easy, I didn't have any difficulty with it' (P8) and another said that it didn't 'take that much effort' (P5). The same participant was the only person to say that they felt more 'satisfied' (P5) after doing the imagination task, but remarked that this feeling was vague. Most participants said that the imagination task was difficult to do. One participant said she might have found it hard because she was 'overthinking it' (P6) and because her 'mind runs away with the portion thing' (P6). Another participant added she found the task complicated, because she's 'not good at understanding how much I eat' (P11). She also remarked that imagining bigger portions of discrete food items was easier than imagining bigger portions of food, such as rice. Another participant didn't find the imagination task 'useful' and 'wasn't doing that as much' (P12) by the end of the trial.

Most importantly, participants did not feel that the imagination task had any effects on them. One participant explained that the imagination task 'didn't have any effect on me at all, mostly because at the moment I am trying to control portion size, so it was a bit hard for me to imagine my previous meal when I've been weighing stuff out' (P6). Another participant said that 'once I put something on a plate, I will eat it regardless' (P11), so the imagination task did not cause her to reconsider her portion size. She also said that the imagination task was 'weird' because she'd 'never get to a point when I'm eating that much' (P11). The effects of the imagination task also seemed to be 'dependant on the time of day' (P8) and were especially weak when the participant was 'hungrier' (P8) than usual. The imagination task made some users feel 'uncomfortable' (P8 and P11).

The finding that the imagination task did not seem to work too effectively is unlikely to be explained by participants rushing over the task, as four (out of six) participants claimed they felt they spent an adequate amount of time doing the imagination task. The time spent on the task varied from seconds (P7 and P12), to couple of minutes (P8 and P11) to 5 minutes (P5 and P6). It is worth noting that half of the users found the instructions for the imagination task confusing, for example one participant said 'I wasn't sure if I was to write down my thoughts, or if I was just to write down what the meal was' (P5) and another remarked that the instructions were to ‘’imagine your meal was bigger’, but it doesn’t say how much bigger’ (P7). Participants were not clear on how ‘specific’ (P11) they had to be when doing the imagination task, and were not sure ‘what the aim was’ (P7). One participant said she would prefer just logging the meal, rather than doing the imagination task (P12).

6.2.12 Theme 4: Effects

6.2.12.1 Raised Awareness. Many participants described that using the chatbot for a week made them more conscious about their food choices. One participant said: ‘[the chatbot] certainly made me more aware of what I was eating’ (P7), and another added: ‘I was just more aware of my hunger’ (P2). Participants also seemed to become more conscious of their portion sizes, for example one participant said: ‘towards the end of the week I was eating far less of portions (…) my portion size and my mindfulness to the ingredients (…) was a lot better than what it was in previous weeks, when I was just putting things in my mouth without thinking about it’ (P5). It was clear that before using the chatbot, some participants did not regularly think about what they’ve already eaten that day, especially when considering their next meal. It was mentioned that without the chatbot ‘it’s so easy just to forget and just to carry on and just eat whatever you fancy’ (P1). The chatbot was described as a good tool to use to help users monitor what they’ve already eaten, and users found it beneficial to have the meal logs ‘all there in one place’ (P1). The chatbot also helped participants be more mindful about their meals, with some users describing that logging meals helped them to pay attention to their hunger and satiety cues, for example ‘I would think ‘am I hungry yet, or should I wait until later’’ (P11). Using the chatbot helped participant to identify problematic or less than optimal eating behaviours. Many participants mentioned that the chatbot helped them ‘to see where I could make improvements’ (P2), and one participant explained: ‘I was having meals very irregularly, so having the chatbot really made me realise that wasn’t good’ (P11). Another participant noted that the chatbot ‘tricks you, so it’s like - oh, if I have to record that I had chips and that I had a chocolate bar, you don’t really want to record that’ (P10), showing that using the chatbot helped participants re-evaluate their food choices.

6.2.12.2 Lower Intake. Participants reported that their increased awareness of what has already been eaten throughout the day translated into healthier food choices and decreased portion sizes. Participants remarked that there were ‘inclined to eat less’ (P8), one participant stated that the chatbot ‘made me want to eat better’ (P11) and another suggested that using the chatbot ‘had a knock-on effect with what I was eating’ (P6). One participant described how she had pizza for dinner one night and the next day she was more mindful about the food she ate and decided to have 'healthier options and like less food really' (P1). Another participant reported a very similar situation, where she ate less the following day because she was reminded of the food she ate the night before (P9).

Interestingly, only those in the imagination condition reported snacking less over the trial period. One participant explained that she snacked less because she struggled to monitor the portion size of her snacks, and so this made the imagination task more difficult for her. She 'just started cutting out snacking, rather than trying to control the portion size' (P6). Another participant explained: 'usually I just snack for the sake of snacking sometimes, but with this app thing I tended not to, because I was thinking to myself 'well, I'd have to log it' so that just naturally compelled me to snack less' (P5). The reason for snacking less was not always evident to all participants, as one user noted 'I definitely ate less than I usually would over the seven days, and I don't know if that's because I've been really busy or if it was subconsciously something to do with having to log it' (P12), but the same participant added that using the chatbot 'did have a positive effect' on her eating habits.

6.2.12.3 Changes to Physical State or Appetite. Most participants reported that they did not observe any changes to their physical state or their level of appetite after using the chatbot. A few participants mentioned feeling a bit less hungry after recalling their meals, but this feeling was 'slightly vague' (P5).

6.2.12.4 Feelings of Guilt. Using the chatbot also had an unintended effect of making some participants feel guilty about the food they ate. All but one participants who felt guilty were in the imagination condition. One participant recalled how one night she went out to the pub to have a meal and 'had a bit of an internal battle' of whether or not to have dessert, because she was remembering the size of her lunch. She 'cracked' and decided to have the dessert, which made her feel 'a bit more guilty and a bit more panicky about weight control and weight gain' (P6). For another participant, logging a meal which was bigger than normal made her think that maybe she 'shouldn't have had that' (P7). One participant reported that imaging her meals as bigger made her feel so guilty that she reported: 'I sometimes imagined that [the meals] were probably smaller than they actually were' (P12). However, not all participants thought that feeling 'a little bid bad' (P5) about their past meals was a negative emotion. For example, one participant said that feeling guilt helped her to 'initiate changes' (P8) to her eating habits, and another participant said guilt was 'like a self-regulation' to help her make better food decisions. Most participants in the meal-recall condition did not report feeling guilty at any point.

6.2.12.5 Intervention Sustainability. Nine out of twelve participants said they would be willing to use the chatbot for a longer period of time. Participants noted that they 'wouldn't have any issues with using it longer term' (P1), because 'it's not really that difficult' (P5). Others explained that they've 'used things similar before' (P8) and that they believe using the chatbot would become 'quite habitual' (P9) and 'better with time' (P11). Some participants explained that they would use a weight loss app only at certain points in their life, for example when they would feel they are 'going off track' (P4), so for them the chatbot is not something they 'need for a year' (P4). One participant noted that she would be willing to use the chatbot for a longer period of time if it just involved logging food, but as for the imagination task 'I don't think that I would be able to keep that up for a year' (P12).

Two participants were not sure if they would be willing to use the chatbot for a longer period of time. One participant was sceptical about becoming better at using the chatbot regularly, as she 'didn't pick up that habit' (P6) over the trial period. She also said: 'I don't think I have the patience for [the imagination task]', which she found difficult. When another participant was asked to explain why she wasn't sure about using the chatbot long-term, she said 'if you're going to be very strict, I might be afraid of failing you' (P10), but she added that generally, she wouldn't mind using the chatbot. One participant specifically said she would not want to carry on using the chatbot: 'I think I'd find that quite tedious. I think I'd struggle to remember to do that all day, every day for that time period' (P7).

6.2.12.6 Perceived Efficacy. Most participants felt somewhat confident that using the chatbot over a longer period of time would help them to lose weight. Some participants noted that using the chatbot 'just makes you more aware of your choices and reminds you of what you've already eaten' (P1) and this can help people to make better food decisions throughout the day, which could potentially lead to weight loss. Some participants noted that the chatbot would only be a successful tool if 'you really took the time' (P8), or if it was 'be in conjunction with exercise as well'. Some participants were unsure of whether the chatbot could help them to lose weight, and either said the effect would be small (P10) or that they wouldn't continue using the chatbot long enough to see the results (P6). One participant said that the chatbot 'has potential' (P12), but also added that 'in terms of actually working to help me lose weight, I'm not convinced as it is currently that it would do too much' (P12). This participant explained that the chatbot would need to offer more weight loss advice, or would need to involve counting calories, in order to result in weight loss.

6.3 Discussion

The aim of this usability study was to explore whether users would enjoy using a novel, memory-based weight loss chatbot, and whether they would find the intervention easy and convenient to use. This was investigated by asking participants to use the weight loss chatbot for a week, and to then talk about their experiences in an interview. It was also researched whether using the chatbot for a week would produce any changes to ratings of interoceptive awareness, cognitive aspects of eating behaviour or to the user's affect. This study was conducted in order to assess whether the chatbot intervention would be suitable for administration over a longer period of time, as an alternative weight loss method. Two versions of the chatbot were trialled; in the meal-recall version participants were asked to recall a meal they ate most recently, right before eating their next meal, and to send details of their recollection as an instant message to the chatbot. In the imagination version, participants were additionally asked to imagine that their meal was bigger and more filling than in reality.

Quantitative results suggested that participants had favourable first impressions of both versions of the chatbot. Both interventions were equally appealing to participants, despite the imagination version including an extra task. However, participants in the imagination group were not informed about the existence of a simpler version of the chatbot, which might have influenced their ratings. Both the pre-trial ratings and the interview data imply that the chatbots had good user acceptability, which is an important aspect of getting people to start the intervention.

After using the chatbot for a week, it was evident that the usability was not the same for the meal-recall and the imagination versions of the chatbot. Firstly, participants in the imagination group logged significantly fewer meals, than those in the meal-recall group, suggesting that adherence might have been affected by having to do the mental visualisation task. This is supported by the finding that participants rated the imagination version of the chatbot significantly lower on convenience and ability to fit seamlessly into their daily routines. The imagination chatbot was also rated higher on the extent to which it was awkward to use, compared to the meal-recall version. Most importantly, participants did not perceive the imagination task to be a useful element of the intervention. The imagination task had an unintended consequence of making users feel guilty about their past food choices, although this was not reflected in PANAS-X guilt ratings. It is also worth noting none of the participants mentioned feeling sick or disgusted by having to perform the imagination task. Most participants had a neutral or a negative opinion of the imagination task, and a few remarked that the visualisation task did not help them reduce their food intake.

Weight loss data, as well as questionnaire data and subjective ratings, support participants' claims that the imagination task did not seem to add any value to the intervention. It's possible that this was not because the imagination task itself does not help to increase the effectiveness of the intervention, but because the instructions were not particularly clear to participants. The instructions given to participants were to imagine that their meal was bigger and more filling than in reality, which might not have been enough to encourage them to fully engage with the visualisation task. It's possible that providing a guided audio recording of the visualisation task, as in Chapter 5, could have made the instructions clearer and this version of the chatbot would be received more favourably.

Unfortunately, the basic set up of the chatbot means it is not possible to embed the audio clip recording into the Messenger conversation, unless this would be via an external link to an audio/video-hosting platform (e.g. YouTube). Given that the imagination version of the chatbot was also rated as less convenient, less able to fit into daily routine and more awkward to use, adding links to audio clips and asking people to access them might further impair usability, and could negatively impact adherence to the intervention. It's worth noting that Whitelock, Kersbergen, et al. (2019) have developed an app which encouraged users to eat more mindfully, and one element of this intervention was an audio clip which helped participants pay more attention to their meal. However, almost 41% of participants did not use the application as intended (e.g. did not listen to the recording frequently), which might suggest that too many features of an intervention can overwhelm the user, and this can lead to poor adherence rates. The same researchers also found that the number of logs was a significant predictor of weight loss after 8-weeks, with each additional log increasing weight loss by 0.02kg (Whitelock et al., 2020). Given these findings, it seems wise to focus research efforts on the simpler meal-recall version of the chatbot, which generated significantly more meal-logs, and is therefore more likely to produce substantial weight loss over a longer period of time. As the imagination version of the chatbot requires further research before it is launched as a longer-term intervention, it will not be included in the subsequent feasibility study.

Another major issue identified was that participants struggled to remember to use the chatbot right before their meal. Despite users liking the fact that the chatbot did not overwhelm them with notifications, most participants said that they would prefer reminders to be sent to them every few hours, rather than every 23 hours. Therefore, reminders will be sent to users more frequently in the feasibility study.

In general, the usability of the basic features of both chatbot versions was rated favourably. Participants appreciated the minimalistic design of the chatbot, both in terms of the interface and the actual task to be completed. Some participants highlighted that not having to list the portion size made the chatbot faster and easier to use, which translated into higher adherence to the intervention. Most users agreed that accessing the chatbot through Facebook Messenger was better than downloading a separate app for the intervention. Facebook Messenger is a familiar platform for many, and the fact that it can be accessed on any device makes it accessible and appealing to users. Only one participant did not use Facebook Messenger on a regular basis, and this made it difficult for her to use the chatbot as intended. Therefore, it seems that chatbot-based interventions are more suitable for users who are already familiar with Facebook Messenger, and already use the app on a daily basis. Some participants noted that the chatbot felt impersonal and robotic to them, and that they would have preferred if the interaction with the chatbot was more meaningful. This is something that could be implemented into future iterations of the chatbot. Nevertheless, most participants reported that they enjoyed using the chatbot.

In terms of the effects that the intervention had on users, it seems that recalling recent meals increased awareness of what has been eaten and in what quantities. Increasing awareness made participants think more carefully about their dietary choices and about their portion size. In many cases, increased awareness led to lower intake, especially of high-calorie snacks. Some participants reported that because of the intervention they started to take their previous meals into account when making decisions about upcoming food intake, and therefore their overall intake was more balanced (e.g. big dinner was followed by smaller breakfast). Despite this marked increase in mindful eating and decreased energy intake, participants did not report feeling more satiated or less hungry following the meal-recall or the imagination task (apart from one participant for whom the feeling of decreased hunger was vague). Similarly, interoceptive awareness scores and tendency to eat mindfully did not increase after the intervention, except for the finding that participants in the imagination group rated their awareness of eating as lower post-intervention, than pre-intervention. Participants did not report an increase or a reduction in food cravings, which is important given that the intervention involves frequent food-related thoughts. Scores on questionnaires assessing cravings, willingness to accept urges to eat and to control impulsive eating, and perceived control over eating were not significantly different in either group pre- to post-trial, which is reassuring in terms of preventing unwanted cognitive 'side-effects' of the intervention. But it's important to remember that one week might not have been enough to generate any substantial changes to people's behaviour and cognition, and therefore it's important to monitor these aspects in the subsequent feasibility study.

When asked whether they thought the chatbot is likely to help them lose weight over a longer period of time, most participants were unsure or disagreed. Those who said it might work also highlighted that the effect is likely to be small, and therefore not meaningful. Others believed that without additional measures (e.g. calorie counting or dietary advice), the chatbot was unlikely to be very effective. At the moment, it is not clear whether the chatbot is likely to result in substantial weight loss, but once more research data is available, it might be beneficial to convince future users of the effectiveness of the chatbot, to increase motivation to continue engaging with the intervention. Whitelock et al. (2020) identified subjective belief in the intervention's effectiveness to be an important motivator for people to engage more with the weight loss app. Despite most users expressing scepticism over the idea that the chatbot could help them to lose weight, three-quarters of the participants were willing to continue using the chatbot long-term, and only one participant said they would definitely not want to continue using the chatbot (the other two were unsure). This shows that the chatbot is an appealing weight loss intervention and that users are willing to engage with it over longer periods of time, which may be attributed to the chatbot's simplicity and ease of use.

Overall, it was found that the simpler version of the chatbot, which asked participants to recall a recent meal immediately before eating the next one, had good usability and user engagement. The imagination task did not seem to produce the desired effects of decreased consumption, and also decreased the chatbot's usability and adherence to the intervention. Therefore, this version of the chatbot will be omitted from subsequent studies. It was also revealed that more frequent reminders to log meals are needed, as users struggled to use the chatbot at the right time without external memory prompts. Using the chatbot for a week did not seem to change eating behaviour or food-related cognition in any meaningful ways.

Chapter 7
Assessing the Feasibility of the Chatbot Intervention

Usability testing, which was the focus of the previous chapter, primarily assesses the design and characteristics of the tool which is being used – questions which such testing may encompass are 'is it well designed', 'is it intuitive', or 'does it consider the needs of end users?' (Norman, 1988). Feasibility testing focusses on whether an intervention is suitable for further testing (Bowen et al., 2009). Feasibility studies test whether participants are likely to find the intervention acceptable, whether they will persist in using and engaging with the intervention for a longer period of time, and whether the intervention is likely to produce the desired results (Bowen et al., 2009; Public Health England, 2020).

Chapter 6 suggested that a chatbot intervention - wherein participants recalled and recorded a previous meal immediately before eating - had good usability and could be a feasible intervention. Participants generally enjoyed using the chatbot, and rated it highly in terms of ease of use and convenience. Thus it appears a Facebook Messenger chatbot was an appropriate method of delivery of the memory-based intervention. What is not yet clear is whether participants would be willing to continue using the chatbot for a prolonged period of time, and whether usage of the chatbot could produce any meaningful changes to body weight, cognition or behaviour. The present study addressed these questions.

Bowen et al. (2009) note that there are eight key areas of focus which a feasibility study may target, including demand (how likely is it that people will express an interest in the intervention?), implementation (can the intervention be implemented successfully?) and acceptability (how likely is it an intervention will be satisfying and attractive to potential users?). These three areas of focus are especially relevant to the aims of the present study. Based on the guidance of Bowen and colleagues, this feasibility study will explore whether participants in the intervention group will be as satisfied with the chatbot as those in the control group, whether the intervention will fit well into people's daily-life activities, whether the intervention will be used regularly by most and whether intervention participants would be willing to continue using the chatbot beyond the study timeframe.

Higher rates of adherence to a weight loss intervention predict greater success in losing weight (Acharya et al., 2009), and greater acceptability of an intervention leads to greater user engagement (Sekhon et al., 2017). Therefore, it was important to conduct an in-depth assessment of how acceptable the intervention was to participants. Sekhon et al. (2017)

proposed a theoretical framework of acceptability, which helps researchers explore this multifaceted construct. They divided acceptability of an intervention into six elements, which contribute to the subjective perception of acceptability: burden (reason for discontinuation), affective attitude (do users feel positive towards the intervention?), ethical consequences (are there any side effects?), opportunity costs (how much must be given up to engage in the intervention?), experience (are users satisfied with the intervention?) and intention (willingness to participate/keep participating). The present study aimed to assess the extent to which the chatbot intervention met all of these six elements of acceptability, and the general feasibility of the intervention.

To this end, participants in this study were allocated to either the intervention or the control group, and were asked to use the chatbot for six weeks. Participants in the intervention group were asked to write down (in the chatbot) what they ate for a previous meal, immediately before eating their next meal, whereas those in the control condition were asked to record their weight in the chatbot once per week. Acceptability and feasibility of the intervention were assessed with questionnaires, as well as through qualitative interviews.

7.1 Method

7.1.1 Sample Size Justification

The primary focus of this chapter is to investigate the feasibility and acceptability of the intervention chatbot, and so the target is to recruit a sample which will be big enough to reach saturation (i.e. the point at which collecting additional data no longer leads to novel findings). In Chapter 6, 12 participants were required before saturation was reached, however given that this trial will be more effortful, it is expected some participants might drop-out. In a conceptually similar study, Whitelock, Kersbergen, et al. (2019) reported a drop-out rate of about 26%. It was therefore decided that 48 participants would be recruited for the intervention (four times the number which was required for the usability study), to allow for participant drop-out and infrequent usage. As it was expected that fewer people would drop out from the control group, 30 participants were allocated to that condition. The selected sample size was also sufficient to detect a large effect size with 80% power (based on Lally et al., 2008).

7.1.2 Ethical Approval

The study was granted ethical approval from the Cambridge Psychology Research Ethics Committee prior to data collection.

7.1.3 Participants

Participants were recruited from Prolific and had to meet the following inclusion criteria: aged between 18-40, resided in the UK, wanted to lose weight, had a BMI of 25 or more, had reliable access to weighing scales, had a Facebook Messenger account, willing to connect with the chatbot using a private Facebook Messenger account, ate at least 3 meals a day (this may or may not have included snacks), not following any weight loss diets or programmes and no current or past diagnoses of an eating disorder. Participants were asked to confirm they met all of the eligibility criteria at the beginning of the survey, and were screened out if they did not.

In total, 130 participants were assessed for eligibility and 78 people were fully enrolled in the study (see Figure 23). Forty-eight participants were allocated to the intervention group and 30 were allocated to the control group.

