Specific Learning Difficulty (SpLD) Coversheet – sensitive marking request

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The Equality Act 2010 requires that ‘reasonable adjustments’ be made for students whose disability is known to the University.

Students with a SpLD typically experience difficulty producing written work as quickly as their peers; they are likely to make spelling errors even in word processed work; their punctuation, formatting and grammar may be uneven and they often omit, repeat or insert small function words or word endings. They will sometimes have poor arithmetic skills and find mathematics and sequencing very difficult.

Good practice guidance on marking essays and giving feedback to those with a SpLD

- While not without structure, written assignments may lack the “polish” demonstrated by their peers. Try not to deduct marks for poor presentation, spelling, punctuation and grammar. Such errors should be understood and overlooked unless accuracy is of vital importance in the subject being assessed.
- Make constructive and straightforward comments using the learning outcomes and assessment criteria for the assignment.
- Students often need examples of good practice in order to improve their writing style. Please try to reference or highlight some of these when correcting work.
- Let the student know that marking is about the learning outcomes/assessment criteria. Make it clear when corrections are for feedback purposes but have not affected the mark.
- If the English is corrected, explain what is wrong with it and why the correction is better; do not correct everything.
- Be sensitive: many students have experienced negative reactions to their written work through lack of understanding in the past.
- Provide electronic feedback where possible.

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Eyes bigger than your stomach? A novel scaling task reveals more evidence for attentional than action-specific effects on the perceived size of food.

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This thesis is dedicated to Cerys Somers, without her this thesis would not exist.

Impact of COVID-19

The COVID-19 pandemic affected many aspects of this thesis. Restrictions put in place to limit the spread of infection affected the delivery of experiments within this thesis (i.e., requiring experiments to be cancelled and redesigned to run online) and the recruitment of participants (i.e., imposed financial restrictions required participants to take part in some experiments without financial reimbursement in exchange for their time). These issues are discussed in more detail within their relevant chapters. However, it should be noted here that the direction of this thesis had to change due to these restrictions. Mainly in the cancellation of a large EEG study shortly before data collection - which is included within this thesis now in Chapter 4 as a proposed study. In addition, the experiment presented in Chapter 5 had to be reprogrammed and redesigned to be deployed online, as in-lab experimentation was not possible.

Contents

Thesis Abstract

Much research supports the existence of top-down effects on visual perception. Within this thesis, two accounts which seek to explain top-down effects on perception are investigated: The Action-Specific Account, which asserts that perception is affected by an individual’s ability to act, and the Attentional Account, which asserts that perception is affected by attention towards an object. These accounts were investigated because they potentially challenge cognitive impenetrability – the assertion that perception is free from cognitive influences. These accounts therefore have ramifications for the concept of modularity and the current understanding of how the mind is organised. However, no research demonstrating top-down effects on perception has successfully avoided the methodological pitfalls which provide alternative explanations for their results. As such, the central aim of this thesis was to develop a method of measuring one example of these top-down effects - changes in object size perception - whilst avoiding said methodological pitfalls. Perception of food size (relative to perceived non-food size) was selected because previous research suggested that changes in perceived food size may affect subsequent eating behaviours. The central finding of this thesis is that attention, independent of action-specific influences, affects perception. Importantly, although top-down attention affects perceptual experience, it is suspected this occurs indirectly through small changes in visual input (fixation locations) - and therefore may not challenge cognitive impenetrability.

To investigate the extent of top-down effects on perception, this thesis also addressed inconsistencies within the broader food perception literature. It was observed that health outcomes related to over-eating were better predicted by food-specific, than domain-general, self-reports. Interestingly, the impulsivity assessed by these food-specific measures (although known to affect attention) did not predict perceived food size. In summary, this thesis addresses methodological issues within the object perception literature and further research is proposed to assess its limitations.

Chapter 1

Thesis introduction

Abstract

This introductory chapter explores the concept of cognitive impenetrability, and its importance in understanding how the mind is organised. Cognitive impenetrability argues that, although visual perception is used to drive action, perceptual processing is modular and insulated from cognitive influences (impenetrable) – and therefore is not influenced by desires, cognitive/intellectual knowledge, or one's own physical attributes. Two accounts of visual perception that potentially challenge the concept of cognitive impenetrability are discussed. These two accounts are different in their assertion as to how cognition affects perception. For example, the Action-Specific Account predicts that an individual's visual perception is affected by their ability to act, whereas the Attentional Account predicts that visual perception is affected by the breadth of attention towards an object. The present chapter discusses these accounts of object perception while exploring some of the research supporting them. Although many research papers have been published claiming to demonstrate top-down effects on perception (such as action-capacity or attention), none to date appear to avoid methodological pitfalls which provide alternative explanations for their observed results. For this reason, this introduction contains a breakdown of the most common experimental pitfalls of research claiming to evidence top-down effects on perception. It is also highlighted that the Action-Specific and Attentional Accounts are worthy of further study because, if either are accurate, they may have important implications for the development of practical interventions, such as those aimed at addictive behaviours. Finally, this introduction

will outline the structure of this thesis, while detailing the investigations and key findings of each chapter.

Introduction

Wade and Swanston (2013) assert that vision is the most dominant of human senses, and further, that visual perception plays an instrumental role in allowing humans to respond to their environment. Therefore, even on the surface, it appears that perception is closely linked to action – especially regarding identifying opportunities to act. In addition, Gibson (2014) claims that visual perception guides action by assessing the environment and identifying relevant possible actions. Importantly, they state that these identifications – or affordances – are specific to the individual perceiving the environment. Simply, although individuals may perceive the same stimulus (or environment) as physically identical, the potential actions inferred from this perception may differ based on a person’s ability to act. Evidence of Gibson’s claims can be seen in Buccino, Sato, Cattaneo, Rodà, and Riggio (2009), in which participants were presented with a mug – the handle of which was either presented towards participants’ dominant or non-dominant hand. Their results demonstrated that motor evoked potentials (muscle activations which occur following motor activations in the brain; Legatt, 2014) in the dominant hand were larger when the handle was facing the dominant hand, compared to when facing the non-dominant hand. This suggests that the affordances of the environment (i.e., mug handle orientation) may have been used to inform action preparation – and likely subsequent action.

Indeed, this view of visual perception as closely linked to action was quantified by Milner and Goodale (1992) who, in reinterpreting work by Ungerleider and Mishkin (1982), presented a revised Two Visual Streams Model (TVSM). In this version of the TVSM, visual perception is separated theoretically into distinct but related networks that together create effective action. Specifically, Milner and Goodale

(1992) asserted that the ventral stream contributes to the identification of objects, as well as their significance - and relationship - to other objects and people. Meanwhile, the dorsal stream assists the control of action by constantly updating and adjusting actions as they are carried out – for example by constantly reassessing the relative location and orientation of an object. This separation of the ventral and dorsal streams is by no means just conceptual – it also reflects a physical separation on a neural level. In fact, the TVSM asserts that, although both the ventral and dorsal stream follow the same (or at least extremely similar) processing from retina to the brain area V1, it is at this point they diverge quite dramatically. The ventral stream leads from the V1 to the occipito-temporal cortex, whereas the dorsal stream leads to the posterior parietal cortex. The physical separation of these two streams has allowed for the successful study of the differences between them. Indeed, their separation in the brain has led to compelling evidence for their functional separation - particularly in the form of neural patients with damage to one stream but not the other. For example, Perenin and Vighetto (1988) found that patients with dorsal stream damage (specifically intraparietal and posterior parietal cortex lesions) presented with Optic Ataxia - difficulties reaching for an object, despite being able to accurately describe its relative position. This suggests that the dorsal stream is not responsible for object identification (at least not entirely), but instead guides action by continually updating the relative position between self and object. By contrast, an individual with ventral stream damage (specifically ventrolateral occipital cortex lesions) titled D.F was unable to identify objects or the faces of their loved ones (despite being able to perceive low-level features such as colour texture, and contrast; Goodale & Wolf, 2009). However, despite these deficits in object recognition and conscious perception of their environment, Goodale, Milner, Jakobson, and Carey (1991) observed that D.F had no deficit in reaching for objects. Dramatically, Patla and Goodale (1996) observed that, regardless of massively inaccurate obstacle size estimation, D.F accurately stepped over obstacles while walking. This suggests that the ventral stream is not responsible for using vision to guide action (at least not entirely). Instead, these studies suggest that the ventral stream is involved in constructing meaning and conscious representations from perceived visual information. Although less drastic, visual illusions demonstrate support for the TVSM in healthy participants – most convincingly, the Hallow Face Illusion (in which a concave model of a face looks convex; Gregory, 1970). Króliczak, Heard, Goodale, and Gregory (2006) instructed their participants to either flick a target from – or slowly point to - a concave model of a face (which participants would consciously perceive as a normal/convex face). Their participants aimed for the perceived illusionary convex face while pointing at the target, but at the true target location (concave face) while attempting to flick the target. This suggests that the dorsal stream uses a target's low-level features to guide action - even when the top-down ventral stream misinterprets visual information. It can therefore be argued that visual and motor networks are distinct but closely related, working simultaneously to generate conscious perception and action. However, it should be noted that this claim that action is not susceptible to visual illusions is controversial. For example, Franz (2000; 2001) demonstrated that the previously observed motor effects (or lack thereof) are not replicated after making changes to the way motor tasks are administered. Their participants took part in the Ebbinghaus illusion grasping task, in which participants presented a small token surrounded by large tokens or the large token surrounded by small tokens (as in the classic Ebbinghaus illusion). Participants were then asked to grasp either the small token surrounded by large tokens or the large token surrounded by small tokens, and found that participants' grasping differed depending on which token they were required to grasp. However, they also observed that this difference in grasping between conditions were not shown the full illusion at once (that is they were only shown the small token surrounded by large tokens or the large token surrounded by small tokens at any one time while grasping). As such, it should be acknowledged that this view of action as not susceptible to visual illusions is still controversial. Recently, the connection between visual perception and action is considered even closer. Specifically, Caiani and Ferretti (2017) proposed an integrated model which they referred to as The Integration Hypothesis. The Integration Hypothesis suggests that the dorsal and ventral streams are not separate but communicate to create appropriate and accurate action. The suggestion that dorsal and ventral streams communicate seems accurate, even anecdotally. For example, if the dorsal stream is responsible for guiding appropriate and accurate action, then the ventral stream must communicate what an appropriate action is (based on previous experience, social etiquette, or the environmental context). This Integration Hypothesis goes further by describing visual perception for action as non-modular – that is, two streams continually communicating and influencing one another - opposed to separate encapsulated streams. Evidence for this integrated model comes from Jeannerod, Decety, and Michel's (1994) dorsal stream lesion patients that interacted with objects. Their patients demonstrated disproportionate grasping movement when interacting with unfamiliar, compared to familiar, objects. This suggests more dorsal and ventral stream communication than first suspected, as their results suggest that ventral processing of an object's identity and non-physical representations (such as grasping convention) may make up for dorsal stream deficits (and related movement planning difficulties). Neural evidence of this integration also exists, for example, the inferior parietal lobe receives input from both the dorsal and ventral streams (Milner & Goodale, 1995). Despite the differences between the TVSM and the Integration Hypothesis, both are clearly asserting that perception and action are separate but closely linked.

Considering this close link between an individual's perception and subsequent actions, this thesis will focus on the potential utility of manipulating an individual's perception in order to reduce harmful behaviours (such as over-eating). However, before doing so, the concept of cognitive impenetrability should also be considered. This is because – although it is generally accepted that vision and perception are fundamentally separate (Firestone and Scholl, 2016) – there are some claims to the counter. For example, the Action-Specific Account (Proffitt & Linkenauger, 2013) suggests that visual perception is affected by action, intention to act, and ability to act. As such, both the TVSM and Integration Hypothesis are congruent with the idea of cognitive impenetrability by Fodor (1983). Cognitive impenetrability asserts that an individual's perception (the way they see the environment in terms of spatial properties) is modular and cannot be affected by cognition – such as an individual's goals, believes or previous knowledge or physical attributes (Pylyshyn, 1980, 1999). Indeed, Fodor (1983) states that the perceptual system is not affected by the knowledge or desire of the perceiver. Put simply, although perceived spatial properties may be used to guide interaction with the environment, individuals do not see their environment differently based on their ability/intention to act. However, recently, there has been a growing movement towards the assertion that top-down effects, such as various forms of desire, intention, and ability may influence what an individual visually perceives (Proffitt & Linkenauger, 2013; Witt & Dorsch, 2009;

Eves, Thorpe, Lewis & Taylor-Covill, 2014). In the context of the present thesis, the top-down effects of interest are the effects of action-capacity and attention on visual perception that suggest an effect of cognition on perception. Effects of cognition on perception have been previously demonstrated by using ‘Mooney’ images (difficult to interpret visual scenes where shadows and shading have been manipulated to be black and white – see Ogilvie & Carruthers, 2016 for an example image). For example, Hsieh, Vul, and Kanwisher (2010) used fMRI to identify patterns of neural activity in participants’ visual cortices while viewing various photos. Specifically, they showed participants an image of a Mooney image, followed by the same image again but this time simply greyscale before being shown the first (Mooney) image again. It was argued by Hsieh et al., (2010) that if visual processing is purely bottom-up and not susceptible to any top-down processing at all, then the neural activity recorded in the visual cortex should be identical while being shown the Mooney image the first and second time (despite the image being disambiguated by being shown the greyscale version between times the Mooney image was displayed). Instead, they observed that neural activity in the visual cortex while viewing the Mooney image for the second time was closest to that observed while viewing the greyscale (compared to viewing the Mooney image for the first time). This was argued to have occurred because, when viewing the Mooney image for the second time, participants recognised the high-level patterns from the greyscale image in the Mooney image. As such, it can be suggested that top-down processes, such as recognition and memory, can affect an individual’s visual perception. However, as pointed out by Firestone and Scholl (2015), the evidence for these effects on perception rely on recognition and memory. For this reason, they are not top-down effects in the purest or most controversial context of this thesis in that they challenge the concept of cognitive penetrability (discussed later in this these). However, the above is not to say that cognitive impenetrability has never been challenged or questioned. For example, de Haas, Schwarzkopf, and Rees (2016) refute Firestone and Scholl's (2016) claim that perception is encapsulated by referring to research which suggests that perception is susceptible to multisensory modulation – that is, the effect of one perceptual sense (such as auditory perception) on another (such as visual perception). Specifically, Shams, Kamitani, and Shimojo (2000) claim to have observed that listening to auditory stimuli can affect the way that visual stimuli is perceived. In their research participants viewed a black screen, on which a white disk flashed for 50ms between one and times. These flashes were accompanied by a various number of beeps in rapid succession 57ms apart, and participants reported how many flashes of the white disk they believed they had been presented. The authors observed that participants consistently incorrectly reported that multiple flashes had been presented when a single flash was accompanied by multiple beeps, thus suggesting that auditory perception at the time of visual perception can affect how visual information is perceived. Although this effect demonstrates changes in perception caused by something other than changes in visual stimuli, the present thesis will not consider these cross-modal or multiple sensory modulation. This is because, although these effects have been shown to effect visual perception (Sekuler et al., 1997) - to paraphrase Firestone and Scholl (2016) - multisensory effects demonstrate how one type of perception may affect another, rather than how cognition affects visual perception. As such, it is argued that multisensory effects do not constitute true top-down effects. Instead this thesis will focus on The Action-Specific Account of visual perception - an example of theoretical work which goes against the idea of cognitive impenetrability by asserting that an individual’s visual perception (what they see in terms of spatial properties) of their environment is driven by their ability to act (see Philbeck & Witt, 2015 for review). Unlike Gibson, who claimed that visual perception guides behaviour by identifying possible actions and then update actions in motion, proponents of the Action-Specific Account assert that the spatial features of the environment (relevant to action) are visually scaled according to an individual’s action capacity - thus presenting opportunity for effective action (Proffitt & Linkenauger, 2013). Put simply, Gibson argued that visual information is used to select action, whereas the Action-Specific Account asserts that the perceived visual information is distorted to encourage/discourage actions depending on the perceiver’s ability to act. There are many studies claiming to have found evidence to support this account (a small selection of which are discussed below). In more detail, Proffitt & Linkenauger (2013) put forward the idea that the physical state of the human body provides ‘perceptual rulers’ which are used to scale visual information. They argued that the perceptual rulers used to scale perceived visual stimuli is related to the action in mind at the time of perception. For example, if you are hungry and want to eat, the perceptual ruler used to scale perceived food may be the maximum capacity of your stomach. Following the logic of the Action-Specific Account, the larger the capacity of an individual’s stomach, the smaller perceived food will be visually scaled due to the increased capacity to eat. In addition, Proffitt & Linkenauger (2013) also argued that visual scaling occurs according to energy expenditure required to act relative to current energy reserves. They argue that this change in perception guides action so that the amount of energy an individual expends does not frequently exceed the amount of energy consumed. This was demonstrated by Schnall, Zadra, and Proffitt (2010), who reported that participants that consumed a sugary drink (and therefore had greater energy reserves) reported a hill as less steep than participants that consumed a sugar-free drink. The authors argued that the greater energy expenditure required (relative to energy reserves) for participants that consumed a sugar-free drink meant that visual information was scaled to discourage hill climbing. Finally, Proffitt & Linkenauger (2013) asserted that visual perception may scale according to an individual’s skill at a task. For example, a skilled golfer may perceive the course’s hole as larger than those with less skill at the sport. This is argued to occur because the hole appears larger relative to the skilled player’s narrower distribution of shots. This Action-Specific Account therefore provides one model of a top-down effect on perception which challenges the idea of cognitive impenetrability. As previously stated, Fodor’s (1983) assertion of perception as cognitively impenetrable is generally accepted (Firestone & Scholl, 2016). Therefore, if proponents of the Action-Specific Account are correct in arguing that action-capacity may affect perceived spatial information, this would have theoretical consequences for understanding how the mind is organised and functions (Witt, 2017). Concrete evidence of action-specific effects on perception would therefore require an overhaul to the understanding of how the mind is organised to reconcile these effects with current models of visual perception which (to knowledge) do not consider top-down effects on perception. It should be noted that in the pursuit to provide this concrete evidence, the Action-Specific Account (and research in favour of it) has been criticised. Although some of these criticisms are discussed within this thesis, see Firestone (2013), Firestone and Scholl (2015), and Collier and Lawson (2019) for detailed review of these criticisms.

Regardless of these controversies, the Action-Specific account has been used to explain why people make different spatial judgments depending on their physical capabilities (e.g., grasping ability; Ishak et al., 2008) or persistent disordered eating (e.g., Anorexia Nervosa; Yellowlees et al., 1988). For example, Witt et al. (2009) assessed whether chronic pain (a condition in which leg and back pain is experienced while walking) affected how individuals perceived their environment compared to healthy controls. To do this, several cones (target objects) were placed in a corridor at varied distances from the participants. Participants were then asked to estimate the distance between themselves and each cone. Their results showed that, at every distance point, those suffering from chronic pain perceived their distance from the cone as further away than controls did. In support of the Action-Specific Account, Witt et al. (2009) argued that distances were perceived as greater by those with chronic pain due to their decreased capacity to traverse the space between themselves and the target objects. The action-specific account has also been used to explain why individuals who wear a heavy backpack reported the visual angle of a hill as significantly steeper than those not burdened under such weight (Bhalla & Proffitt, 1999). Again, participants were not actually climbing the hill. Following the logic of the Action-Specific Account, the results of Bhalla and Proffitt (1999) suggest that participants wearing heavy backpacks may have perceived the hill as steeper due to the extra physical exertion required because of the increased weight. These studies suggest that perception of distances may be affected by an individual’s ability to move through their environment. It should be noted that the effect of weight on changes in perception is the result of physical differences in objective weight and the extra physical exertion that requires, rather than the perceived or conscious perception of the weight or how much exertion is perceived.

It is important to note that in the experiments discussed so far participants were instructed to merely estimate distances without behavioural relevance (they were not asked to act but simply to perceive and report). However, Witt et al (2016) asserted that action-specific effects may influence behavioural decisions, that is, how a person decides to act based on their visual perception of a stimulus. For example, Sugovic, Turk and Witt (2016) observed that overweight participants estimated distances from them as further compared to normal weight counterparts. An action-specific explanation of these results might suggest that overweight participants avoid physical exertion because activities appear more demanding due to the increased exertion required to move their additional weight (this would also explain why overweight individuals are less likely to undertake exercise than their healthy weight counterparts; Blair, 1993). This line of reasoning is partially supported by Eves, Thorpe, Lewis, and Taylor-Covill (2014) who demonstrated that individuals which estimate stairs as steeper are more likely to avoid stairs when an alternative (e.g., an escalator) is available. Again, following the Action-Specific Account, participants that perceived stairs as steeper may have avoided taking the stairs because it would be require more exertion relative to their current energy reserves. As such, Witt (2016) argue that action-specific effects such as these may influence behavioural decisions like whether to avoid physical exertion based on how demanding the task appears. This may potentially create a cycle of exercise avoidance in overweight individuals, thus making further weight gain more likely. For this reason, the investigation of action-specific effects may be important in the development of interventions aimed at disrupting unhealthy behaviours such as overeating and exercise avoidance following weight gain.