7.1.4 Design

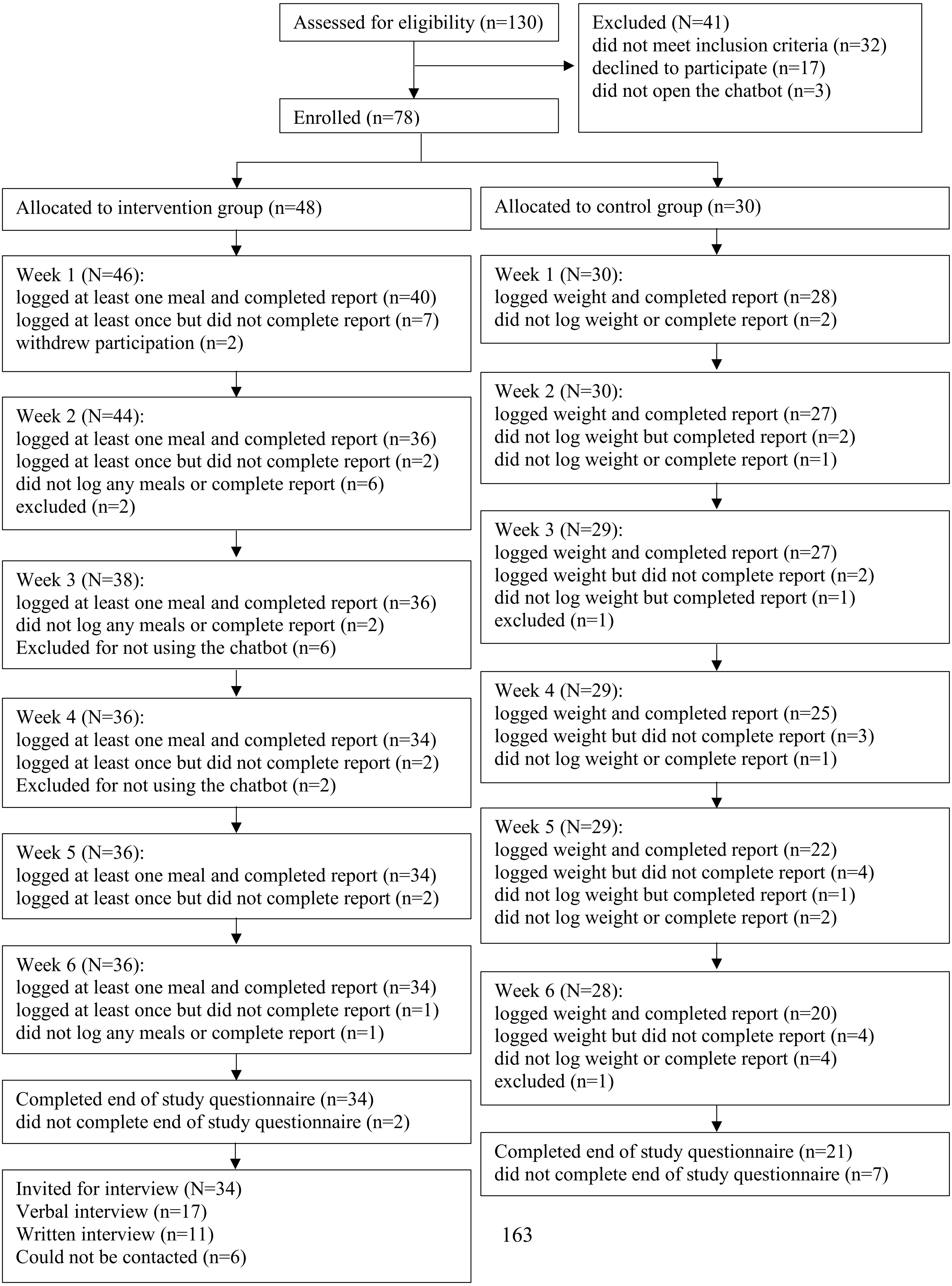
Participants were randomly allocated to one of two groups: the intervention group or the control group. In the intervention group, participants were asked to recall their most recently eaten meal every time they were about to eat another meal or snack, and they were asked to record this information and send it as a message to the chatbot. In the control group, participants were asked to weigh themselves once per week, and to send this information as a message to the chatbot. Both versions of the chatbot were hosted on Facebook Messenger.

7.1.5 Materials

7.1.5.1 Intervention Group Chatbot. The same chatbot was used in the present experiment, as in the usability study (Chapter 6). The only differences between these chatbots were that the imagination version of the chatbot was not used and that reminders were sent out by the chatbot if a meal had not been logged for three hours (as opposed to 23 hours, as in the usability study, Chapter 6).

Figure 23

Flowchart showing the number of participants at each stage of the trial



7.1.5.2 Control Group Chatbot. The control chatbot was similar to the intervention chatbot, but instead of instructing participants to recall a past meal, participants were asked to weigh themselves once a week and to record this information in the chatbot. The reminders were sent out once a week (on the weigh-in day). Once current weight was recorded in the chatbot, participants received an automatic reply from the chatbot saying 'That's saved, thanks! Please return to the chatbot next week to record your weight'.

7.1.5.3 Questionnaires. A number of the same questionnaires were used in the present study, as in the usability study (Chapter 6). These included: Six-Item Gastric Interoception Scale, Dutch Eating Behaviour Questionnaire (DEBQ – restraint), Mindful Eating Behaviour Scale (MEBS), Food Awareness and Acceptance Questionnaire (FAAQ), thought and guilt subscales of the Food Cravings Questionnaire (FCQ-T), PANAS-X (positive affect, negative affect, and guilt subscales) and Loss of Control Over Eating (LOCES). See Chapter 6 for descriptions of the questionnaires and scales used.

7.1.5.4 Acceptability Ratings. Participants in both groups were asked to rate the chatbot's acceptability before and after the trial. After watching the instructional video, participants were asked to rate how different the intervention seemed, and how much more/less appealing it was from other weight loss methods they have heard of. Expected efficacy was assessed by asking participants to rate how effective they thought the chatbot would be at helping them lose weight. They were also asked to rate how likely they thought the chatbot was to help them improve their eating habits and choices, and to rate how likely they were to enjoy or struggle with the chatbot. After completing the trial, participants were asked to rate the chatbot on the following aspects: how much they enjoyed using it, how easy and convenient they found it to be, how much they struggled to use the chatbot regularly, how awkward they found using the chatbot, how well the chatbot fitted into their daily routine, how much the chatbot helped them to improve their eating habits and memory for the food they ate, the extent to which the chatbot helped them to increase the amount of attention they paid to their meals, and how willing they would be to continue using the chatbot for a longer period of time. All ratings were given on a 1-5 Likert scale (see Appendix CC for anchors).

7.1.6 Procedure

7.1.6.1 Initial Survey. Participants first confirmed that they met the eligibility criteria, and then saw an explanation of what the trial was about and what they would have to do (the instructions were different for the two groups). Next, participants were asked to digitally sign a consent form, and to decide whether they were willing to use the chatbot as instructed for the next six weeks. Those who agreed to participate were asked to provide their demographic information: age, sex, ethnicity, employment status, level of education, weight and height. Then, all participants completed the Six-Item Gastric Interoception Scale, DEBQ restraint, MEBS, FAAQ, FCQ-T, PANAS-X and LOCES in a randomised order. Once these questionnaires were completed, participants were reminded that the study required them to use their Facebook Messenger account to access the chatbot, and were asked to specify what their Facebook username was. This was done so that engagement with the trial could be monitored, and all personal information was deleted after completion of the study. Then, participants in the intervention group viewed a short video (https://youtu.be/3-qF7ZeBG3A) which explained what the trial entailed and what the participants were supposed to do. Those in the control group were given written instructions with screenshots of the chatbot instead (the instructions were so simple that it was not feasible to develop another instructional video).

After watching the video, or reading through the instructions, participants were asked a few multiple-choice questions to test their understanding of the task. Participants could only proceed if all of these questions were answered correctly, but the questions could have been attempted an unlimited number of times. Next, participants rated various aspects of perceived acceptability of the chatbot. Lastly, they were instructed to begin using the chatbot right away and were given the link to connect their Facebook Messenger account with the chatbot. In order to assess whether energy intake would decrease following the intervention, participants were also asked to complete a log on intake24, a website which hosts a computerised dietary recall system (www.intake24.co.uk). The website asked participants to recall all meals from the past 24 hours, and helped them to identify all ingredients of the meals, as well as the portion sizes (which were assessed via photographs). Intake24 has good validity (Foster et al., 2019; Simpson et al., 2017) and has been described as user-friendly, simple to understand, as well as easy and enjoyable to use (Rowland et al., 2018). Participants completed this 24-hour log twice (before and after the trial) and it did not form a part of the intervention chatbot.

7.1.6.2 Weekly Reports. Participants in both the intervention and the control group were asked to complete a weekly report. The report was designed in Qualtrics and was completed online (see Appendix DD). Participants in both groups rated the acceptability of the chatbot on a 1-5 Likert scale anchored ‘strongly disagree’ to ‘strongly agree’, and were given the chance to describe their experience of using the chatbot over the past week. Participants were encouraged to comment on things such as whether they remembered to use the chatbot at the right time, whether they enjoyed using the chatbot and whether they struggled with anything in particular that week, but they were allowed to write about anything they deemed relevant. Those in the intervention group were also asked to record their current weight. Participants who did not log any meals for 14 consecutive days were withdrawn from the experiment. Those who were withdrawn were no longer asked to complete the weekly reports and were not invited to complete the final survey.

7.1.6.3 Final Survey. At the end of the six-week trial, participants who were not withdrawn from the trial for non-usage were asked to complete the same questionnaires they had initially completed before the trial, and were asked to report their current weight. Perceived acceptability of the chatbot was rated on a 1-5 Likert scale anchored 'strongly disagree' to 'strongly agree' (see Appendix Z). A debrief was provided at the end of the questionnaire.

7.1.6.4 Interview. All participants who were in the intervention group and completed the final questionnaire were invited for an online interview to discuss their experiences of using the chatbot. The semi-structured interviews were conducted online over Zoom with 17 participants. Another 11 participants did not wish to participate in a verbal interview, and so gave their responses on an online questionnaire instead. Six eligible participants could not be contacted, and so they did not take part in the interview. The questions asked during the verbal and written interviews were the same (see Appendix EE). In general, participants were asked to describe their experience of using the chatbot, what they enjoyed or struggled with in particular, and what effects (if any) the chatbot had on their eating behaviour. Only the participants' voices were recorded (webcams were off). Verbal interviews were recorded and transcribed by the experimenter. At the end of the interview participants were fully debriefed and thanked for their participation.

7.1.6.5 Payment. In total, participants could earn £20 if they completed all parts of the study. They were paid £1.70 for completing the initial questionnaire (about 20 minutes), £0.50 for completing an intake24 log before and after the trial (about 5 minutes each), £1 for each weekly report (there were 6 reports, each took about 2-3 minutes), £6.30 for completing the final questionnaire (approximately 20 minutes long) and £5 for participating in the interview (about 15 minutes long).

7.1.7 Analysis Details

Quantitative data was analysed with SPSS v.27. Outliers were defined as falling more than 3.29 or less than -3.29 SD from the mean (Kim, 2013). The effect of group (intervention vs. control) on ratings of chatbot acceptability, weight loss and eating-related cognition were examined with one-way ANOVAs or repeated-ANOVAs where pre- and post-trial ratings were available. To test whether any of the pre- to post-trial differences in eating-related cognition scores were a possible mechanism for weight loss, a mediation analysis was carried out using PROCESS (Hayes, 2017). A thematic analysis was conducted to analyse the qualitative data, based on the guidance of Braun and Clarke (2006) and Castleberry and Nolen (2018). Interviews were recorded, transcribed and imported into NVivo v.12. An inductive coding method was employed, where nodes were generated without trying to fit them into a pre-existing framework or expected themes (Braun & Clarke, 2006; Nowell et al., 2017). Generated nodes were firstly reviewed for clarity, relevance and redundancy, and were then merged, collapsed or removed as required. Then, nodes were collected into overarching themes, which were divided into sub-sections for clarity.

7.2 Results

7.2.1 Participant Exclusion

None of the BMIs calculated met the criteria for being an outlier. Despite all participants confirming that they met the eligibility criteria of BMI ≥ 25kg/m^2, in practice, six participants (of which five were in the intervention group) had a BMI which was lower (*M*=24.22, *SD*=0.99, range 22.39- 24.98). Of these, two (both in the intervention group) dropped out before the end of the trial. Excluding the four remaining participants with a BMI<25kg/m^2 did not significantly affect the results of the main analyses.

7.2.2 Participant Demographics

The two groups did not differ significantly in terms of baseline characteristics, including BMI, age and dietary restraint (see Table 32). However, average baseline BMI in the intervention group fell into the ‘overweight’ category, whereas average BMI of the control group fell into the ‘obese’ category. Although this difference was not statistically significant, main analyses were re-run with baseline BMI as a covariate, which was not significant in any of the analyses (see Appendix FF). The sample predominantly consisted of White females with overweight/obesity who were employed. In both groups, approximately half of the participants completed a higher education course (undergraduate and above). Participants also did not differ on most aspects of cognition, however the intervention group reported focussing on their food more whilst eating and having a higher positive affect in the past week. Given that no other group differences were significant, and the fact that the *p* values were close to the .05 threshold, no further action pertaining to these differences was taken.

Table 32

Comparison of baseline participant characteristics of the intervention and control groups

	Intervention (n=48)	Control (n=30)	
Sex (F/M)	38/10	21/9	$X^2(1)=0.84$, $p=.359$
Age	30.35 (5.46)	29.63 (6.65)	$F(1,76)=0.27$, $p=.604$
Baseline weight	84.33 (16.68)	89.63 (18.78)	$F(1,76)=1.69$, $p=.197$
Baseline BMI	29.56 (4.90)	31.39 (6.00)	$F(1,76)=2.18$, $p=.144$
Normal weight (BMI≥18.5 and <25)	n=5 (10.4%)	n=1 (3.3%)	
Overweight (BMI≥25 and <30)	n=25 (52.1%)	n=15 (50.0%)	
Obese (BMI≥30)	n=18 (37.5%)	n=14 (46.7%)	
Baseline self-reported 24-hour intake (kcal)	2146.48 (1046.41)	1987.28 (1142.68)	$F(1,76)=0.40$, $p=.530$
Occupation: Employed	n=35 (72.9%)	n=25 (83.3%)	
Occupation: Student	n=6 (12.5%)	n=2 (6.7%)	
Occupation: Unemployed/Other	n=7 (14.6%)	n=3 (10.0%)	
Education: A-levels or below	n=22 (45.8%)	n=17 (56.7%)	
Education: Undergraduate	n=13 (27.1%)	n=9 (30.0%)	
Education: Higher	n=13 (27.1%)	n=4 (13.3%)	
Ethnicity: White/White British	n=40 (83.3%)	n=25 (83.3%)	
Ethnicity: Black/Black British	n=4 (8.3%)	n=0 (0.0%)	
Ethnicity: Mixed/Multiple	n=0 (0.0%)	n=1 (3.3%)	
Ethnicity: Asian/Asian British	n=4 (8.3%)	n=4 (13.3%)	

Baseline 6-item Gastric Interoception Scale	3.34 (0.53)	3.19 (0.49)	F(1,76)=1.50, *p*=.224
Baseline MEBS: Eating while focussing on food	3.95 (0.70)	3.63 (0.67)	*F*(1,76)=4.14, *p*=.045*
Baseline MEBS: Eating while paying attention to hunger and satiety cues	3.18 (0.81)	2.97 (0.77)	*F*(1,76)=1.31, *p*=.257
Baseline MEBS: Being aware of eating	3.06 (1.15)	2.89 (1.15)	F(1,76)=0.42, *p*=.520
Baseline MEBS: Eating while not being distracted	2.61 (0.77)	2.67 (0.65)	*F*(1,76)=0.12, *p*=.728
Baseline Food Acceptance (FAAQ)	40.19 (5.03)	41.37 (7.57)	F(1,76)=0.68, *p*=.411
Baseline DEBQ restraint	2.64 (0.61)	2.58 (0.67)	F(1,76)=0.20, *p*=.660
Baseline Food Cravings score (FCQ-T)	3.05 (0.80)	3.15 (0.96)	*F*(1,76)=0.26, *p*=.613
Baseline Loss of Control over Eating (LOCES)	2.76 (1.06)	2.90 (1.01)	*F*(1,76)=0.32, *p*=.575
Baseline negative affect (PANAS)	2.18 (0.79)	2.34 (0.96)	*F*(1,76)=0.70, *p*=.407
Baseline positive affect (PANAS)	2.77 (0.80)	2.40 (0.76)	*F*(1,76)=4.04, *p*=.048*
Baseline guilty affect (PANAS)	2.31 (0.88)	2.53 (1.11)	*F*(1,76)=0.91, *p*=.344

Note. Standard Deviations are presented in parentheses. Please see Methods for details on scales used. Higher ratings indicate greater endorsement.
*significant at *p*<.05.

Quantitative Analysis

7.2.3 Pre-trial Impressions

Overall, participants rated the two chatbot versions similarly in terms of perceived acceptability (see Table 33). However, participants rated the likelihood that the chatbot will help them to lose weight as significantly higher in the intervention group, than in the control group, suggesting that the intervention had good expected efficacy.

Table 33

Pre-trial acceptability ratings of the two versions of the chatbot

	Intervention	Control	
Intervention different to others	3.17 (1.33)	3.00 (1.31)	$F(1,76)=0.29$, $p=.589$
Intervention appealing	3.69 (0.88)	3.53 (0.94)	$F(1,76)=0.54$, $p=.465$
Intervention will lead to weight loss	3.50 (0.95)	3.27 (0.87)	$F(1,76)=1.20$, $p=.278$
Intervention will help to improve eating habits	3.58 (0.79)	2.87 (0.94)	$F(1,76)=13.07$, $p=.001$*
Intervention likely to be enjoyable	3.52 (1.07)	3.30 (1.09)	$F(1,76)=0.78$, $p=.381$
Likely to struggle to use the intervention regularly	2.17 (1.04)	2.23 (1.14)	$F(1,76)=0.07$, $p=.791$

Note. Standard Deviations are presented in parentheses. Ratings made on a 1-5 scale. Higher ratings indicate greater endorsement.
*significant at $p<.001$.

7.2.4 Drop-Out

Initially, 48 participants were allocated to the intervention group, and 30 were allocated to the control group. By the end of the trial, 25% (n=12) of the intervention group participants dropped out from the study, compared to 6.7% (n=2) of control group participants. In the intervention group, there were no significant differences in age ($t[46]=1.02$, $p=.312$) or baseline

BMI (t[46]=0.01, p=.991) between those who dropped out and those who completed the study. There were also no significant differences between those who dropped out and those who remained in terms of the pre-trial assessments of the chatbot (all p values >.20).

7.2.5 Missing Data

Participants recorded their weight once per week – those in the intervention group were asked to state their weight whilst completing the weekly report, and those in the control group were asked to log their weight in the chatbot. Thus, participants reported their weight at eight different time-points (initial survey, weeks 1-6, and the final survey). Not all participants recorded their weight on all occasions resulting in missing data. Little's MCAR test was not significant, $X^2(48)=37.02$, p=.875, implying that these data points were missing at random. Each missing data point was replaced using the last observation carried forward method (i.e. weight from previous week was used). In total, 19 data points were imputed.

Of those that remained in the intervention group to the end of the trial, 94.4% (n=34) completed the final questionnaire, whereas only 75% (n=21) of control group participants completed it. Therefore, data for the final survey items for these nine participants was imputed using Multiple Imputation in SPSS. Participants who did not complete the final questionnaire (n=9) did not significantly differ from those who completed it in terms of age, $F(1,62)<.01$, p=.972, pre-intervention weight, $F(1,62)<.01$, p=.995, or pre-intervention DEBQ restraint score, $F(1,62)=.01$, p=.908. Therefore, it was assumed that final questionnaire data was missing at random. For each missing score, the following variables were included in the imputation model as predictors: group, age, sex, ethnicity, employment status, education level, baseline weight and baseline score of the variable being imputed (where available). Five imputations were generated for each variable, and their average was used in the analysis. Out of those participants who did not drop out from the study, two participants did not complete their Intake24 logs pre-trial, and 10 participants did not complete the log post-trial. These missing data points were also imputed using Multiple Imputation, in the same way as described above.

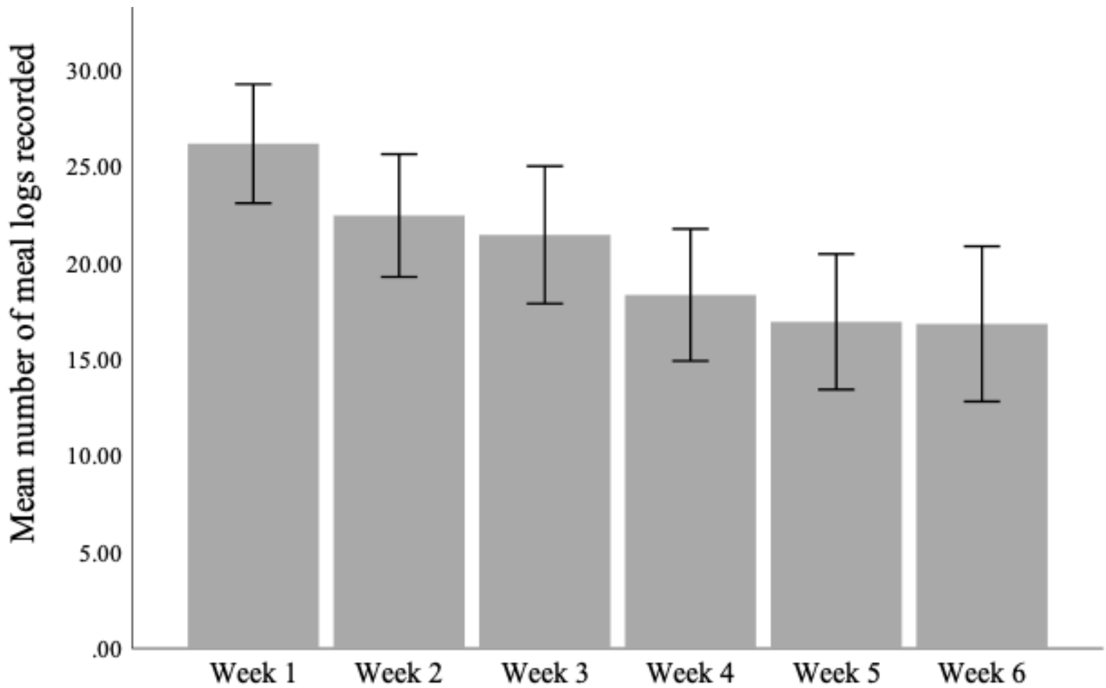
7.2.6 Chatbot Usage and Adherence

On average, participants logged 122 meals over the trial period (SD=52.24; range: 27-290). A repeated-measures ANOVA was conducted to explore how the number of meals logged each week changed over time (see Figure 24). This analysis was performed only for the intervention group participants (as there was no meal-logging in the control condition). As Mauchly's test of sphericity was significant (X^2[14]=83.63, p<.001), and therefore the assumption of sphericity was violated, the Greenhouse-Geisser correction was applied. The ANOVA revealed a significant effect of time on the number of meals recorded in the chatbot, $F(2.36, 82.60)=13.66$, $p<.001$, $\eta_p^2=.281$. Post-hoc repeated contrasts revealed that there was a significant decrease in the number of meals logged between weeks 1 and 2, $F(1,35)=13.09$, $p=.001$, $\eta_p^2=.272$, as well as between weeks 3 and 4, $F(1,35)=6.70$, $p=.014$, $\eta_p^2=.161$. No other contrast was significant.

Over the course of the trial, 66.7% of participants recorded at least one meal log each week, and this number increased to 88.9%, if those who dropped out from the study were not included in the analysis. On average, participants who completed the trial used the chatbot for 34.56 days ($SD=8.17$), out of the 42 days of the trial (82.2%). This meant that an average of 3.47 logs ($SD=1.10$) were made on each day the chatbot was used, indicating that the chatbot was mostly used as intended. When the total number of logs was averaged across all 42 experimental days, the average number of logs per day was 2.90 ($SD=1.24$).

Figure 24

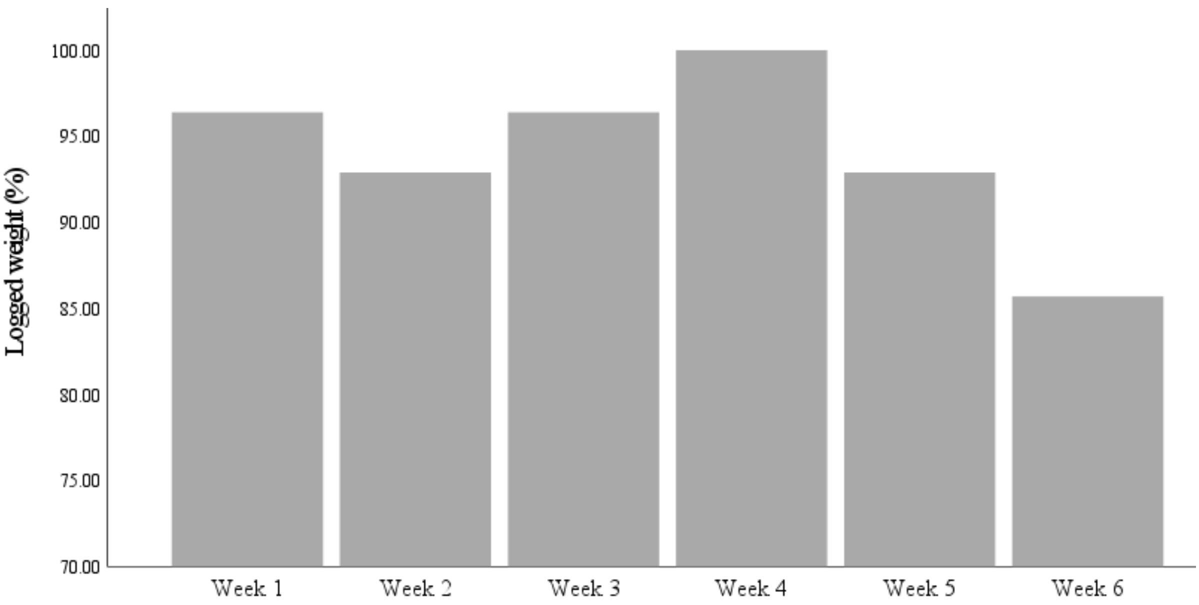
Mean number of meals logged in the intervention chatbot each week (n=36; error bars represent 95% CI)



Contrastingly, in the control group there were no significant differences in terms of the number of participants who logged their weight in the chatbot each week, as determined by a Cochran's Q test, $X^2(5)=6.09$, $p=.298$ (see Figure 25).

Figure 25

Proportion of participants who logged their weight in the control-group version of the chatbot each week



7.2.7 Pre- to Post-Trial Changes in Acceptability

Differences in pre- to post-trial acceptability ratings of the chatbot (see Table 34) were assessed with a repeated-measures ANOVA, which included group as the independent variable. There was a significant difference between how much participants thought they would enjoy using the chatbot and how much they actually enjoyed using it, $F(1,62)=5.48$, $p=.022$, but there seemed to be no significant differences between the two groups, $F(1,62)=1.08$, $p=.303$. There was also a significant increase between perceived and actual struggle to use the chatbot regularly, $F(1,62)=17.42$, $p<.001$, $\eta_p^2=.219$, and the interaction term was significant, $F(1,62)=6.23$, $p=.015$, $\eta_p^2=.091$. Post-hoc paired *t*-tests revealed that the difference between perceived and actual struggle ratings was significantly different in the intervention group, $t(35)=-5.30$, $p<.001$, Cohen's $d_z=-0.88$, but it was not significant in the control group, $t(27)=-1.06$, $p=.301$. Lastly, there seemed to be a mismatch between participants' expectations regarding how likely the chatbot was to help improve their eating habits and their actual experiences, as demonstrated by a significant decrease in pre- to post-trial ratings, $F(1,62)=14.67$, $p<.001$, $\eta_p^2=.191$. The interaction between these score differences and group was significant, $F(1,62)=5.99$, $p=.017$, $\eta_p^2=.088$, and post-hoc paired *t*-tests revealed that pre-to post-trial differences were only significant for the intervention group, $t(35)=4.74$, $p<.001$, $d_z=0.79$, and not for the control group, $t(27)=0.92$, $p=.364$.

Table 34

Pre- and post-trial chatbot acceptability ratings for the two groups

	Intervention (n=36)		Control (n=28)	
	Pre-trial	Post-trial	Pre-trial	Post-trial
Will enjoy/ enjoyed using chatbot	3.53 (1.03)	2.97 (1.28)	3.36 (1.10)	3.14 (1.27)
Will struggle/ struggled to use chatbot regularly	2.03 (1.00)	3.31 (1.24)	2.14 (1.11)	2.46 (1.29)
Chatbot will help/helped to improve eating habits	3.58 (0.77)	2.61 (1.18)	2.89 (0.96)	2.68 (1.31)

Note. Standard Deviations are presented in parentheses. Ratings made on a 1-5 scale. Higher ratings indicate greater endorsement.

7.2.8 Post-Trial Ratings of Acceptability

Participants in the intervention group rated the chatbot to be significantly less convenient, less capable of fitting into their daily routine and more awkward to use, in comparison to the control group participants (see Table 35). The chatbot was equally easy to use for both groups, and the intervention chatbot did not seem to improve memory for recent meals, or increase attention paid to eating during mealtimes, over and above the control-group chatbot. Perhaps surprisingly, both groups were equally willing to continue to use the chatbot long-term.

Table 35

Post-trial ratings of acceptability for the two groups

	Intervention (n=36)	Control (n=28)	
Chatbot was convenient	3.00 (1.15)	3.82 (0.82)	$F(1,62)=10.28$, $p=.002$, $\eta_p^2=.142$*
Chatbot fit well into routine	2.83 (1.11)	3.82 (0.86)	$F(1,62)=15.11$, $p<.001$, $\eta_p^2=.196$**
Chatbot was awkward	3.67 (1.20)	2.50 (1.11)	$F(1,62)=16.01$, $p<.001$, $\eta_p^2=.205$**
Chatbot was easy to use	3.67 (1.07)	4.11 (1.07)	$F(1,62)=2.68$, $p=.107$

Chatbot improved memory for recent meals	3.31 (1.14)	2.82 (1.25)	$F(1,62)=2.61$, $p=.111$
Chatbot increased attention paid to meals	3.39 (1.10)	2.82 (1.31)	$F(1,62)=3.55$, $p=.064$
Willing to continue to use the chatbot long-term	2.83 (1.14)	3.21 (1.34)	$F(1,62)=1.51$, $p=.223$

Note. Standard Deviations are presented in parentheses. Ratings made on a 1-5 scale. Higher ratings indicate greater endorsement.
*significant at $p<.05$; **significant at $p<.001$

7.2.9 Weight Loss

There were some discrepancies in terms of the weight reported by participants between the initial survey and week 1 report (a seven-day gap), and between weight reported during week 6 and that reported in the final survey (a one-day gap). Two participants reported they lost 12kg in one week (between the initial survey and week 1 report) and one participant reported that she lost 6kg in one day (between week 6 report and final survey). As all of these differences had a *z*-score higher than 3.29, they were excluded from further weight loss analyses.

A repeated-measures ANOVA revealed that participants lost a significant amount of weight pre- to post-trial, $F(1,59)=18.15$, $p<.001$, $\eta_p^2=.235$ (see Table 36). However, the interaction between group and weight loss was not significant, $F(1,59)=1.17$, $p=.283$, suggesting participants in the intervention group did not lose significantly more weight than the control participants (see Table 36). Next, a repeated-measures ANOVA, including weight reported at all eight time-points, was conducted. As Mauchly's test was significant, $X^2(27)=288.89$, $p<.001$, the Greenhouse-Geisser correction was applied. The overall model was significant, $F(2.73,160.87)=10.71$, $p<.001$, $\eta_p^2=.154$, but the interaction term was not, $F(2.73, 160.87)=0.64$, $p=.577$. Repeated contrasts revealed no significant differences between reported weight on a week-to-week basis, suggesting weight loss was gradual over the six-week period (see Figure 26).

Table 36

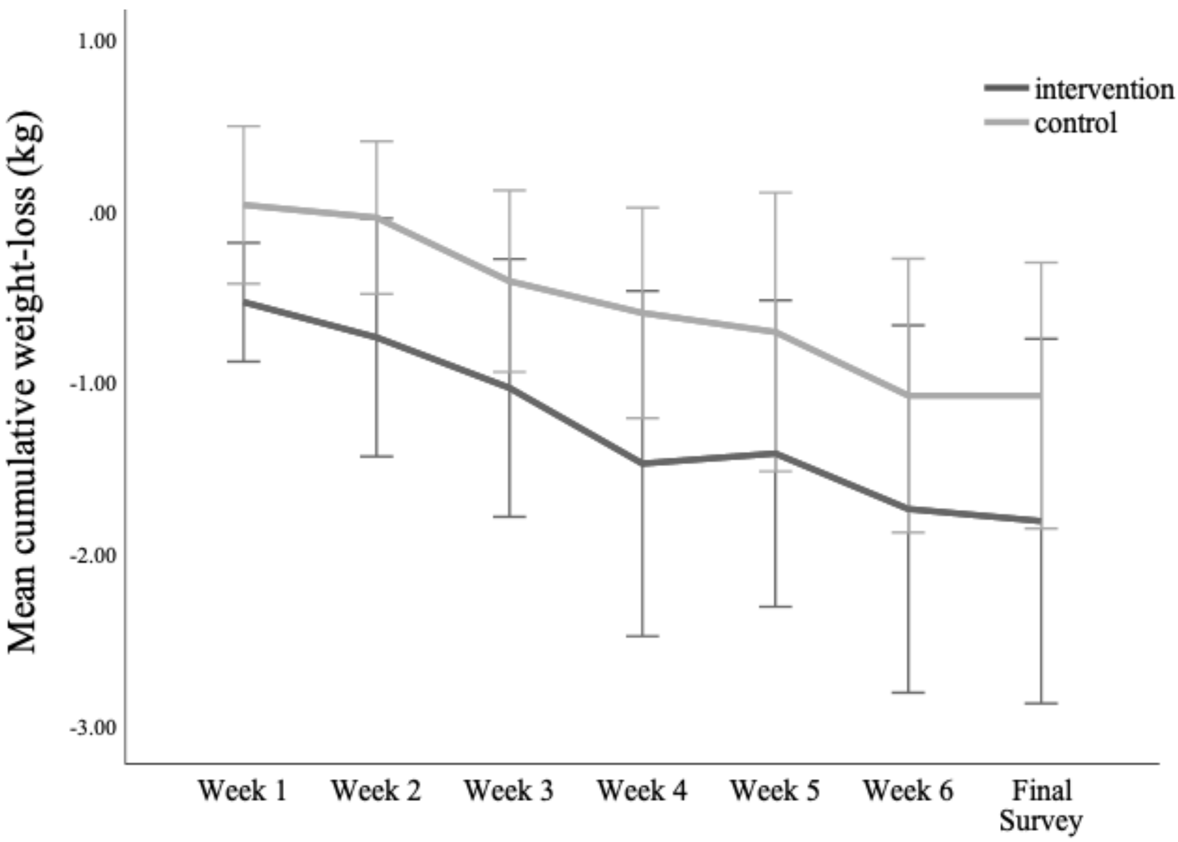
Mean pre- and post-trial weight, as well as mean weight loss of participants in the two groups

	Intervention group (n=34)	Control group (n=27)
Mean weight pre-trial (kg)	83.65 (14.19)	89.37 (17.33)
Mean weight post-trial (kg)	81.84 (13.12)	88.30 (18.22)
Mean weight loss (kg)	-1.81 (3.04)	-1.07 (1.96)

Note. Standard Deviations are presented in parentheses.

Figure 26

Line graph showing mean cumulative weight loss throughout the trial, for the intervention and control groups (error bars represent 95% CI)



The proportion of participants who gained or lost weight was not different between the two groups, $X^2(4)=3.33$, $p=.505$ (see Table 37).

Table 37

Proportion of participants who lost or gained weight, or whose weight remained the same in the two groups

	Intervention (n=34)	Control (n=27)
Gained weight	23.5% (n=8)	22.2% (n=6)
No weight change	11.8% (n=4)	22.2% (n=6)
Lost <5% body weight	52.9% (n=18)	44.4% (n=12)
Lost 5-10% body weight	5.9% (n=2)	11.1% (n=3)
Lost >10% body weight	5.9% (n=2)	0% (n=0)

7.2.10 Self-Reported Energy Intake

Participants completed a 24-hour meal log both before and after the trial. There was a significant decrease pre- to post-trial in terms of how many calories participants reported eating over a 24-hour period, $F(1,62)=5.56$, $p=.022$, $\eta_p^2=.082$, but the interaction was not significant, $F(1,62)<.01$, $p=.981$ (see Table 38).

Table 38

Self-reported energy intake (in kcal) over a 24-hour period, pre- and post-trial, for the two groups

	Intervention (n=36)		Control (n=28)	
	Pre-trial	Post-trial	Pre-trial	Post-trial
Self-reported intake (kcal)	1862.79 (734.37)	1538.55 (680.60)	2007.50 (1176.57)	1676.45 (928.16)

Note. Standard Deviations are presented in parentheses.

7.2.11 Pre- to Post-Trial Changes in Cognition

A series of mixed ANOVAs, with group as the between-subjects variable and pre- to post-trial cognitive measure scores as the within-subjects variable, were conducted (see Table 39).

Table 39

Pre- and post-trial cognitive measure scores, as a function of group

	Intervention		Control	
	Pre-trial	Post-trial	Pre-trial	Post-trial
Six-Item Gastric Interoception Scale	3.42 (0.53)	3.38 (0.54)	3.19 (0.50)	3.19 (0.48)
MEBS facet				
Eating while focussing on food	3.94 (0.70)	3.90 (0.70)	3.70 (0.63)	3.78 (0.82)
Eating while paying attention to hunger and satiety cues	3.20 (0.78)	3.08 (0.74)	2.90 (0.75)	3.08 (0.86)
Being aware of eating	3.02 (1.23)	3.18 (1.08)	2.89 (1.19)	2.95 (0.97)
Eating while not being distracted	2.73 (0.79)	2.85 (0.63)	2.69 (0.66)	2.74 (0.63)
FAAQ scores	40.53 (4.51)	42.78 (6.26)	40.93 (7.45)	44.14 (5.12)
DEBQ restraint	2.69 (0.55)	2.99 (0.44)	2.54 (0.67)	2.57 (0.74)
Food cravings	3.02 (0.85)	2.94 (0.95)	3.17 (0.99)	3.07 (0.87)
LOCES	2.74 (1.12)	2.37 (0.88)	2.85 (1.03)	2.69 (1.07)
PANAS Negative affect	2.15 (0.75)	2.31 (0.88)	2.32 (0.99)	2.08 (0.81)
PANAS Positive affect	2.94 (0.76)	2.79 (0.80)	2.35 (0.76)	2.80 (0.88)
PANAS Guilt	2.33 (0.90)	2.28 (1.03)	2.52 (1.15)	2.53 (1.13)

Note. Standard Deviations are presented in parentheses. See method for details on scoring. Higher ratings indicate greater endorsement.

7.2.11.1 Interoceptive Awareness. There were no significant differences in terms of pre- to post-trial scores on gastric interoceptive awareness, $F(1,62)=0.07$, $p=.796$. There were no differences between the two groups, $F(1,62)=0.05$, $p=.820$.

7.2.11.2 Tendency to Eat Mindfully. Neither of the four facets of the Mindful Eating Behaviour Scale were affected pre- to post-intervention. There were no changes to ratings of eating while focussed, $F(1,62)=0.03$, $p=.860$, or to eating while paying attention to hunger and satiety cues, $F(1,62)=0.07$, $p=.799$. Similar ratings of being aware of eating were reported at both time-points, $F(1,62)=0.60$, $p=.440$, and there were no differences in reported scores of eating while not being distracted, $F(1,62)=0.81$, $p=.372$. None of the interaction terms between the groups were significant (all p values >.05).

7.2.11.3 Control Over Impulsive Eating. Food Acceptance and Awareness (FAAQ) scores significantly increased pre- to post-intervention, $F(1,62)=8.24$, $p=.006$, $\eta_p^2=.117$. However, the interaction term was not significant, $F(1,62)=0.26$, $p=.614$.

7.2.11.4 Dietary Restraint. Dietary restraint scores significantly increased after the intervention, $F(1,62)=5.50$, $p=.022$, $\eta_p^2=.081$. However, there was no interaction between the change in scores and group, $F(1,62)=3.58$, $p=.063$.

7.2.11.5 Food Cravings and Loss of Control Over Eating (LOCES). As expected, food cravings scores were not affected by the trial, $F(1,62)=1.38$, $p=.245$, and the interaction term was not significant, $F(1,62)=0.01$, $p=.919$. However, scores on the loss of control over eating scale significantly decreased post-trial, $F(1,62)=6.54$, $p=.013$, $\eta_p^2=.095$. The interaction term was not significant, $F(1,62)=1.04$, $p=.312$.

7.2.11.6 Affect. Using the chatbot for six weeks did not seem to impact negative affect, $F(1,62)=0.15$, $p=.697$ (interaction: $F[1,62]=3.71$, $p=.059$). Positive affect did not seem to be impacted overall, $F(1,62)=1.99$, $p=.164$, however the interaction term was significant, $F(1,62)=7.46$, $p=.008$, $\eta_p^2=.107$. Post-hoc paired-samples *t*-tests revealed that the pre- to post-trial difference in positive affect scores was not significant in either the intervention group, $t(33)=1.03$, $p=.310$, or in the control group, $t(20)=-1.49$, $p=.151$, but that the direction of the trend was different (such that positive ratings trended upwards for the control group and downward for the intervention group). Guilt ratings remained unchanged pre- to post-trial in both groups, $F(1,62)=0.03$, $p=.869$ (interaction: $F[1,62]=0.06$, $p=.813$).

7.2.11.7 Mediators of Weight Loss. Variables which had significant pre- to post-trial increases or decreases were assessed as potential mediators of the effect the chatbot had on weight loss. Although no group differences were found in terms of weight loss, a mediation analysis was still conducted to assess whether the a x b path is significant, which would imply partial mediation.

There were no group differences in pre- to post-trial differences in self-reported intake, $b=-39.60$, $t(59)=-0.14$, $p=.889$ (a path). Differences in self-reported intake predicted the magnitude of weight loss, $b=0.001$, $t(58)=2.01$, $p=.049$, 95% CI[0.000, 0.001] (b path), but the a x b path interaction was not significant, 95% CI[-0.59, 0.35]. The magnitude of the difference between pre- and post-trial FAAQ scores was not predicted by group, $b=0.89$, $t(59)=0.45$, $p=.655$ (a path). FAAQ score differences did not predict weight loss, $b=-0.04$, $t(58)=-0.80$, $p=.430$ (b path) and the indirect effect (a x b path) was not significant, 95% CI[-0.40, 0.14].

Pre- to post-trial differences in DEBQ restraint were comparable between the two groups, *b*=-0.27, *t*(59)=-1.86, *p*=.068 (*a* path), and the magnitude of the difference in restraint scores did not predict weight loss, *b*=-0.49, *t*(58)=-0.81, *p*=.422 (*b* path). The *a* x *b* interaction did not reach statistical significance, 95% CI[-0.36, 0.42]. Lastly, pre- to post-trial differences in LOCES scores were not different between the two groups, *b*=0.20, *t*(59)=0.92, *p*=.363 (*a* path). The magnitude of the pre- to post-trial difference in LOCES scores did not predict weight loss, *b*=0.28, *t*(58)=0.67, *p*=.508 (*b* path), and the indirect effect (*a* x *b* path) was not significant, 95% CI[-0.18, 0.43].

An additional linear regression was carried out to assess whether the total number of meal-logs predicted weight loss. This analysis was only done for those in the intervention group (as the control group participants did not log any meals). The analysis revealed that the magnitude of weight loss in the intervention group was not predicted by the total number of meals logged over the six-week period, *b*=-0.01, *t*(34)=-0.85, *p*=.403. As almost all participants in the control group logged their weight once per week, it was not appropriate to explore whether weight loss was predicted by frequency of weight-logging. The magnitude of weight loss was also not predicted by the number of days on which the chatbot was used (out of the 42 days that the trial lasted), *b*=-0.02, *t*(34)=-0.23, *p*=.817, but it is worth noting that 75% of the sample accessed the chatbot on at least 30 out of 42 test days (adherence > 70%).