This may be even more relevant as action-specific effects are not only observed in relation to distance perception. In fact, action-specific effects on perception may be observed in a wide variety of circumstances. For example, it can be argued that action-specific effects may influence an individual's perception of food items and drive eating behaviours. Yellowlees, Roe, Walker and Ben-Tovim (1988) reported what could be considered action-specific effects on how those with and without Anorexia Nervosa perceive the size of food. In their research, participants were presented food objects and instructed to scale a computerised duplicate of the item on an adjacent screen until it matched the dimensions of the target. Within their experiment, participants with Anorexia Nervosa scaled food items as larger than control participants. Although controversial, Yellowlees et al. argued that those with Anorexia Nervosa perceive food items as larger than controls. This was done by presenting participants with a food object, and then asking them to manipulate an identical digital image of the object until it matched the dimensions of the target object. They observed that participant's with Anorexia Nervosa scaled food object images until they were larger than the target. Importantly, this was not the case for control participants. Such results could provide compelling evidence in favour of the action-specific account - as it may be that the food items were perceives as larger by those with Anorexia Nervosa due to their reduced capacity to eat relative to healthy controls (thus food objects were visually scaled as larger in order to discourage large consumption). However, their results are controversial due to the existence of the El Greco Fallacy in their methodology. Specifically, using their methodology, participants could not have possibly have perceived the target food as larger than the target object because the target and scaling object were identical (Firestone and Scholl, 2015). For this reason, any perceptual effect which had altered the way the target object was perceived would have affected the scaling item in the same way and cancelled each other out. Therefore, it is impossible for Yellowlees et al., to have actually observed the perceptual effects they claimed to using their methodology. Importantly, this is not an assertion that the effect they reported does not exist, only that they could not have observed it using an identical target and scaling object. The El Greco Fallacy was also committed by Nichelle et al., (2019), who showed participants an image of a food portion (e.g., pasta) before asking them to select the image they had just been shown from a selection of three varied portion sizes. They reported that participants were accurate at reporting the size of the target object by selecting the portion size that matched the target portion. However, due to the El Greco Fallacy, it would not have been possible for them to have observed any other result because, again, the target and response stimulus were identical. For this reason, even if an effect of perception had made the portion look larger to participants, they would not have been able to observe it using their methodology. However, it should be noted that these two examples are by no means the only studies on top-down effect of food size perception that – further examples are categorised by their appropriate pitfalls and discussed later in the thesis. As such it is of critical important that this thesis endeavours to develop a methodology for assessing potential top-down effects on perception that is not susceptible to the methodological pitfalls suffered by previous research. In this way, robust evidence of top-down effects on perception may be observed for the first time in the context of food perception (if such effects really do exist).

However, action-specific effects may not be the only top-down factor influencing perception and behaviour. Visual attention may affect perception similarly to action-specific effects. Importantly, a review of research on attention by Brosch, Pourtois, Sander, and Vuilleumier (2011) describes attention as consisting of three distinct sub-processes, namely endogenous, emotional, and exogenous attention. Endogenous attention is defined as top-down and voluntary shifts in attention which are driven by an individual’s internal state and goals (Desimone & Duncan, 1995). Another top-down attentional process is emotional attention, this process is driven by the emotional relevance of a stimulus (Vuilleumier, 2005). Although this is also considered a top-down form of attention, it is not focused on in the present thesis because (within this thesis) stimuli are matched across conditions within each experiment. Therefore, the emotional relevance of stimuli is expected to be identical across conditions, and therefore have no impact on reported results. Finally, exogenous attention is defined as bottom-up, automatic attention which is driven by visual factors such as colour, stimulus onset or location (Jonides & Yantis, 1988; Egeth & Yantis, 1997). Exogenous attention is, unlike endogenous attention, of less central concern in the present thesis because it does not involve cognition. In contrast, top-down endogenous attention has repeatedly been shown to affect perception in a meaningful way though manipulation of participants’ goals (e.g., Anton-Erxleben, Henrich, & Treue, 2007; Cole, Riccio, & Balcetis, 2014; Ward & Scholl, 2015). As such, it is stressed that exogenous and endogenous attention are not confused. Importantly, endogenous attention as a top-down effect on perception (from here on referred to as the Attentional Account) does not necessarily challenge the concept of cognitive impenetrability in the same way as the Action-Specific Account because the way an object is perceived may be the result of how the object is attended to (e.g., fixation location or duration), rather than altering spatial information directly. Simply, perception may be acting consistently given the changes in visual input caused by attentional effects. For example, Popien, Frayn, von Ranson, and Sears (2015) demonstrated that eye-gaze fixations when viewing food differ in obese individuals compared to healthy controls. Specifically, both groups fixated on food objects for longer than non-food objects after fasting, but only obese participants demonstrated this effect while satiated. Although not presently known, it is possible that this increased fixation duration may affect the perceptual input between obese and non-obese participants, and in turn cause over-eating. Such a possibility would explain both why only the obese participants showed this attentional bias while satiated, and why obese participants are more likely to eat in the absence of hunger (Tanofsky-Kraff et al., 2008). Imagine if identical food items were reported as different sizes between obese and non-obese participants (due to the increased attentional bias in obese participants). This difference is likely to be because the two groups fixated on the food items differently, rather than fixated on them the same way but perceived them as physically different. However, because endogenous attention (and therefore object fixation locations) are within a person's control, endogenous attentional effects must not be overlooked as a potential top-down effect on perception. However, although Firestone and Scholl (2016) illustrate that attentional effects do not directly impact visual perception (as they are unlikely to affect visual processing), it is clear that an individual's perceptual experience may be affected by the small changes in fixation location caused by top-down shifts in attention.

In the context of this thesis, attentional bias refers specifically to attentional narrowing. Attentional narrowing is a type of attentional bias which occurs when an individual’s attention is focused more centrally on the target (Gable & Harmon-Jones, 2008). Kirsch, Heitling and Kunde (2018) have demonstrated that reports of object size may be affected by how narrowed an individual’s attention is. In their experiment, participants attended to the centre of a computer screen before being presented a visual cue to one size of the screen. This visual cue varied in size (larger to promote a wider attentional breadth, and smaller to promote a more narrow attentional breadth). After the presentation of the visual cue, two circles were presented on screen (one larger than the other; one in the location of the previous visual cue, and another on the other side of the screen). Their participants’ task was to report whether the two circles were the same size or not. Their results suggest that participants were significantly more likely to report the smaller circle as the same size as its larger counterpart if it had been prompted by a smaller – rather than larger – cue. This was argued to occur because the smaller cue prompts a significantly more narrow attentional focus. However, despite the evidence above that suggests attentional breadth is responsible (at least in part) for the perceived size of an object, no published research to date explains how attentional breadth causes these changes. Howver, Anton-Erxleben, Henrich and Treue (2007) suggest that narrowing visual attention may make the object look larger by reducing the distance between the stimulus boarder and attentional focus. In terms of food perception, a bias in size perception such as this makes sense. For example, an increase in the perceived size of food when hungry in comparison with non-food objects means that food items are more likely to stand out within an individual’s conscious mental representation of a visual scene, and thus make food more likely to be identified and consumed.

The idea that endogenous attention may impact an individual's perception of an object was also supported by Anton-Erxleben, Henrich and Treue (2007). In their experiment, participants were presented a cue (a black square), which prompted participants to attend more to one half of the computer screen. Following this, participants were shown two random dot patterns, one on each side of the screen. One of these dot patterns was always a standard size, while the other varied. Participants were tasked with indicating which dot pattern was larger. Their results suggested a significant increase in the perceived size of the dot pattern on the cued side. They argue that this occurred as the cue caused participants to actively attend to this dot pattern over its counterpart. Importantly, this result was not observed when no cue was presented. Another example was provided by Cole, Riccio and Balcetis (2014), who demonstrated that when individuals narrow their attention towards a target item, it is reported as perceptually closer (and thus larger in size) than when attention is not narrowed. Their experiment took place in a park during the summer, participants were instructed to look at an ice box (target object) containing a cool drink. The experimenter stood perpendicular to the participant's view of the icebox and participants then instructed the experimenter to move closer or further away until they were the same distance from the participant as the icebox. Half of the participants were told to imagine a spotlight over the icebox and avoid looking at the rest of the environment (narrowed attention), while the others could move their attention naturally. Cole et al.'s results indicated that participants in the narrowed attention condition positioned the experimenter significantly closer to them than those in the free attention condition. This suggests that when attention is narrowed, attended objects may appear closer and larger than when attention is not narrowed. Additionally, Cole et al. conducted a second experiment to determine whether changes in perception caused by attentional narrowing influence participants' behaviour. In this experiment, participants were instructed to walk towards a 'finish line' while wearing ankle weights. Similarly to the previous study, participants were instructed to narrow their attention towards the finish line or attend naturally to the environment while walking. Participants were timed while walking and then completed the Borg Rating of Perceived Exertion (Borg 1982) to report the intensity of their exercise. Their results indicated that walking times were faster, and subjective feelings of exertion lower, in the narrowed attention group compared to the free attention group. Cole, Riccio and Balcetis (2014) argue that these results imply that while a participants' attention is narrowed their exercise is improved. It is easy to see how, mirroring the argument that Witt (2016) put forwards for the Action-Specific Account, the results of Cole, Riccio and Balcetis (2014) show how endogenous attention may influence behavioural decisions (specifically, the likelihood of a person engaging in exercise). This evidence forms the basis of the previously mentioned Attentional Account. Interestingly, although these results may seem incongruent with the size-distance relationship (which asserts that closer objects are perceived as smaller rather than larger; Foley, 1972), this is not necessarily the case. The reason for this is that perceptual effects such as this are reliant on changes other than those in physical stimuli. Specifically, the Attentional Account posits that changes in attention manipulate perceived object size by reducing the distance between the stimulus boarder and attentional focus. As such, it is possible that shifts in attentional breadth occur sub-consciously following the perception of physical features of an object in the visual field resulting in the conscious mental representation of an object's size. Put differently, the same visual information enters the eye identically in all scenarios, however the conscious mental representation of this information is altered depending on the space between distance between the stimulus boarder and attentional focus caused by shifts in attentional breadth.

The examples from research provided in this introduction suggest that action-specific and attentional effects may be closely linked as they can explain the same behaviours (e.g., exercise avoidance). In fact, the links between predictions of the Action-Specific and Attentional accounts are so close that, at times, they may even predict the same outcomes within an experimental study. In relation to food perception, it may be that Yellowlees et al's (1988) participants with Anorexia Nervosa scaled food items as larger than controls due to their reduced capacity to eat (following the logic of the Action-Specific Account). However, the Attentional Account would also predict this same outcome for a different reason. Specifically, individuals with Anorexia Nervosa have been shown to have an increased attentional bias towards food items compared to healthy controls (see Ralph-Nearman et al., 2019, for a review of this evidence), and biasing attention towards an object can make it appear larger (Anton-Erxleben, Henrich & Treue (2007). An attentional account would therefore assert that the attentional bias toward food in those with Anorexia Nervosa would lead to increased food size perception compared to healthy controls. Therefore, although there is evidence for both action-specific and attentional effects on perception, it is important that research separates the predictions of accounts asserting the existence of top-down effects on perception.

Before any such research is carried out, one must first consider the existing criticisms of research currently claiming to demonstrate top-down effects on perception. Critically, Firestone and Scholl (2016) claimed there is no evidence that supports the existence of top-down effects on perception that cannot also be explained by experimental biases or other similar effects (for a more detailed view of this debate. see Witt, 2017, and Collier & Lawson, 2018). Firestone and Scholl (2016) argue that there are six pitfalls which apply to most, if not all, research claiming top-down effects on perception, thus invalidating such claims. A targeted explanation of each is given below. Firestone and Scholl acknowledged that although it may not be possible for all these pitfalls to be avoided in a single study, they provide a checklist for ensuring that research reporting top-down effects on perception is not easily invalidated. The current thesis has considered the most pressing of these pitfalls for its investigation of the action-specific and attentional accounts of food size perception. Namely, the reliance on an overly confirmatory research strategy, effects of judgement rather than perception, demand characteristics, low-level visual differences between stimuli, peripheral effects of attention, contaminating effects of memory, and the El Greco Fallacy.

Pitfalls of previous research:

Pitfall 1: An overly confirmatory research strategy:

The first pitfall is a lack of disconfirmatory findings in research investigating top-down effects on perception. A disconfirmatory finding is the observed absence of an effect when it should not occur. An example of research effectively utilising disconfirmatory findings is Collier and Lawson (2018), in which they adapted the procedure used by Ishak, Adolph, and Lin's (2008). In the original Ishak et al. (2008) study, participants were tasked with reaching through an aperture and grabbing candy on the other side. Importantly, they were instructed only to attempt grabbing the candy if they believed their hand was small enough to fit through the aperture.

Ishak et al. (2008) observed that participants were accurate at assessing whether their hand would fit through the adjustable aperture - allowing them access to the candy. Interestingly, they reported that participants were also accurate at this task when wearing a prosthesis glove which increased the size of their hand. This suggests that participants were able to successfully estimate their action capacity, even following changes to their bodily state. These results could be argued to provide evidence that changes in action capacity affected participant’s behavioural decisions through action-specific visual scaling. Specifically, participants remained accurate at assessing whether their hand could fit through the aperture (as measured by the number of attempts to grab candy when their hand did not fit) while wearing the prosthesis glove because their action-capacity (and thus the perceived size of the aperture) was reduced. This may, in turn, have led to more conservative estimates of whether their hand could reach the candy on the other side of the aperture. This can be seen in Ishak et al’s (2008)’s results - although participants (regardless of prosthesis) rarely attempted to reach candy when their hand could not fit, they made significantly less attempts to reach the candy while wearing the prosthesis (even in trials where their hand could have fit through the aperture). An action-specific explanation of this result may suggest that visual scaling had occurred while wearing the prosthesis (i.e., the aperture may have been perceived as narrower) to discourage acting. However, as this research contained no disconfirmatory hypotheses which support this action-specific claim, it is not possible to rule out explanations other than visual scaling (such as demand characteristics). Disconfirmatory hypothesis testing could clarify the existence of potential action-specific effects on the candy grabbing in Ishak et al. (2008) by including conditions in which participants simply report aperture size. According to

Witt, Proffitt, and Epstein (2005), action-specific effects should only occur when an individual intends to act. Simply reporting the size of an aperture, unlike reaching to grab candy, does not require intention to act dependent on action capacity and therefore should not be affected by any potential visual scaling regardless of wearing a prosthesis glove.

To this end, Collier and Lawson (2018) adapted the methodology of Ishak et al. (2008) to assess the predictions of the Action-Specific Account and provide such disconfirmatory findings. In their experiment, participants reported an aperture's size by manipulating the distance between two black lines on computer screen until their distance matched the width of the aperture. In addition, half of their participants were asked if they believed they could fit their hand through the aperture (intention to act), while the other half were not (no intention). This latter group tested disconfirmatory findings because action-specific scaling effects should only occur when an individual intends to act (Witt, 2005). Their results indicated that when asked whether they could fit their hand through the aperture (intention to act group), participants reported apertures as narrower while wearing a prosthesis glove. This provides the expected confirmatory finding following the logic of the Action-Specific Account. Explicitly, if an individual is less able to fit their hand through the aperture when wearing the prosthetic glove, then they perceive said aperture as narrower. However, participants also reported the aperture as narrower while wearing the prosthesis glove even when not asked if they could fit their hand through it. This latter observation may suggest one of several things. For example, it may be the case that Witt et al. (2005) was mistaken and action-specific effects on perception and action-decisions may occur automatically, regardless of whether an individual intends to act. Alternatively, their results may suggest that reporting a narrower aperture while wearing the prosthesis glove was due to experimental bias and not top-down effects on perception. Regardless of what their results may mean for the debate regarding the existence of action-specific effects on perception, the results of Collier and Lawson (2018) highlight the importance of attempting to obtain disconfirmatory findings, as argued by Firestone and Scholl (2016).

Pitfall 2: Perception versus judgement:

The second pitfall argues that many studies demonstrating top-down effects on perception actually demonstrate changes to a participant's (post-perceptual) judgement rather than perception. In essence, some measures may accidentally assess how an individual interprets or infers visual information rather than how they spatially perceive it. Firestone and Scholl (2016) argued that, as many properties (such as size) can be both perceived and judged, this pitfall is particularly problematic for studies which reply on verbal or written estimations. For example, van Koningsbruggen, Stroebe & Aarts (2011) investigated perception of food size by displaying an image of food to participants and instructing them to provide an estimation of that object's size in centimetres. Their experiment investigated the perception of food size in dieters and normal eaters after exposure to a tempting food prime (the cover of a culinary magazine showcasing a dessert) or control prime (a food-free cover of a gardening magazine). Following this prime, participants were presented with an image of a muffin and asked to provide a written estimate of the muffin's height in cm. Their results demonstrated that, following a food-based prime, those who were dieting perceived food as significantly larger than those who were not dieting. Although it is possible that these results reflect differences in perception between dieters and non-dieters, as food size was reported using written size estimations, it is not possible to rule out whether the observed effects were caused by differences in judgement. The reason for this is that it is not possible for participants to spatially perceive objects in cm, instead they must judge cm size of the objects based on what they perceived. For example, dieters may have perceived food items to be spatially identical to non-dieters but post-perceptually judged food to be larger. One possible explanation for why differences in judgement may be expected between dieters and non-dieters is that dieters have a goal conflict between eating enjoyment and weight control (Stroebe et al., 2008). Furthermore, even if this conflict in goals is not responsible for the difference Koningsbruggen et al. (2011) observed, their method made it impossible to rule out the potential effect of judgement on their results. As such, studies concerning effects on perception should avoid using tasks of estimation which require a statement of non-perceivable measurements (such as cm) and instead attempt to create scaling task that taps into perceptual information directly, such as the arrows Collier and Lawson (2018) used to assess perceived aperture size.

Pitfall 3: Demand and response bias:

Orne (1962) states that demand characteristics are those in which participants will do their best to provide the experimenter with results they are attempting to observe. This was more recently demonstrated by Nichols & Maner (2008). In their experiment, a confederate (posing at a fellow participant) told participants that - regardless of what the experimenter said – the experiment was testing whether people select images on the left or right when given a choice of two images. They also told the participant that the researchers expected people to choose images on the left more frequently. Participants were then presented paired photo sets (one on the left and right) and had to state which of each pair they found most visually pleasing. They observed that participants reported significantly more left selections compared to right - even though research since suggests that people prefer and select images to the right (Chokron & De Agostini, 2000). Their results therefore demonstrate that when participants are aware of the study's hypothesis, they may act to confirm it - even when the opposite result are actually expected. Indeed, if it is possible to intentionally (and rather obviously) manipulate a participant's behaviour, it stands to reason that it may also be possible to do this unintentionally. For example, Durgin et al. (2009) argue that Bhalla & Proffitt's (1999) observed over-reporting of hill steepness while wearing a heavy backpack (described earlier in this introduction) could be explained by demand characteristics. Specifically, they argue that because participants were given no reason for wearing the heavy backpack, they may have successfully guessed the experimental hypothesis (hills appear steeper while wearing a heavy backpack) and responded accordingly. When Durgin et al. (2009) attempted to replicate Bhalla & Proffitt's (1999) results, they found that no significant difference in hill steepness estimation was observed when participants were given a reasonable (but false) cover story for wearing a heavy backpack (i.e., the backpack contained EMG recording equipment). This pitfall therefore demonstrates how the design of an experiment may cause participants to be swayed into responding a particular way. As such, studies investigating top-down effects on perception should attempt to mask their hypothesis, or at least ask participants to report what they believe to be the hypothesis at the end of the experiment.

In addition to hypothesis guessing, Collier and Lawson (2017) explored the effects of conflation (the effect of one type of estimate on another) on estimates of object size. In their experiment, participants were presented with an object and then asked to report the graspability of the object (how difficult the object was to grasp) immediately before reporting the perceived object’s size – this occurred on every trial. Their results found that Action-Specific effects on perception of object size were only observed when participants reported graspability immediately before object size in every trial. This result suggests that considering the graspability of an object may have affected participant reports (but not perception) of an object’s size. Therefore, when comparing different measures of object perception, these should be completed in counterbalanced blocks where possible to minimise the chance of conflation.

Pitfall 4: Low-level differences:

This pitfall suggests that reported top-down effects of perception may be the result of physical changes in stimuli across experimental conditions. Therefore, such changes should be avoided where possible. Where this is not possible, additional conditions in which low level fixtures are matched/disrupted would be beneficial to the argument that effects on perception are truly top-down. Examples of this include maintaining high-level features while disrupting low-level features (for example by scrambling the images, as in Cano, Class & Polich, 2009) and maintaining low-level features while disrupting high-level features (for example by blurring the relevant stimuli, as in Firestone & Scholl, 2015a). Within the context of food perception, Balas, Auen, Thrash and Lammers (2020) demonstrated that both children’s and adult’s categorisation of an object as a food/non-food item was affected by disrupting the high-level features of an object via image blurring. Specifically, they found that all participants were less accurate at categorising an object as food/non-food when images were blurred. These results suggest that high-level features of stimuli are important for objects to be categorised as food/non-food. Therefore, it is recommended that when comparing perception of food and non-food objects, differences in high-level features are controlled for as much as possible.

Pitfall 5: Peripheral attentional effects:

As mentioned previously, attention can be broken down into top-down endogenous attention (as shown by Cole, Riccio and Balcetis, 2014) or bottom-up exogenous attention (as shown by Jonides & Yantis, 1988). However, regardless of endogenous attention being controlled by goals (Desimone, & Duncan, 1995), Firestone and Scholl (2016) argued that both types of attention are peripheral because they do not affect perception directly (although this view of perception as cognitively impenetrable is debated, see Rauss, Schwartz, & Pourtois, 2011; Firestone & Scholl, 2016 for review). Instead, they argue that attention changes the way an object is fixated on, and this fixation is what causes apparent changes in perception. Firestone and Scholl (2016) go further by stating that many top-down effects (including action-specific effects) used to explain differences in perception are often actually the result of differences in peripheral attention - and are therefore not top-down effects on perception at all. Interestingly, Witt (2017) replied that although understanding whether action-capacity affects perception directly (by manipulating spatial information) or indirectly (by influencing peripheral attention) is important in understanding cognitive impenetrability, it is secondary to the discussion as to whether action-capacity affects perception at all. Witt argued that the perceptual experience is the same regardless of whether reported changes in perception are direct or indirect. Put another way, it is possible that action-specific effects could guide the way that an environment is attended to and in turn affect perception. Such an effect, following Witt's (2017) argument, would be the same for the perceiver as if the spatial information were affected directly, and thus just as likely to affect behavioural outcomes. Indeed, subsequent research shows support for the idea that action-specific effects change perception by directing attention (Kirsch, Kitzmann & Kunde, 2021). This same argument could be made for endogenous attentional effects independent of action-specific influence – it is unimportant whether endogenous attention changes perceptual information directly, or by altering object fixation because the perceptual experience (and potential influence on subsequent behaviours) is the same. For this reason, Witt's (2017) claim that action-specific effects may alter perception by driving attention is central to the current thesis. It is important to separate what an individual is expected to see due to action-specific effects and what they are expected to see due to attentional effects. Doing so will discern whether differences in endogenous attention allocation are driven by action-specific effects on perception, or whether such action-specific effects just so happen to align with predictions from the Attentional Account. However, it should be noted that, as exogenous attentional effects are bottom-up, and are driven by factors other than goals and internal states (such as colour and stimulus onset), these should still be controlled for where possible. The reason for this is that because exogenous attention also has the capacity to affect attention by shifting fixation locations (Firestone and Scholl, 2013), such effects can only confuse and obscure observed results if left uncontrolled.