Qualitative Analysis

7.2.12 Theme 1: Initial Appeal of the Chatbot

7.2.12.1 Novelty. Almost everyone who participated found the chatbot to be initially appealing. Only one participant said that the chatbot ‘wasn’t visually attractive for me at all, because it’s text based’ (P8). On the other hand, a large number of participants noted that the chatbot ‘was quite an innovative idea’ (P18) and that ‘it was something new’ (P13). Some users pointed out that they ‘never really done anything like that before’ (P1) and that the chatbot was ‘quite a good idea’ (P2) specifically because ‘it was different than other things I was using so far’ (P2). Because of the novelty of the chatbot, many participants were willing to ‘give it a go (…) see if it worked’ (P14), perhaps even despite having tried other methods previously.

7.2.12.2 Reasons for Enrolling in the Study. A few people decided to enrol in the study because they were ‘intrigued’ (P5) and ‘wanted to see how it will be’ (P20). One participant said: ‘I wasn’t sure how it would work, in terms of weight loss, but I thought ‘well, it’s probably the simplest weight loss thing that I’ve seen suggested’ and it’s quite novel, so…’

(P7). The chatbot was perceived as 'easy to use' (P11), 'intuitive' (P23) and as a tool which needed 'little effort' (P7). One user liked the idea of the chatbot because 'there was plenty of freedom, I could file everything I wanted' (P4). The majority of participants decided to start using the chatbot because they saw its potential to help them 'to eat responsibly' (P20) and to be 'more conscious about what I was eating' (P11). Others were enticed because they were 'expecting to lose weight' (P24), with one user noting 'I'm a younger person wanting to lose a little bit of weight and become healthier' (P27) and another saying 'I was quite excited (…) I needed to loose 6kgs (…) I was basically looking for some sort of motivation and this study came along and helped me to control my portion size' (P21).

7.2.13 Theme 2: Design and Usability

7.2.13.1 Ease of Use. Many participants praised the chatbot's design because 'it was easy to do (…) very straightforward' (P1) and 'not anything complicated' (P2). In addition, one user said: 'everything I was eating, I could easily describe (…) so that was kind of easy to use' (P11). People thought the chatbot was 'self-explanatory' (P22) and 'very clear' (P4), and that 'the whole process was really well explained' (P6). One participant said: 'I liked how (…) right before your next meal, it would tell you exactly what you need to do (…) it told you what you need to log, so that was good' (P1).

7.2.13.2 Chatbot Concept. There were a few people who disliked the timing of the meal logs, and they said they would have preferred to 'log food after you eat it, instead of logging the previous meal' (P25). One participant said she found it 'a wee bit awkward' and said: 'I would have preferred to just eat my breakfast, then record it, eat my lunch, then record it (…) so the two events were sort of happening at the same time' (P5). Another participant pointed out that she 'kept on getting out of sync (…) quite a few times I've put down what was in front of me, instead of the one before' (P7) and this resulted in confusion as to what she should record at the next meal.

7.2.13.3 Choice of Platform. About half of the participants felt that 'the idea of it being on Facebook Messenger was a good thing, you didn't have to download anything extra, so I think it was quite appealing from that point of view' (P15). One participant said: 'because it was just Facebook Messenger, I thought it was easy, because my Messenger is nearly always open anyway, so it was quite easy to use' (P3). Another added 'the fact that it was on Facebook Messenger, that was definitely a positive for me, because it was easily accessible' (P5) and one participant remarked 'the majority of young people use (…) Facebook messenger so it seemed like a very good idea' (P18). Those who liked having the chatbot on Facebook Messenger said that was because 'I'm one of those people that are kind of glued to their phone anyway (…) so I always have it with me' (P16), and because 'I use the messaging app anyway, it was like 'oh yeah, I need to do that!', so it was handy having it in the message thing' (P1).

However, there were also users who disliked the chatbot being on Facebook Messenger. One participant said she 'found it quite difficult to remember to use' (P11) the chatbot because, as she explained, 'I don't really use Facebook Messenger very often' (P11). She added: 'it would be easier for me if it could be translated to (…) an app that I do use more regularly, which is kind of similar to Facebook Messenger, such as WhatsApp' (P11). Another participant said that 'a standalone app would have been much better' (P12). One participant even said that they would only consider continuing to use the chatbot if it was 'like an app on your phone, separate to Messenger' (P6).

7.2.13.4 Comparison to Other Apps. The chatbot was frequently compared to other weight loss apps available, and most of these comparisons were favourable to the chatbot. Participants noted that 'it wasn't as complicated as for example using apps, where you have to weigh your meals and stuff like that' (P2) and that 'things like MyFitnessPal [are] quite (…) time consuming, like splitting the meal up into different components and finding the right brand, I find that quite hard to sustain' (P16). Even though participants acknowledged that 'it would be more (…) beneficial if I could add all that stuff (…) but I know that obviously takes a little bit longer and is more difficult' (P2), and that being able to quickly describe a previous meal was 'lot more manageable' (P16). Users found it beneficial that they were not asked to 'work out how much everything weighed (…) the chatbot was so much easier to just input and leave, not mess about and figure things out' (P17).

A small number of participants found other apps to be better than the chatbot. One participant said that Fitbit 'spurs you on, it tells you you're doing really well (…) it recognises that, kind of gives you a little nudge, comment' (P13). It was also pointed out that with the other apps, 'it doesn't really matter when you log (…) whereas this, you kind of had to remember to do it every time' (P9), implying it was difficult for that participant to log just before a meal, as this time frame was too specific for them.

7.2.13.5 Remembering to Use the Chatbot. Participants frequently reported that they only 'forgot completely once or twice during the whole six weeks (…) about 95% of the time it [logging] was on time' (P9) and that they 'remembered to use it regularly, however there was the odd day where I would forget' (P13). Many users relied on their own memories to remember to use the chatbot, for example one participant said: 'most of the time it was in my mind that I have to write down before eating' (P20) and another said 'I learned to use it (…) it wasn't very hard to remember to do it, to be honest' (P12).

The majority of people pointed out that they only struggled to remember to use the chatbot in certain situations. Some users said they forgot to log because 'I didn't have my phone with me when I would go into the kitchen' (P10) or because 'when I didn't have my phone on me, I struggled to log a lot of lunchtimes' (P27). A number of people also commented that they 'struggled logging small snacks' (P25). Others said they forgot when they were 'distracted' (P19), for example by being 'more focussed on preparing a meal for my daughter and for myself' (P2), or 'with kids getting ready for school' (P24). Some users remarked that they would struggle to remember to log their meals when they were 'in a meeting at work or on a longer phone call' (P21) or when they were 'out and about' (P22). Most frequently, users struggled to remember to use the chatbot at the right time 'out of my normal routine' (P11). This was commonplace during 'Easter' (P1, P11), 'weekends' (P10) and 'nightshifts' (P18). As one participant put it, 'sometimes life got in the way' (P22).

Unexpectedly, a large number of participants reported struggling to remember to use the chatbot near the end of the trial, at a time when one might have expected them to develop a habit of using it. One participant said 'I didn't mind it at first, but towards the end it was quite sluggish (…) obviously towards the end that's when I whacked it' (P17), and another added 'towards the end I started using it less because I didn't remember (…) I felt like it became more of a chore to do and I would only log when I'd remember' (P25). Other people mentioned that 'as time went on I did find myself forgetting about it and then having to catch up' (P26) and 'having to remember to use it on time, it was an effort, especially towards the end' (P9).

7.2.13.6 Reminders. In order to help participants to remember to log their meals, the chatbot sent out a reminder three hours after a meal was logged. However, for the majority of participants, reminders were not only the most problematic aspect of the chatbot, but also the primary reason why they did not enjoy the trial as much as they could have. It is worth noting that in three instances a technical error occurred, and the reminders were not sent at the correct time – instead of being sent out every three hours, some participants received them minutes after logging their meal, or at varying delays which were not consistent and were too frequent. At some point, these participants stopped receiving reminders for a few days. Unfortunately, it is not known what caused this error, however, as this is not a design flaw per se, this issue will not be addressed further.

The biggest issue participants seemed to have with the reminders was that ‘you’d get a reminder three hours later, and that wasn’t necessarily when I was eating’ (P11). This was problematic because ‘the notification would pop up, and I dismissed it, but then that was the only reminder you had’ (P11). This situation was quite common, with a user reporting ‘I saw the reminders popping up, but they weren’t really with my mealtimes, because my food schedule isn’t as regular’ (P2), and another saying ‘as they were not on my timing, I didn't read them when received, so they stayed in my notifications’ (P20). Others also agreed that the reminders ‘came at random times, not near a mealtime’ (P14) and didn’t ‘make sense (…) because I would be at work, or like I wouldn’t be eating at those times’ (P1). It was also noted by some that the frequent reminders encouraged them to eat, perhaps even if they weren’t hungry. One participant said that when she got a reminder she thought ‘why would you have expected me to eat again, it’s only three hours. So do you want me to eat again?!’ (P7) and another said: ‘at first I wasn’t sure if it was telling me that I should be eating at that time’ (P3).

Another problem seemed to be notifications which were ‘annoying’ (P22) when they came through ‘late at night’ (P22). Participants complained that the reminders came through ‘at silly o’clock’ (P24), ‘during my sleep, like every time I was taking a nap’ (P12) or ‘just as I was going off to sleep’ (P15). Users deemed such late reminders ‘weird’ (P9), ‘annoying’ (P12) and ‘random’ (P5) as they said: ‘I’m not gonna (sic) eat overnight!’ (P9). One person said that she ‘wouldn’t really look at’ the reminders which appeared overnight, ‘so in the morning it kind of wouldn’t be relevant, or wouldn’t really be useful to me’ (P10). Late night reminders seemed to interfere with some participants’ sleep, as they said ‘I always forget to put my phone on silent (…) I did learn eventually (…) I learned to put ‘do not disturb on’, so that taught me a lesson’ (P16) and another saying ‘the last reminder in the evening usually, it was coming quite late (…) if I forgot to put it on silent, it was like 11pm or midnight when the reminder was coming through’ (P2). Some participants decided not to mute the notifications on their phones as they did not want to ‘forget it accidentally’ (P16), but others said ‘I have my notifications turned off (…) ‘cos I’d have a notification come through at something like three o’clock in the morning (…) I just started to completely ignore them’ (P7). For one participant, the reminders were so unhelpful that she ‘had to put in a reminder to remind me’ to log a meal (P8). Another one added ‘it was all on myself to remember to enter my meals’ (P4).

7.2.14 Theme 3: Acceptability

7.2.14.1 Motivation. Participants were asked to specify what motivated them to continue using the chatbot over the trial period. Many people said that they carried on using the chatbot because they were 'trying to lose weight' (P1, P2, P9, P28). One participant added that it was good to 'discipline yourself to do something as simple as that (…) having the discipline to get up and exercise or to make something healthy (…) having that chatbot app just kind of… was part of that' (P1). Other participants were motivated because the chatbot was 'helping me keep track of all my eating habits' (P19) and encouraged them to 'stay focussed on healthy food' (P4). One participant carried on using the chatbot because she said: 'I think it does make a difference, it helps you to make better choices and to eat smaller portions' (P6).

Another popular reason why people used the chatbot was to 'trial' (P7) the intervention and 'try and see what sort of an impact it did have (…) if it was good, how it might make you think more about what you were having' (P14). One participant said she 'never really stuck to anything' so she made an effort to use the chatbot regularly 'to see if it would work' (P16) and another user made a similar point, saying: 'I wanted to see if it would actually help with losing weight or not, so I made sure I completed the trial fully, so I could get an answer for sure' (P26). Some participants continued the trial because they 'started it and I wanted to finish it really' (P13) and that 'I like to finish the projects I start, so that was extra motivation for me' (P19). Others wanted to use this as an opportunity to 'see things through' as they said: 'I often sign up to things and will quit/give up (…) I was determined for myself' (P22).

A large proportion of users also mentioned they 'wanted to be a helpful participant' (P18) because they did not want to 'let people down' (P2) and 'wanted to make good results for the researcher (…) I know how important this is' (P25). This was echoed by another participant who said she carried on using the chatbot so that 'I could give you the best results' (P9). Another said: 'I know that people actually do use this to do the studies (…) for me to help someone do that, that's my motivation' (P17). In a similar vein, some people were 'quite committed' (P2) because 'there was a monetary reward' (P16). Others added that 'money was rewarding' (P27) and that it 'motivated me' (P25).

7.2.14.2 Enjoyment. There were few people who said they thoroughly enjoyed the trial, but most had a positive opinion of it and believed they would have enjoyed it even more if a few changes would be made. One participant, who was especially enthusiastic about the trial, said: ‘I was enjoying it completely (…) I definitely miss it now. I was a bit sad when I saw the message on Messenger that I no longer need to log my meals’ (P21). Other participants also found the chatbot ‘quite enjoyable to do’ (P14), ‘liked using it’ (P1), and thought ‘it was a positive experience’ (P7). The chatbot was seen as ‘quite helpful’ (P12), ‘a very good initiative’ (P12) and a ‘great project’ (P18). One participant added that the chatbot ‘wasn’t intrusive (…) it just became second nature [it was] useful (…) I could actually scroll back and see what I’d eat in a day’ (P16), and another one remarked ‘it reminds you what you ate before and it kind of helps you make better choices’ (P12).

Other people thought that ‘it was okay’ but also said: ‘I don’t think it’s 100% for me’ (P2). Some added that ‘it wasn’t awful, I didn’t hate doing it’ (P17) and another participant mentioned that ‘it wasn’t unpleasant, I wouldn’t say I enjoyed it, just it became kind of routine, something to do. I wouldn’t say enjoyable in the sense that I was like excited to do it, but it wasn’t a negative thing, it didn’t impact me too much’ (P16). There were also a few users who noted that ‘although it was very easy to use and very straightforward, I lost interest after a while’ (P24). It was also pointed out that ‘I did enjoy the chatbot at the start (…) however, as time went by, I realised that I would forget to use it and end up logging my meals late’ (P25). Two participants said: ‘overall I enjoyed taking part’ (P28), ‘but I don’t think it is very helpful if you are losing weight, because it is literally just you entering your food’ (P26).

Unfortunately, there were also instances of participants saying they did not enjoy all aspects of the chatbot. One participant said: ‘it became slightly a bit of a chore’ (P14), another thought ‘it was a bit boring (P4) and ‘very repetitive’ because ‘it just gives the same message every time’ (P17). This meant some participants found it ‘hard to keep motivated’ (P28). Others ‘found it a bit… laborious, I found it a little bit hard to remember to use it every time (…) in that way I found it a bit not enjoyable’ (P5) and ‘quite tedious (…) I would go entire days without using it or would accidentally dismiss the notification and forget that way’ (P23). A few users thought the chatbot was ‘annoying most times’ (P24) because ‘there was no engagement, and it was just me talking to myself essentially’ (P23). It was suggested that ‘people need humans for inspiration (…) people do a better job of convincing you, rather than a chatbot with an automatic reply’ (P23). It was also stated that the chatbot was not found enjoyable when ‘I didn’t really see a result of using the chatbot’ (P26) and when ‘it really didn’t help a lot to help me lose weight’ (P4).

7.2.14.3 Mismatch Between Expectations and Reality. Another finding from the interviews was that for a lot of participants there was a mismatch between their expectations of the chatbot and the reality of using it. For instance, one participant said: ‘it was an alright concept, but how it was implemented, I don’t find the implementation was very good’ (P12) and another said ‘loved it to begin with (…) but found it very repetitive’ (P28). Another participant expressed their discontent with the fact that the chatbot was more ‘like an online diary’ (P6). She said: ‘the name ‘chatbot’ to me suggested that it was going to chat back to me (…) if you’re going to call it a diary, people will know it’s going to be a bit boring (…) and if you want to keep it a chatbot, I would just make it more interactive’ (P6).

7.2.14.4 Time Investment. Frequently, the chatbot was described as ‘not time consuming’ (P21), ‘quick and easy’ (P9) and participants said that ‘it was less than a minute a day’ (P12) or ‘it took me seconds to just input my meals each time’ (P19). Primarily, the chatbot was not seen as ‘a massive time constraint’ (P14) because some users were ‘always on my phone’ (P28) and ‘it’s just (…) typing on your phone, so it’s something we’re doing a lot each day anyway’ (P2). A few people said that ‘at the start I found it so fun and interesting, but as the novelty wore off, I realised that it was quite long’ (P25) and although ‘it wasn’t a lot of time and effort (…) it was definitely maybe a wee bit more than when I initially signed up thought it was going to be’ (P5).

7.2.14.5 Effort. Most participants thought that the chatbot ‘didn’t require too much effort from me’ (P15), and described the chatbot as ‘effortless’ (P21), and this was mostly because of how quick it was. However, not everyone agreed. One participant said: ‘I think I’ve used it around five-six times a day (…) so it required a little bit of effort in terms of remembering (…) it required like a constant effort to remember when to enter the meals’ (P4). Another participant had a similar situation, as for her ‘most of [the effort] was just trying to keep the notification on my phone screen so that I could actually remember to use it’ (P23). Another also said: ‘as the weeks went on and I would (…) forget to input my data at the right time, it felt like a bit more effort’ (P18). It was further highlighted that ‘there is a lot of mental effort to remember to do it’ (P9). In addition, one participant pointed out that ‘you do have to be invested, because it takes a bit of effort to do it (…) I feel like if you could make it more interactive, that would be worth the effort’ (P6).

7.2.14.6 Willingness to Continue with the Chatbot. Reassuringly, 74% of participants said they would be ‘willing to use the chat for a longer period of time’ (P19). Some participants said they ‘would be willing to give it a go, because it potentially looks like it’s working’ as they ‘lost weight during the period of the chatbot’ (P11). Similarly, another participant was also willing to carry on with the chatbot, as she thought ‘it helped me loose four kilograms and I still feel motivated’ (P21). Another participant was motivated to carry on to ‘see how long term it would work. Would I keep up doing it? Would it change my eating habits? Would I lose more weight? I think it would be interesting to see’ (P22). Another user said they would be willing to carry on ‘If I saw progress in weight loss’, however they also added ‘for me I think there are better ways’ (P27). Other users were willing to continue, but only if changes were implemented to the chatbot. One participant said: ‘I’d probably have another go and keep going, if things like the summary thing were added to it’ (P14) and another one said ‘with some improvements, I would be happy to keep on using the chat’ (P4). Others said they would use the chatbot if they were able to ‘say how much of what I’ve eaten’ (P3), if there were more ‘tips and encouragement, some sort of feedback’ (P2), if the chatbot was more ‘interactive’ (P6) or if they saw ‘small changes, like entering your weight’ (P26).

The remaining 26% of the sample were not willing to continue at all. Some said: ‘I don’t think I would have the motivation to do that’ (P17), ‘I just don't think I am invested enough’ (P25) and ‘I already struggled with the six weeks’ (P18). Another user felt ‘trapped in a way that I have to keep doing it’ (P24) and one even said that they would be unwilling to continue ‘unless I was paid to do so’ (P23). A commonly given reason for not wanting to continue was that that ‘I’ve seen no benefit’ (P9) ‘from like a weight loss perspective’ (P5).

7.2.15 Theme 4: Effects of Using the Chatbot

7.2.15.1 More Regular Eating. An interesting effect of the chatbot was that participants reported it ‘reminded me that I have to eat’ (P8) and helped them to eat ‘more frequently and regularly’ (P24). Participants said: ‘it [the chatbot] would kind of remind you to eat regularly as well, so you don’t get overly hungry’ (P1), and this was echoed by one participant who said that using the chatbot helped to improve her food portions so that ‘I never felt extremely full, I didn’t feel really hungry’ (P27). The chatbot helped users to think ‘about food more frequently throughout the day’ (P11) and it made them ‘more aware of the gaps between my meals’ (P2). Similarly, one participant said: ‘it made me, on days I was working, eat more regularly, so I wasn’t going long periods without anything, and then having like a massive meal. I’d have smaller things, but a bit more regular’ (P3). Another participant benefitted from using the chatbot as ‘it probably helped me to focus more on proper lunches and proper dinners at set times, instead of eating junk food' (P4), whereas another used the chatbot as an aid to 'get a routine in place' (P16).

7.2.15.2 Better Food Choices. When asked about the effects of using the chatbot on their diet, most participants mentioned that 'it made me choose better, healthier foods' (P24) and that 'I snacked less and had better portion sizes' (P27). Participants said: 'I think it makes you think (…) [about] healthier choices and also choices that you know are gonna (sic) fill you up a bit more (…) I didn't want to type like lots and lots of things' (P1), and 'it really helped me see how bad my eating pattern was (…) I was able to make better healthy choices and I was able to reduce my food portion' (P12). Daily meal logging helped some users realise 'I don't have a varied diet or eat enough fruit and vegetables' (P22) and using the chatbot 'was a good way to try to stay focussed on healthy food' (P4). For others, using the chatbot prompted thoughts such as 'was I really hungry or just bored?' (P22) and it helped them to recognise 'mistakes when it comes to food and drinks of my choice' (P19).

Many people reported they 'started to eat smaller portions of food' (P19) and eating 'fewer sweets' (P19), 'especially if the day before was a cheat day or an excess day' (P16). Users made better food choices for reasons such as: 'I knew if I was putting in like pizza and chips every day, I wouldn't feel very positive about that' (P10) and 'because you know you have to then, (…) log that in (…) it really makes you think double if you really need something' (P6). One participant reported that 'I wasn't snacking as much as what I normally do, because I had to account to someone' (P3). In a similar way, another participant also said 'when I was eating something unhealthy, or eating a big portion, I could really see it written down in front of me (…) I'd be like 'oh no, that doesn't look very good' and I'd, you know, for the next day or so, I would try and counterbalance that and be better' (P13). Interestingly, one participant said that she would use the chatbot as a 'self-diagnosis' tool to see whether 'that chocolate brownie last night with ice cream, that's why I'm not feeling great' (P16).