Pitfall 6: Memory and Recognition:

Another pitfall of research suggesting that perception is affected by top-down effects is related to memory and recognition. This pitfall suggests that some tasks which aim to test perception are contaminated by also assessing memory (unintentionally). An example of this can be seen in Cole, Riccio and Balcetis' (2014) study on distance perception. In their study, the icebox was perpendicular to the experimenter being used to report distance (by instructing the experimenter to move forwards or backwards until the participants' distance from the experimenter mirrored the participant's distance from the icebox). This means that participants could not have seen the target and experimenter simultaneously, and instead would have had to move their head (and indeed their perception) away from the target and towards the experimenter. This is important because participants would have had to use their memory of perceived distance from the icebox to instruct the experimenter to move. As such, although the authors claimed their results were caused by attentional effects, it is not possible to rule out the potential effect of memory. To give another example, Kirsch, Kitzmann and Kunde (2021) demonstrate that action capacity affects perception by driving changes in attention. However, it should be noted that this study also suffers from the contaminating effects of memory because participants' reported object size after the target had left the screen. Therefore, the lack of on-line judgements in Kirsch, Kitzmann, Kunde (2021) means that it is possible the observed effects were effects on memory (rather than perception), because participants had to recall the objects size for reporting. As such, it is recommended that tasks assessing top-down effects on perception involve on-line perceptual reporting. Doing so will help to remove the effects of memory from contaminating any potentially observed perceptual effects.

The El Greco Fallacy:

In addition to the 6 pitfalls listed above, the El Greco Fallacy (Firestone, 2013) is a concern for the methodology of studies such as Yellowlees et al. (1988) that could demonstrate the existence of top-down effects on perception. In brief, this fallacy argues that when a target stimulus and its scaling counterpart are identical, then no top-down effects should be observable, as any distortion in the visual perception target should also affect the scaling stimulus. This fallacy is discussed in detail, with examples, in Chapter 2 of this thesis.

Motivations for the present thesis:

Considering the above, it is important that research be carried out to test these supposed action-specific and attentional effects on perception while avoiding methodological concerns. Such research would then provide evidence for top-down effects on perception, should any exist, while also ensuring that results are not easily explained by experimental bias or other commonly occurring non-perceptual effects. However, before such research can be carried out, a method must first be created to separate the claims of the Action-Specific and Attentional accounts while also avoiding the methodological concerns discussed above. As such, the central aim of this thesis was to develop and present a novel food-specific measure for investigating top-down effects on perception while controlling for methodological pitfalls which may provide an alternative explanation for results (Firestone, 2013; Firestone & Scholl, 2016). It should be noted that this was attempted by Collier (2017) in the context of food size perception, but a re-examination would be beneficial to draw more certain conclusions (see Chapter 2 of this thesis for full details). Ascertaining whether action-specific or attentional effects alter an individual’s perception of their environment may be important because, as claimed by Witt et al. (2016), top-down effects on perception may also affect subsequent influences on behavioural decisions. This is particularly pertinent in the case of food size perception because these effects on perception may result in over/under-eating, which can have severe consequences for a person’s health and survival. For this reason, in this thesis, experiments examining top-down effects on perception will centrally concern participant’s perception of food size. The reason for this is that food size perception can be explained by both attentional and action-specific effects. For example, methodological concerns aside, results suggesting that food is perceived to be larger by those with Anorexia Nervosa (such as Yellowlees et al., 1988) can be explained by either a reduced capacity to eat (action-specific) or an increased attentional bias towards food (attention). In addition to this, Firestone (2013) pointed out that it is not clear what benefit action-specific scaling might have on everyday perception, but it is argued here that the same cannot be said about attentional effects on perception. For example, consider the potential role of attentional effects on the consumption of food. Attentional bias towards food has been identified as a factor that may predict an individual’s success at stopping harmful addictive behaviours such as over consumption (Calitri, Pothos, Tapper, Brunstrom, & Rogers, 2010; Spieker, 2013; Werthmann, Jansen & Roefs, 2015; Zoltak, Veling, Chen & Holland, 2018). For this reason, re-training attention to reduce an individual’s attentional bias towards tempting or addictive, hyperpalatable food may be effective in reducing their deleterious tendency to consume said substances. Indeed, Attwood et al., (2008) observed that smoking participants could be successfully trained to have a greater or lessened attentional bias towards smoking cues following a modified visual probe task. These groups also experienced greater or lessened smoking cravings, respectively, following the completion of the experiment. However, no research to date has demonstrated a significant and consistent reduction in smoking behaviour following a period of attentional bias modification via a visual probe task. Therefore research should consider other methods of attentional re-training that may be used to reduce affective behaviours. For example, one way in which an attentional intervention could reduce harmful behaviour is impulsivity training via a Food Go/No-Go Task (a task in which it is measured how frequently participants respond to images of food when they have been instructed not to). Although Go/No-Go Tasks have previously been used to train impulsivity by proving feedback after an object has been mistakenly responded to (e.g., Houben & Jansen, 2011). Impulsivity has been suggested to be linked (in a positive direction), with attentional bias (Munk, Schmidt, & Hennig, 2020), and impulsivity has been observed to affect an individual's tendency to over-eat (Loxton, 2018). It has been shown that interventions using Food Go/No-Go tasks to reduce impulsivity towards food are successful at reducing calorie consumption (Houben & Jansen, 2011). Although unknown at present, it could be the case that by re-training an individual's impulsivity towards food, their attention towards food, and as such their perception of it, are also re-trained. An investigation into the role of psychological constructs on size perception also presents the opportunity to conduct novel research into the neural underpinnings of changing size perception. This is important, as research has already been conducted on whether neural interventions can be administered to reduce over-eating. For example, Lapenta, Di Sierve, de Macedo, Fregni and Boggio (2014) manipulated frontal N2 responses and impulsivity using transcranial direct current stimulation (tDCS). They assessed their participants' urge to eat and their Frontal

N2 response during a FGNG task before and after two sessions of either active or sham (pretend) anode-right/cathode-left tDCS. They observed that urge to eat and N2 response during food No-Go trials were reduced following active but not sham tDCS. This result suggests that facilitating neural activity in the right frontal cortex reduces participants' food-related impulsivity. Interestingly, they observed that participants receiving active tDCS ate less when presented an opportunity to eat, compared to those in the sham tDCS group. These results demonstrate the importance of frontal N2 in urge to eat and consumption. Specifically, greater frontal N2 responses when inhibiting response to food suggests greater demands on the neural inhibition system, causing greater impulsivity and subsequent over-eating. A behavioural intervention on over-eating was demonstrated by Houben and Jansen (2011), who taught participants to inhibit response to chocolate during a Food Go/No-Go Task. In their experiment, the letters 'p' and 'f' were associated with Go/No-Go trials and participants pressed the spacebar (Go) or inhibit response and press nothing (No-Go). Letters were presented over images of empty plates (neutral stimuli), chocolate (experimental stimuli). For some of their participants, all photos were associated with the go letter and no-go letter equally, while for some, chocolate was always presented with the no-go letter. Following this Go/No-Go task participants were presented with an opportunity to eat chocolate. They observed that chocolate consumption was significantly lower in participants for which chocolate was always associated with no-go letter). As such, it could be argued that these interventions may be an effective way of reducing impulsivity towards food and subsequent over-eating. However, despite this interest in investigating whether neural or behavioural interventions can affect eating behaviour, little research has been carried out on the representation of object size perception in neural activity

(Chen, Wu, Qiao, Liu, 2020). Thus, further research into the neural underpinnings of object size perception, especially in relation to known psychological constructs and their relative neural activations, would help to further quantify the impact of top-down effects on perception – as it is currently unknown whether neural interventions on eating behaviour also have an effect on how food objects are perceived. This thesis will explore these themes and address some of the open questions regarding food perception.

However, another key issue must be addressed before an investigation into the impact of psychological constructs - and their related neural activities - on food size perception can be conducted. This issue is the current lack of consistency across studies, within the literature on food-related behaviours (and perception), regarding how psychological constructs related to food are measured. To use impulsivity as an example, there are many different surveys with the aim of measuring self-reported impulsivity and to complicate matters further, impulsivity can also be assessed using several task-based measures (Allom, Panetta, Mullan, & Hagger, 2016). For example, some surveys appear to measure domain-general impulsivity (e.g., the Barratt Impulsivity Scale; Patton, Stanford, & Barratt, 1995), whereas others claim to measure food-specific impulsivity (e.g., the Three Factor Eating Questionnaire R18; Karlsson, Persson, Sjöström, & Sullivan, 2000). Domain-general and food-specific surveys such as these are not only different in the questions they ask, but also in what they measure from a theoretical perspective. However, despite the existence of these multiple surveys, and the clear theoretical differences between them, there has been no published attempt to compare the similarities and differences between them (such as their ability to predict health outcomes related to over-eating). This lack of guiding research has led to surveys, such as those measuring impulsivity, being used interchangeably across research papers (Brindal & Golley, 2021; Smith, Lavender, Leventhal & Mason, 2021). As such, given that there are conceptual differences between various surveys assessing impulsivity, research comparing these measures is required to provide a clearer guide to those researching impulsivity towards food. Additionally, achieving more clarity as to which measures of impulsivity are most closely related to over-eating will help to ensure that any top-down effects on perception observed in relation to these psychological constructs are not the result of methodological flaws – such as inappropriate survey selection.

Overview of the present thesis

In sum, size perception of food will be the central concern of this thesis. This is because perception (and eating) of food may be clearly linked with both action-capacity (Proffitt, 2008) and attentional bias (Gable and Harmon-Jones, 2010). Also, although not always the case, both the Action-Specific and Attentional Accounts may explain the same observed results concerned with food perception under some circumstances (e.g., Yellowlees et al., 1988). Finally, food size perception was selected for study in this thesis because an understanding of how food perception may change (if indeed it does change) would be useful for interventions on problematic eating behaviours. For example, impulsivity training could be undertaken in instances where cognitive behavioural therapy proves ineffective (see Atwood & Friedman, 2020, for a review of cognitive behavioural therapy as a treatment to reduce instances of binge-eating). However, it is important that before such interventions are carried out, more basic research should be conducted to assess which methods are most appropriate for measuring psychological constructs related to top-down effects on perception.

In brief, there has been a great effort to determine whether top-down effects (such as action-specific or attentional effects) are responsible for the way an individual perceives their environment (Bhalla & Proffitt, 1999; Eves et al., 2014; Witt et al., 2009). However, it appears that many studies fall prey to conceptual or methodological pitfalls, meaning their results are explainable by factors other than these top-down effects (Firestone & Scholl, 2016). The Action-Specific Account, which argues that action capacity may influence what is spatially perceived, is a prominent example of this. Regardless, the Action-Specific Account is worthy of further study due to its potential for understanding behavioural decision making and involvement in detrimental behaviours (such as avoiding exercise; Eves et al., 2014). In addition to this, experiments investigating attentional effects on perception are also needed as, although they may explain many top-down effects on perception (such as Yellowlees et al., 1988), these are not necessarily distinct form the Action-Specific Account (Witt, 2017; Kirsch, Kitzmann & Kunde, 2021). Thus, attempting to separate attentional effects on perception from the predictions of the Action-Specific Account seems essential for assessing whether action capacity influences behaviour directly, indirectly by affecting attention, or not at all. Beyond theoretical understanding, assessing the potential influences of top-down effects on perception could increase understanding of harmful behaviours, such as binge-eating, and could even help in the development of interventions for these behaviours. Further to this, if it can be discerned whether top-down effects on perception are linked to psychological traits such as impulsivity, then it would be interesting to observe whether the neural correlates of these psychological constructs are also able to provide a predictor of perceived object size. Observing such a relationship would help to further quantify the effects that top-down influences have on visual perception. The present thesis proposes a novel scaling task for assessing top-down effects on perception while avoiding the pitfalls put forward by Firestone and Scholl (2015) and separating the predictions of the Action-Specific Account from those predicted by the Attentional Account. Here, the Scaling Task is also used to discern how top-down effects on perception may affect everyday behaviour.

Chapter 2 of this thesis provides a detailed breakdown of this novel scaling task and how it avoids the pitfalls of previous top-down research (Firestone & Scholl, 2016) as well as other methodological issues, such as the El Greco Fallacy (Firestone, 2013). Within this chapter, the Scaling Task was used to disentangle the assumptions of the Action-Specific and Attentional Accounts by examining the perceived size of food and non-food items in individuals who had recently eaten or undergone fasting. In this examination, no evidence for action-specific effects were found. Instead, the observed results suggest that differences in perception may be caused by endogenous attentional effects independent of action-specific influence. This chapter demonstrates top-down effects on perception while successfully avoiding methodological pitfalls which may provide alternative explanations for the observed results. In addition, this research is also the first to disentangle the predictions of the Action-Specific and Attentional Accounts of visual perception.

Chapter 3 describes an investigation comparing measures of psychological constructs believed to affect an individual’s attention towards an object (motivation and impulsivity; Munk, Schmidt, & Hennig, 2020; Loxton, 2018). This investigation focused on comparing the relative reliability of these measures and their ability to predict BMI (a health-outcome related to over-eating). The results demonstrate that food-specific measures, both of behavioural motivation and impulsivity, are more consistent and better predictors of health-outcomes than their domain-general counterparts, and as such should be used when conducting research regarding food/eating or involving food-based stimuli. This research is the first to compare measures of behavioural motivation and impulsivity on their ability to predict health-outcomes.

Chapter 4 describes a prepared study that aims to assess whether and how behavioural motivation and impulsivity affect food perception. Electroencephalography (EEG) was included in the design to assess the neural correlates and relationships between self-reports/behavioural measures and scaled food-size. Establishing whether top-down effects on perception are reflected in cortical activity related to early-stage perceptual processes (vs. later post-perceptual processes) is key to understanding how top-down effects affect processing of food stimuli. This discovery would also inform intervention research relying on neuromodulatory techniques, such as transcranial direct current stimulation (tDCS), to affect behavioural change in response to food (e.g., Lapenta, Di Sierve, de Macedo, Fregni & Boggio, 2014). However, because of restrictions placed on in-person experimentation due to the COVID-19 pandemic (see note at the start of Chapter 4 for more detail) the prepared study is presented as a research proposal only. This research would be the first to locate the neural correlates responsible for shifting size perception.

Chapter 5 contains an online version of the Scaling Task, which primarily attempted to expand on the results reported in Chapter 2. This was done by assessing whether attentional effects on perception can be observed when examining psychological constructs related to attention. Specifically, the study presented in this chapter assesses the relationship between behavioural motivation and impulsivity, and perceived size of food objects. The findings of this experiment indicate that neither behavioural motivation nor impulsivity provided a significant predictor of reported food or non-food size. Although neither of these results align with the attentional account, several potential explanations for this are outlined. This research is the first to investigate whether differences in size perception across individuals occur in due to differences in psychological constructs (specifically behavioural motivation and impulsivity).

Chapter 6 provides a discussion of the experiments presented in this thesis. The current thesis presents a novel scaling task for objectively assessing top-down effects on object perception while avoiding the pitfalls presented by Firestone and Scholl (2015). It is concluded that initial results present no evidence of action-specific effects on perception. Instead, the findings from the Scaling Task suggest that attentional effects may drive perception without any influence from action-specific capacity, contrary to Witt (2017) and Kirsch, Kitzmann, and Kunde (2021). However, further investigation is required to assess the reliability of this novel Scaling Task. This discussion chapter also considers the limitations of the research within this thesis, in addition to directions for future research.

Chapter 2

A method to measure supposed top-down effects on perception

Abstract

It has been argued that visual perception is influenced by top-down effects, such as action-capacity or attentional breadth (The Action-Specific and Attentional Accounts, respectively). However, no published support for these effects has avoided the methodological pitfalls that provide alternative explanations of their results. This chapter presents the True-to-Size Scaling Task – a novel procedure for assessing perception of object size while avoiding such pitfalls. In this task, participants manipulated a scaling cross to match the dimensions of a presented object. To assess whether the Scaling Task was affected by judgement, such as estimation tasks (in which reports of object size are given in written reports), participants also completed trials in which written reports of object size were given in millimetres. To test whether stomach capacity affected perception of food size, participants completed the procedure once after breakfast and once following an over-night fast. The results demonstrate that only the True-to-Size Scaling Task captured the change in perception expected when individuals had fasted. Specifically, it was observed that healthy sweet foods and unhealthy savoury foods were reported as relatively larger after fasting compared to when satiated. Importantly, no significant differences between conditions were observed in relation to non-food objects, suggesting that the observations regarding food may have implications for everyday perception. Additionally, because food items (but not non-food items) were perceived as relatively larger while fasting, it appears that attentional breadth (independent of action-specific effects) may influence object size perception.

Introduction

There is a lack of consensus as to which methods are best for assessing perception of food. In terms of food size perception, various measures provide support for two differing accounts of object perception: The Action-Specific Account and the Attentional Account. This chapter presents a novel Scaling Task for assessing perception of food size while avoiding the pitfalls of previous research. The predictions of the Action-Specific and Attentional Accounts are also tested in this chapter. This is accomplished by having participants report the size of food and non-food objects after an overnight fast and after a meal.

The Action-Specific Account claims that visual perception is affected by a person's ability to interact with their environment (Proffit & Linkenauger, 2013). Specifically, Proffit and Linkenauger (2013) argue that the physical state of the human body provides 'perceptual rulers' to scale visual information, and that the ruler used at time of perception is one that pertains to relevant action. For example, a hungry person may scale visual information using their maximum stomach capacity as a perceptual ruler. Bhalla and Proffitt (1999) observed such action-specific effects. They reported that individuals wearing a heavy backpack perceived hill steepness as greater than non-backpack controls. The authors argued that this occurred because the increased energy demands of carrying extra weight reduced their capacity to traverse the hill. Put simply, participants scaled the visual information (i.e. the steepness of the hill) using their relevant perceptual ruler (i.e. their bodies' energy reserves given the physical demands of climbing the hill). This assertion challenges the idea of cognitive impenetrability put forwards by Fodor (1983), as it suggests that cognition (believed action-capacity) can affect perception. The Action-Specific Account may also explain why individuals think about food differently when hungry compared to satiated, such as an increased desire to eat chocolate (Lambert, Neal, Noyes, Parker & Worrel (1991). Collier (2018) highlighted that action-specific effects on food perception, if they really exist, should be observable as hungry individuals have an increased capacity to eat.

Alternatively, perception of environment may change dependent on attention allocation within the visual field. Such an attentional account of visual perception is supported by research such as Cole, Riccio, and Balcetis (2014), who observed that targets are reported closer (and therefore larger) when participants narrow their attention towards the target. It should be noted that here attentional bias refers to attentional narrowing, in which breadth of attention is reduced to focus more centrally on the target (Gable & Harmon-Jones, 2008). Kirsch, Heitling and Kunde (2018) demonstrated that the perceived size of an object can be increased to a greater or lesser extent depending on how narrowed an individual's perception is. Unlike the Action-Specific Account, this attentional explanation of perceptual changes may not challenge the idea of cognitive impenetrability (Fodor, 1983), as attentional narrowing may change the way the eye fixates on an object, and this change in visual input explains differences in perception.

Although no study has compared the Action-Specific and Attentional Accounts directly, there are several measures which may be used to support one account or the other (e.g. van Koningsbruggen, Stroebe & Aarts 2011; Yellowlees et al., 1988; Cole, Riccio & Balcetis, 2014). This is problematic because Witt (2017) has argued that action-specific effects may affect perception indirectly by driving attention. As such, to truly test the existence of action-specific effects on perception, the predictions of the action-specific and attentional effects must be separated.

The present research will do this by comparing object size perception after participants have fasted to when satiated. This should be sufficient to separate the predictions of the Action-Specific and Attentional accounts. Following the logic of the Action-Specific Account, a relevant perceptual ruler for viewing food (such as the stomach's current capacity) should result in participant's perceiving food items as smaller after fasting due to an increased capacity to eat. Conversely, following the Attentional Account, participants should perceive food items as larger after fasting due to an increased attentional bias towards food (Stamataki et al., 2019) compared to when satiated. In the present experiment, participants will use a scaling cross (+) to reproduce the dimensions of food and non-food items. In addition, participants also provided a written estimation of object size in cms. "Double size" versions of these reports are also included, in which participants must report the dimensions of the object were it to double in size. Participants completed the experiment both following a meal and following an overnight fast.

The present experiment is by no means the first to investigate shifts in the perception of food. However, it is perhaps the first to successfully observe results not contaminated by experimental bias or other such factors. Although there have been many methods designed for the purpose of assessing food size perception (e.g., van Koningsbruggen, Stroebe & Aarts 2011; Kissileff et al., 2016; Milos et al., 2013; Yellowlees et al., 1988; Cole, Riccio & Balcetis, 2014; Nichelle et al., 2019) these methods all contain experimental flaws which may provide an alternative explanation for their results. Most similar to the present research is Yellowlees, Roe, Walker & Ben-Tovim (1988). They provided the first notable measure of how visual perception of food may be flexible. In their scaling task, participants were presented with a food item and instructed to manipulate a digital photo of the item until it matched the dimensions of the food. They observed that participants with Anorexia Nervosa scaled food items as larger than controls. Such results would provide compelling evidence in favour of the Action-Specific Account as this increased food size perception in those with Anorexia may be caused by a reduced ability to eat. However, there are alternative explanations for their results (see ‘El Greco Fallacy’ later in this chapter). Issues with research methodology in experiments demonstrating top-down effects (such as action-specific effects) on perception are common. Most notably, Firestone and Scholl (2016) argue that all evidence of top-down effects on perception can be explained by experimental biases or similar effects. They outline 6 pitfalls which provide alternative explanations for research that claims top-down effects alter perception. This chapter presents a novel Scaling Task like Yellowlees et al (1988) but with several key changes. Below is a description of how the proposed Scaling Task avoids the pitfalls put forwards by Firestone and Scholl (2016).