7.2.15.3 Mindfulness and Awareness. Many participants reported that using the chatbot helped them to 'think more about the food I was eating, and how much I was eating' (P19). Users reported being 'more mindful of what I'd eaten the night before' (P16) and more 'aware of my eating habits' (P19). As a result, some people said: 'there definitely wasn't any mindless eating' (P11) and others recalled instances where 'instead of having like absent-mindedly half a packet of biscuits, maybe having like one or two' (P15). Importantly, participants felt that the chatbot was 'not being judgemental, because it's not saying 'oh hey, you shouldn't have chips'' (P8) and it 'is just there to say thank you and doesn't make any comment or judgement about what you are eating' (P11).

7.2.15.4 No Effects. A number of participants reported that the chatbot 'did not improve my eating' (P18) 'because you're reading back what you've eaten the day before' (P17). Some people said: 'I still ate and drank exactly what I wanted to eat and drink. There were no changes to my usual diet because of the chatbot' (P23) and this was because the recording of the meal happened 'after the fact' (P5). Others also reported 'eating mostly as normal' (P28) or eating 'whatever was available' (P20). Some wondered 'how much of it [behaviour-change] is from the chatbot and how much it's from (…) resources on how to eat better' (P2).

7.2.16 Theme 5: Suggested Features and Changes

7.2.16.1 Reminders. Given how much participants struggled to benefit from the reminders the chatbot sent out, it was unsurprising that most suggestions on how to improve the chatbot were related to these notifications. Participants agreed that 'being able to customise when you get a notification, would be a much better, much needed addition' (P12) because then 'it's more in tune with your own schedule' (P10). Being able to have 'reminders at defined times' (P19) would help people make their eating 'a lot more structured' (P16) and 'regular' (P14), because most users 'certainly have set mealtimes' (P11). Some said it would be 'a better idea' (P12) to 'set up how often you would like to be reminded' (P22), and others said that fixed reminder times would work better 'during the week' because 'weekends I can be a bit more different [with my eating times]' (P5). One participant remarked 'if somehow it [the chatbot] detects my pattern of eating or calculate time for next meal, and send reminders on that time, it would be helpful and [would] make the experience more enjoyable' (P20). Another suggestion was to have 'more regular and repeated' reminders because 'that would kind of alleviate' the issue of the reminders not coinciding with mealtimes (P11).

7.2.16.2 Changes to Automatic Messages. It was frequently noted that the chatbot was 'repetitive' (P28) and 'boring' (P4) and that 'it would have been a bit easier to interact if the chatbot's responses varied every once in a while' (P18). Users reported that using 'different sentences' (P4) or slightly different 'wording' (P17) could have made the chatbot 'more personalised' (P26).

7.2.16.3 Encouragement. The most popular feature requested was 'messages of encouragement, or like motivation, keep going, words like that' (P6). Participants were hoping that the chatbot would be 'sending positive replies, sending motivation' (P26) and that it would provide 'feedback or encouragement to go for like healthier choices' (P2). Users said that such messages 'would have been better' (P17) as they 'could help and make you remember to log all your meals, as you'd think about that message throughout the day' (P27) and could help keep them 'motivated' (P28). Some also thought the feedback from the chatbot should be 'entertaining' (P4) and 'interactive' (P6) because 'even grown-ups like to have like badges and those kinds of things for logging so many times (…) even if it's pre-recorded, to say well done, keep going, good choices today' (P6).

7.2.16.4 Feedback and Summaries. Many users felt that the chatbot would be better 'if it gave you some sort of feedback' (P13). One suggestion was 'an end of the week summary of what you've had (…) so you could just sort of look back and think 'okay, I've had that, I might have something different next time'' (P14). Participants said a weekly summary would be useful because 'I did like looking back through the conversations with it, to see what I've eaten that week and what I enjoyed (P3). Others wanted the chatbot to tell them 'how much you gained or lost that week' (P26) or give them information 'in terms of how much I had, how much I burned' (P8). A few people also wanted the chatbot to provide 'facts based on the things you eat, for example if I entered a KitKat a message could say 'did you know you would have to walk X amount of miles to walk that off'' (P28) or to include 'a five-a-day counter or a portion counter of what you've had' (P3).

7.2.16.5 Changes to Meal-Logging. Several suggestions were made as to how logging of the meals could be improved. A few participants said 'I would have liked to add pictures (…) for me it would have been good to like have that visual diary as well' (P1), and 'seeing an image of what I'd eaten before might have helped, like rather than just writing it out' (P15). This was related to the fact that some users thought 'it'd be good if you had to tell it how much of something you had, like if it was a family sized packet of crisps, or just you know like a regular individual packet' (P3) and pictures would help with that aspect of logging.

7.3 Discussion

The primary aims of the present experiment were to assess the feasibility and acceptability of a weight loss intervention based on the meal-recall effect. Feasibility was assessed based on guidance from Bowen et al. (2009), and it was found that the chatbot satisfied some of the criteria. In general, participants accessed the chatbot on most trial days and most logged an adequate proportion of meals. Yet, it is clear this was not the case for all participants, as 25% of those in the intervention group dropped out, compared to about a 7% drop-out rate in the control group. Nevertheless, this drop-out rate was comparable to that observed by Whitelock, Kersbergen, et al. (2019) in a conceptually similar study, where 26% of participants did not remain in the study until its completion. The attrition rate in this study was also comparable to – and slightly below - the average drop-out rate in weight loss studies (31%), which was derived from a meta-analysis of 80 studies (Franz et al., 2007). Another criterion for feasibility which was met was that participants were relatively willing to continue using the intervention chatbot for a longer period of time, especially if a few minor changes were made to the interface. Unfortunately, in comparison to the control group, intervention group participants were significantly less satisfied with the chatbot and reported struggling to use it regularly more often, which made it difficult for them to fit the chatbot into their daily routine. This is perhaps unsurprising given the discrepancy in effort and time required to participate in the two versions of the trial, but it nevertheless suggests changes must be made to the design of the chatbot in order to increase user satisfaction and to decrease the mental effort required to use the chatbot regularly.

It was important for the chatbot to be perceived as an acceptable intervention, as this can lead to greater user engagement (Sekhon et al., 2017), which in turn predicts greater adherence and probability of successful weight loss (Acharya et al., 2009). Acceptability was assessed with the theoretical framework proposed by Sekhon et al. (2017). In general, the acceptability of the intervention was adequate – most participants were able to identify a number of ways in which the chatbot helped them, for instance it improved their eating habits and helped them to lose weight, and few people reported that they felt completely negative towards the chatbot. However, as previously mentioned, user satisfaction and regular engagement with the chatbot were problematic aspects of the trial, suggesting there is scope for improvement to make the intervention more rewarding and satisfying for users.

The acceptability of the chatbot could also be improved in terms of the burden and opportunity costs associated with the intervention, as it was revealed many people struggled to fit the chatbot into their daily routines, and some people felt they were not being motivated enough throughout the trial. One way in which this could be achieved is by improving the reminders which are sent out by the chatbot, for example by allowing users to personalise the frequency and timing of their reminders. Making the chatbot more interactive, for instance by using more varied responses, and perhaps including some motivational quotes or dietary advice, could increase adherence and satisfaction with the chatbot. However, this requires further user-testing, as a previous study demonstrated that giving the chatbot a 'personality' did not necessarily improve adherence over and above that observed in the present study, where on average 2.38 meals were logged in the interactive chatbot per day over a 21 day trial period (Moses, 2018). Thus, future research into most effective ways of securing user engagement, satisfaction and results from using a weight loss chatbot are warranted. It is also important to highlight that individual preferences might play a role in how additional features are assessed. In the present experiment, a number of contradictions were noted in terms of participants' opinions. For instance, some participants appreciated that the chatbot did not require them to list any quantities of the food they were eating, whereas others claimed this would be a useful addition to the chatbot. Similarly, some people praised the chatbot for not being judgemental about what they were logging, whereas others were disappointed the chatbot did not comment on their dietary choices. Thus, individual preferences must be taken into account when designing subsequent iterations of the chatbot.

In terms of weight loss, the intervention seemed to produce meaningful results. Participants in the intervention group lost an average of 1.81kg, and those in the control group lost an average of 1.07kg, however this difference was not statistically significant. Interestingly, weight loss in the intervention group was not predicted by the number of days on which the chatbot was accessed or by the total number of meals logged over the six-week period. It may seem that this finding contrasts with previous articles which found that higher adherence to an intervention predicted greater weight loss (Lemstra et al., 2016). However, an alternative interpretation is that a ceiling effect might have been observed. Participants who did not use the chatbot regularly were excluded from the trial, and most of those who remained in the trial accessed the chatbot on more than 70% of trial days, and logged an average of 3.47 meals per day, so perhaps a lack of variance in logging frequency and regularity obscured any potential effects. Future studies could collect data from frequent as well as infrequent users to assess the effect of adherence on weight loss.

Contrary to the initial hypotheses, it seems that the chatbot intervention did not affect eating-related cognition. Gastric interoceptive awareness and tendency to eat mindfully were not impacted by the intervention. Food acceptance and awareness, as well as dietary restraint increased after the intervention, but the scores increased in both groups, suggesting this effect cannot be attributed to the intervention. Similarly, loss of control over eating decreased, but there were no group differences. None of these pre- to post-trial changes predicted weight loss. Weight loss was only predicted by a reduction in self-reported energy intake over a 24h period, however this reduction was comparable in the intervention (-324.25kcal) and the control (-331.05kcal) groups. One interpretation of these results is that, in comparison to simple weekly weight-logging, the chatbot intervention does not significantly impact eating-related cognitions. An alternative account is that cognition is impacted in some way, however the questionnaires selected for this experiment did not capture such changes. This seems likely, especially in light of the fact that the intervention chatbot resulted in greater weight loss than simple weight-logging (in terms of absolute numbers). Future studies would benefit from including a wider variety of cognitive tests and measures to assess the effect of this intervention more broadly.

An important finding of this study was that participants did not think the chatbot judged their food choices, even if they were energy dense or not very nutritious. Previous studies have highlighted that food-tracking apps such as MyFitnessPal can produce feelings of guilt, shame and stress in as much as 25% of its users (Gowin et al., 2015). In these previous studies, participants reported being obsessed with tracking everything, feeling a lot of pressure to stay within the limits the app was giving them, and even developing disordered eating as a result (Gowin et al., 2015; Lupton & Maslen, 2019). The memory-based chatbot in the present experiment did not assess what was eaten, whether it was healthy or calorific, or whether a particular goal has been met. Participants praised not having to record precise quantities of the food they were eating, unlike in other calorie-counting apps, and the chatbot did not seem to elicit any negative cognitions after six weeks of usage (e.g. no change in reported levels of food cravings or in uncontrollable eating scores). It is likely that the chatbot did not elicit feelings of guilt and shame in people, because its focus was on the meal-recall effect and not on restrictions and goal pursuit. The focus of the study (to recall previous meals) was reiterated during the instructional video the participants watched, however participants were not presented with findings from previous studies investigating the meal-recall effect and were not told about the possible mechanisms behind the effect. Therefore, it would be worthwhile for future studies to investigate whether thoroughly educating participants about the theory behind the chatbot's design could increase engagement, adherence and perhaps reported effectiveness of the chatbot.

The general results of this study are comparable to those reported by Whitelock et al., (2020). The mindful eating app developed by these researchers also seemed to improve participants' eating habits, and helped them to make better dietary choices and to reduce their portion sizes. As in the current study, participants who used the mindful eating app identified perceived lack of progress to be a barrier which prevented them from using the app regularly. It was also noted that being able to earn stars and badges for regular app usage motivated some participants, which was something participants in the present study felt was lacking from the chatbot. However, Whitelock and colleagues also highlighted that in some cases missing out on a star or a badge was demotivating to participants, and therefore future designs of memory-based weight loss interventions should consider how to achieve a good balance between motivation and discouragement.

Similarly, participants who used the mindful eating app were able to take photographs of their meals, which a few of the participants in the present experiment requested. But, usage of the photograph feature declined significantly towards the end of the mindful eating study, implying that this feature may not be necessary for sustained user engagement. Whitelock et al. also noted that boredom with an intervention can decrease adherence and can impact results, a finding which has also been highlighted by the present experiment. Additionally, recent research has shown that photographing a meal can delay sensory-specific satiety from manifesting (Bayliss & Wu, 2021), which can impact how much food is eaten. Thus, it does not seem essential that features such as photograph-taking are added to the chatbot, even if such features are requested by the users. Perhaps an explanation as to why certain features are or are not included would help to level user expectations and the actual experience of using the chatbot.

In terms of weight loss, the effect observed by Whitelock and colleagues was smaller (1.2kg lost over eight weeks) than that observed in the present study (1.8kg lost over six weeks). However, in the mindful eating app study, lower body weight post-trial was predicted by the frequency of meal logging, whereas in the present experiment neither the numbers of log days, nor the total number of meals logged predicted weight loss or body weight post-trial. Yet, Whitelock et al. reported that in their study, each additional log was equal to 0.02 kg of weight loss, whereas in this study each additional meal log was equal to 0.03kg of weight loss. Therefore, despite a lack of a statistically significant relationship between meal logging and weight loss, it seems that using the chatbot over a longer period of time could produce clinically relevant results.

In summary, the chatbot seems to be a feasible and somewhat acceptable intervention for weight loss, although its ability to improve food-related cognition is not clear. Meaningful weight loss was observed in the intervention group, and although participants in the control group lost less weight, this difference was not statistically significant. Adherence to the intervention was adequate and general acceptability was good, but a number of concerns were highlighted. These concerns, which included reminder timing and interactivity of the chatbot, should be addressed before future versions of the chatbot are tested. It is also worth testing whether slight changes to the design of the chatbot, which would help to increase engagement and user satisfaction, could lead to even better weight loss results. The memory-based chatbot seems to be a promising and feasible intervention for weight loss. Despite its simple design, it seemed to produce similar results to a complex smartphone apps, which included many features such as photos, rewards, and mindful-eating exercises. This could benefit future studies into memory-based weight loss interventions because, unlike smartphone apps, iterations of the chatbot can be produced quickly, inexpensively and without coding experience.

Chapter 8
General Discussion

The three main aims of the present thesis were as follows: a) to replicate the finding that recalling a recent meal suppresses subsequent intake, compared to recalling a different event (i.e. the meal-recall effect), b) to assess if visualising a recent meal as bigger and more satiating than in reality would further enhance the meal-recall effect, and c) to evaluate the usability and feasibility of the meal-recall effect as a potential memory-based weight loss intervention. The potential mechanism of the meal-recall effect was also discussed, however due to restrictions associated with the Covid-19 pandemic, the presented findings are theoretical. The following sections will outline how each experiment reported in this thesis helped to answer the three main aims outlined above.

8.1 Overview of Findings

8.1.1 Replication and Mechanism

The first aim of the thesis, namely, to replicate the meal-recall effect, was addressed in Chapter 3. In this experiment, participants were asked to either recall a recently consumed meal, or to recall their journey into the laboratory, and were then asked to participate in an ostensible taste test (during which intake was covertly measured). Due to in-person testing restrictions being introduced in response to the pandemic, data collection had to be ceased prematurely and the study was severely underpowered. However, the data trended in the hypothesised direction, as those in the lunch-recall group ate around 14g fewer biscuits than those in the journey-recall group. Chapter 4 outlined an attempt to replicate the meal-recall effect using an online set-up, and food photographs as a proxy for actual intake. The first attempt at replicating the meal-recall effect online was unsuccessful. A large sample was recruited for this study, and so there was adequate statistical power to detect medium-small effects, suggesting this was an unlikely explanation for the failed replication. It seemed that there were a number of issues with the methodology employed in that study, which could potentially explain why no significant differences were found between the groups. A review of the methodology used in the first experiment suggested that food photographs should clearly show differences between the depicted portion sizes, and that all photographs should be shown together at once, to make comparing the portion sizes easier. It was also suggested that the effect might not have replicated, because participants were allowed to spend a very short amount of time on the recall task. These design issues were addressed and corrected in the second experiment.

Implementation of these changes was a successful strategy, as the meal-recall effect was replicated in the second experiment. It was found that participants who recalled a recent meal selected a smaller portion of biscuits they would like to eat, than those who recalled a meal from the day before. However, the observed effect size was a lot smaller than those achieved by previous studies – in the online experiment, the difference in biscuit portion size between the two conditions was approximately 4.5g (ω_p^2=0.01). In comparison, in laboratory-based studies, the average reduction in intake was about 17g (ω_p^2=0.05-0.61), and so it seems that an online set-up greatly decreased the magnitude of the meal-recall effect. This is perhaps unsurprising, given the difficulty of assessing intake remotely and without real food. Estimating a desired portion size through the use of photographs is a highly artificial task, and many participants might not have had experience in gauging prospective intake in this manner. Estimating desired intake through photographs also lacks physiological responses, for example cephalic reflexes or sensory-specific satiety, which are typically elicited when eating. Thus, it appears that when investigating the meal-recall effect, an online experimental set-up is best suited for exploratory studies to gather preliminary data, and laboratory-based experiments are more appropriate for estimating true effect sizes.

A supplementary aim of the replication studies was to determine what the underlying mechanism of the meal-recall effect might be. Chapter 2 presented evidence to suggest that, in theory, the most likely mechanism is likely to be an increase in interoceptive awareness and subsequent improvement in processing gastrointestinal signals. It was argued that in general, recent meal memories help to resolve ambiguous internal signals (e.g. am I hungry or nauseous?) and this helps to regulate intake. Consciously recalling a meal memory may simply potentiate this process, by temporarily improving interoceptive ability, which enables an individual to perceive any lingering satiety signals more strongly. Then, when faced with a decision of how much to eat, a person who recalled a recent meal is more likely to rely on their internal cues to determine an appropriate portion size. Recalling a recent meal may also re-activate satiety signals associated with the meal memory, and this might also help an individual to eat less at a subsequent snacking opportunity.

Evidence for this potential mechanism was collected in Experiments 1 and 2 of Chapter 4. As the meal-recall effect was not replicated in Experiment 1, it is not surprising that the results did not elucidate what the mechanism of the meal-recall effect might be. However, despite the meal-recall effect manifesting in Experiment 2, the data did not support the proposed mechanisms. As state interoceptive awareness is usually measured in-person, and there are no established questionnaires for assessing it remotely, three different questionnaires were given to participants: self-monitoring, BPQ, and six-item gastric interoception. Each questionnaire had a slightly different focus on interoceptive awareness - for instance self-monitoring and BPQ contained questions related to whole-body interoceptive awareness, whereas the gastric interoception scale focussed on measuring appetite and hunger/satiety signals. It was hypothesised that recalling a recent (as opposed to a distant) meal would result in higher scores on all measures, however the data did not support this prediction. Self-monitoring scores were significantly *lower* after recalling a recent meal, and there were no group differences for the BPQ and gastric interoception scores. However, none of the measures moderated the relationship.

There are a number of reasons why such a pattern of results was observed. It may be that state interoceptive awareness is not measured particularly well by questionnaires, especially those administered remotely. It is also possible that potential group differences were obscured by the fact each questionnaire was only administered once, after the meal-recall manipulation. Administering the questionnaires before and after the manipulation could have reduced between-subject variance, helping to highlight potential effects. An alternative explanation is that because the three questionnaires focussed on different aspects of interoceptive awareness, they measured different facets of this ability, which could explain the variability of the observed results. Future experiments, especially those conducted in-person, are required to help elucidate how interoception interacts with the relationship between memory and eating behaviour. Laboratory-based measures of interoceptive awareness (e.g. heartbeat perception or the water load test) should also be employed, as they are validated to detect subtle fluctuations in interoception, unlike the questionnaires employed in this study.

In a similar vein, another hypothesis which was tested was that baseline interoceptive awareness could have moderated the relationship between recall cue and biscuit portion size, so that the meal-recall effect would be strongest in people who have a low baseline interoceptive ability. Although the analysis revealed no significant interactions, this may be explained by the fact that very few participants had low scores on the MAIA, and this could have potentially obscured any interactions. However, at present, there is no evidence to support the claim that baseline interoception can moderate the meal-recall effect.

Unexpectedly, it was also found that participants reported significantly lower positive affect, and higher negative affect after recalling a recent meal. It was unclear why positive affect ratings were the highest following recall of a meal eaten the day before. On the other hand, significantly higher negative affect could have been caused by participants feeling guilty after recalling a recent meal. Guilt ratings did not differ between the two recall groups, and there were no significant pre- to post-recall changes in guilt, but because the negative affect scale included more questions, it may have been more sensitive and might have acted as a proxy for guilt. An alternative interpretation of these results is that recalling a recent meal evokes general negative feelings, not just those related to guilt. As shown in Chapter 7, eliciting the meal-recall effect every day did not lead to significant pre- to post-intervention changes in guilt. However, the intervention did seem to slightly impact mood. The actual analysis of pre- to post-recall negative mood scores was not significant, but the interaction term was marginally significant (p=.059). Negative affect scores seemed to increase in the intervention group, and to decrease in the control group. These changes were relatively small (intervention: 0.16-point increase; control: 0.24-point decrease on a 1-5 scale), but could potentially suggest that the meal-recall effect may be partially driven by an increase in negative affect, rather than by guilt.

Contrary to the hypotheses, none of the appetite ratings varied as a function of recall cue, suggesting that recalling a recent meal does not affect subjective appetite sensations. Yet, it is uncertain how the online set-up of the experiment influenced the sensitivity of the FFSQ, which measures different, more subtle facets of appetite. In terms of absolute values, mental hunger was lowest after recent meal recall, compared to recalling a meal from the day before (albeit this difference was not statistically significant). This seems to fit in with the explanation that recalling a recent meal might re-activate satiety signals associated with the previous meal, and might make them easier to distinguish. Future laboratory-based experiments on the meal-recall effect would benefit from including the FFSQ, to help define the role mental hunger and mental fullness play in the meal-recall effect.