Pitfall 1: Lack of Disconfirmatory Findings

Firestone and Scholl (2016) assert a robust effect should be not only observable, but also absent when appropriate. In food perception, such disconfirmatory findings could be incorporated by assessing whether top-down effects are also observed when viewing non-food items. As such, top-down effects on food perception (e.g. those with Anorexia Nervosa perceiving food as larger than controls) should not be replicated for non-food because, according to the Action-Specific Account, those with Anorexia Nervosa may have less capacity to eat food but neither group is able to eat non-edible objects. Alternatively, those with Anorexia Nervosa bias attention towards food (Ralph-Nearman et al., 2019). Therefore, following the Attentional Account, perceptual effects on food should differ between food and non-food objects. As such, disconfirmatory findings are sought in the present research using non-food trials. If both food and non-food objects are reported as significantly larger after fasting, then these results are unlikely to be caused by top-down effects on perception.

Pitfall 2: Perception versus Judgement

While previous methodologies could demonstrate altered perception, it is not possible to claim this because many do not consider the entanglement of perception and judgement. Firestone and Scholl (2016) distinguish judgement and perception as strictly different. Specifically, judgement is an inference based on visual information, whereas perception refers to what is seen in terms of spatial features. These two factors are difficult to tease apart, as features such as object size can be both judged and perceived. Within food research, van Koningsbruggen, Stroebe and Aarts (2011) had dieters and non-dieters report muffin height in cms. It was argued that dieters perceived food as larger than controls as they reported the muffin as taller. However, estimating food size in this way may reflect judgement rather than perception. Specifically, dieters may simply judge food to be larger than controls and reflect this judgement in their cm reports. This is not to say that dieters do not perceive food as larger than non-dieters, only that it is not possible to conclude this from cm estimations. Therefore, following recommendation from Firestone and Scholl (2016), studies researching spatial perception should avoid relying on verbal or written estimations such as cms and instead reflect the spatial features of a target. For this reason, the current research ensures that it measures perception by deploying a scaling measure like Yellowlees et al. (1988). To demonstrate the importance of this decision, written cm estimations were included in the present research to assess whether introducing elements of judgement would change reports of object size.

In the present study, the role of judgement is also assessed using “Double-Size conditions”. In these conditions, participants must report (via scaling or cm estimates) the dimensions of a target object if doubled in size. These conditions are included because the dimensions of an object double its current size cannot be perceived. Instead, it can only be judged from spatial information using the target’s displayed size. If while scaling a cross (+) to report object size, results do not differ between True-to-Size and Double-Size versions, then it can be concluded that scaling also measures judgement rather than perception.

Pitfall 3: Demand Characteristics and Response Bias

Bhalla & Proffitt (1999)’s observed over-reporting of hill steepness while wearing a heavy backpack can be explained by demand characteristics. Durgin et al., (2009) demonstrated that when participants were given a reasonable cover story for wearing the backpack, no significant differences in estimation were observed. In the present study it would be difficult to create a convincing cover story for asking participants to manipulate a cross (+) until it matches the dimensions of a target. As such, following Firestone and Scholl (2016)’s recommendation, participants will report what they believe the hypothesis of the experiment was. Subsequently, participants that correctly predict the hypothesis will be removed from the study. This addresses Firestone and Scholl (2016)'s concern that participants may affect results by attempting to confirm what they think is the hypotheses.

Pitfall 4: Low-Level Visual Differences

Researchers must ensure that results are not caused by low-level visual differences between stimuli. This is particularly important when including disconfirmatory hypotheses. For example, an observation of action-specific effects on food but not non-food items might actually be driven by the visual differences between item types. In the present research this pitfall was avoided by using identical stimuli in both fasting and satiated conditions. Therefore, if participants report food as larger or smaller than non-food in both fasted and satiated conditions then results may have been caused by low-level visual differences between food and non-food stimuli.

Pitfall 5: Peripheral Attentional Effects

Firestone and Scholl (2016) highlight that some reported top-down effects on perception may be caused by attentional differences towards stimuli. However, Witt (2017) argued that this does not rule out the possibility of action-specific effects on attention, as action-specific effects may change perception indirectly by driving attention. Kirsch, Kitzmann, Kunde, (2021) claim to have demonstrated exactly this. Their participants completed two versions of an on-screen hitting task before assessing the relative size of an on-screen object. A difficult version of the hitting task (reduced action-capacity) was compared to an easier version of the same task. The authors argue that greater size perception occurred in the difficult version of the hitting task as the increased task difficulty (and therefore reduced action-capacity) should have led to more focused attention compared to the easier version. Interestingly, Kirsch et al. (2021) also demonstrated that size perception is affected in a similar way without the involvement of action-specific mechanisms (i.e. removing the hitting task and instead simply narrowing or widening attention). However, their assertion that action-specific effects may change size perception by driving attention does not account for situations in which the Action-Specific and Attentional Accounts oppose each other. The present research attempts to address this by assessing effects on size perception while the Action-Specific and Attentional Accounts are expected to make contrary predictions. Specifically, if action-specific effects drive attention, then attention towards food should be widened after fasting and therefore food should be observed as smaller. This widening is expected because if Witt is correct in asserting that Action-Specific effects on perception may occur indirectly by modulating attention, then a widening in attentional breadth must occur in order for the object to appear as smaller in line with increased capacity to eat – and thus encourage greater than usual food consumption. However, if action-specific effects do not drive attention, then attention towards food should be narrowed and therefore food should be observed as larger after fasting.

Pitfall 6: Memory and Recognition

To accurately report perception without contamination from memory, participants must report while both the target and means of reproduction are present. For example, Cole, Riccio and Balcetis' (2014)'s results are contaminated by memory, as participants had to look away from the target to instruct experimenter movement. As participants could not perceive the target (distance to icebox) and means of replication (distance to experimenter) simultaneously, they must remember their distance from the icebox in order to report it. Due to the involvement of memory, such methods cannot observe top-down effects on perception. To avoid this, participants in the present research will replicate target item dimensions while both the target and scaling cross (+) are adjacent on-screen.

Additional precautions against memory contamination were taken in the present research. For example, participants should not give written estimations of food size in cms (such as van Koningsbruggen et al., 2011; Forwood et al., 2015; Collier, 2018) because measurements, such as 5cm, cannot be perceived. Instead, they can only be recalled and applied in relation to perceived spatial information. In essence, participants must rely on their memory of how large a cm to estimate. Although memory is often not expected to differ between groups, this highlights the potential unreliability of using such methods. As such, it is difficult to discern whether any study using written estimations can observe effects on perception. For this reason, the present research will deploy a scaling task and compare these results to conditions in which written estimations are used.

The El Greco Fallacy

Other methodological concerns may explain supposed top-down effects on perception. For example, Firestone and Scholl (2014) argued that perceptual effects should not be observable if the target stimulus and the means of replication are identical. This is because any perceptual effect acting on the target should act on the means of replication in the same way – thus cancelling each other out. This is referred to as the El Greco Fallacy. The reason that Yellowlees et al. (1988) commit this fallacy is because the object being scaled (target food item) and the image being manipulated were the same. For this reason, any perceptual bias that affected the target item, should have also affected participants perception of the scaling object, thus cancelling each other out. Therefore, Yellowlees et al. (1988) should not have observed a significant difference in food scaling between participants with Anorexia Nervosa and controls. This is not to say there is no bias affecting the way that some individuals perceive food objects, only that it is not possible to observe these when target and scaling items are identical. Instead, it is most likely that their results most likely to be the result ofreflect demand characteristics which are robust across all participants with Anorexia Nervosa (for example, hypothesis guessing on the part of these participants). The El Greco Fallacy is a common issue within food research which is not specific to scaling or cm reports. For example, Nichelle et al., 2019 showed participants an image of a portion of a target food (e.g., pasta), and asked them to select from images of matching portions (the same food as the target but in different portion sizes) which most closely matched the portion of the target. Their results suggested that participants were accurate at reporting the size of the target object by selecting the portion size that matched the target portion. However, this study could not reliably demonstrate differences in perception because the target and matching images were all of the same item (and thus, if a perceptual effect had occurred, then it would not be observable). The present research avoids the El Greco Fallacy because participants report object size by manipulating a scaling cross (+) to match the target's dimensions. There is no reason that perceptual effects caused by food will also affect the scaling cross, thus potential effects on target stimuli should be observable.

The present research

The present study aims to test the existence of top-down effects on perception while accounting for methodological pitfalls which provide alternative explanations for observed results. This is done by using a novel scaling task to assess the size individual’s perceived food and non-food to be following and overnight fast and after a meal. Following the Action-Specific Account, individuals should perceive food as smaller after fasting (compared to when satiated) due to an increased capacity to eat. Conversely, following the Attentional Account, participants should perceive food as larger after fasting (compared to when satiated) because of the increased attentional bias towards food when hungry. As such, the first hypothesis is that food objects will be perceived as either smaller or larger by participants when hungry compared to when satiated.

In the present experiment, disconfirmatory hypotheses are included as the non-food object conditions. If any perceptual effects on food also apply to non-food, then it may be that results were caused by methodological flaw. This assertion is made as neither account predict effects on non-food in this context. Explicitly, non-food items should not be affected by the same perceptual ruler, or attentional narrowing, as food. Therefore, the second hypothesis is that perceptual effects observed for food will not be observed for non-food.

To determine the possible role of judgement and memory on supposed measures of perception, the current research compares the estimation task (similar to van Koningsbruggen et al., 2011) and a novel scaling task (similar to Yellowlees et al., 1988). Unlike the estimation task, this scaling task is not expected to be contaminated by judgement and memory. Therefore, the third hypothesis is that reports of perceived food size will differ between the True-to-Size scaling task and the True-to-Size estimation task.

Further disconfirmatory hypotheses are included as the “Double-Size tasks”, within which participants must report double the target’s displayed dimensions. These conditions were included to further assess whether introducing judgement would affect reports. Therefore, the fourth hypothesis is that reports of food size will differ between the True-to-Size - and Double-Size - versions of the Scaling Task.

Methodology

Participants

It was not possible to conduct an a priori or criterion power analysis as there were no appropriate previous studies to base this calculation. For example, although Yellowlees et al. (1998) or van Koningsbruggen et al., (2018) could be used for this power analysis, their results were likely not caused by truly perceptual effects. As such, it would be inappropriate to use their results as the basis for a power analysis. As such, 20 right-handed students (13 females) from the University of Essex were recruited. The mean age of participants was 25.6(7.49) years. All participants were native English speakers with normal or corrected to normal vision. Participants did not include those with a history of eating disorders or dietary restrictions which affect food consumption.

Design

A 2 x 2 repeated-measures design with the two factors ‘Satiety’ (whether or not food had been eaten on the day of experiment) and ‘Image’ (whether image shown to participants was of a food or non-food object) was used. Benjamini and Hochberg (1995) method t-tests were used to assess whether effects of hunger on food perception were specific to particular food types. The dependent variable in the present research was participants’ error when estimating/scaling in millimetres (mm). This error value was calculated by subtracting the scaled/estimated size of the scaling cross/written measurement provided from the actual dimensions the target object was displayed on screen, thus providing an absolute measure of participant scaling/estimation accuracy.

Materials

48 images (24 food & 24 non-food) were taken from the Food-Pics image database (Blechert, Meule, Busch & Ohla, 2014) and Foodcast Research Image Database (FRIDa; Foroni, Pergola, Argiris & Rumiati, 2013). The objects in the images were displayed on a white background. The images cannot be shown here for copyright reasons. The food images were subdivided into 4 categories based on their caloric content and taste profile: healthy sweet foods, healthy savoury foods, unhealthy sweet foods, and unhealthy savoury foods. Like the categorisation used in Goldstone et al. (2009), healthy foods contained a maximum of 150 calories per 100grams (for example an apple), while unhealthy foods contained a minimum of 300 calories per 100g (for example a donut). The 24 food items were equally split into these categories – 6 images of each food category. This was done to determine whether certain food groups, for example those which are high in calories, are exclusively

perceived as larger when hungry. A grey cross (+) was presented on-screen during the scaling tasks for participants to report object size - this is referred to as the scaling cross. For the True-to-Size versions of tasks, image size was fixed so the longer axis (horizontal or vertical) of each image appeared at a random 5mm interval between 70mm and 130mm. Meanwhile, the shorter axis was presented at a size that maintained the image’s aspect ratio. Double-Size versions of tasks were similar, except the longest axes were displayed at half the size (i.e. between 45mm and 65mm) to allow participants space to make the scaling cross twice the size of displayed images. The distance between the centre of the target object and the scaling cross was 270mm, with participants face 660mm from the screen. The experiment was carried out using Inquisit 5 (Millisecond Software, Seattle, USA) and displayed on a 55cm Retina 4K display Apple iMac computer.

Procedure

Every participant took part in the experiment twice: once after breakfast (1-2 hours before experimentation) and another following a 15 hour overnight fast, counterbalanced between participants. These timings were like those used in previous food research (Massicotte, Deschênes, & Jackson, 2019; Sänger, 2019). Participants were tested individually, in a quiet, dimly lit environment and took part in the 4 tasks (each detailed below) in a counterbalanced order. At the start of each session, participants reported their subjective feelings of hunger using a seven-point Likert scale (1 = not hungry at all, 7 = very hungry). Participants were instructed not to use their hands or other instruments to measure image size. One practice trial per condition was carried out for each task to ensure that instructions were understood. There was no time limit on any of the trials or tasks in this experiment. As such, images stayed on-screen, and participants pressed the enter key to progress after reporting. Each task was performed in blocks (i.e. participants completed all trials of one task before moving onto the next). Participants were presented objects in a random order within each task. After completing the second session of the study, participants wrote down what they believed the hypotheses to be.

True-to-Size estimation task

Each trial began with an object presented in one random quarter of the screen. Following this, participants wrote down the size they perceived the item to be. Participants used pen and paper to report the item's height and width in cm, including the use of decimal places. Importantly, participants wrote their reports without removing their gaze from the screen.

True-to-Size scaling task

Like the True-to-Size estimation task, each trial began with an image presented in a random quarter of the screen. However, unlike the estimation task, the target was accompanied by a cross (+) which appeared in the screen quarter diagonal to the target. See Figure 1 for an illustrative example. Participants used the arrow keys to manipulate the dimensions of the cross until it matched that of the onscreen object (up-arrow to increase - and down-arrow to decrease - the height of the cross; right-arrow to increase - and left-arrow to decrease - the width of the cross).

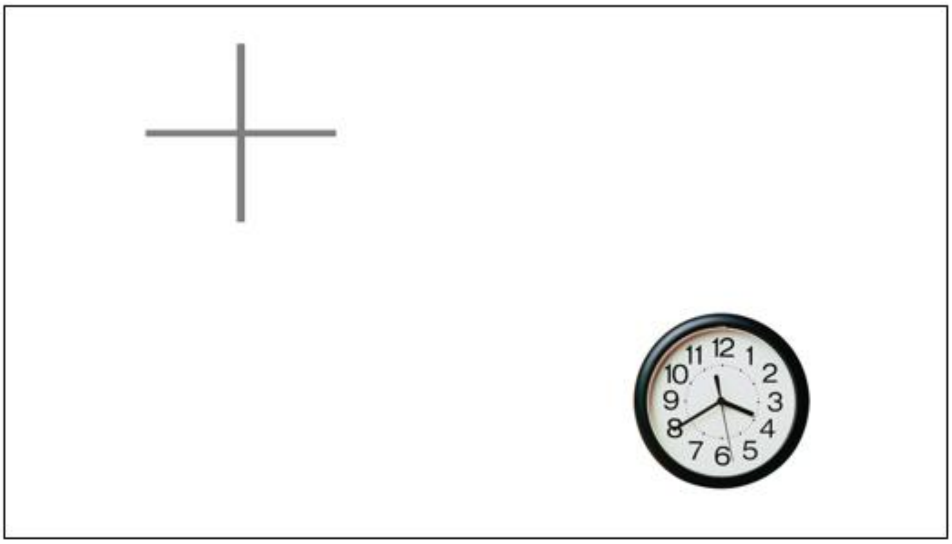

Figure 1. Illustrative example of the Scaling Task. Note that the Estimation Task was identical but without of the scaling cross.

Double-Size estimation task

The Double-Size estimation task was like the True-to-Size version with the exception that participants wrote down how large the target would be if it doubled in size.

Double-Size scaling task

The Double-Size scaling task was like the True-to-Size version with the exception that participants scaled the cross to how large the target would be if doubled in size.

Data Preparation:

Due to technical errors within the data collection software, Inquisit 5 occasionally omitted trials from the data collection, although this occurred rarely (0.875%). Little's MCAR test (Little, 1988) confirmed that data were missing completely at random $\chi 2$ (77) = 14.250, DF = 77, p = 1.00. Missing values were therefore estimated using Expectation–maximization (EM; Acock, 2005; Sainani, 2015).

Results:

A repeated measures t-test assessed participants' subjective feelings of hunger between the two sessions. This t-test revealed that participants reported greater subjective feelings of hunger after fasting [t (19) = 5.94, p = 0.00001].

Four within-subjects ANOVAs (2x2) assessed how the two repeated measures variables (Satiety and Object) may impact reported size of objects. Throughout the analysation of the below repeated measures ANOVAs, Greenhouse-Geisser corrections were applied whenever sphericity was violated. Bayesian probabilities associated with null ($H_0|D$) and alternative hypotheses ($H_1|D$) were calculated in addition to frequentist statistics to allow for clearer inferences about the probabilities of non-significant effects (see Masson, 2011). These probabilities range from 0 (no evidence for hypothesis) to 1 (very strong evidence for the hypothesis). The ANOVAs and T-tests were completed using the averages from each object type in each category. It should be noted that, compared to the ANOVAs which contained 24 of each item type (food vs. non-food items), the t-tests were assessed with only 6 of each items test (6 for each food type). Mean performance as a function of Satiety and Object in each task can be seen in Figures 2-5. These figures suggest a general tendency for participants to under-report the size of any given object, but less so after fasting.

Following ANOVAs for each task, planned Benjamini and Hochberg (1995) corrected t-tests assessed whether reported size changed only for certain types of object (e.g. only unhealthy sweet foods). Williams, Jones and Tukey (1999) recommend the use of this follow up test over the Bonferroni as its sequential approach to controlling false discovery yields greater statistical power. The statistics of these AVOVAs and their respective follow-up tests are presented in turn below.

Importantly, no participant correctly identified any hypotheses. Some participants did mention a suspected effect of hunger on perception, this was not specific to just food object size. Though this does not entirely rule out experimental bias, it does make it unlikely to have caused the reported objects sizes. Therefore, no participants were excluded from analysis.

True-to-Size estimation task

A 2x2 ANOVA revealed no significant main effect of Satiety, [F (1, 19) = 0.485, MSE = 236.723, p = 0.495, partial η2 = 0.025 , p (H_0 | D) = 0.780]. There was also no significant main effect of Object [F (1, 19) = 0.036, MSE = 57.850, p = 0.852, partial η2 = 0.002, p (H_0 | D) = 0.814]. Finally, the interaction between Satiety and Object was non-significant [F (1, 19) = 0.036, MSE = 57.850, p = 0.852, partial η2 = 0.002, p (H_0 | D) = 0.996].

Following this, Benjamini and Hochberg corrected t-tests assessed whether reported size changed for certain types of object. These comparisons revealed no significant effects of hunger on participants' perception of object size: Non-food [t (19) = .856, p

= .403], Healthy sweet food [t (19) = .155 p = .878], Healthy savoury food [t (19) = .182, p = .858], Unhealthy sweet food [t (19) = 1.628, p = .120], Unhealthy savoury food [t (19) = 2.586, p = .018] (not significant after adjusting for multiple corrections). These results demonstrate that neither food nor non-food size estimation were affected by satiety (see Figure 2).

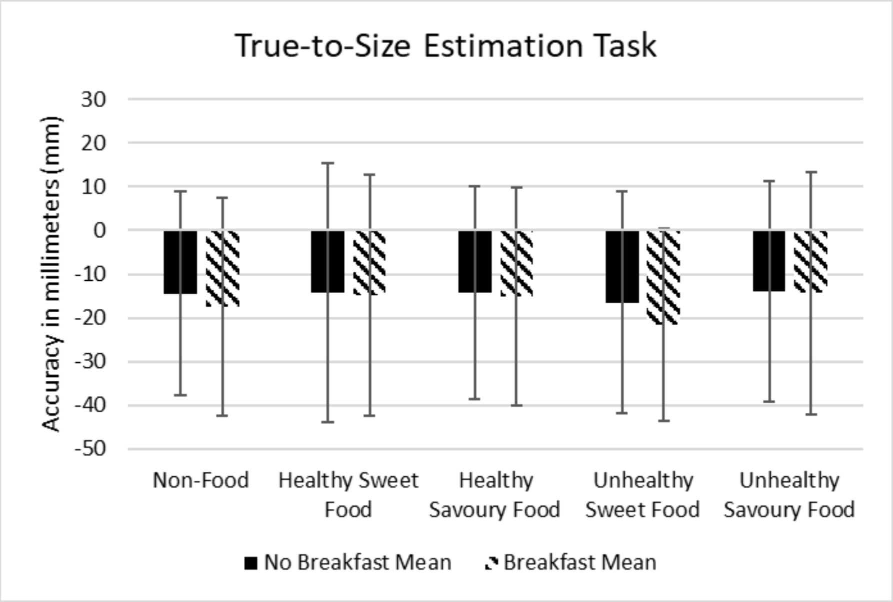

Figure 2. Mean error and standard deviation in the True-to-Size Estimation Task after breakfast and overnight fast. * = Significant difference.

Double-Size estimation task

A 2x2 ANOVA revealed a significant main effect of Satiety [F (1, 19) = 5.359, MSE = 1504.809, p = 0.032, partial η2 = 0.220, p (H_0 | D) = 0.271] in that participants reported items as larger after fasting. The main effect of Object was not significant [F (1, 19) = 0.134, MSE = 82.386, p = 0.719, partial η2 = 0.007, p (H_0 | D) = 0.806]. The interaction between Satiety and Object was also not significant [F (1, 19) =

0.216, MSE = 30.175, $p = 0.648$, partial $\eta2 = 0.011$, $p (H_0 | D) = 0.996$]. Benjamini and Hochberg corrected t-tests showed that Satiety did not affect perceived size of any object type: Non-food [$t (19) = 1.968$, $p = .064$], Healthy sweet food [$t (19) = 2.339$, $p = .030$] (not significant after adjusting for multiple corrections), Healthy savoury food [$t (19) = 1.707$, $p = .104$], Unhealthy sweet food [$t (19) = 1.388$, $p = .181$], Unhealthy savoury food [$t (19) = 1.930$, $p = .069$]. These results demonstrate that, both food and non-food objects are reported as relatively larger after fasting, however, this is not significant when controlling for multiple comparisons (see Figure 3).

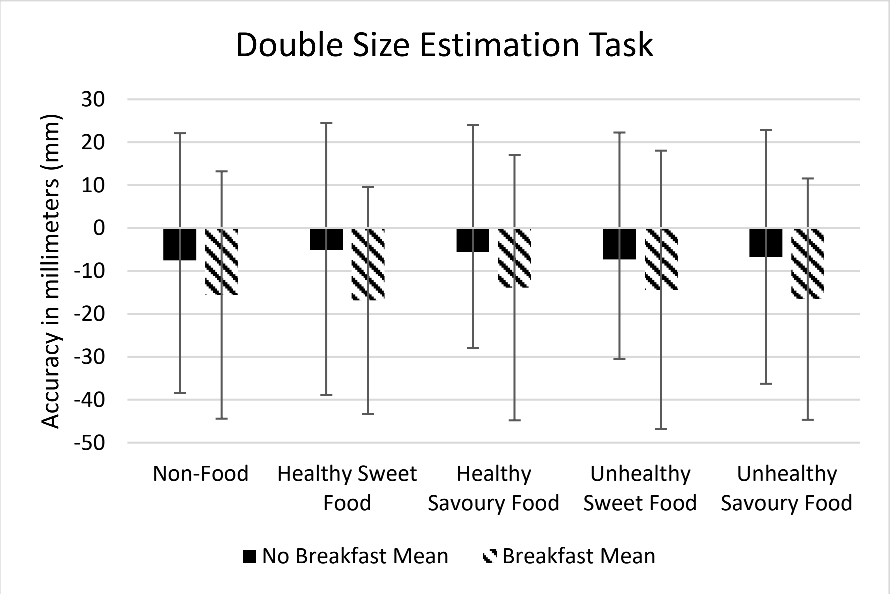

Figure 3. Mean error and standard deviation in the Double-Size Estimation Task after breakfast and overnight fast. * = Significant difference.

True-to-Size scaling task

A 2x2 ANOVA revealed a significant main effect of Satiety [$F(1, 19) = 11.662$, $MSE = 44.812$, $p = 0.003$, partial $\eta 2 = 0.380$, $p(H_0 \mid D) = 0.035$] in that participants reported food and non-food objects as significantly larger after fasting. The main effect of Object was not significant [$F(1, 19) = 0.006$, $MSE = 25.373$, $p = 0.941$, partial $\eta 2 = 0.0003$, $p(H_0 \mid D) = 0.816$]. No significant interaction was found between Satiety and Object [$F(1, 19) = 0.643$, $MSE = 17.866$, $p = 0.433$, partial $\eta 2 = 0.033$, $p(H_0 \mid D) = 0.994$]. Benjamini and Hochberg corrected t-tests revealed that only healthy sweet food [$t(19) = 3.140$, $p = .049$] and unhealthy savoury food [$t(19) = 3.831$, $p = .001$] were reported as significantly larger when participants were fasting. This was not the case for non-food [$t(19) = 2.318$, $p = .032$], healthy savoury food [$t(19) = 1.378$, $p = .184$], or unhealthy sweet food [$t(19) = 1.00$, $p = .330$], which were not significant after adjusting for multiple corrections. A post-hoc power analysis indicated both comparisons were at over 85% power. Given that Fitzner & Heckinger (2010)'s review of statistical power stated that 90% is generally acceptable for clinical application, 85% was considered sufficient to accept these results as sufficiently powered. In addition, a repeated-measures Bayesian t-test was conducted on the non-food comparison to assess the confidence in the null hypothesis. This result revealed no/anecdotal support for the alternate hypothesis [$BF_{10} = 1.99$]. As a comparison, this same test was also run for healthy sweet foods [$BF_{10} = 8.61$], and unhealthy savoury foods [$BF_{10} = 32.98$]. These results suggest that although all object types may be reported as larger after fasting, only healthy sweet food and unhealthy savoury food remained significant after controlling for multiple comparisons (see Figure 4).

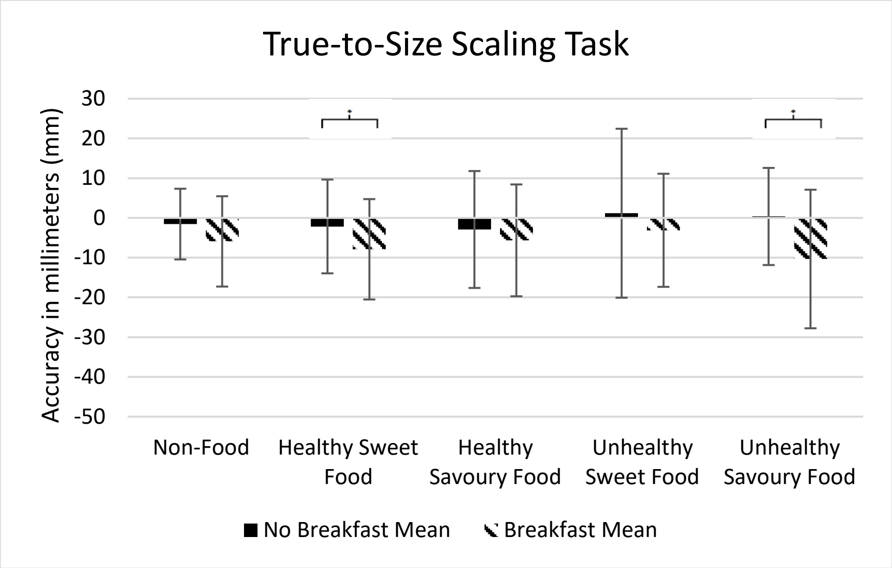

Figure 4. Mean error and standard deviation in the True-to-Size Scaling Task after breakfast and overnight fast. * = Significant difference.

Double-Size scaling task

A 2x2 ANOVA revealed a non-significant main effect of Satiety [F (1, 19) = 0.796, MSE = 149.796, p = 0.384, partial η2 = 0.040, p (H_0 | D) = 0.747]. The main effect of Object was also non-significant [F (1, 19) = 0.019, MSE = 87.660, p = 0.892, partial η2 = 0.001, p (H_0 | D) = 0.815], as was the interaction between Satiety and Object [F (1, 19) = 3.692, MSE = 24.739, p = 0.070, partial η2 = 0.163, p (H_0 | D) = 0.692]. Benjamini and Hochberg corrected t-tests showed that Satiety did not affect perceived size of any object type: Non-food [t (19) = .098, p = .923], Healthy sweet food [t (19) = 1.641, p = .117], Healthy savoury food [t (19) = 1.148, p = .265], Unhealthy sweet food [t (19) = 2.231, p = .038] (not significant after adjusting for multiple corrections), Unhealthy savoury food [t (19) = -.479, p = .637]. These results demonstrate that neither Satiety nor the Object type effect participant reports (see Figure 5).

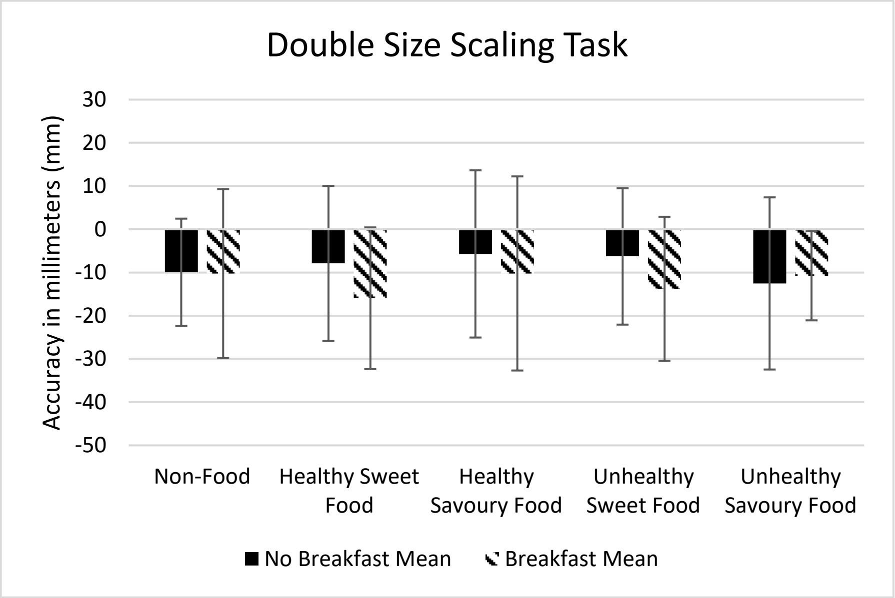

Figure 5. Mean error and standard deviation in the True-to-Size Scaling Task after breakfast and overnight fast. * = Significant difference.

To ensure that participants had completed the Scaling Tasks reliably - specifically that they actually scaled larger objects as such compared to smaller objects when presented - a regression was conducted to assess whether displayed object dimensions was a significant predictor of reported object size in the scaling task. The rational for this analysis was that if displayed dimensions do not predict reported object size, then the observed results in this study would almost certainly be the result of some kind of experimental bias or non-perceptual interference. The regression indicated that displayed object dimensions explained 0.38% of the variance in the reported size of objects in the Scaling Task which was significant [F (1, 941) = 566.364, p = .001]. The results of this regression suggests that reported size of objects in the Scaling Tasks were primarily driven by the displayed size of objects on the screen – suggesting that participants carefully engaged with the task.

Discussion

The aim of the present experiment was to develop a novel task for assessing the perceived size of objects while avoiding the methodological pitfalls committed by previous research. The present research also aimed to investigate two mechanisms claimed to effect size perception; namely the Action-Specific and Attentional effects (Proffit & Linkenauger, 2013; Witt 2017; Anton-Erxleben, Henrich & Treue, 2007; Cole et al., 2014; Kirsch et al., 2021). This was done by assessing perception of food size when Action-Specific and Attentional Account predictions should oppose one another (i.e., following an overnight fast).

The results of the present experiment demonstrated that, in the True-to-Size Scaling Task, participants reported healthy sweet and unhealthy savoury foods as relatively larger following an overnight fast. This result validates the first hypothesis which predicted that food items will be reported as relatively smaller or larger after fasting. Importantly, this observed difference in food was not replicated in non-food. This result validates the second hypothesis which predicted that differences in reported food size across satiety conditions would not also affect non-food items. Further, differences in reported food size across satiety states in the True-to-Size Scaling Task were not also observed for the True-to-Size Estimation Task. This finding validates the third hypothesis that observed results between the True-to-Size Scaling Task and True-to-Size Estimation Task will differ. Finally, the results demonstrate that differences in reported food size across satiety states in the True-to-Size Scaling Task were not also observed for the Double-Size Scaling Task. This result validates the fourth hypothesis that results between the True-to-Size Scaling Task and Double-Size Scaling Task will differ. Together these results suggest that, while avoiding the pitfalls of previous research, attentional effects rather than action-specific ones, affect perceived size of food items. Further, by separating the predictions of the Action-Specific and Attentional Accounts, the present results suggest that attentional effects on perception are not driven by action capacity as suggested by Witt (2017) and Kirsch et al. (2021). It should be noted that, in the True-to-Size Scaling Task, healthy sweet food and unhealthy savoury food was not only reported as larger but also more accurately after fasting. Such information is missing from most food perception research - as it is typical to publish participants' reported size rather than their average error (e.g., van Koningsbruggen et al., 2011). This is an important distinction from previous research, as here hungry individuals do not report food as larger than it is, instead perception of food size is more accurate after fasting. Presenting participants' reports relative to the physical dimensions of presented stimuli provides more informative data. Therefore, future studies should report their findings as error from spatial dimensions, rather than comparing reported size.

To ensure that results were not caused by pitfalls committed by previous research, several measures were put in place within the present research:

Pitfall 1: Lack of Disconfirmatory Findings

Disconfirmatory hypotheses, in which no significant effects of fasting on perception were expected, were principally included via the addition of non-food conditions. The absence of perceptual effects on reported size of non-food objects suggest that the observed effects on food are meaningful for everyday perception. If the effects of fasting were observed for both food and non-food objects during the True-to-Size Scaling Task, then it could have been concluded that these effects would cancelled each other out and have no impact on everyday perception. This assertion was further supported by Bayesian t-test which, according to the classification scheme for Bayes factors BF_{10} (Lee and Wagenmakers, 2014), revealed no/anecdotal support for the alternate hypothesis, compared to the moderate/strong evidence for the alternate hypothesis observed for healthy sweet foods, and very strong evidence for the alternative hypothesis for unhealthy savoury foods.

Pitfall 2: Perception versus Judgement

Two demonstrations of judgement contaminating purported measures of perception were included in this study. The first was the difference between reports during the True-to-Size versions of the scaling and estimation tasks. Unlike spatial properties, centimetres cannot be perceived, they can only be judged relative to an individual's understanding and familiarity with the measurement. This explains why the perceptual effects of fasting observed in the True-to-Size Scaling Task were not replicated in the True-to-Size Estimation Task. Further, this argument that judgement would not reflect perceptual effects was demonstrated using the Double-Size Tasks. Again, unlike presented spatial dimensions, the dimensions of an object – were it doubled in size - requires judgement based on the spatial features perceived. This explains why the effects of fasting on food perception were not replicated in the Double-Size version of the Scaling Task. These results demonstrate the importance of ensuring that judgement does not contaminate perceptual reports. The former of these may also explain how Collier (2018)'s use of centimetre estimates may be responsible for the absence of fasting effects on food size perception in their study.

Pitfall 3: Demand Characteristics and Response Bias

Firestone and Scholl (2016) suggested that participants should be asked to identify the study’s hypotheses in experiments where it is not possible to reasonably implement a cover story to prevent demand characteristics or response bias. Following their suggestion, if participants correctly identify the hypotheses, it cannot be ruled out that their reports are free from response bias. No participant successfully identified the hypotheses of the present research, as such it is reasonable to assert that reports were not affected by response bias.

Pitfall 4: Low-Level Visual Differences:

The effect of low-level visual differences was controlled by using identical stimuli when participants were satiated and fasting. In the True-to-Size Scaling Task, only healthy-sweet and unhealthy savoury foods were reported as relatively larger in the fasting condition. If this was caused by low-level visual differences, then the same result should have been observed while participants were satiated. As such, it can be argued that the observed results were caused by attentional effects driven by fasting, rather than visual differences between stimuli groups.

Pitfall 5: Peripheral Attentional Effects:

The possibility that top-down effects on perception (such as action-specific effects) are caused by peripheral attentional effects was investigated by setting the predictions of the Action-Specific and Attentional Accounts against each other. Witt (2017) and Kirsch et al. (2021) argue that action capacity affects perception by driving attention. Following this, proponents of the Action-Specific Account would expect action-capacity (an increased capacity to eat) to widen attention and therefore food items be perceived as relatively smaller after fasting. However, participants reported food items as relatively larger in the True-to-Size scaling task after fasting. This suggests action-capacity does not affect perception by driving attention. It is likely previously observed action-specific effects may have been caused by peripheral attentional effects and misattributed to action-capacity.

Pitfall 6: Memory and Recognition

Memory was ruled out as an explanation of results by presenting targets on-screen while participants reported perceived size. This measure supports the assertion that results arose from attentional effects, rather than memory, as participants did not need to remember object size while reporting.

The El Greco Fallacy

In addition to the above, the El Greco Fallacy (Firestone, 2013) was also accounted for. This fallacy argues that no perceptual effects can be observed when the means of replication are the same as the target. Yellowlees et al (1988) committed this fallacy when participants scaled an image of food to match the dimensions of a presented target (the same food item). They argued that anorexic participants scaled food items as larger than controls. However, because the scaled item and target were identical, any perceptual effect on the target would alter the scaling item equally and cancel each other out. Therefore, their results cannot have been caused by perceptual effects. This was negated in the present research as participants scaled a cross rather than a copy of the target item. As no perceptual effect on target objects would also affect the scaling cross, it is argued that the results were caused by perceptual differences.

Directions for future research

The proposed methodology provides a systematic account of how to test for the existence of top-down effects on perception while avoiding methodological pitfalls which may provide alternative explanations of results. In developing this methodology, this research demonstrates that supposed action-specific effects do not affect perception of object size - not even indirectly by driving attention. It is argued here that attention alone affects perception by narrowing or widening an individual's focus on an object, thus resulting in said object being perceived as relatively larger or smaller, respectively. In essence, the findings do not necessarily challenge cognitive impenetrability and may support Firestone and Scholl's (2016) claim that perception acts consistently across scenarios given the same visual input. However, visual input may change due to attentional effects (e.g., small changes in fixation location), thus resulting in reported perceptual changes. Future research may assess whether the perceptual effect observed in this study was caused by attention driven changes in visual input. This could be done by repeating the True-to-Size Scaling Task and adding passive viewing while utilising eye-tracking. Such a study would expect to replicate the present results and observe a narrower range of gaze fixations during passive viewing of food after fasting.

This study highlights the effects of contaminating perceptual reports with judgement and demonstrates the importance of avoiding non-scaling reports, such as the cm estimates used in van Koningsbruggen et al. (2011). However, when using scaling methods, future research must ensure that the means of reproduction are not the same as the target (e.g. Yellowlees et al., 1998), as any perceptual effects would then be unobservable. Although the methodology presented in this chapter was targeted at assessing perception of food size, this method could be adapted to assess other top-down effects on perception. For example, controls in this study could be used to validate the findings of Cole et al. (2014). Specifically, removing the effects of memory by ensuring the experimenter and the ice box are both in the participant’s visual field while reporting distance. Further, disconfirmatory hypotheses could be added when attempting to validate Cole et al.’s (2014) findings. They assert that desire for a cold drink on a hot day caused participants to perceive the target as closer. Therefore, participants could also report their distance to a hot coffee. If only the cold drink is reported as closer, this would provide more evidence that their results were caused by an attentional bias towards the cold drink, rather memory or demand characteristics.

Interestingly, the results of this experiment suggest that only healthy sweet and unhealthy savoury foods are perceived as relatively larger after fasting. Given that many studies on food perception (e.g., Liu et al., 2019; Ahn, Ham & Kim, 2019; To et al., 2019) use exclusively chocolate because it has been rated as the most tempting food item (Tan, Tan & Tan, 2021), it is surprising that unhealthy sweet foods (which included chocolate) were not reported as relatively larger after participants had fasted. The following are several reasons why only some food items were perceived as significantly larger after fasting: Healthy sweet and unhealthy savoury foods may be perceived as larger after fasting for evolutionary reasons. For example, Davis (2014) argues that hyper palatable foods, with their high levels of sugar, fat, and salt, compared to natural foods were evolutionarily advantageous. It is possible that - although food groups were broken down into categories - these groups were still too broad. It is possible that chocolate was perceived as relatively larger after fasting but the other images in the unhealthy sweet category were not. Unfortunately, there are insufficient data points for each stimulus image to make these comparisons. Secondly, unhealthy sweet food (unlike less hyper-palatable foods) may have appeared maximally tempting in both fasting and satiated conditions. In such a situation, chocolate may evoke equal attentional narrowing across conditions – meaning no difference in reported size was observed (supported by Figure 4 in which it can be seen that unhealthy sweet foods are reported as the largest in both fasting and satiated conditions). This argument that hyper-palatable unhealthy sweet foods will be desired similarly (and therefore attended to as narrowly) when satiated or fasting conforms with the concept of sensory-specific satiety (Rolls, 1986), in which the desire to eat a particular food decreases after consuming it (e.g., desire to eat pasta decreases after eating a portion of pasta) but will not decrease desire to eat a different food, regardless of satiety (e.g., desire to eat ice cream is not decreased after eating pasta). As unhealthy sweet foods rarely make up a full meal, it could be asserted that participants find these foods as desirable (and therefore equally attention narrowing) while satiated as after fasting. More studies comparing categories of food would be useful to inform future research into food perception because few studies have investigated differences across categories of food. Goldstone et al. (2009) provides one example in categorising food by caloric content, however few studies compare food in smaller categories, such as their nutritional content or taste – as in the present study. Therefore, it is suggested that future research separate food stimuli into categories as there appears to be some differences in perception between food items.

In conclusion, the methodology presented in this chapter provides a promising way to both assess novel top-down effects on perception and validate previously published findings using additional controls.

Chapter 3

Comparing food-specific and domain-general surveys of behavioural motivation and impulsivity

Abstract

To assess whether the differences in perception reported in Chapter 2 may be expanded to psychological constructs related to over-eating (such as behavioural motivation and impulsivity), questionnaires must be selected to measure these constructs. However, within the food perception literature, there are multiple surveys that assess these psychological constructs and very little research compares how effective such questionnaires are at predicting health outcomes related to over-eating (e.g., Body Mass Index; BMI). This is an issue because one of the ways in which these surveys may differ is whether they target the domain-general or food-specific facet of their psychological construct, despite being used interchangeably within the literature. For this reason, the present chapter includes a comparison of domain-general and food-specific questionnaires assessing behavioural motivation (Behavioural Inhibition and Behavioural Approach Scales, and Adult Eating Behaviour Questionnaire, respectively) and impulsivity (Barratt Impulsiveness Scale and Three Factor Eating Questionnaire R18, respectively) in their ability to predict a health outcome related to over-eating (i.e., BMI). The results of this chapter demonstrate that, unlike their domain-general counterparts, food-specific questionnaires assessing behavioural motivation and impulsivity predict an individual’s BMI to a significant extent while controlling for the effects of gender (which have both already been shown to predict BMI). In addition, only food-specific measures of behavioural motivation and impulsivity correlate significantly, as

predicted by previous research. These results suggest that, when investigating food perception and eating behaviours, researchers should employ food-specific measures of behavioural motivation and impulsivity when possible – as these appear to be better predictors of behavioural outcomes.