There was no evidence to suggest that recalling a recent meal leads to an increase in portion appropriateness scores or to higher negative evaluation scores (even when motivation to manage impressions was included as a covariate). There was some evidence to suggest that negative affect might have acted as a proxy for guilt, however actual guilt ratings were not impacted by recalling a recent meal, as there were no group differences in terms of post-recall ratings or pre-to-post recall changes. These findings were unexpected. It was predicted that guilt may have been a partial mediator of the relationship, given the vast amount of literature suggesting that thinking about past food choices can elicit feelings of guilt (Piqueras-Fiszman & Jaeger, 2016; Polivy et al., 1986). It was also slightly surprising to learn that portion appropriateness scores and negative evaluation scores were not affected by the recall cue, as anticipated. As there are no validated questionnaires or scales to assess these constructs, it's possible that a lack of group differences is simply due to methodological flaws or the online set-up of the experiment.

However, these results may also imply that the meal-recall effect is not driven by any conscious effort to restrict intake. This conclusion is further supported by the fact that the results of Arthur et al. (2021), who argued that the meal-recall effect was driven by conscious thoughts, were not replicated in the present thesis. The authors argued that conscious restriction was involved because dietary restraint scores predicted prospective intake in the control condition, but not in the experimental condition. A conceptually identical analysis was conducted using data from experiment 2 (Chapter 4), but the results were not replicated, as dietary restraint was not a significant moderator in the relationship. Therefore, it seems that conscious thoughts about restraint and social norms are unlikely to be driving the meal-recall effect, and the associated suppression of snack intake.

8.1.2 Manipulating Meal Memories

The second aim of the study, to assess whether manipulating recent meal memories can further strengthen the meal-recall effect, was explored in Chapter 5. It was shown that participants who imagined that their recent meal was bigger and more satiating than in reality consumed fewer biscuits, than those who performed other mental visualisation tasks. Contrary to the hypotheses, participants who visualised their recent meal as bigger remembered it as significantly smaller, than those who performed other visualisation tasks. This suggests that the decrease in snack intake associated with the mental visualisation task is unlikely to be caused by participants actually modifying their memories to remember their previous meal as bigger. However, it is not clear how remembering the meal as significantly smaller than in reality could contribute to the effect. It is also interesting to note that hunger was rated as significantly lower following the imagination task. This change in hunger was not present in any other group, and previous studies have also not found any changes to appetite ratings following recent meal recall (Higgs, 2002; Higgs et al., 2008; Szypula et al., 2020). Thus, this decrease in hunger seems specific to the mental enlargement exercise. Results from the proof-of-concept study suggest that imagining a recent meal as larger might elicit feelings of disgust, which might explain why hunger ratings also decreased in this group. However, disgust was not formally tested as a potential mediator of the relationship, and so caution is required when interpreting these results.

An additional hypothesis tested in Chapter 5 was that mentally visualising a consumption episode (with a focus on what it felt like to chew and swallow the food) would create an even stronger meal-recall effect, than one elicited after standard instructions to simply recall a recent meal. However, visualising and mentally simulating the details of a recent eating episode did not seem to have the desired effect of decreasing snack intake. Similar findings were previously observed by Szypula et al. (2020), as participants who were guided through remembering their previous meal, for example by being prompted to recall where they had it or what the textures and flavours they associated with the meal, led participants to eat more biscuits, than those who were not prompted for details. In the study presented in Chapter 5, the differences in biscuit intake between the 'Recall + Rumination' group and the control conditions were not statistically significant, but in terms of absolute values, fewest biscuits were eaten in the two experimental groups. These results suggest that the meal-recall effect seems to be best elicited by simple instructions, without specific prompts for details. They also highlight that small variations to the recall task can affect whether the meal-recall effect manifests or not.

8.1.3 Developing and Testing a Weight Loss Intervention

The third aim of this thesis addressed the extent to which a memory-based weight loss intervention, which was based on the meal-recall effect, was usable and feasible. A Facebook Messenger chatbot was designed so that a user would be able to record their past meal in the app, immediately before eating their next meal. Given how successful the mental visualisation task was (Chapter 5), two versions of the chatbot were developed – one version simply asked the users to recall and describe a recent meal, whereas the other version also required the users to perform an additional mental visualisation task. The usability of the chatbot was assessed by asking 12 users to test the intervention for one week, and to then describe and rate their experiences. The simpler version of the chatbot (i.e. just recalling the details of a recent meal) was rated favourably by the testers. The chatbot was rated as convenient to use and simple to fit into a person's daily routine. The testers also commented that using the chatbot was mostly enjoyable, and that they became more conscious about the foods they were eating, and their portion sizes, as a result of engaging in the intervention. However, the version of the chatbot which also included an imagination task was not well received by the participants. Including the imagination task in the intervention significantly decreased engagement with the chatbot, and decreased its usability in terms of convenience, awkwardness, and ease of fitting it into daily routine. Most importantly, the imagination task was not perceived as a useful element of the intervention by the users, and some people remarked they would have preferred to just log their meals, without having to visualise them as bigger and more filling. In light of these results, the feasibility study was conducted only for the simpler version of the chatbot, without the imagination task.

The feasibility study explored a number of questions. Firstly, the study assessed whether participants would find the intervention acceptable enough to carry on using it for a prolonged period of time, in this case for a period of six weeks. It was also assessed whether using the chatbot long-term would affect usability ratings. Lastly, it was investigated if using the chatbot would lead to weight loss, and/or changes to eating-related cognition. In the study, participants were allocated to the intervention group (recalling a recent meal before eating the next meal) or the control group (logging weight once per week). A larger sample size was also recruited, to maximise statistical power (48 participants in the intervention group).

The feasibility and acceptability of the chatbot were adequate, but many opportunities for improvement were also identified. Firstly, the drop-out rate from the study was substantial, as 25% of participants stopped using the chatbot before the end of the trial period. However, it was noted that similar attrition rates were recorded in previous studies. Most people found using the chatbot to be a positive experience, and the majority of users reported that the chatbot had some encouraging effects on their eating habits and portion sizes. Nevertheless, a number of issues pertaining to user satisfaction and engagement were identified. Acceptability ratings seemed to be lower than those given in the usability study – ability to fit into daily routine ratings were especially impacted (M=3.83 in usability study vs. M=2.83 in feasibility study), as were ratings of awkwardness around using the chatbot (M=1.67 in usability study vs. M=3.67 in feasibility study). It was determined that reminders, which were not well aligned with participants' eating times, were one of the major issues which impacted user satisfaction. It was also noted that users wanted the chatbot to be more interactive and less repetitive, in order to enjoy using it more. Thus, relatively simple changes to the chatbot would potentially increase users' acceptance of and satisfaction with the chatbot.

Interestingly, participants in the intervention group lost more weight than those in the control group (M=1.81kg vs. M=1.07kg, respectively). Although this difference was not statistically significant, it offers a promising avenue for further research into the efficacy of a memory-based weight loss intervention. Contrary to the hypotheses, no changes to eating-related cognition were detected after participants used the chatbot for six weeks. Given the online set-up of the experiment, and limited data pertaining to the potential mechanism of the meal-recall effect, it is possible that these results were observed simply due to measurement limitations. Due to restrictions to in-person testing, all cognitive assessments were made through online questionnaires, which may not accurately reflect subtle changes in aspects such as interoceptive awareness.

One important finding from the feasibility study was that participants did not perceive the chatbot to be judgemental, even if the food they recorded was not very nutritious. Using the chatbot did not seem to elicit feelings of guilt in the majority of the sample, whereas calorie-counting apps such as MyFitnessPal can cause about a quarter of its users to feel shame, guilt or stress because of food (Gowin et al., 2015). Such feelings can contribute to the development of eating disorders, which can lead to malnutrition (Levinson et al., 2017). The focus of the chatbot is not on restriction of food or on commenting on a person's food or portion size choices. This potentially makes it a safer weight loss tool, which can help people to develop a healthy, balanced approach to eating, which is not dominated by restrictions and food rules. However, some improvements must be implemented in the chatbot, before it can be launched on a larger scale.

8.2 Potential Implications of the Research

The findings presented in this thesis have a number of implications. Firstly, the meal-recall effect was replicated online, using food photographs as a measure of prospective intake. Being able to conduct experiments on the meal-recall effect online is important, as laboratory-based taste tests are effortful and can sometimes be limited by lack of facilities to prepare the food (Wilkinson et al., 2012). They are also associated with other issues such as limited food choices, food spoilage and waste (Bucher et al., 2012). The results reported in this thesis suggest that researchers wishing to conduct further studies pertaining to the meal-recall effect can use an online set-up to avoid dealing with the aforementioned issues associated with laboratory-based experiments. Additionally, being able to elicit the meal-recall effect away from the laboratory, without the presence of an experimenter, implies that it can be used in digitally delivered weight loss interventions.

The experiments in Chapter 4 provide support for the idea of using a simplified portion size selection task to assess prospective intake (Pink & Cheon, 2021). The results imply that using only a few photographs of food portion sizes may be more effective than using a large number of photographs. It is also important to note that the observed effect size in the online replication study (experiment 2, Chapter 4) was much smaller than that observed in laboratory studies (ω_p^2=0.01 vs. ω_p^2=0.05-0.61, see Chapter 1). This suggests researchers wishing to employ an online study design to examine the meal-recall effect should take this into consideration when calculating the sample size they will require to adequately power their study. Lastly, as the first attempt at replicating the meal-recall effect online was unsuccessful, it seems that the meal-recall effect is prone to interference from contextual factors and can be easily disrupted. This has previously been observed in laboratory-based experiments (Collins & Stafford, 2015; Szypula et al., 2020), and although it is not clear why small changes to the experimental paradigm can eliminate the meal-recall effect, it is important to consider this issue when designing future experiments.

The findings of the imagination study (Chapter 5) have a number of applications in the real world. Visualising a recent meal as bigger than in reality significantly decreased subsequent snacking. The way this task was incorporated into the intervention in the present thesis was not suitable for long-term use. However, there is potential for imagining a recent meal as bigger than in reality to become a novel way of helping people to cope with cravings and excessive snacking. It seems that the visualisation task could have decreased snack intake, because it elicited feelings of disgust. This argument was supported by preliminary evidence, showing that disgust ratings increased after imagining a recent meal as larger and more satiating than in reality (proof-of-concept study; Chapter 5). It would be interesting for future research to examine how eliciting feelings of disgust could be used as a strategy to help people manage their food intake, given how simple and effective the visualisation task is.

In terms of using the meal-recall effect as a weight loss intervention, the results reported in this thesis suggest that such an intervention could be implemented on a larger scale. It seems that using a messaging app, such as Facebook Messenger, as a host platform for a weight loss intervention is an acceptable and convenient way of delivering it to the users. Increasing the range of apps offering the intervention (e.g. WhatsApp) would further increase the rates of engagement with the chatbot. Embedding the intervention into an existing platform is a cheaper and easier alternative to developing a new app. This approach also helps to address the issue of app usage dropping significantly over time, as the user is motivated to regularly open the hosting app without specifically intending to engage with the intervention. This can act as an additional reminder, and can decrease the burden associated with daily use of the intervention.

The results presented in this thesis suggest that regularly recalling the details of a recent meal immediately before the next meal can help to improve people's food choices, their awareness of what and how much they eat, and can help users to decrease the frequency of undesirable eating behaviours such as mindless snacking. The results also offer a possibility that the meal-recall effect could be used as a weight loss intervention. Although the difference in weight loss between the control group (-1.07kg) and the intervention group (-1.81kg) was not statistically significant, it was encouraging to see that, in terms of absolute values, weight loss was greater in the meal-recall group. The intervention seemed to work even when users were relatively vague about the details of their previous meals, for example when they did not specifically mention the ingredients of a meal or the portion size. This is a significant finding, as it implies engaging in the intervention does not require a significant time commitment and it also minimises the likelihood of unhealthy eating-related cognitions developing. Calorie-counting apps such as MyFitnessPal can contribute to the development of eating disorders, and the restrictions perpetuated by such apps can make users preoccupied with food-related thoughts and behaviours, which can ultimately lead to weight-gain (Gowin et al., 2015; Lupton & Maslen, 2019). A memory-based weight loss intervention, such as the one trialled in the present thesis, has great potential to become a convenient weight loss tool, which will encourage users to develop better eating habits. Based on the results reported in this thesis, future iterations of the chatbot can be designed to increase adherence, engagement, and satisfaction with the intervention.

8.3 Relevance of the Findings

Although intake is strongly influenced by biological factors, such as hormones, nerves and organs, there is a rapidly increasing body of literature to suggest that cognition also plays an integral role in the regulation of eating behaviour (Higgs & Spetter, 2018). Our society is currently facing an obesity epidemic, with approximately 64% of the UK population having excess body weight (National Health Service, 2020). Yet, according to a recent NHS report, 67% of UK adults meet the official guidance for weekly activity levels (National Health

Service, 2020), and in 2015 almost half of the population declared that they were trying to lose weight (Mintel, 2016). Out of these respondents, two thirds declared they were always on a diet (Mintel, 2016). Moreover, it is typical for people to regain the weight they lost, or to even become heavier than they were before their weight loss efforts (Swanson & Dinello, 1970). This suggests that the available guidance and behavioural interventions (i.e. eat less and move more) alone are insufficient to tackle the problem of overweight and obesity. Instead, diet and physical activity may bring more substantial weight loss effects when combined with cognition-based interventions (Bean et al., 2008; Phelan et al., 2009).

One example of such a cognitive intervention is mindfulness training, wherein participants are encouraged to focus on their current experiences, and to accept them without judgement (Creswell, 2017). A meta-analysis has shown that mindfulness training can lead to significant weight loss (Olson & Emery, 2015), however all studies included in the report required some form of training and teaching. The meal-recall effect differs from other weight loss interventions, such as mindfulness, because it requires minimal training, which can be delivered through a short set of written instructions. Eliciting the effect (i.e. recalling a recent meal) requires minimal effort, and it does not promote caloric restriction or judge participants' dietary choices. This is important, because weight loss methods can sometimes promote unhealthy eating-related thoughts and behaviours, which may transform into eating disorders (Gowin et al., 2015; Lupton & Maslen, 2019).

Nevertheless, as the experiments in the present thesis have shown, it seems necessary to further understand the meal-recall effect and its mechanism, before a large-scale intervention is launched. As the experiments presented in this thesis have revealed, the meal-recall effect can be a good tool to help reduce people's intake, but it is also prone to interference by seemingly trivial factors, such as elaborating on a meal memory. From a theoretical point of view, the effect of memory on subsequent intake is well established. Rats with hippocampal dysfunction eat more and gain weight (Davidson et al., 2009; Henderson et al., 2013), and are unable to discriminate between states of hunger and satiety (Davidson & Jarrard, 1993). Humans without a functioning hippocampus are capable of eating multiple meals consecutively without feeling full (Rozin et al., 1998), and their general ability to discriminate between hunger and satiety is impaired (Hebben et al., 1985b). Furthermore, disrupting the encoding of meal memories (via distraction) in neurotypical participants seems to have a profound effect on later intake (Robinson, Aveyard, et al., 2013). But, memory disruption seems to produce more consistent results than enhancing the formation of meal memories (Tapper & Seguias, 2020; Whitelock, Gaglione, et al., 2019). Moreover, whereas the effect of distraction on subsequent intake seems to be robust to changes in methodology (Robinson, Aveyard, et al., 2013), the effect of recalling or strengthening a meal memory is easily disrupted by slight changes to the experimental paradigm (Szypula et al., 2020). Why, then, is the effect of recent meal recall so vulnerable to interference?

As the present thesis has shown, there is no simple answer to this question. Establishing what the mechanism of the meal-recall effect might be could prove to be vital in order to understand why it appears to be so elusive. The results of experiments carried out to date suggest that recalling a recent meal decreases subsequent intake through interoception and/or appetite changes (see Chapter 2). In this thesis, I proposed that remembering a previous meal temporarily increases interoceptive awareness, which in turn helps people to discriminate between and act upon ambiguous internal signals (e.g. hunger vs. nausea). Given the importance of meal memories for the perception of satiety and appropriate eating behaviour, consciously accessing a recent memory of eating may help to re-activate or potentiate any lingering satiety signals leftover from the meal, which inhibits subsequent intake. Yet, the evidence collected in this thesis to implicate interoceptive awareness or changes to appetite as the mechanism(s) of the meal-recall effect was limited. There of course exists the possibility that a different mechanism could explain the meal-recall effect – perhaps recalling a recent meal does not temporarily increase interoceptive awareness, but rather produces a physiological or a hormonal reaction. Or maybe remembering a recent meal helps to diminish the effects of food insecurity, which is typically associated with weight gain (Nettle et al., 2016). It is also possible that the mechanism proposed in this thesis is correct, but that the questionnaires employed were unsuitable for detecting subtle changes to interoceptive awareness. In either case, the results of the experiments reported here have uncovered an interesting avenue which should be further pursued in future research studies.

On a final note, it is worth developing and testing memory-based interventions, because of their potential to help break the vicious cycle of obesity. Briefly, it is proposed that the vicious cycle of obesity occurs when the hippocampus is impaired due to the individual carrying excess weight, and that this may interfere with the formation and/or retrieval of food-related memories (Kanoski & Davidson, 2011). Without clear meal memories, people may eat excessive amounts of food (much like amnesic patients) and therefore gain more weight, which further perpetuates the cycle (Kanoski & Davidson, 2011). The cycle could potentially be broken at any point, for example by devising interventions to help people eat less. But, monitoring of food intake is much more effortful (Lowe, 2003), than remembering past meals (see Chapters 6 and 7), which may suggest that a strategy focussed on the memory aspect of the cycle may be more effective at breaking it. It was encouraging to see that the effect could be replicated in a diverse sample of participants (see Chapter 4), suggesting the meal-recall effect may be a suitable candidate for a weight loss intervention. However, the robustness, effectiveness and acceptability of memory-based interventions are yet to be fully evaluated. Showing that cognition plays a vital role in weight gain and weight loss is an important milestone in modern psychology, but it has not yet been explored in as much detail as the physiological aspect of eating behaviour. More research into this area would be valuable to fully understand how memory can be used to aid weight loss.

8.4 Strengths and Limitations

The experiments presented in this thesis have a number of unique strengths, as well as some limitations. Chapter 3 described a laboratory-based replication of the meal-recall effect, and Chapter 5 focussed on a conceptual replication and extension of the relationship between meal memories and intake. As highlighted by Robinson et al. (2018), laboratory studies of human eating behaviour are distinct from other types of experiments, as they have specific advantages and challenges associated with them. Thus, it is essential for experimental methods involving food intake to be complete, consistent, and not biased, to increase the validity of the findings. The two bogus taste tests conducted in Chapters 3 and 5 met many of the recommendations outlined by Robinson et al. (2018). The potential effect of demand characteristics was minimised, as the true experimental aim was concealed from the participants. Participants completed additional, unrelated tasks, in order to make the cover story for the experiments (i.e. investigating how mood affects taste) more believable. For instance, participants completed a mood questionnaire multiple times throughout the two studies. This strategy seemed successful as only one participant (out of 176) guessed the true aims of the study, and this was because she had previously completed the bogus taste test in another study.

The next guideline pertains to standardising appetite before the taste test. This was only done in the mental visualisation study (Chapter 5), and not in the replication study (Chapter 3). Standardising appetite before the taste test requires participants to attend a laboratory session during which they are served a meal. This is problematic in many respects, as the time commitment of the participants increases, food restrictions and preferences can affect the characteristics of the recruited sample (e.g. picky eaters may not want to participate), and there is often a lack of facilities for food preparation. To make the testing session shorter, and the experiment easier to carry out, participants in the replication study (Chapter 3) were simply instructed to eat their lunch two hours before the testing session. Participants were free to pick the time at which they wanted to be tested, and so could align their normal mealtimes with the experimental requirements. In the imagination study (Chapter 5), it was essential for participants to have eaten the same meal, of the same size, as it was assessed whether memory for the size of the meal changed as a function of the visualisation task performed. Although this design was advantageous in terms of experimental control, it was also a limitation in some respects. Not all participants perceived the pre-determined portion size as adequate – for some the portion was too small, for others it was too big. The extent to which participants felt satisfied with the portion size of their lunch was not a significant predictor of biscuit intake, but the amount of lunch leftover was a significant covariate in the model. Therefore, even though serving participants a fixed lunch was essential to the experimental design, it could have impacted the observed results.

Another guideline proposed by Robinson et al. (2018) was met, as an *a priori* power analysis and sample size calculation was performed for all experiments in this thesis. Effect size estimations were based on previous findings, and were appropriately adjusted depending on factors such as method novelty and potential drop-out. Only the laboratory-based replication study (Chapter 3) was not adequately powered, as testing had to be prematurely terminated due to Covid-19 restrictions. Another advantage of the present research is that the participants recruited for most of the experiments were diverse and the samples were representative. Previous experiments were conducted on rather specific populations; for example Higgs (2002) recruited unrestrained female undergraduate students, and Higgs et al. (2008) only recruited young, healthy female students with a BMI in the normal range (i.e. 19-25 kg/m^2). Other research groups recruited participants with similar characteristics. For instance, Collins and Stafford (2015), Vartanian et al. (2016) and Yeomans et al. (2017) all recruited young females who were predominantly undergraduate students. Szypula et al. (2020) were able to replicate the meal-recall effect with a more diverse sample. Participants in that study were aged 20-73, had BMIs between 17-31 kg/m^2, had a variety of dietary restraint levels, and were actively recruited from non-student populations. A quarter of the sample comprised males. As one of the primary aims of this thesis was to test the meal-recall effect as a weight loss intervention, it was important to show that it was not specific to a certain populations. Indeed, the meal-recall effect was replicated (online) when the recruited sample was not restricted in terms of age, BMI, and restraint, student status and when approximately half of the participants were male (experiment 2, Chapter 4). Similarly, a representative sample of participants was recruited for the usability study (Chapter 6) and the feasibility study (Chapter 7), and there was some evidence to suggest the meal-recall effect had an impact on these individuals.