Introduction

Much research has investigated how neural activity may indicate differences in food perception and subsequent eating behaviours (see Stasi et al., 2018’s review of neuroimaging and food choice). More specifically, these neural activities are linked to psychological factors associated with over-eating, such as behavioural motivation (Gable and Harmon-Jones, 2010; Harmon-Jones & Allen, 1997; McGeown & Davis, 2018) and impulsivity (Loxton, 2018; Lapenta, Di Sierve, de Macedo, Fregni, & Boggio, 2014; Schmidt & Martin, 2015). As both these factors are implicated in over-eating, it is important to understand how these may affect perception of food. However, different surveys are used within the literature to measure behavioural motivation and impulsivity (impulsivity can also be measured with a variety of task measures). Furthermore, in the cases of both behavioural motivation and impulsivity, surveys measuring each of these constructs seem to be used interchangeably with no justification for the selection made (e.g., Castellanos et al., 2009; Halali, Lapveteläinen, Karhunen, & Kantanen, 2020; Guzek, Skolmowska, & Głąbska, 2021; Gough, Christiansen, Rose, & Hardman, 2021). This is problematic because the current surveys available differ considerably. One way in which these surveys may differ is whether they assess domain-general or domain-specific psychological constructs. Regardless of these differences, no published research has compared the effectiveness of these surveys in predicting behavioural outcomes. The objective of the present research was to go some way towards addressing this issue. Specifically, the present research compared the effectiveness of domain-general measures of behavioural motivation and impulsivity with their food-specific counterparts. Both behavioural motivation and impulsivity were investigated as they are both related to over-eating and, according to Quilty and Oakman (2004), are separate but correlated constructs. Behavioural motivation represents the tendency to approach or avoid a target, and impulsivity represents a propensity to fail at inhibiting an automatic response. They are conceptually related as a participant's automatic response to a stimulus, such as food, may be to approach or avoid it. Due to their relatedness, both are of equal importance and are described below in turn.

Behavioural motivation survey measures

Behavioural motivation is measured by surveys in two halves, one half measuring approach motivation, and the other measuring avoidance motivation. These two forms of behavioural motivation represent an individual's tendency to approach or avoid a target, respectively (Harmon-Jones & Allen, 1997). Some of these surveys are rating scale, such as the Behavioural inhibition/behavioural approach scales (BIS/BAS; Carver & White, 1994) which assesses propensity to engage or avoid acting in a global context, and the Adult Eating Behaviour Questionnaire (Hunot et al., 2016), which assesses propensity to engage with or avoid food. One other survey measuring behavioural motivation has been developed; the Sensitivity to Punishment and Sensitivity to Reward Questionnaire, which measures global motivation to approach reward and avoid punishment. However, this survey was not included in the present research as it is comprised of Yes-No questions. Therefore, only the rating scale surveys were included to provide an appropriate comparison. The BIS/BAS scales are comprised of 24 items (13 approach, 7 avoidance, and 4 filler items). Examples of items include "I go out of my way to get things I want" and "Criticism or scolding hurts me quite a bit". The items are scored on a 4-point scale, with higher scores indicating more approach/avoidance motivation, respectively. The

Adult Eating Behaviour Questionnaire contains 35 items (17 approach, 18 avoidance). Examples of items include “I look forward to mealtimes” and “I refuse new foods at first”. These items are scored on a 5-point scale, in which higher scores indicate greater approach/avoidance motivation, respectively.

Gable and Harmon-Jones (2010) demonstrated that behavioural motivation affects attention. Specifically, they showed that behavioural approach motivation causes attentional bias while viewing images of food. This was done by presenting images of either desserts or rocks and assessing attentional focus using Navon figures. These Navon figures were images of a large letter constructed by smaller, closely spaced letters (for example, an F made of Ts). Participants then stated whether they identified the global or local letter first (the large letter or the smaller letters, respectively). Their participants were slower to respond with a global biased response (i.e., identifying the large letter first) following exposure to dessert images compared to rocks. This result suggests that attention is automatically narrowed following food exposure, as participants were slower to identify global letters because they had to re-widen their attention before responding. This result also demonstrates that evoking behavioural approach motivation (by visually presenting food images) causes a narrowing of attention, as evidenced by the reduction in global response bias following food images. Importantly, although behavioural motivation may align with perceived pleasantness of an object (e.g., approach motivation/liking of desserts and avoidance motivation/disliking of bugs), Berkman & Lieberman (2010) demonstrated that they are distinct constructs. Specifically, they showed participants demonstrate approach motivation towards an unpleasant target if engaging with it aligns with their present goal. This was done by detailing to participants a fictional tribe. This tribe had identical tastes as the western participants except that members of the tribe ate bugs but were disgusted by steak. In an MRI scanner, participants were shown images of edible objects and asked if they would eat it as a member of said tribe. Berkman & Lieberman (2010) argue that participant's selecting to "eat" should involve enough engagement to invoke approach motivation. Their results show that left-frontal asymmetry (implicated in both perceived pleasantness and behavioural motivation) was larger when viewing bugs compared to other unpleasant objects (such as mouldy food), suggesting greater approach motivation regardless of object pleasantness. The effects of behavioural motivation on food perception are important as Davis et al. (2007) has demonstrated that behavioural approach motivation is a significant predictor of over-eating and preference for high fat and sugar food. Specifically, they observed moderate positive relationships between self-reports of behavioural motivation and self-reported preference for high fat and sugar foods, and over-eating. They also observed that over-eating and preference for high fat and sugar foods in turn were significant predictors of BMI. This suggests that behavioural motivation may (at least indirectly) affect physical health outcomes such as BMI. Therefore, if behavioural motivation predicts overeating, which leads to negative health outcomes, then it is essential the best measure is used to assess behavioural motivation towards food.

However, as previously stated, there are various surveys for assessing behavioural motivation. One complication for studies investigating food-based behaviour is selecting from surveys which are domain-general (e.g., the BIS/BAS scales by Carver & White, 1994), or those which assess a domain-specific facet of behavioural motivation (e.g., the Adult Eating Behaviour Questionnaire by Hunot et al., 2016). Although there is discussion over models of behavioural motivation (Davis et al., 2007), no published work compares these surveys in terms of their appropriateness for assessing behavioural motivation in response to food. As such, the present study will compare two surveys measuring behavioural motivation. One domain-general measure of behavioural motivation (BIS/BAS scales; Carver & White, 1994) and one food-specific measure of behavioural motivation (Adult Eating Behaviour Questionnaire; Hunot et al., 2016).

By their very nature of being food-specific measures of behavioural motivation, it is hypothesised that food-specific measures in this research will have greater internal consistency than their domain-general counterparts. The rationale for this first hypothesis is that narrower focus on the behaviours assessed in the food-specific surveys will lead to more consistent answering by participants. A weak-to-moderate positive relationship between domain-general and food-specific surveys is also expected for both approach and avoidance behavioural motivation. The basis for this second hypothesis is that the food-specific measure of behavioural motivation focuses on only one aspect of behavioural motivation that the domain-general counterpart should also cover (hence, positive correlations are expected) as well as the other, non-food-related motivations it measures (hence, only a weak to moderate relationship is expected). The third hypothesis is that the food-specific measure of behavioural motivation will provide a better predictor of BMI compared to its domain-general counterpart. This is hypothesised because the lack of specificity to food and over-eating in domain-general measures of behavioural motivation is expected to reduce its ability to predict outcomes related to over-eating such as BMI.

Impulsivity survey measures

Impulsivity makes it difficult for individuals to inhibit their automatic response to an object (Bechara, Damasio, & Damasio, 2000). Impulsivity impacts how participants respond to a variety of stimuli in a range of domains, from anti-social behaviours (Maneiro, Gómez-Fraguela, Cutrín, & Romero, 2017) and drug usage (Chuang et al., 2017), to uncontrolled over-eating (Guerrieri et al., 2007).

Guerrieri et al. (2007) demonstrated the effects of impulsivity on food consumption. They observed that self-reports of impulsivity were related to the amount an individual would eat when possible. Specifically, those with greater self-reported impulsivity consumed more food during a fake taste test. The amount of food eaten during this fake taste test was quantified by measuring the weight of candies in a bowl both before and after participants did the tasting. In addition to self-reports, impulsivity can be measured through tasks such as the Food Go/No-Go task. One example of this is Teslovich et al. (2014), in which they assessed how frequently participants responded to food and non-food objects despite being instructed not to – such responses are called false flags. Their results indicated that participants committed significantly more false flags when presented with food compared to non-food objects, suggesting greater impulsivity in response to food. Importantly, the results of Guerrieri et al., (2007) found that both survey and task measures of impulsivity provide significant predictors of food intake during a fake taste test. Therefore, it makes sense that Schag, Schönleber, Teufel, Zipfel, and Giel’s (2013) review of studies researching impulsivity in obese and binge-eating participants concluded that impulsivity is linked to over-eating. Loxton’s (2018) subsequent review of impulsivity and over-eating also concluded that there was a link between impulsivity and tendency to over-eat.

Unlike behavioural motivation, most (if not all) surveys assessing impulsivity use rating scales. The Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995) is domain-general and provides a global measure of an individual's ability to inhibit behaviour. Similarly, the Urgency, (lack of) Premeditation, (lack of) Perseverance, Sensation Seeking, Positive Urgency (UPPS-P Impulsive Behaviour Scale; Cyders, 2007), assesses a domain-general tendency to act rashly in response to positive and negative stimuli. The Barratt Impulsiveness Scale was used instead of the UPPS-P in the present study because it is the most used survey of impulsivity and applied in the widest range of contexts (Fox & Hammond, 2017). There are also food-specific measures of impulsivity. For example, the Three Factor Eating Questionnaire R18 (Karlsson, Persson, Sjöström, & Sullivan, 2000) which assesses disposition towards impulsive eating; and the Dutch Eating Behavior Questionnaire (van Strien, Frijters, Bergers, & Defares, 1986) which assesses an individual's ability to restrict food intake to control weight gain. In a comparison of these food-specific surveys' validity, Allison, Kalinsky and Gorman (1992) observed that the Three Factor Eating Questionnaire was least susceptible to dissimulation. Specifically, their participants were instructed to either answer the surveys sincerely or try to give a good or bad impression of themselves in their answers. Their results evidenced that scores across all three conditions were closest for the Three Factor Eating Questionnaire. These results suggest the Three Factor Eating Questionnaire is the least susceptible to demand characteristics. Although they did not compare these scales on their actual ability to predict eating-behaviour, this is still an important finding for selecting surveys related to over-eating, as individuals may feel embarrassed about their food-related attitudes or behaviours (Ceylan, Aydinoglu & Morwitz, 2020; Dickinson & McClinchy, 2011). For this reason, the Three Factor Eating Questionnaire was used instead of the Dutch Eating Behavior Questionnaire in the present study. Similar to behavioural motivation, no published research has compared the effectiveness of domain-general and domain-specific surveys in predicting impulsivity related health outcomes (such as BMI). The present research will go some way towards addressing this by comparing the ability of the Barratt Impulsiveness Scale and Three Factor Eating Questionnaire in predicting BMI. The Barratt Impulsiveness Scale is comprised of 30 items. Examples of items include “I do things without thinking” and “I am more interested in the present than the future”. The items are scored on a 4-point scale, with higher scores indicating more impulsivity. The Three Factor Eating questionnaire contains 18 items. Examples of items include “Sometimes when I start eating, I just can’t seem to stop eating” and “Being with someone who is eating often makes me hungry enough to eat”. These items were scored on a 4-point scale, in which higher scores indicate greater impulsivity. Similarly to behavioural motivation, the fourth hypothesis is the prediction that a weak-to-moderate positive correlation will be observed between domain-general and food-specific impulsivity surveys. Again, similarly to behavioural motivation, the fifth hypothesis is that the Three Factor Eating Questionnaire R18 will provide a better predictor of BMI compared to the Barratt Impulsiveness Scale.

Finally, it should be noted that, as well as behavioural motivation and impulsivity being related to food behaviours, there are also other powerful predictors of BMI which should be considered. For example, gender will be included as a control due to its previously observed relationship with BMI. For example, Kanter & Caballero’s (2012) review of global BMI data suggests that, in developed countries, significantly more men are overweight and obese than women. Therefore, the present study will only consider surveys to be significant predictors of BMI if they are able to provide a significant prediction of BMI while controlling for the effects of gender.

Methodology

Participants

The present research collected responses from 641 individuals (74.4% female), with a mean(SD) age of 26.93(11.16) years. Participants were recruited through mailing lists within the University of Essex and social media groups related to food. No participants reported dietary restrictions or history of eating disorder, as individuals that met either of these criteria were asked not to complete the survey. 641 participants completed they survey and there was no need for participant removal. Of these 641 participants, 180 individuals provided both their height and weight so that their BMI may be calculated. The mean(SD) BMI of those participants was 21.88(4.82).

Materials

The present research employed four surveys. The BIS/BAS scales (Carver & White, 1994) were used as the domain-general measure of behavioural motivation and the Adult Eating Behaviour Questionnaire (Hunot et al., 2016) was its food-specific counterpart. The Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995) was used as the domain-general measure of impulsivity and the Three Factor Eating Questionnaire R18 (Karlsson, Persson, Sjöström, & Sullivan, 2000) was used as its food-specific counterpart.

The behavioural motivation surveys were each split into approach and avoidance scales, and scores within each scale were averaged. These approach and avoidance averages were four of the six independent variables within the present research – two for domain-general behavioural motivation (approach and avoidance; BAS/BIS) and two for food-specific behavioural motivation (approach and avoidance; Adult Eating Behaviour Questionnaire). Scores for domain-general impulsivity (Barratt Impulsiveness Scale) were averaged for analysis. Following the procedure from de Lauzon et al. (2004), scores from the food-specific measure of impulsivity (Three Factor Eating Questionnaire) were transformed into a 0 – 100 scale score for each participant using the following formula:

[((raw score - lowest possible raw score) / possible raw score range) x 100]

Participants also completed a short demographics questionnaire in which they reported their gender, height, weight, food allergies/intolerances, and any other eating restrictions (such as religion and vegetarianism), and any history of eating disorders.

Procedure

Participants always reported demographics first, followed by the four experimental surveys. These surveys were completed in a random order in one online session via Qualtrics (Qualtrics, Provo).

Results

Cronbach's Alphas (α) were calculated to measure the internal consistency of each scale (see Table 1). According to Cortina (1993), a Cronbach's Alpha of .8 indicates good internal consistency.

Table 1. Cronbach's Alpha (a measure of internal consistency) within each survey

	Behavioural Approach Motivation	Behavioural Avoidance Motivation	Impulsivity
Domain-General	BIS/BAS: .83	BIS/BAS: .83	Barratt Impulsiveness: .80
Food-Specific	Adult Eating Behaviour: .88	Adult Eating Behaviour: .85	Three Factor Eating: .87

Table 1 demonstrates that, according to George & Mallery's (2003) guidelines, all measures had good internal consistency, with the Barratt Impulsiveness Scale on the borderline between good and acceptable internal consistency. Food-specific measures of both behavioural motivation and impulsivity had greater internal consistency than their domain-general counterparts. This suggests that food-specific surveys were answered more consistently than domain-general surveys – however it unclear as to whether this is a meaningful difference.

Before assessing whether there is a correlation between domain-general and food-specific measures of behavioural motivation and impulsivity, a power analysis was conducted in GPower 3.1. As the survey was given out to as many individuals as possible, a criterion power analysis was conducted to ascertain the required effect size for significantly powered results from the sample of 641 participants. Fitzner & Heckinger's (2010) review of statistical power stated that 90% is significant power and generally accepted for clinical application. Therefore, at 90% power, an effect size of .12 was necessary to deem correlations as significantly powered. As such, significant outputs below an effect size of .12 were deemed non-significant.

With the above power analysis completed, Pearson's correlations were carried out to assess whether food-specific measures were related to their domain-general counterparts (see Table 2).

Table 2. Relationships between domain-general measures of behavioural motivation and impulsivity and their food-specific counterparts. ***significant $p < 0.001$ at 90%

	Food-Specific Measures			
		Adult Eating Behaviour Approach	Adult Eating Behaviour Avoidance	Three Factor Eating
Domain-General Measures	BIS/BAS Approach	.15***		
	BIS/BAS Avoidance		.15***	
	Barratt Impulsiveness			.27***

Table 2 demonstrates significant weak (Ratner, 2009) positive correlations between domain-general surveys and food-specific measures. This result indicates that food-specific measures are indeed focusing in on a specific facet of behavioural motivation/impulsivity.

Pearson's correlations were carried out as a control to assess whether both domain-general and food-specific measures supported the assertion by previous research that behavioural motivation and impulsivity are related constructs. Tables 3.A and 3.B demonstrate the relationship between behavioural motivation and impulsivity as measured by domain-general and food-specific measures.

Tables 3.A and 3.B. Relationship between behavioural motivation and impulsivity as measured by domain-general and food-specific surveys. *Note.* * p < .05 at 90% power.

Table 3.A - Domain-General Measures			
	BIS/BAS Approach	BIS/BAS Avoidance	Barratt Impulsiveness
BIS/BAS Approach	1	- .03	.01
BIS/BAS Avoidance		1	.05
Barratt Impulsiveness			1

Table 3.B - Food-Specific Measures			
	Adult Eating Behaviour Approach	Adult Eating Behaviour Avoidance	Three Factor Eating
Adult Eating Behaviour Approach	1	- .39***	.73***
Adult Eating Behaviour Avoidance		1	- .27***
Three Factor Eating			1

Tables 3.A and 3.B indicate discrepancies in the observed relationships between behavioural motivation and impulsivity when measured with domain-general and food-specific surveys. While all food-specific scales were significantly related, none of the domain-general scales were significantly related at 90% power. Furthermore, the domain-general measures did not support the assertion by previous research that behavioural motivation and impulsivity are related (Quilty & Oakman, 2004).

These findings suggest that the domain-general measures may be less statistically powerful than their food-specific counterparts.

In contrast, food-specific surveys support the assertion by previous research that behavioural motivation and impulsivity are related constructs (Quilty & Oakman, 2004). Specifically, there was a significant strong positive correlation between food-specific approach motivation and impulsivity, and a significant moderate negative correlation between food-specific avoidance motivation and impulsivity.

As the measures included in this research were selected due to their usage in food perception research, further Pearson's correlations assessed the extent these surveys were related to BMI (see Table 4). Due to the reduced number of participants that supplied both height and weight, another criterion power analysis was carried out in order to account for the reduction in statistical power before correlating the questionnaire responses to BMI. This time only the 180 participants which gave weight and height data were included. This power analysis indicated that to achieve 90% power, any correlation with BMI must achieve an effect size of 0.24 to be considered significant. Again, this adheres to Fitzner & Heckinger (2010)'s review of statistical power.

Table 4. Correlations with BMI. Significant correlations (*) $p < 0.001$ at 90% power.

	Behavioural Approach Motivation	Behavioural Avoidance Motivation	Impulsivity
Domain-General	BIS/BAS: .07	BIS/BAS: - .08	Barratt Impulsiveness: .14
Food-Specific	Adult Eating Behaviour: .30*	Adult Eating Behaviour: - .27*	Three Factor Eating: .28*

Following the observation that only food-specific measures of behavioural motivation and impulsivity significantly correlated with BMI, three separate hierarchical multiple regressions assessed whether any of these significantly predicted BMI. The results of each regression are discussed in turn below:

Behavioural motivation approach as a predictor of BMI:
First, a three-step hierarchical multiple regression was carried out with BMI as the dependent variable. As gender has previously been demonstrated to impact BMI, this was inserted in step one as a control. In step 2, the domain-general measure of behavioural approach motivation (BAS) was entered, and the food-specific measure of behavioural approach motivation (Adult Eating Behaviour) was entered in step 3. This step order was selected as the Adult Eating Behaviour Approach, but not the BAS, was a significant correlate of BMI and thus was of the most interest.

Table 5. The predictive ability of gender and behavioural approach motivation on BMI.

	Step 1			Step 2			Step 3		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	- 1.58	.85	- .14	- 1.84	.87	- .16*	- 2.30	.84	- .20**
BAS				.89	.07	.10	.04	.06	.48
Adult Eating Approach							.13	.30	.32***
F(df) for ΔR^2	= (2, 178) 3.43			= (1, 178) 3.43			= (1, 178) 8.54***		
ΔR^2	.02			.01			.10		
Adjusted R^2	.01			.02			.11		

Note. * p < .05, ** p < .01, *** p < .001

This regression indicated that gender did not contribute to the model significantly [F (1, 178) = 3.43, p = 0.66] but explained 2% of the variance in BMI in step 1. In step 2, the domain-general measure of behavioural approach motivation (BAS) was added. Although it explained 1% of the variance in BMI the R^2 change was not significant [F (1, 177) = 1.85, p = .175]. Finally, the food-specific measure of behavioural approach motivation (Adult Eating Behaviour Approach) was added in step 3. This addition explained a further 10% in the variance of BMI and the resulting R^2 change was significant [F (1, 176) = 19.75, p = .0002]. With all 3 independent variables included in the final stage of the regression, only the food-specific measure of behavioural motivation (BAS) was significant. Gender, BAS, and Adult Eating Behaviour Approach together explained 11% of the variance in BMI. The outcome of this regression suggests that, unlike BAS, the Adult Eating Behaviour Approach demonstrates the ability to predict BMI independent of gender, and its domain-general counterpart. This suggests that the food-specific measure of behavioural approach motivation is a significantly better predictor of BMI than the domain-general BAS scale.

Behavioural motivation avoidance as a predictor of BMI:

Next, another three-step hierarchical multiple regression was carried out with BMI as the dependent variable. Again, gender was inserted in step one as a control. In step 2, the domain-general measure of behavioural avoidance motivation (BIS) was entered. Finally, the food-specific measure of behavioural avoidance motivation (Adult Eating Behaviour Avoidance) was entered in step 3. This step order was selected as the Adult Eating Behaviour Avoidance, but not the BIS, was a significant correlate of BMI and thus was of the most interest.

Table 6. The predictive ability of gender and behavioural motivation avoidance on BMI.

	Step 1			Step 2			Step 3		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	- 1.58	.85	- .14	-1.43	.90	- .13	- 1.03	.88	- .09
BIS				- .05	.09	- .04	- .00	.90	.00
Adult Eating Avoidance							- 1.83	.53	- .26**
F(df) for ΔR^2	= (1, 178) 3.43			= (1, 177) 0.32			= (1, 176) 5.26**		
ΔR^2		.02			.00			.06	
Adjusted R^2		.01			.01			.07	

Note. * p < .05, ** p < .01, *** p < .001

This regression indicated that gender did not contribute to the model significantly [F (2, 178) = 3.43, p = .06] but explained 2% of the variance in BMI in step 1. In step 2, the domain-general measure of behavioural avoidance motivation (BAS) was added - it explained less than 1% of the variance in BMI and the R^2 change was not significant [F (1, 177) = 1.87, p = .57]. Finally, the food-specific measure of behavioural avoidance motivation (Adult Eating Behaviour Avoidance) was added in step 3. This addition explained a further 6% in the variance of BMI and the resulting R^2 change was significant [F (1, 176) = 5.26, p = .002]. With all 3 independent variables included in the final step of the regression, only the food-specific measure of behavioural motivation (Adult Eating Behaviour Avoidance) was significant. Gender, BIS, and Adult Eating Behaviour Avoidance together explained 7% of the variance in BMI. The outcome of this regression suggests that, unlike BIS, the Adult Eating Behaviour Avoidance demonstrates the ability to predict BMI independent of gender and its domain-general counterpart. This suggests that the food-specific measure of avoidance motivation is a significantly better predictor of BMI than the BIS.

Impulsivity as a predictor of BMI:

The final three-step hierarchical multiple regression also used BMI as the dependent variable. Again, gender was inserted in step 1 as a control. In step 2, the domain-general measure of impulsivity (Barratt Impulsiveness) was entered. Finally, the food-specific measure of impulsivity (Three Factor Eating) was entered in step 3. This step order was selected as Three Factor Eating, but not Barrett Impulsiveness, was a significant correlate of BMI and thus was of the most interest.

Table 7. The predictive ability of gender and impulsivity on BMI.

	Step 1			Step 2			Step 3		
Variable	**B**	**SEB**	**β**	**B**	**SE B**	**β**	**B**	**SEB**	**β**
Gender	- 1.58	.85	- .14	- 1.53	.85	- .133	- 1.80	.82	- .16*
Barratt Impulsiveness				2.16	1.15	.14	1.02	1.15	.07
Three Factor Eating							.06	.02	.28***
F (df) for ΔR^2	= (1, 178) 3.43			= (1, 177) 3.55			= (1, 176) 13.76***		
ΔR^2	.02			.02			.07		
Adjusted R^2	.01			.03			.09		

Note. * p < .05, ** p < .01, *** p < .001

This regression indicated that gender contribute to the model non-significantly [F (2, 178) = 3.43, p = .66] and explained 2% of the variance in BMI in step 1. In step 2, the domain-general measure of impulsivity (Barratt Impulsiveness) was added, and explained a further 2% of the variance in BMI - the R^2 change was significant [F (1, 177) = 3.51, p = .06]. Finally, the food-specific measure of impulsivity (Three Factor Eating) was added in step 3. This addition explained a further 7% of the variance in BMI and the resulting R^2 change was significant [F (1, 176) = 7.01, p = .0003]. With all 3 independent variables included in the final stage of the regression, only the domain-general measure of impulsivity (Barratt Impulsiveness) was not significant. Gender, Barratt Impulsiveness, and Three Factor Eating together explained 9% of the variance in BMI. The outcome of this regression suggests that the Three Factor Eating predicts BMI independent of gender, and Barratt Impulsiveness - indicating that the food-specific measure of impulsivity is a significantly better predictor of BMI than its domain-general counterpart.

Discussion

The aim of the present research was to investigate which measures of behavioural motivation and impulsivity provide the best predictors of BMI in a non-specific adult population. This was done by collecting self-reports of behavioural motivation using the BIS/BAS (which measures domain-general behavioural motivation) and comparing them to responses in the Adult Eating Behaviour Questionnaire (which measures food-specific behavioural motivation). This same comparison was also made for measures of impulsivity. Specifically, the Barratt Impulsiveness scale (a domain-general measure of impulsivity) was compared with the Three Factor Eating R18 (a food-specific measure of impulsivity). The objective was to clarify within the literature whether food-specific measures of psychological constructs are beneficial, compared to domain-general counterparts, when investigating human-food interactions.

The results demonstrate that both domain-general measures of behavioural motivation and impulsivity, and their food-specific counterparts have good internal consistency. It should, however, be noted that all food-specific measures had greater internal consistency than their domain-general counterparts' – this was especially true for impulsivity. As expected, these results validate the first hypothesis - that food-specific measures will have greater internal consistency than their domain-general counterparts. In addition, this observation suggests that domain-general and food-specific measures of behavioural motivation and impulsivity are both consistent, and each item within the surveys likely assesses the targeted psychological construct.

The main aim of this study was to assess whether or not food-specific surveys of behavioural motivation and impulsivity provide better predictors of eating behaviour (in this case an indirect measure of eating - BMI) than their domain-general counterparts. Correlations initially assessed whether a relationship was present between each survey and BMI. This analysis revealed that only the food-specific measures were of sufficient power to claim week-but-significant relationships with BMI (and by extension, over-eating). With these significant relationships established, three separate hierarchical multiple regressions assessed the ability of each survey to predict BMI. These regressions indicated that neither scale of the domain-general BIS/BAS provided a significant predictor of BMI beyond gender. Conversely, both scales of the food-specific Adult Eating Behaviour Questionnaire provided a significant predictor of BMI beyond gender, and their domain-general counterparts. These results validate the third hypothesis and suggest that the food-specific measure of behavioural motivation is a better predictor of BMI than its domain-general counterpart.

Similar results were observed in the hierarchical regression assessing the predictive ability of impulsivity measures on BMI. However, one key difference in the results between behavioural motivation and impulsivity should be noted. Unlike either scale for behavioural motivation, the domain-general measure of impulsivity did provide a significant predictor of BMI beyond gender before the food-specific measure was added to the model. Importantly, it should also be noted that this significance did not persist once the food-specific measure had been added. This suggests that the food-specific Three Factor Eating R18 explains the same variance in BMI as the Barratt Impulsiveness scale and more. This validates the fifth hypothesis that the food-specific measure of impulsivity is a better predictor of BMI than its domain-general counterpart.

Finally, the present research validated the second hypothesis in recording significant weak positive correlations between domain-general surveys and their food-specific counterparts. Similar significant weak positive correlations were also found between the domain-general and food-specific measures of impulsivity – validating the fourth hypothesis. This analysis aimed to provide a rudimentary validation for the present study’s comparisons, for which it is assumed that the domain-general and food-specific measures assess different forms of the same underlying psychological construct. Of course, if no positive correlation had been found then it would have been impossible to make such an assumption. The assertion that the domain-general and food-specific measures are assessing the same psychological constructs is also supported by the results of the regression analyses which followed these correlations. Specifically, within these regressions, the predictive power of the BIS and BAS on BMI was considerably diminished by the addition of the food-specific Adult Eating Behaviour Questionnaire to the model. As such, it is reasonable to assume that this drop in predictive power occurred because the Adult Eating Behaviour Questionnaire explains the same variance in BMI as BIS/BAS and more. Again, this makes sense given the argument that, unlike its domain-general BIS/BAS, the food-specific Adult Eating Behaviour Questionnaire was designed to target food-based behaviours. Similar results were found when analysing impulsivity, in that the predictive power of the domain-general measure of impulsivity was diminished by the addition of the food-specific measure to the model. Again, it is argued that this drop in predictive power of the domain-general measure occurred because the food-specific measure explained the same variance and more. These results together provide a rudimentary validation for the relationship between domain-general and food-specific measures, as it can be assumed they measure the same underlying psychological constructs, behavioural motivation and impulsivity, respectively. However, it should be considered that only some of the participants supplied the information required to calculate their BMI. Given the previously discussed research on social desirability in food and eating research, it is possible that participants of greater weight or BMI did not supply their information for BMI, and were therefore subsequently excluded from BMI prediction analysis.

In summary, food-specific surveys of behavioural motivation and impulsivity relate to BMI, and predict it more accurately than their domain-general counterparts. This suggests that the comparisons made in this research are valid, as additional analysis indicates that domain-general and food-specific surveys measure different forms of their respective psychological constructs. However, it must be highlighted that only food-specific scales of behavioural motivation and impulsivity related to each other in the way asserted by Quilty & Oakman (2004). The significant weak-to-moderate relationships found between food-specific behavioural motivation and impulsivity support the assertion by Quilty & Oakman (2004) that behavioural motivation and impulsivity are separate but related constructs. No significant correlations between any of the domain-general scales were observed. Therefore, it might not be that food-specific measures were better predictors of BMI because they are domain-specific, but because the domain-general measures were not reliable enough to assess behaviour within a single domain.

It is important to acknowledge the limitations of this study. Firstly, it was inferred from the participants' BMI that they were over-eating, however, this may not actually be the case. Future research should assess both participants BMI and recent eating habits (for example calorie intake or episodes of over-eating). Such evidence would reinforce the claim that food-specific measures of behavioural motivation and impulsivity can better predict over-eating – which in turn leads to increased BMI. In addition, the present research did not control for participants' exercise routines. Future research should consider including this control measure as Fock and Khoo (2013) claim that exercise plays an important role in the changes and maintenance of an individual's BMI over time. Finally, the present research only investigated self-reports of behavioural motivation and impulsivity. However, it is also common to measure impulsivity of participants using task-based measures. Future research could attempt to replicate the present findings while also comparing domain-general and food-specific Go/No-Go tasks. At present there is no research indicating whether it is beneficial to amend pre-existing tasks to include food-stimuli. The results of the current study present additional directions for future research. For example, the present results indicate that food-specific measures of impulsivity and behavioural motivation may better predict over-eating. Future research could test this by replicating the present experiment and providing participants an opportunity to eat. In such an experiment, the amount eaten may provide a measure of over-eating. An example of this could be the 'bogus taste test' used by Guerrieri, et al. (2007), in which participants were asked to eat and rate various foods on their taste (and to eat as much of the food as they wanted to help them give these ratings). In reality, the experimenters were actually interested in how much food the participants ate – not their ratings of the food taste. Therefore, using the bogus taste test in a replication of the present research may demonstrate the effects of behavioural motivation and impulsivity on over-eating without relying on indirect measures such as BMI or self-reported eating behaviours. This is important as Stice, Palmrose, and Burger (2015) reported that individuals with higher BMI are more likely to underreport their caloric intake.

In conclusion, the present research showed that food-specific measures of behavioural motivation and impulsivity assess the same psychological constructs as their domain-general counterparts. However, food-specific measures are significant predictors of BMI above and beyond gender, and their domain-general counterparts.

Chapter 4

A proposed method for assessing the neural correlates of size perception

Impact of COVID-19 Statement

The following experiment was designed to assess whether differences in neural activity can predict the size individuals perceive food items to be. This experiment would provide useful insights as to the nature of food perception based on neural activity associated with over-eating. However, the study had to be cancelled shortly before data collection began due to COVID-19 restrictions discussed previously in this thesis. It is therefore described in this chapter as a planned experiment only.

Abstract

Despite research claiming to demonstrate top-down effects on perception, no published research to date has attempted to link these perceptual changes to the neural activation of psychological factors related to over-eating. This is problematic as interventions for over-eating manipulate neural activations to reduce over-eating. This proposal details the first method for investigating whether psychological factors related to over-eating, and corresponding neural activity within the brain, predict the expected perceptual effects. Behavioural motivation and impulsivity are suggested for investigation because they are both related to visual attention – which according to the Attentional Account should affect perception of object size. Within this proposal, food-specific measures are recommended, namely the Three Factor Eating Questionnaire (impulsivity), Adult Eating Behaviour Questionnaire (behavioural motivation), and a FGNG task (a behavioural task that measures inhibition in response to food). The three electrophysiological correlates of interest in relation to behavioural motivation are frontal alpha-oscillatory power asymmetries at rest and during motivationally-relevant elicitation, and the mean amplitude of the frontal late positive component (event-related potential). In relation to impulsivity, peak frontal N2 and frontal P3a event-related potentials are the electrophysiological correlates of interest. A series of hierarchical multiple regressions are suggested to discern whether self-reported, behavioural, or neural (electrophysiological) correlates of behavioural motivation and impulsivity affect the perceived size of objects. The proposed study has implications for informing neural interventions on over-eating.

Introduction

A multitude of research has investigated how the brain's response to food images may change dependent on a range of factors. These include internal factors such as emotion (Blechert, Goltsche, Herbert & Wilhelm, 2014) and hunger (Stockburger, Schmälzle, Flaisch, Bublatzky & Schupp, 2009), and external factors such as whether the item being looked at is food or not (Gable and Harmon-Jones, 2010). Furthermore, it has been shown that certain brain responses associated with food perception may result in over-eating. For example, Ochner et al. (2009) demonstrated that an individual's hunger, disinhibition, and appetitive responsivity (a facet of food-specific behavioural approach motivation) were all significant predictors of resting-state right-greater-than-left frontal alpha asymmetry. Alpha activity refers to oscillations in the 8-12 Hz range, and is traditionally viewed as being negatively related to neural activation (Ochner et al., 2009). As such, participants in Ochner et al.'s (2009) study presented with neural activation that was greater in the left – compared to right – frontal cortex. This is consistent with research which argues that left-greater-than-right asymmetry in frontal neural activation is indicative of increased behavioural approach motivation (Berkman & Lieberman, 2010). Therefore, Ochner et al.'s study demonstrated that hunger, disinhibition and appetitive responsivity predicted increased behavioural approach motivation (as measured by alpha asymmetry). McGeown and Davis (2018) observed that individuals with a right-greater-than-left frontal alpha asymmetry (suggesting a left-frontal asymmetry in neural activity) also demonstrated an attentional bias towards food, compared to non-food, and were likely to have a higher BMI than individuals with a left-greater-than-right-frontal alpha asymmetry. This observation was achieved via a visual probe task in which participants were shown either a food or non-food image in each trial before being presented with the letter ‘X’ on one side of the screen. Participants simply had to indicate by keypress (as quickly as possible) which side of the screen the target probe appeared on – with faster reaction times in response to food, compared to non-food, indicating greater attentional bias. The findings of McGeown and Davis’ (2018), and Ochner et al. (2009) are important because (as explained in Chapter 3) behavioural approach motivation and impulsivity are related to over-eating. As such, it is possible that neural activations associated with these psychological constructs may be indicative of a tendency to over-eat - leading to increased BMI.

However, despite the above research into the neural activates surrounding food perception and their link to over-eating, very little is known as to whether these observed differences in neural activation correspond to differences in perception of food. Such perceptual differences would provide further explanation as to why certain groups (such as those with high approach motivation or impulsivity) are susceptible to over-eating. Research has already demonstrated the possibility that perception of food is affected by its spatial properties and environment. For example, it has been evidenced that food in blue packaging is reported as healthier than the same food in red packaging (Huang & Lu, 2016), preferred music improves rated pleasantness of perceived food compared to non-preferred music (Kantono et al., 2016), and that food presented on a white plate is rated as more intensely flavourful, sweet, and liked compared to when presented on a black plate (Piqueras-Fiszman, Alcaide, Roura & Spence, 2012). Furthermore, Chapter 1 of this thesis explains in detail the theoretical arguments for the existence of differences in food perception based on internal bodily states and psychological constructs. Chapter 2 details the development of a new method which may objectively assess an individual’s perception of object’s size. This method is suggested for use in the proposed research to assess whether psychological constructs and neural activation related to over-eating (specifically behavioural approach motivation and impulsivity) predict an individual’s perception of an object’s size. The neural correlates of interest (markers of behavioural approach motivation and impulsivity) are discussed in turn below along with their related psychological constructs.

Behavioural approach motivation as a predictor of perceived food size:

Behavioural approach motivation is an individual’s natural tendency to engage with positive stimuli (Harmon-Jones & Allen, 1997), although depending on current goals, it is possible for behavioural approach motivation to occur in response to negative stimuli (Berkman & Lieberman, 2009). It should be noted that observations of behavioural approach motivation in response to visual stimuli are distinct from assessments of object valence (Berkman & Lieberman, 2010). Gable and Harmon-Jones (2010) demonstrated that images of food invoked approach motivation and caused a narrowing of attention (a form of attentional bias) in participants using Navon figures (described in Chapter 3 of this thesis). This is a key finding, as following the Attentional Account, this narrowing of attention may cause participants to perceive food as relatively larger than non-food. Specifically, the reduction in global bias they observed suggests attentional narrowing (that is, fixating more centrally on the target) which is associated with objects being perceived as larger (Kirsch, Heitling & Kunde, 2018). As such, if food caused Gable and Harmon-Jones’ (2010) participants to narrow their attention then it is likely the food items were also perceived as relatively larger than objects that did not cause this narrowed attention (i.e., non-food objects). After establishing behavioural motivation as a potential driver of the attentional narrowing demonstrated to affect perception of food objects, Chapter 3 of this thesis outlined the link between behavioural motivation and over-eating. Chapter 3 also demonstrated that food-specific behavioural motivation was a significant predictor of BMI – suggesting that behavioural motivation (and related attentional narrowing) may cause over-eating and weight gain by affecting perception of food objects. As such, behavioural motivation – and its related neural correlates - are of interest for this proposed investigation into the predictors of food size perception. To assess whether measures of behavioural motivation may predict perception of object size, the multiple measures of behavioural motivation included in the proposed research (frontal alpha asymmetries; late positive potentials) are discussed in turn below.

Right-greater-than-left frontal alpha asymmetry:

One of the most common neural activities linked with behavioural approach motivation is alpha-band asymmetry between the left and right hemispheres of the frontal cortex (Harmon-Jones & Gable, 2018). Specifically, greater neural activation in the left, compared to right, hemisphere of the prefrontal cortex (indicated by greater-right-than-left alpha power) is associated with increased behavioural approach motivation (Berkman & Lieberman, 2010). An early example of research linking this alpha asymmetry to behavioural motivation is Coan and Allen (2003), who demonstrated a significant positive relationship between self-reports of behavioural approach motivation (specifically the BIS/BAS; Carver & White, 1994) and frontal right-greater-than-left alpha asymmetry. More recently, such frontal asymmetries have been reported both while participants are in a resting state and following motivationally-relevant elicitation (active state). As there are theoretical differences between alpha activation during these two states, both are discussed below.

Resting state frontal alpha

Harmon-Jones and Allen (1997) asserted that resting-state frontal alpha asymmetry reflects a behavioural tendency to approach stimuli - as outlined by Carver & White's (1994) behavioural activation system. Ochner et al. (2009) built on this work by investigating behavioural approach motivation in relation to food. In their experiment, participants filled in a battery of appetite measures and then had their resting-state EEG recorded while they had their eyes open, and again while their eyes were closed. They observed that self-reports of appetitive responsivity (food-specific approach motivation) predicted resting-state alpha frontal asymmetry. Specifically, they reported a positive association between self-reported appetitive responsivity and right-greater-than-left frontal alpha asymmetry. These results therefore suggest that participants' self-reported approach motivation was positively associated with greater neural activation in left, than right, frontal cortex.

In addition, Gable and Harmon-Jones (2008) and Ochner et al. (2009) suggest that both self-reports of behavioural approach motivation and a related neural correlate (resting-state right-greater-than-left frontal alpha asymmetry) may impact attentional bias towards an object. Following the logic of the attentional account described in Chapter 2, it may be expected that both behavioural motivation and right-greater-than-left frontal alpha asymmetry impact the size an object is perceived to be. Therefore, due to the positive association between behavioural approach motivation and attentional bias (described in Chapter 3), and the effects of attentional bias on object size perception, it is hypothesised that self-reports of behavioural motivation will predict the reported size of food objects in the Scaling Task. Specifically, it is expected that higher scores in self-reports of behavioural approach motivation (as measured by the Adult Eating Behaviour Questionnaire; Hunot et al., 2016) will be positively associated with food items' scaled size. This result would suggest that participants see food items as larger depending on their self-reports of behavioural motivation even without prior exposure to food. Importantly, self-reported behavioural approach motivation is expected to predict the scaled size of food items, but not of non-food objects (Hypothesis 1). A similar result is expected when examining resting-state frontal alpha asymmetry. It is hypothesised that resting-state right-greater-than-left alpha asymmetry will predict the scaled size of food items. Specifically, greater right-frontal asymmetry (indicative of left-greater-than-right neural activation) is expected to be positively associated with the scaled size of food items. This result would suggest that participants actually see food items as larger the greater their right-frontal alpha asymmetry. Resting state alpha asymmetry is expected to predict the scaled size of food items, but not of non-food items (Hypothesis 2).