However, it is also worth noting that while the online set-up of experiments in Chapters 6 and 7 yielded a diverse, representative sample, it also meant that reported body measurements could not be verified. Previous research has shown that only about 50% of participants accurately report their height, and 30% under-report it (Bowring et al., 2012). Accuracy of self-reported weight is even lower, particularly in women, with only about a third of participants able to estimate it correctly, and 52% of participants under-reporting it (Bowring et al., 2012). Given that one of the main aims of the feasibility study (Chapter 7) was to assess weight loss, the fact that participants' weight was not objectively verified was a major limitation. In a conceptually similar study, Whitelock, Kersbergen, et al. (2019) found no significant weight loss following eight weeks of app usage, when body measurements were objectively recorded in the laboratory. Although a lack of significant findings could be attributed to the design of the intervention itself (see Chapter 7 for a discussion), it is possible that the results observed in the feasibility study were simply due to a reporting bias or measurement error. Future studies must include independent height and weight measurements in order to assess the efficacy of the meal-recall chatbot.

A final limitation of the present thesis is that the mechanism of the meal-recall effect could not be fully explored, as the studies were conducted online. For instance, it was hypothesised that interoceptive awareness played a role in the effect, but validated measures of interoception (e.g. heartbeat perception or the water load test) require in-person testing. Interoceptive awareness was assessed with questionnaires instead, but these were not originally designed to distinguish temporary fluctuations in interoception. Thus, the results observed in the present thesis may not reflect true effects, and may have been affected by the remote delivery of the experiment. In a similar way, relying on online questionnaires in Chapters 6 and 7 to assess pre- to post-intervention changes in cognition could be the reason why no significant improvements were observed. Conducting these experiments again in a laboratory setting could help establish why the meal-recall effect occurs and how it may help people to lose weight.

8.5 Concluding Remarks

The data presented in this thesis suggests that recalling a recently consumed meal reduces real and prospective intake of palatable snacks. Manipulating the memory of a recently consumed meal can further suppress subsequent snacking, however more research is required to elucidate an effective strategy to implement such mental simulation exercises into a long-term intervention for weight loss. The thesis showed that an intervention, in which participants were asked to recall a recent meal immediately before eating their next meal, has the potential to be acceptable and effective. However, in order for such a memory-based intervention to be launched at a greater scale, it is important to consider a more nuanced design (potentially incorporating some machine learning algorithms). The results of the experiments reported across the chapters of this thesis contribute to our understanding of the meal-recall effect, and highlight how the effect can be used to help people lose weight, however they also support previous evidence that the effect itself is vulnerable to disruption from minor changes in methodology. Further laboratory-based research into the meal-recall effect is warranted, to help elucidate the mechanism of the effect and to better understand its potential as a weight loss intervention.

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Appendices

Appendix A

The Dutch Eating Behavior Questionnaire (van Strien et al., 1986)

Restrained Eating						
1. When you have put on weight do you eat less than you usually do?	not relevant	never	seldom	sometimes	often	very often
2. Do you try to eat less at mealtimes than you would like to eat?		never	seldom	sometimes	often	very often
3. How often do you refuse food or drink offered to you because you are concerned about your weight?		never	seldom	sometimes	often	very often
4. Do you watch exactly what you eat?		never	seldom	sometimes	often	very often
5. Do you deliberately eat foods that are slimming?		never	seldom	sometimes	often	very often
6. When you have eaten too much, do you eat less than usual the following day?	not relevant	never	seldom	sometimes	often	very often
7. Do you deliberately eat less in order not to become heavier?		never	seldom	sometimes	often	very often
8. How often do you try not to eat between meals because you are watching your weight?		never	seldom	sometimes	often	very often
9. How often in the evening do you try not to eat because you are watching your weight?		never	seldom	sometimes	often	very often
10. Do you take your weight into account with what you eat?		never	seldom	sometimes	often	very often
Emotional Eating						
11. Do you have a desire to eat when you are irritated?	not relevant	never	seldom	sometimes	often	very often
12. Do you have a desire to eat when you have nothing to do?	not relevant	never	seldom	sometimes	often	very often

13. Do you have a desire to eat when you are depressed or discouraged?	not relevant	never	seldom	sometimes	often	very often
14. Do you have a desire to eat when you are feeling lonely?	not relevant	never	seldom	sometimes	often	very often
15. Do you have a desire to eat when somebody lets you down?	not relevant	never	seldom	sometimes	often	very often
16. Do you have a desire to eat when you are cross?	not relevant	never	seldom	sometimes	often	very often
17. Do you have a desire to eat when something unpleasant is about to happen?		never	seldom	sometimes	often	very often
18. Do you have a desire to eat when you are anxious, worried or tense?		never	seldom	sometimes	often	very often
19. Do you have a desire to eat when things are going against you and when things have gone wrong?		never	seldom	sometimes	often	very often
20. Do you have a desire to eat when you are frightened?	not relevant	never	seldom	sometimes	often	very often
21. Do you have a desire to eat when you are disappointed?	not relevant	never	seldom	sometimes	often	very often
22. Do you have a desire to eat when you are emotionally upset?	not relevant	never	seldom	sometimes	often	very often
23. Do you have a desire to eat when you are bored or restless?	not relevant	never	seldom	sometimes	often	very often
External Eating						
24. If food tastes good to you, do you eat more than usual?		never	seldom	sometimes	often	very often
25. If food smells and looks good, do you eat more than usual?		never	seldom	sometimes	often	very often
26. If you see or smell something delicious to eat,		never	seldom	sometimes	often	very often

do you have a desire to eat it?						
27. If you have something delicious to eat, do you eat it straight away?		never	seldom	sometimes	often	very often
28. If you walk past the baker do you have the desire to buy something delicious?		never	seldom	sometimes	often	very often
29. If you walk past a snack-bar or café, do you have the desire to buy something delicious?		never	seldom	sometimes	often	very often
30. If you see others eating, do you also have the desire to eat?		never	seldom	sometimes	often	very often
31. Can you resist eating delicious foods?		never	seldom	sometimes	often	very often
32. Do you eat more than usual, when you see others eating?		never	seldom	sometimes	often	very often
33. When preparing a meal are you inclined to eat something?		never	seldom	sometimes	often	very often

Appendix B

Mood Questionnaire

Appendix C

Visual Analogue Scales to Measure Appetite (Pen and Paper Version)

Please place a mark on the line, to reflect how you feel right now.

1. **How hungry do you feel right now?**

Not at all	________________________________	Extremely

2. **How full do you feel right now?**

Not at all	________________________________	Extremely

3. **How much do you desire to eat right now?**

Not at all	________________________________	Extremely

4. **How disgusted do you feel right now?**

Not at all	________________________________	Extremely

Appendix D

Visual Analogue Scales to Measure Appetite (online version)

Please think about how you are feeling **RIGHT NOW, AT THIS VERY MOMENT**. Now, please make make the following ratings:

Not hungry at all | Very, very hungry

How hungry do you feel?

Not full at all | Very, very full

How full do you feel?

Not guilty at all | Very, very guilty

How guilty do you feel?

Not strong at all | Very, very strong

How strong is your desire to eat?

None | A very, very big portion

How much food do you think you could eat?

Appendix E

The Five Factor Satiety Questionnaire (Karalus, 2011)

Mental Hunger:

Please think about how you are feeling **RIGHT NOW, AT THIS VERY MOMENT** and rate the following statements:

None	Barely detectable	Weak	Moderate	Strong	Very strong	Strongest imaginable

Rate the extent to which you are currently thinking of food

Rate your current willingness to eat

Rate your current appetite for a meal

Rate your current urge to eat

Rate your current motivation to eat

Rate your current appetite

No desire	Barely detectable	Weak	Moderate	Strong	Very strong	Greatest imaginable desire

Rate your current desire to eat something savoury

Rate your current desire to eat a snack

Rate your current desire to eat something fatty

Rate your current desire to eat something salty

Rate your current desire to eat any food

Rate your current desire to eat something sweet

Rate your current desire to eat your favourite food

Physical Hunger:

Please think about how you are feeling **RIGHT NOW, AT THIS VERY MOMENT** and rate the following statements:

Not at all	Barely detectable	Weak	Moderate	Strong	Very strong	Strongest imaginable

Rate the extent to which you currently have stomach cramps

Rate the extent to which you feel famished

Rate the extent to which you currently feel stomach pain

Rate the extent to which your stomach currently aches

Rate the extent to which your stomach is currently rumbling

Physical Fullness:

Please think about how you are feeling **RIGHT NOW, AT THIS VERY MOMENT** and rate the following statements:

Not at all	Barely detectable	Weak	Moderate	Strong	Very strong	Strongest imaginable

Rate the extent to which your stomach currently feels empty

Rate the extent to which your stomach currently feels bloated

Rate the extent to which your stomach feels like it is currently bursting

Rate the extent to which your stomach currently feels stuffed

Rate the extent to which your stomach is currently growling

Mental Fulness:

Please think about how you are feeling **RIGHT NOW, AT THIS VERY MOMENT** and rate the following statements:

None	Barely detectable	Weak	Moderate	Strong	Very strong	Strongest imaginable

Rate your feeling that the meal or snack you last ate was of a sufficient size

Rate your satisfaction with your feeling of fullness from the food you last ate

Rate your satisfaction with the food you last ate

Rate your appetite satisfaction from the food you last ate

Rate your feeling of fullness from the food you last ate

Food Liking:

Please think about how you are feeling **RIGHT NOW, AT THIS VERY MOMENT** and rate the following statements:

Greatest imaginable disliking	Dislike extremely	Dislike very much	Dislike moderately	Dislike slightly	Neutral	Like slightly	Like moderately	Like very much	Like extremely	Greatest imaginable liking

Rate your liking of the odour of the food you last ate

Rate your overall liking of the food you last ate

Rate your liking of the texture of the food you last ate

Rate your liking of the flavour of the food you last ate

Rate your liking of the appearance of the food you last ate

Appendix F

Multidimensional Assessment of Interoceptive Awareness (MAIA; (Mehling et al., 2018) **– version 2**

	Never					Always
1. When I am tense, I notice where the tension is located in my body.	0	1	2	3	4	5
2. I notice when I am uncomfortable in my body.	0	1	2	3	4	5
3. I notice where in my body I am comfortable.	0	1	2	3	4	5
4. I notice changes in my breathing, such as whether it slows down or speeds up.	0	1	2	3	4	5
5. I ignore physical tension or discomfort until they become more severe.	0	1	2	3	4	5
6. I distract myself from sensations of discomfort.	0	1	2	3	4	5
7. When I feel pain or discomfort, I try to power through it.	0	1	2	3	4	5
8. I try to ignore pain.	0	1	2	3	4	5
9. I push feelings of discomfort away by focussing on something.	0	1	2	3	4	5
10. When I feel unpleasant body sensations, I occupy myself with something else, so I don't have to feel them.	0	1	2	3	4	5
11. When I feel physical pain, I become upset.	0	1	2	3	4	5
12. I start to worry that something is wrong if I feel any discomfort.	0	1	2	3	4	5
13. I can notice an unpleasant body sensation without worrying about it.	0	1	2	3	4	5
14. I can stay calm and not worry when I have feelings of discomfort or pain.	0	1	2	3	4	5
15. When I am in discomfort or pain I can't get it out of my mind.	0	1	2	3	4	5
16. I can pay attention to my breath without being distracted by things happening around me.	0	1	2	3	4	5
17. I can maintain awareness of my inner bodily sensations even when there is a lot going on around me	0	1	2	3	4	5
18. When I am in conversation with someone, I can pay attention to my posture.	0	1	2	3	4	5
19. I can return awareness to my body if I am distracted.	0	1	2	3	4	5
20. I can refocus my attention from thinking to sensing my body.	0	1	2	3	4	5

21. I can maintain awareness of my whole body even when a part of me is in pain or discomfort	0	1	2	3	4	5
22. I am able to consciously focus on my body as a whole.	0	1	2	3	4	5
23. I notice how my body changes when I am angry.	0	1	2	3	4	5
24. When something is wrong in my life, I can feel it in my body.	0	1	2	3	4	5
25. I notice that my body feels different after a peaceful experience.	0	1	2	3	4	5
26. I notice that my breathing becomes free and easy when I feel comfortable.	0	1	2	3	4	5
27. I notice how my body changes when I feel happy/joyful.	0	1	2	3	4	5
28. When I feel overwhelmed, I can find a calm place inside.	0	1	2	3	4	5
29. When I bring awareness to my body, I feel a sense of calm.	0	1	2	3	4	5
30. I can use my breath to reduce tension.	0	1	2	3	4	5
31. When I am caught up in thoughts, I can calm my mind by focusing on my body/breathing.	0	1	2	3	4	5
32. I listen for information from my body about my emotional state.	0	1	2	3	4	5
33. When I am upset, I take time to explore how my body feels.	0	1	2	3	4	5
34. I listen to my body to inform me about what to do.	0	1	2	3	4	5
35. I am at home in my body.	0	1	2	3	4	5
36. I feel my body is a safe place.	0	1	2	3	4	5
37. I trust my body sensations.	0	1	2	3	4	5

Appendix G

The Six-Item Gastric Interoception Scale

Please consider how you are feeling RIGHT NOW, AT THIS VERY MOMENT and rate the extent to which you agree with the following statements:

My body is telling me whether or not I need food right now	1 – Strongly Disagree	2 – Disagree	3- Neither Agree nor Disagree	4 - Agree	5 – Strongly Agree
Right now I can't tell if I'm hungry or nauseous	1 – Strongly Disagree	2 – Disagree	3- Neither Agree nor Disagree	4 - Agree	5 – Strongly Agree
If I were to eat right now, I would eat everything on my plate, whether or not I was hungry	1 – Strongly Disagree	2 – Disagree	3- Neither Agree nor Disagree	4 - Agree	5 – Strongly Agree
I am aware of how full I am right now	1 – Strongly Disagree	2 – Disagree	3- Neither Agree nor Disagree	4 - Agree	5 – Strongly Agree
I am aware of how hungry I am right now	1 – Strongly Disagree	2 – Disagree	3- Neither Agree nor Disagree	4 - Agree	5 – Strongly Agree
I will eat my next meal at a set time, whether or not I'll be hungry	1 – Strongly Disagree	2 – Disagree	3- Neither Agree nor Disagree	4 - Agree	5 – Strongly Agree

Appendix H

Body Perception Questionnaire Very Short Form (BPQ-VSF; (Cabrera et al., 2018)

Please consider how you are feeling RIGHT NOW, AT THIS VERY MOMENT. Now, please rate the statements below. Remember to rate whether or not you are aware of feeling (or not feeling) a certain sensation, not whether you are actually experiencing it at this very moment.

I am aware of any dryness in my mouth	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of how fast I am breathing	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any swelling in my body	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any muscle tension in my arms and legs	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any feelings of being bloated because of water retention	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any goose bumps I may be having	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any stomach or gut pains I may be having	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any stomach distention or bloatedness	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any tremors in my lips	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware of any hairs ‘standing up’ on the back of my neck	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

I am aware whether or not I have an urge to swallow	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am aware how hard my heart is beating	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Appendix I

Positive and Negative Affect Schedule – Expanded (Watson & Clark, 1994)

This scale consists of a number of words and phrases that describe different feelings and emotions. Read each item and then mark the appropriate answer in the space next to that word. Indicate to what extent you have felt this way during the past week . Use the following scale to record your answers:

General Dimension Scale	**Emotion**					
Negative Affect	Afraid	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Scared	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Nervous	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Jittery	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Irritable	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Hostile	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Guilty	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Ashamed	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Upset	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Distressed	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
Positive Affect	Active	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Alert	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Attentive	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Determined	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

	Enthusiastic	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Excited	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Inspired	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Interested	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Proud	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Strong	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
Guilt	Guilty	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Ashamed	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Blameworthy	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Angry at self	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Disgusted with self	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely
	Dissatisfied with self	Very slightly or not at all	A little	Moderately	Quite a bit	Extremely

Appendix J

Portion Appropriateness Questionnaire

Please recall the portion sizes of biscuits you selected earlier on in the study, and rate the following statements:

I think that the portion I selected was of an appropriate size	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Other people would say that the portion I selected was of an appropriate size	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The portion I selected was neither too big nor too small	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The portion I selected is an amount that an average person would eat	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
The portion I selected is an amount that is natural for me to eat	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

The portion I selected is an amount others would consider neither too big nor too small	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Other people would not approve of the size of the portion I selected	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Appendix K

Fear of Negative Evaluation – Straightforwardly-Worded Items

(Rodebaugh et al., 2004)

Please read the following statements and rate the extent to which you agree with them RIGHT NOW, AT THIS VERY MOMENT.

I am afraid that others do not approve of me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am afraid that people are finding fault with me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I worry that people are thinking about me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am overly concerned with what other people think of me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am afraid people are noticing my shortcomings	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am worried about the impression I am making	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am worried about what others are thinking of me, even though I know it doesn't make any difference	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Appendix L

Motivation to Manage Impressions Scale (Lee-Wingate et al., 2014)

Please read the following statements and rate the extent to which you agree with them:

It matters what other people think of me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I don't think social obligations are important	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I spend a lot of time worrying about what people think of me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am always courteous, even to people who are disagreeable	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I usually abide by all the rules	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
It is important that other people respect me as a good person	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
It is important that other people think very highly of me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I have never said anything to deliberately hurt someone else's feelings*	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

* Removed from analysis to improve Cronbach's alpha

Appendix M

Fear of Covid-19 Scale (Ahorsu et al., 2020)

Over the past few months we have all been affected by the COVID-19 pandemic to some extent. We would like to ask you a few questions about how you feel about the virus TODAY.

I am most afraid of Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
It makes me uncomfortable to think about Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I worry a lot about Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Covid-19 is almost always terminal	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Covid-19 is an unpredictable disease	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
My hands become clammy when I think about Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am afraid of losing my life because of Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
When watching news and stories about Covid-19 on social media, I become nervous or anxious	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I cannot sleep because I'm worrying about getting Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
My heart races or palpitates when I think about getting Covid-19	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Appendix N

Self-Monitoring Questionnaire (version 1)

Please rate the extent to which you agree with the following statements.

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

I am aware of my shape/figure

I am aware of what I already ate today

I am focusing on my bodily reactions (for example, signals from my stomach)

I am focusing on my level of fulness

I am focusing on my level of hunger

I am aware of how much food I already ate today

I am focusing on what my body looks like

Appendix O

Self-Monitoring Questionnaire (version 2)

Please rate the extent to which you agree with the following statements.

RIGHT NOW, AT THIS VERY MOMENT...

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

I feel connected to the sensations of my body

I am focussing on the signals from my body

It is easy for me to describe how I am feeling at the moment

I am focussing on what my body feels like

I am focussing on my level of fulness

I am aware of the current state of my body

I am focussing on my level of hunger

Appendix P

Transcripts for the Imagination Tasks

'Recall + Handling'

Think about the lunch you ate today. Recall what the food on the plate looked like (7 seconds pause). The rice and sauce that you had was in the middle of the plate. Now, imagine what it would look like if it was all pushed to the left side of the plate (7 second pause). Picture the rice and the sauce were pushed around the edges of the plate, almost falling out, but staying on the plate. Imagine what this would look like (15 seconds pause). Imagine you picked all of the rice up in your hands. Now, try to visualise what this would feel like (7 seconds pause). What if all of the rice would be placed inside a mug? Take a few moments to think about what this would look like (7 seconds pause). Now, imagine that the rice and the sauce were placed inside a bowl and that you tried to balance the bowl on top of your head. Imagine what this would feel like (7 seconds pause). This is the end of the exercise, you may now open your eyes and take your headphones off.

'Recall + Rumination'

Think about the lunch you ate today. Picture what your meal looked like on the plate and how much rice and sauce you got (7 seconds pause). Go back to the moment you ate your meal, recall what it was like to physically eat your rice and sauce. Take a few seconds to remember this sensation (15 seconds pause). The rice and the sauce you ate had different textures, so now remember what it felt like to chew and swallow your food (7 seconds pause). Recall what you thought about the meal before you ate it (7 seconds pause). Transport yourself back to the moment when you were eating your rice and sauce. Think about how eating your meal made you feel and try to bring these feelings back into your mind (7 seconds pause). Remember what it looked like when you picked the rice up with a fork, and what it looked like when you put the food in your mouth. Visualise this in your mind (7 seconds pause). This is the end of the exercise, you may now open your eyes and take your headphones off.

'Recall + Enlargement'

Think about the lunch you ate today. Remember what you had and what the meal tasted like (7 seconds pause). Recall the size of the rice and sauce portion you received. Now, imagine that it was twice as big. Take a few seconds to imagine this (7 seconds pause). Now, picture yourself eating both of these portions of rice and sauce. Imagine physically doing the eating, the chewing and the swallowing (15 seconds pause). Remember what you felt like after you finished eating your rice. Imagine you felt very full, so full you could hardly move. Take a few moments to imagine what this would feel like (7 second pause). Now, imagine that you ate your meal more slowly and so you took much longer to finish eating your meal (7 second pause). Recall whether you thought that your lunch was satisfying after you finished eating it. Take a few moments to imagine that you thought your lunch was much more satisfying and filling (7 seconds pause). This is the end of the exercise, you may now open your eyes and take your headphones off.

'Food Picture + Handling'

Think about the meal you just saw on the photograph. Recall what the food on the plate looked like (7 seconds pause). The pasta and sauce that you saw were in the middle of the plate. Now, imagine what it would look like if all of the food was moved to the left side of the plate (7 second pause). Picture the pasta and the sauce being pushed around the edges of the plate, almost falling out, but staying on the plate. Imagine what this would look like (15 seconds pause). Imagine you picked all of the pasta up in your hands. Now, try to visualise what this would feel like (7 seconds pause). What if all of the pasta would be placed inside a mug? Take a few moments to think about what this would look like (7 seconds pause). Now, imagine that the pasta and the sauce were placed inside a bowl and that you tried to balance the bowl on top of your head. Imagine what this would feel like (7 seconds pause). This is the end of the exercise, you may now open your eyes and take your headphones off.

'Non-Food Picture + Handling'

Think about the objects you just saw on the photograph. Recall what they looked like on the plate (7 seconds pause). The elastic bands and paperclips that you saw were in the middle of the plate. Now, imagine what it would look like if all of the objects were moved to the left side of the plate (7 second pause). Picture the bands and the paperclips being pushed around the edges of the plate, almost falling out, but staying on the plate. Imagine what this would look like (15 seconds pause). Imagine you picked all of the paperclips up in your hands. Now, try to visualise what this would feel like (7 seconds pause). What if all of the paperclips would be placed inside a mug? Take a few moments to think about what this would look like (7 seconds pause). Now, imagine that the bands and the paperclips were placed inside a bowl and that you tried to balance the bowl on top of your head. Imagine what this would feel like (7 seconds pause). This is the end of the exercise, you may now open your eyes and take your headphones off.

Appendix Q

Mood Questionnaire (used in the Chapter 5)

Please rate the following statements.

Not at all 0 — Extremely 10

How thirsty do you feel right now?

How hungry do you feel right now?

How tired do you feel right now?

How stressed do you feel right now?

How happy do you feel right now?

How relaxed do you feel right now?

How bloated do you feel right now?

How nervous do you feel right now?

How excited do you feel right now?

How irritable do you feel right now?

Appendix R

Questions used to assess subjective imagination ability (Chapter 5)

Please select the most appropriate rating for you:

How good are you at imagining things with a high level of detail?	Extremely bad	Somewhat bad	Neither good nor bad	Somewhat good	Extremely good
How good are you at producing unique images and ideas with your imagination?	Extremely bad	Somewhat bad	Neither good nor bad	Somewhat good	Extremely good
When you imagine something, how good are you at changing or adding detail to that image or idea?	Extremely bad	Somewhat bad	Neither good nor bad	Somewhat good	Extremely good

Appendix S

Questions used to assess subjective memory ability (Chapter 5)

I generally have a good memory for everyday events (e.g. what happened last week)	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I tend to remember exactly where and when something happened	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Other people can rely on my memory of what happened over the past week or two	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
When I recall an event, I can remember who I spent time with and who I spoke to	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I can clearly remember what happened to me over the past two weeks	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Sometimes I realise that I've remembered a detail that didn't happen – for example, I've remembered someone being there that wasn't	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Appendix T

Results of analyses from Chapter 5, conducted without participants who did not finish the entire meal

	Overall model	**Group interaction (if applicable)**
Age	$F(4,116)=1.82$, $p=.131$	
BMI	$F(4,116)=1.38$, $p=.246$	
Restraint (DEBQ)	$F(4,116)=0.35$, $p=.842$	
Disinhibition (TFEQ)	$F(4,116)=0.74$, $p=.569$	
Source memory score	$F(4,116)=1.48$, $p=.213$	
Subjective memory ability	$F(4,116)=1.21$, $p=.309$	
Subjective imagination ability	$F(4,116)=0.19$, $p=.942$	
Pre- to post-lunch hunger	$F(1,116)=498.19$, $p<.001$	$F(4,116)=1.81$, $p=.131$
Pre-meal hunger	$F(4,116)=1.78$, $p=.138$	
Post-meal hunger	$F(4,116)=0.57$, $p=.684$	
Enjoyed lunch	$F(4,116)=1.24$, $p=.298$	
Lunch Satisfying	$F(4,116)=0.82$, $p=.514$	
Lunch portion size adequate	$F(4,116)=0.28$, $p=.888$	
Lunch similar to usual meals	$F(4,116)=1.70$, $p=.154$	
Pre- to post-imagination task hunger	$F(1,116)=0.04$, $p=.834$	$F(4,116)=8.01$, $p<.001$
Pre-imagination hunger	$F(4,116)=1.57$, $p=.187$	
Post-imagination hunger	$F(4,116)=2.54$, $p=.043$*	
Imagined events were immersive	$F(4,116)=2.23$, $p=.070$	
Imagined events seemed real	$F(4,116)=2.21$, $p=.072$	
Imagined events were detailed	$F(4,116)=1.80$, $p=.134$	
Imagined events were believable	$F(4,116)=1.89$, $p=.117$	
Events were easy to imagine	$F(4,116)=2.12$, $p=.083$	
Biscuit intake	$F(4,116)=4.33$, $p=.003$*	
Average biscuit liking	$F(4,116)=0.98$, $p=.422$	
Frequency of biscuit consumption	$F(4,116)=0.38$, $p=.822$	
Physical portion size estimation:		
Recall + Enlargement	$t(25)=-2.44$, $p=.022$*	
Recall + Handling	$t(23)=-1.68$, $p=.106$	
Recall + Rumination	$t(21)=-1.83$, $p=.081$	
Food Picture + Handling	$t(25)=-1.22$, $p=.235$	
Non-Food + Handling	$t(22)=-1.89$, $p=.072$	

Overall group differences	$F(4,116)=0.29$, $p=.886$	
Picture portion estimation	$X^2(8)=4.35$, $p=.825$	

Appendix U

Mindful Eating Behavior Scale (Winkens et al., 2018)

Please rate the following statements:

Expected domain 1: Eating while focussing on the food					
I notice flavours and textures when I'm eating my food	Never	Seldom	Sometimes	Often	Very often
I stay aware of my food while eating	Never	Seldom	Sometimes	Often	Very often
I notice how my food looks	Never	Seldom	Sometimes	Often	Very often
I notice the smells and aromas of food	Never	Seldom	Sometimes	Often	Very often
It is easy for me to concentrate on what I eat	Never	Seldom	Sometimes	Often	Very often
Expected domain 2: Eating while paying attention to hunger and satiety cues					
I trust my body to tell me when to eat	Never	Seldom	Sometimes	Often	Very often
I trust my body to tell me what to eat	Never	Seldom	Sometimes	Often	Very often
I trust my body to tell me how much to eat	Never	Seldom	Sometimes	Often	Very often
I rely on my hunger signals to tell me when to eat	Never	Seldom	Sometimes	Often	Very often
I rely on my fullness signals to tell me when to stop eating	Never	Seldom	Sometimes	Often	Very often
I trust my body to tell me when to stop eating	Never	Seldom	Sometimes	Often	Very often
Expected domain 3: Being aware of eating					
I snack without being aware that I am eating	Never	Seldom	Sometimes	Often	Very often
I eat automatically without being aware of what I eat	Never	Seldom	Sometimes	Often	Very often
I eat something without really being aware of it	Never	Seldom	Sometimes	Often	Very often
Expected domain 4: Eating while not being distracted					

My thoughts tend to wander while I am eating	Never	Seldom	Sometimes	Often	Very often
I think about things I need to do while I am eating	Never	Seldom	Sometimes	Often	Very often
I multitask while I am eating	Never	Seldom	Sometimes	Often	Very often
I eat at my desk or computer	Never	Seldom	Sometimes	Often	Very often
I watch television while I am eating	Never	Seldom	Sometimes	Often	Very often
I read while I am eating	Never	Seldom	Sometimes	Often	Very often

Appendix V

Food Acceptance and Awareness Questionnaire (Juarascio et al., 2011b)

Directions: below you will find a list of statements. Please rate the truth of each statement as it applies to you. Use the following rating scale to make your choices.

	1	2	3	4	5	6	7
	Never true	Very seldom true	Seldom true	Sometimes true	Frequently true	Almost always true	Always true
I continue to eat a healthy diet, even when I have the desire to overeat or make poor eating choices.	①	②	③	④	⑤	⑥	⑦
It’s OK to experience cravings and urges to overeat, because I don’t have to listen to them.	①	②	③	④	⑤	⑥	⑦
It’s not necessary for me to control my food urges in order to control my eating.	①	②	③	④	⑤	⑥	⑦
I need to concentrate on getting rid of my urges to eat unhealthily.	①	②	③	④	⑤	⑥	⑦
I don’t have to overeat, even when I feel like I want to overeat.	①	②	③	④	⑤	⑥	⑦
Controlling my urges to eat unhealthily is just as important as controlling my eating.	①	②	③	④	⑤	⑥	⑦
My thoughts and feelings about food must change	①	②	③	④	⑤	⑥	⑦

before I can make changes in my eating.							
Despite my cravings for unhealthy foods, I continue to eat healthily.	①	②	③	④	⑤	⑥	⑦
Before I can make any important dietary changes, I have to get some control over my food urges.	①	②	③	④	⑤	⑥	⑦
Even if I have the desire to eat something unhealthy, I can still eat healthily.	①	②	③	④	⑤	⑥	⑦

Appendix W

Food Cravings Questionnaire – Trait (Cepeda-Benito et al., 2000; Meule et al., 2012)

Please rate the following statements:

I feel like I have food on my mind all the time	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I find myself preoccupied with food	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I can't stop thinking about eating no matter how hard I try	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I spend a lot of time thinking about whatever it is I will eat next	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I daydream about food	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Whenever I have a food craving, I keep on thinking about eating until I actually eat the food	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
If I am craving something, thoughts of eating it consume me	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I hate it when I give into cravings	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

I often feel guilty for craving certain foods	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
When I eat what I am craving I feel guilty about myself	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Appendix X

Loss of Control over Eating – Brief (Latner et al., 2014)

During the past week, how often did you experience the following?

1. I continued to eat past the point when I wanted to stop.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day
2. I felt like I had 'blown it' and might as well keep eating.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day
3. I felt helpless about controlling my eating.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day
4. My eating felt like a ball rolling down a hill that just kept going and going.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day
5. I found myself eating despite negative consequences.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day
6. I felt like the craving to eat overpowered me.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day
7. I felt like I could not do anything other than eat.	not at all	on 1-2 days	on 3-4 days	on 5-6 days	every day

Appendix Y

Pre-Intervention Chatbot Ratings (Chapter 6)

Please rate the following statements:

Thinking about weight-loss methods and interventions in general, how different is the chatbot from other interventions?	1- Very different	2	3	4	5- Very similar
Thinking about weight-loss methods and interventions in general, how appealing is the chatbot, compared to other interventions?	1- Much less appealing	2	3	4	5- Much more appealing
How likely do you think this chatbot is to help you lose weight (if you were to use it for a longer period of time)?	1- Very unlikely	2	3	4	5- Very likely
This chatbot will help me to improve my eating habits.	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I will enjoy using this chatbot.	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I will struggle to use this chatbot regularly.	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree

Appendix Z

Post-Intervention Chatbot Acceptability Ratings (Chapter 6 and 7)

Please rate the following statements:

I enjoyed using the chatbot	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I found the chatbot easy to use	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I found the chatbot convenient to use	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I struggled to use the chatbot regularly	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I sometimes found it annoying or awkward to use the chatbot	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I found it easy to fit the chatbot into my daily routine	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
Using the chatbot helped me to improve my eating habits	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
Over the course of the trial, my memory for the food I ate improved	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
The chatbot made me pay more attention to the food I was eating	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree
I would be willing to use this chatbot in the future, for longer periods of time (e.g. 6 months)	Strongly Disagree	Disagree	Neither agree nor Disagree	Agree	Strongly Agree

Appendix AA

Usability Study Interview Questions (Chapter 6)

Questions for all participants:

1. How appealing was this weight-loss intervention to you?
2. How easy or difficult did you find it to access the chatbot?
3. Did you know exactly what to do as soon as you opened the chatbot?
-If yes – what made you confident about using it?
- If not – what confused you or what could have been clearer?
4. Did you struggle with anything in particular, whilst using the chatbot?
5. Did you find any of the features confusing or annoying?
6. Could anything have made your experience better?
7. Did you enjoy using the chatbot?
8. Did you record your portion size as well as the contents of your meal?
- If not, why?
- If yes, did you struggle with describing the portion size? How did you know what your portion size was?
9. Would you be willing to use the chatbot every day for a month, or even for a year? Why yes/no?
10. How easy or difficult was it for you to remember to use the chatbot just before your next meal?
11. What strategies did you use to remember to use the chatbot?
12. Did you forget to log any of the meals?
- If so, what did you do?
13. How did logging your meal make you feel? Was it a positive, a negative or a neutral experience?
14. Did you experience any changes in your physical state after recalling the recent meal?
- If so, what changes did you observe?
15. Did recalling a recent meal affect your appetite in any way?
- If so, in what way?
16. Did you experience any changes in your emotional state or your mood after recalling the recent meal?
- If so, what changes did you observe?
17. Did you observe any changes to your behaviour after using the chatbot for a week?
- If so, what changes did you observe?
18. Do you think this chatbot would help you lose weight, if you used it for a longer period of time?
19. Is there anything else you would like to add?

Appendix BB

Results of analyses from Chapter 6, conducted with BMI as a covariate

	Overall model	**BMI (covariate)**
Pre-trial impressions		
Intervention appealing	$F(2,9)=0.67$, $p=.535$	$F(2,9)=0.94$, $p=.357$
Intervention different to others	$F(2,9)=0.03$, $p=.972$	$F(2,9)<0.01$, $p=.956$
Intervention will lead to weight-loss	$F(2,9)=1.19$, $p=.348$	$F(2,9)=1.71$, $p=.223$
Post-trial impressions		
Chatbot usage (total logs)	$F(2,9)=3.71$, $p=.067$	$F(2,9)=1.11$, $p=.320$
Pre- to post-trial changes in perceived/actual usability		
Intervention enjoyable	$F(1,9)=0.03$, $p=.863$	$F(1,9)=0.07$, $p=.795$
Struggle to remember to use	$F(1,9)=13.27$, $p=.005$	$F(1,9)=5.52$, $p=.043$
Intervention improves eating habits	$F(1,9)=0.06$, $p=.816$	$F(1,9)=0.28$, $p=.612$
Post-trial impressions of chatbot usability		
Ease of use	$F(2,9)=2.07$, $p=.183$	$F(1,9)=2.49$, $p=.149$
Convenient to use	$F(2,9)=7.53$, $p=.012$	$F(1,9)=2.48$, $p=.150$
Awkward to use	$F(2,9)=6.65$, $p=.017$	$F(1,9)=2.37$, $p=.158$
Fits well into daily routine	$F(2,9)=8.48$, $p=.009$	$F(1,9)<0.01$, $p=.989$
Improved memory for recent meals	$F(2,9)=0.51$, $p=.618$	$F(1,9)=1.02$, $p=.339$
Pay more attention to meal	$F(2,9)=1.02$, $p=.399$	$F(1,9)=1.75$, $p=.219$
Willingness to use long-term	$F(2,9)=1.17$, $p=.353$	$F(1,9)=2.34$, $p=.160$
Pre- to post-trial differences in cognition		
Interoceptive awareness	$F(1,9)=0.01$, $p=.930$	$F(1,9)=0.19$, $p=.674$
MEBS (eating while focussing on food)	$F(1,9)=0.44$, $p=.524$	$F(1,9)=0.06$, $p=.818$
MEBS (eating while paying attention to hunger and satiety cues)	$F(1,9)=0.16$, $p=.696$	$F(1,9)=0.05$, $p=.835$
MEBS (being aware of eating)	$F(1,9)<0.01$, $p>.999$	$F(1,9)=0.06$, $p=.816$
MEBS (eating while not being distracted)	$F(1,9)=0.70$, $p=.425$	$F(1,9)=0.73$, $p=.415$
Trait Food Cravings (FCQ-T)	$F(1,9)<0.01$, $p=.993$	$F(1,9)=0.16$, $p=.698$
Food Acceptance and Awareness Questionnaire (FAAQ)	$F(1,9)=2.15$, $p=.177$	$F(1,9)=1.97$, $p=.194$
Loss of Control over Eating – Brief (LOCES)	$F(1,9)=0.82$, $p=.390$	$F(1,9)=0.39$, $p=.546$
Negative affect	$F(1,9)=0.32$, $p=.584$	$F(1,9)=2.20$, $p=.173$
Positive Affect	$F(1,9)=0.04$, $p=.849$	$F(1,9)=0.07$, $p=.801$
Guilt	$F(1,9)=0.19$, $p=.677$	$F(1,9)=0.43$, $p=.529$

Appendix CC

Pre-Trial Chatbot Acceptability Ratings (Chapter 7)

Item	**Scale**
Thinking about weight-loss methods and interventions in general, how different is the chatbot from other interventions?	1 (very different) – 5 (very similar)
Thinking about weight-loss methods and interventions in general, how appealing is the chatbot, compared to other interventions?	1 (much less appealing) - 5 (much more appealing)
How likely do you think this chatbot is to help you lose weight (if you were to use it for a longer period of time)?	1 (very unlikely) – 5 (very likely)
How likely do you think this chatbot is to help you improve your eating?	1 (very unlikely) – 5 (very likely)
How much do you think you will enjoy using this chatbot?	1 (not at all) – 5 (very much)
How much do you think you will struggle to use this chatbot?	1 (not at all) – 5 (very much)

Appendix DD

Weekly Chatbot Report (Chapter 7)

Do you agree with the following statements?

I enjoyed using the chatbot this week	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I disliked using the chatbot this week	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I struggled to use the chatbot this week	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Using the chatbot helped me to eat smaller portions this week	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
Using the chatbot helped me to make better food choices this week	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I am confident that I will continue to use the chatbot in the coming week	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Please tell us about your experiences of using the chatbot this week. You can tell us about anything you think might be relevant.

Things you might write about include:
Did you use the chatbot regularly? Did you struggle at any point? Are you enjoying the trial?

Appendix EE

Feasibility Study Interview Questions (Chapter 7)

1. When you first found out about the chatbot, how appealing did you find it to be?

2. Did you enjoy using the chatbot?
- if so, what did you find enjoyable?
- if not, what did you not enjoy?

3. Did you remember to use the chatbot regularly?
- if yes, did you need any external reminders?
- if not, why?

4. Did you struggle with anything in particular, whilst using the chatbot?

5. Did you find the chatbot annoying or confusing?
- if so, why?

6. Could anything have made your experience better?

7. What motivated you to carry on using the chatbot?

8. Did you have to invest a lot of time and effort into using the chatbot?

9. How willing would you be to continue using the chatbot for a longer period of time?

10. Did using the chatbot help to improve your eating?
- if so, in what ways?

11. Did using the chatbot help you to improve the way you think about food or your food choices?
- if so, in what ways?

12. Did using the chatbot change your behaviour in any way?

13. Is there anything else you would like to add?

Appendix FF

Results from Chapter 7, conducted with BMI as a covariate

	Overall model	**Baseline BMI as a covariate**
Pre-trial impressions		
Intervention different to others	$F(2,75)=0.24$, $p=.784$	$F(1,75)=0.20$, $p=.658$
Intervention appealing	$F(2,75)=0.32$, $p=.729$	$F(1,75)=0.10$, $p=.752$
Intervention will lead to weight-loss	$F(2,75)=1.18$, $p=.312$	$F(1,75)=1.17$, $p=.284$
Intervention will help to improve eating habits	$F(2,75)=6.59$, $p=.002$	$F(1,75)=0.25$, $p=.622$
Intervention likely to be enjoyable	$F(2,75)=0.84$, $p=.436$	$F(1,75)=0.90$, $p=.345$
Likely to struggle to use the intervention regularly	$F(2,75)=0.06$, $p=.942$	$F(1,75)=0.05$, $p=.824$
Pre- to post-trial changes in acceptability		
Will enjoy/enjoyed using chatbot	$F(1,61)=0.11$, $p=.747$	$F(1,61)=0.51$, $p=.478$
Will struggle/struggled to use chatbot regularly	$F(1,61)=.20$, $p=.653$	$F(1,61)=0.05$, $p=.822$
Chatbot will help/helped to improve eating habits	$F(1,61)=0.05$, $p=.826$	$F(1,61)=0.73$, $p=.396$
Post-trial ratings of acceptability		
Chatbot was convenient	$F(2,61)=5.70$, $p=.005$	$F(1,61)=1.11$, $p=.297$
Chatbot fit well into routine	$F(2,61)=8.25$, $p=.001$	$F(1,61)=1.32$, $p=.255$
Chatbot was awkward	$F(2,61)=7.92$, $p=.001$	$F(1,61)=0.06$, $p=.802$
Chatbot was easy to use	$F(2,61)=1.32$, $p=.274$	$F(1,61)<0.01$, $p=.950$
Chatbot improved memory for recent meals	$F(2,61)=2.42$, $p=.097$	$F(1,61)=2.18$, $p=.145$
Chatbot increased attention paid to meals	$F(2,61)=1.79$, $p=.176$	$F(1,61)=0.08$, $p=.773$
Willing to continue to use the chatbot long-term	$F(2,61)=0.84$, $p=.436$	$F(1,61)=0.19$, $p=.262$
Self-reported energy intake	$F(1,61)=0.76$, $p=.388$	$F(1,61)=0.24$, $p=.623$
Pre- to post-trial changes in cognition		
Interoceptive awareness	$F(1,61)=0.05$, $p=.820$	$F(1,61)=0.04$, $p=.851$
Eating while focussing on food	$F(1,61)=0.16$, $p=.687$	$F(1,61)=0.15$, $p=.704$
Eating while paying attention to hunger and satiety cues	$F(1,61)=1.27$, $p=.264$	$F(1,61)=1.40$, $p=.241$
Being aware of eating	$F(1,61)=<0.01$, $p=.974$	$F(1,61)=0.01$, $p=.925$
Eating while not being distracted	$F(1,61)=0.85$, $p=.361$	$F(1,61)=0.62$, $p=.436$
Food Acceptance and Awareness Questionnaire (FAAQ)	$F(1,61)=0.42$, $p=.520$	$F(1,61)=1.28$, $p=.263$
Dutch Eating Behaviour Questionnaire (DEBQ) – Restraint	$F(1,61)<0.01$, $p=.981$	$F(1,61)=0.13$, $p=.720$
Trait Food Cravings (FCQ-T)	$F(1,61)=0.61$, $p=.439$	$F(1,61)=0.30$, $p=.588$
Loss of Control over Eating – Brief (LOCES)	$F(1,61)=0.20$, $p=.660$	$F(1,61)<0.01$, $p=.977$