Motivationally-relevant elicitation of frontal alpha

Smith, Reznik, Stewart and Allen (2017) have argued that motivationally-relevant elicitation is preferable to resting-state EEG recordings due to their increased ability to capture meaningful associations between neural activity and motivational responses to stimuli. An example of motivationally-relevant elicitation is outlined in McGeown and Davis (2018). In their experiment, participants' EEG was recorded while they watched a video of a confederate eating crisps. Their results demonstrated that attentional bias towards food, compared to non-food (as measured by a visual probe task) was positively associated with BMI but only when participant's frontal neural asymmetry was left-greater-than-right (as evidenced by right-greater-than-left alpha power). Importantly, this relationship between attentional bias and BMI did not occur when participant's frontal neural asymmetry was right-greater-than-left (as evidenced by left-greater-than-right alpha). This research demonstrates that active-state left-frontal neural asymmetry moderates the effect of attentional bias on BMI. Therefore, it is hypothesised here that right-greater-than-left frontal alpha asymmetry recorded following motivationally-relevant elicitation (passive viewing of food objects) will predict the size that food objects are scaled to. Specifically, it is expected that right-greater-than-left frontal alpha asymmetry will be positively associated with the scaled size of food objects. This result would suggest that participants actually see food items as larger following motivationally-relevant elicitation, in this case, passive exposure to food images. Importantly, right-frontal alpha asymmetry recorded during motivationally-relevant elicitation is expected to predict the scaled size of food but not of non-food objects (Hypothesis 3).

Late positive potential (LPP)

In addition to the frontal alpha asymmetries discussed above, the visual event-related potential (ERP) known as the late positive potential (LPP) has also been investigated in relation to food-based behavioural motivation (e.g., Nijs, Franken, & Muris, 2008). Littel et al.'s (2012) review of LPPs in behavioural motivation research defined the LPP as a large positive deflection arising between 300 and 800ms from stimulus onset. Balconi, Falbo and Conte (2012) provide an example of a significant relationship between self-reports of behavioural approach motivation and LPPs.

Specifically, they observed that self-reports of approach motivation (as measured by BIS/BAS) were positively related to frontal and posterior LPPs recorded during passive viewing of images of positive (compared to neutral) stimuli. This result suggests that frontal and posterior LPPs may be electrophysiological components reflecting behavioural approach motivation. This idea is reinforced by Sarlo, Übel, Leutgeb, & Schienle (2013) who observed that food images that had previously been reported to incite approach motivation (May, Juergensen, & Demaree, 2016) were associated with greater frontal LPPs during passive viewing compared to neutral images. The findings of these studies together suggest that frontal LPPs are related to approach motivation and are increased when participants view stimuli that incite approach motivation (such as food). As described earlier in this chapter, objects which invoke behavioural motivation may also lead to narrowing of attention, and therefore affect the way in which an individual perceives the size of a viewed object. Therefore, it is hypothesised that frontal LPPs will provide a significant predictor of the scaled size of food objects during the Scaling Task. Specifically, the size of frontal LPPs are expected to be positively associated with the scaled size of food items but are not expected to predict the scaled size of non-food objects (Hypothesis 4). It should be noted that Cunningham, Espinet, DeYoung and Zelazo (2005) have argued that LPPs related to behavioural motivation may occur in both frontal and posterior brain regions with frontal LPPs typically beginning before their posterior counterparts by around 125 – 225ms. As frontal and posterior LPPs are so closely related, only frontal LPPs will be investigated in the proposed research.

Impulsivity as a predictor of perceived food size:

Impulsivity is characterised as difficulty inhibiting responses to desired stimuli (Bechara, Damasio, & Damasio, 2000). Although impulsivity towards food may be successfully measured through surveys such as the Three Factor Eating Questionnaire (de Lauzon et al., 2004) used in Chapter 3, Schag, Schönleber, Teufel, Zipfel and Giel (2013) have argued that impulsive individuals only over-eat compared to controls in specific situations such as following exposure to food cues, after fasting, or during elevated stress levels. For this reason, impulsivity will be assessed in the proposed study using a behavioural measure which involves exposure to food cues. Specifically, a Food Go/No-Go (FGNG) task is suggested over a similar food-specific Stop-Signal Task as Allom, Mullan and Hagger's (2016) meta-analysis of studies training inhibitory control concluded that effects of training observed from the FGNG Task are larger and more consistent than those from the Stop-Signal Task. An example of a FGNG task procedure comes from Teslovich et al. (2014), who demonstrated behavioural impulsivity in the form of Food Go/No-Go task performance by measuring false flags – this is when participants respond to an object when they are supposed to inhibit their response. They observed significantly more false flags in response to food images compared to images of non-food objects, suggesting that participants found it more difficult to control their responses to food objects. As such, it is easy to understand how impulsivity is also an attribute that is linked with over-eating. The link between impulsivity and over-eating is supported by Loxton's (2018) review of the over-eating and food addiction literature. They concluded that there is consistency between impulsivity and over-eating across the over-eating spectrum. Put simply, the effect of impulsivity in increasing food intake is present in both clinical and non-clinical participants. Chapter 3 of this thesis also highlighted the link between impulsivity and over-eating by observing that food-specific impulsivity was a significant predictor of an individual’s BMI. This result suggested that over-eating caused by impulsivity may lead to weight gain. As such, impulsivity and its related neural correlates are of interest as it may be the case that changes in impulsivity alter the way that food objects are perceived and thus contribute to over-eating. As research on impulsivity and response inhibition often implicates the N2 and P3a components of visual ERPs, both are included in the proposed research and discussed below.

N2 and P3a activity

N2 is defined as the second negative peak in an ERP waveform, usually occurring around 200ms from visual stimulus onset (Folstein & Van Petten, 2008) in frontal regions such as electrode sites Fz and FCz (Rydkjær et al., 2016). Frontal N2 has been argued to represent early inhibition, specifically the initial conflict between an automatic and a desired response (Gajewski & Falkenstein, 2013). An example of the frontal N2 being implicated in impulsivity comes from Watson and Garvey (2013). Their study compared N2 activation in participants undergoing a FGNG task in which No-Go trials were either food or non-food objects. Their results demonstrated that participants had a significantly larger N2 when inhibiting responses to food compared to non-food images. This research demonstrates that frontal N2 activity is dependent on the stimulus an individual is exposed to. Subsequently, research has attempted to reduce over-eating by using neural interventions (such as tDCS) to manipulate the activation of brain activity linked to over-eating. For example, Beaumont et al., (2021) conducted a systematic literature of research on the effects of TDCS on over-eating. Their review concluded that tDCS research demonstrates success as an intervention on eating behaviour, stating that consumption is much more reliably reduced in individuals with binge-eating impulsivity characteristics than in those with frank obesity. Their review therefore suggests that tDCS may only be effective at reducing over-eating in certain individuals. This complication supports that of a previous review by Krause and Cohen Kadosh (2014) concluded that response to tDCS is dependent on a number of individual differences, such as the participant’s age, gender, brain state (e.g., attention, wakefulness and fatigue), hormonal levels (specifically Oestrogen and progesterone), and pre-existing neural activity within the targeted brain region. However, the effectiveness of these measures is less important than the endeavour of the researchers using them. It is argued that any intervention on over-eating should also aim to understand what perceptual or cognitive mechanism changes take place in order to successfully affect over-eating. One particularly relevant example of the potential effects of tDCS on over-eating comes from Lapenta, Di Sierve, de Macedo, Fregni and Boggio (2014). They provide a compelling link between frontal N2 responses and impulsivity by employing transcranial direct current stimulation (tDCS). To do this they measured participants’ urge to eat and their EEG during a FGNG task – these were done both before and after participants underwent two sessions of either active or sham (pretend) anode-right/cathode-left tDCS over the frontal cortex (specifically F4 and F3, respectively, according to the EEG 10–10 system). Their results demonstrated that both the urge to eat and N2 response during food (vs. non-food) No-Go trials were reduced following active but not sham tDCS, suggesting that facilitating neural activity in the right frontal cortex (and inhibiting neural activity in the left frontal cortex) via anode right/cathode left tDCS reduces participants’ food-related impulsivity. Interestingly, they also found that participants who received active tDCS consumed less calories when presented with the chance to eat, compared to their sham group counterparts. The results of their study therefore highlight the potential implication of frontal N2 activity in feeling the urge to eat and consuming calories. Specifically, it suggests that greater frontal N2 responses during food No-Go trials are indicative of greater demands on an individual's inhibitions, thus resulting in greater impulsivity and may lead to subsequent over-eating.

Another neural correlate suggested to be involved in impulsivity is frontal P3a. P3a is defined as a positive peak observed around 250-300ms from visual stimulus onset (Rydkjaer et al., 2017), which is largest in amplitude over frontal regions such as electrode sites Fz and FCz (Huster, Enriquez-Geppert, Lavallee, Falkenstein, & Herrmann, 2013). Importantly, P3a is not to be confused with P3b (a similarly timed neural response) occurring over temporal-parietal regions involved in memory processing (Polich, 2007). Also, although Polich (2007) conclude that P3a and P3b have been implicated in attentional allocation, only P3a is related to top-down control of attention. For these reasons, P3a was selected for investigation in this proposal. P3a, unlike N2, is argued to reflect the inhibition of the overt response to a stimulus (Gajewski & Falkenstein, 2013). Gajewski and Falkenstein (2013) also demonstrate that the frontal P3a is involved in impulsivity. This was done by altering the complexity of the Go/No-Go task (for example instructing participants to inhibit responses to the word 'press' instead of 'stop' as normal). They reported that P3a amplitude was decreased, and false flags were most frequent, during the most complex variation of their task. These results suggest that a lower P3a amplitude during No-Go trials indicates an increased difficulty with inhibiting automatic responses to a stimulus. This conclusion is supported by Lapenta et al. (2014), who investigated P3a during No-Go trials (in addition to the reduction in N2 activity discussed above). Their two sessions of active anode right/cathode left tDCS over the frontal cortex not only increased participants' P3a in response to food items during No-Go trials (greater inhibition of automatic responses), but also reduced participant's urge to eat and calorie intake compared to those who received sham tDCS. This study therefore further demonstrates that smaller P3a responses to food may indicate increased impulsivity and contribute to over-eating.

Munk, Schmidt, and Hennig (2020) argue that there is a relationship between impulsivity and attentional processing. They argue that P3a activity may be indicative of an attentional threshold required for an individual's attention to be drawn to stimuli. Specifically, individuals with smaller P3a responses during inhibition may be more susceptible to allocating their attention to salient stimuli, whereas an individual with greater P3a responses may be able to better control their attentional focus. It is suspected that this P3a activation level may provide an indication of how easily an individual's attention is narrowed towards salient stimuli (such as food). Therefore, following the attentional account of object perception put forward in Chapter 1, it is hypothesised in the proposed study that P3a activity during Food No-Go trials will predict reported food size in the scaling task. Specifically, it is expected that P3a response in food No-Go trials will be negatively associated with the scaled size of food items. This result would suggest that participants with smaller frontal P3a amplitudes, are more susceptible to allocating increased attention towards food items, and therefore (following the Attentional Account) are more likely to perceive food items as larger than participants with greater frontal P3a amplitudes. Importantly, P3a amplitude during food No-Go trials is expected to predict the scaled size of food but not of non-food items (Hypothesis

5). It has been argued here that P3a during No-Go trials may influence perceived object size due to its proposed link to attention. However, no such theoretical association between N2 and object perception currently exists. Regardless, N2 is suggested for investigation in the proposed research as an exploratory analysis because N2 and P3a are closely related in terms of their relationship to behavioural impulsivity (as evidenced by No-Go trials in FGNG tasks). As such, it is tentatively hypothesised that, similarly to P3a, food No-Go N2 size will predict the scaled size of food objects. Specifically, it is expected that N2 amplitude during food No-Go trials will be positively associated with the scaled size of food objects. Such a result would suggest that participants with larger N2 responses during inhibition see food items as physically larger. Importantly, N2 amplitude during food No-Go trials is expected to predict the scaled size of food but not of non-food items (Hypothesis 6). Finally, a behavioural measure of impulsivity, specifically false flags, will be measured in addition to frontal N2 and P3a during No-Go trials. These false flags would indicate whether behavioural impulsivity (ability to successfully inhibit response to food objects during No-Go trials in the FGNG task) predicts the size at which food items are scaled to in the Scaling Task. It is predicted that the number of false flags during food No-Go trials will positively predict scaled size of food objects during the scaling task, in that participants with more false flags during food No-Go trials will perceive food objects as larger (Hypothesis 7).

Previous research, such as Lapenta et al., (2014) have used neural modulation techniques (e.g., tDCS) to change brain activity in an attempt to reduce over-eating. However, such research has not considered whether these neural modulation techniques affect an individual’s perception of the objects themselves. Therefore, at present, neural activity is being manipulated to reduce over-eating with little understanding as to how these manipulations may affect the participants' interpretation of their environment. The proposed study is novel in that it goes some way towards addressing this – specifically by ascertaining whether behavioural motivation, impulsivity and their related neural activities affect object perception. The novel Scaling Task (described in Chapter 2 of this thesis) is suggested as the measure of object perception.

In simple terms, following the Attentional Account of object perception proposed in this thesis, the amount of attention an individual allocates to an object may influence the way it is perceived (as demonstrated in Chapter 2 of this thesis). Specifically, the more attention allocated, the larger the participant reports the object's size. The present study aims to build on this research by assessing the neural correlates of two broad characteristics which have been suggested to be related to attention allocation (approach motivation and impulsivity). As such, the proposed study seeks to assess whether the neural correlates underpinning food-specific behavioural approach motivation (frontal alpha asymmetry and frontal LPP) and food-specific impulsivity (frontal N2 and P3a) serve as predictors of object size perception.

Methodology

Participants

A power analysis was conducted in GPower 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009) to determine the required sample size for obtaining significantly powered results. Following Fitzner & Heckinger's (2010) review of statistical power, 90% power is generally accepted for clinical application. Therefore, 90% power was selected as the threshold for this power analysis. Based on the regression analyses conducted in Chapter 3 of this thesis, in which self-reported food-specific behavioural approach motivation predicted BMI with an effect size of .32 the analysis suggested a sample of 83 individuals should be sufficient. Participants will not be currently following any diet, have any food allergies (or any other reason to restrict food intake – such as medical constraints, vegetarianism, or religious restrictions) or history of eating disorders. Due to previously observed differences in task dependant alpha observed between right- and left-handed individuals (Galin, Ornstein, Herron, & Johnstone, 1982), participants will be right-handed and have no visual impairments beyond corrected-to-normal vision. Participants' gender and age will also be recorded for analysis, but they will not be recruited on this basis.

Design

The proposed study will use four different regression analyses to address hypotheses 1 to 7. The first of these assesses the predictive power of self-report food-specific behavioural approach motivation, and related neural correlates, on scaled size of food. The second regression will do the same in relation to scaled size of non-food objects. For the purpose of these two regressions, self-reported food-specific behavioural motivation will be measured by the Adult Eating Behaviour Questionnaire (Hunot et al., 2016). Participant's scores to each question in this scale will be averaged and form one of the predictor variables in both regressions. The second and third predictors will be frontal alpha asymmetry (difference between alpha power at frontal electrodes F3 and F4) for both resting state and motivationally-relevant elicitation state (during the observation of food and non-food items respectively). A fourth predictor will be the amplitude of frontal LPPs at frontal electrodes F3/4, in response to visual stimuli relevant to each regression (food and non-food objects, respectively). All predictors will be entered into the regression model at the same time to test the individual and combined predictive powers of each variable.

The third regression analysis will assess the predictive power of behavioural impulsivity, and related neural correlates, on scaling of food objects. The final regression will do the same but in relation to non-food objects. For these two regressions, behavioural impulsivity will be measured by frequency of unsuccessful inhibition during No-Go trials (false flags), alongside mean amplitude of frontal N2 and P3a at electrodes Fz and FCz recorded in response to object onset during No-Go trials involving food and non-food, respectively. As with the previous regression, all predictors will be entered in the regression at the same time to test the individual and combined predictive powers of each variable.

These four regressions together will indicate whether self-reported, behavioural, or neural indicators of behavioural approach motivation and impulsivity are adequate predictors of differences in food size perception (like the effects of fasting observed in Chapter 2).

Materials

The Adult Eating Behaviour Questionnaire (Hunot et al., 2016) will be used as a self-report measure of food-specific behavioural approach motivation. This is the same questionnaire used in Chapter 3 to assess food-specific behavioural approach motivation. Chapter 3 outlined the good reliability and validity of this survey.

There will be two tasks within this experiment: A Passive Viewing/Scaling task and a Food Go/No-Go task. The images for these tasks were taken from food image databases, specifically the Food-Pics image database (Blechert, Meule, Busch & Ohla, 2014) and the Foodcast Research Image Database (FRIDa; Foroni, Pergola, Argiris & Rumiati, 2013). There will be 24 images in total (12 food and 12 non-food objects). These food images will be further grouped into foods that are healthy sweet food and unhealthy savoury food (as these were the most sensitive the attentional effects in Chapter 2). As in Chapter 2, healthy foods contain under 150 calories per 100grams while unhealthy foods contained over 300 calories per 100g (similar to the categorisation used in Goldstone et al., 2009). Presentation order of images will be randomised. The reason for this sub-categorisation of food item is because of the discrepancy between stimuli used in the literature. For example, Wolz et al. (2017) conducted EEG research which investigated individuals' cravings, N2 and LPPs following exposure to either food or neutral images. However, they only used chocolate (unhealthy sweet) as the stimuli for their food images. They argued that chocolate was used because it is one of the most difficult foods to inhibit eating. By providing a wider variety of stimuli than previous research, the proposed research will have the potential to conduct exploratory analysis to make comparisons between these different categories of stimuli – similar to Chapter 2.

In the Passive Viewing/Scaling task, these images will be displayed on screen at sizes in which their longest dimension appears at 5mm increments between 80mm and 140mm. The shorter dimension shall maintain the objects' original size ratio. In Scaling trials participants will use a manipulable scaling cross (+) to report the dimensions of the X and Y axis of the presented object. To avoid confusion between this scaling cross and the fixation point indicating where an image is to appear on-screen, a circular black fixation point with a white cross running through it named 'ABC' (see Thaler, Schütz, Goodale, and Gegenfurtner, 2013 for an image of this fixation point) will be used to focus participants' attention at the start of each trial.

In the Food Go/No-Go task, all images will be displayed on screen so that their longest dimension appears at 140mm. The shorter dimension shall maintain the objects' original size ratio.

Procedure

Before the start of the experiment, participants will complete a short demographics survey detailing their age and gender. Participants will also complete the Adult Eating Behaviour Questionnaire (detailed in Chapter 3 of this thesis). Following this, participant's resting-state frontal alpha asymmetry will be assessed. For this, participants will undertake eight 60-second rounds of idling. During four rounds they will have their eyes open while looking at a blank white computer screen and in the remaining four they will have their eyes closed.

Participants will then take part in an adapted version of the scaling task from Chapter 2. Importantly, as suggested in Chapter 2, the proposed experiment will only include the True-to-Size version of the Scaling Task. In addition, scaling task trials will be interspersed by passive viewing trials (images of food and non-food objects will be shown without scaling) to obtain enough trials for EEG/ERP analysis. Each of these two trial types are described in turn below:

Passive Viewing Trials

At the start of passive viewing trials, a fixation point will be displayed in the centre of the screen for 500ms before an inter-stimulus interval (a blank white screen) is presented for a randomly chosen period of 1,400 ms +/- 100 ms. Following this, either a food or non-food image will appear centrally on the screen for 2,000ms. After which, either another Passive viewing trial or Scaling trial will occur. At least two passive viewing trials will occur between scaling trials, however the exact number will be randomised on a trial-by-trial basis. In each scaling trial, the image presented in the previous passive viewing trial will be displayed to motivate participants to consider images in terms of their size throughout the entire task. It should be noted that EEG will only be analysed for passive viewing trials and not scaling trials due to the expected eye movements during adjustment of the scaling cross. Each image will be displayed 16 times as passive viewing trials, for a total of 384 trials (192 food and 192 non-food trials).

Scaling trials

In scaling trials, the screen will be split into 4 invisible quadrants. At the start of each Scaling trial, a fixation point will appear in a random quadrant of the screen for 500ms. Following this, a blank white screen is presented for 1,400 ms +/- 100 ms, after which a food or non-food image will be displayed where the fixation point had been. This image will be displayed for 2,000ms before the scaling cross joins it on-screen in the quadrant diagonal to the target. As in Chapter 2, participants will use the arrow keys of the computer keyboard to scale the cross to the same size as the target item while the target is still on screen. There will be no time limit for this task. Once participants have finished scaling, they will press enter to confirm their scaling and then passive viewing trials will commence. Each image will be displayed 4 times as scaling trials, for a total 96 trials (48 food and 48 non-food items).

Food Go/No-Go Task

The procedure of this FGNG task will be based on previous EEG-centred FGNG studies, namely Lapenta, Di Sierve, de Macedo, Fregni and Boggio (2014) and

Teslovich et al. (2014). First, fixation point ‘ABC’ will appear in the centre of the screen for 500 ms. Following this, a blank white screen will be presented for 1,600 ms +/- 100 ms. Subsequently, an image of a food or non-food object will appear centrally on screen for 500 ms. Another blank white screen will then be presented for 1,600 ms +/- 100 ms. Then the next trial will begin with the presentation of the next image for 500 ms.

Participants will be instructed to press the spacebar when a Go stimulus is present and to do nothing when a No-Go stimulus is presented. For example, participants will be instructed to press the spacebar when an image of food is presented on screen and inhibit responses when an image of non-food is presented on screen. Participants will be informed of Go and No-Go associations with food and non-food images at the start of each block. Halfway through the experiment, the Go and No/Go stimuli associations will be swapped. 25% of trials will be No-Go trials.

In addition to EEG/ERPs in response to food and non-food images, behavioural measures will also be taken during this task. Specifically, the number of false flags in No-Go trials (pressing the spacebar when response should have been inhibited). Each image will be displayed 13 times as No-Go stimuli, for a total of 156 No-Go trials per condition (food and non-food items associated with No-Go responses, respectively). To maintain the required ratio of Go to No-Go trials, each image will be displayed 39 times for a total of 468 Go trials per condition (food and non-food items associated with Go responses, respectively). This procedure consists of eight blocks of 156 trials. The number of trials was informed by Luck’s (2005) suggestions for gathering valid data on medium-sized ERP components such as N2.

EEG recording and EEG/ERP analysis

EEG will be recorded using NeuroScan 4.5 (Compumedics, Melbourne, Australia) with 64 Ag/AgCl electrodes positioned according to the international 10 -10 system (Easycap GmbH, Herrsching, Germany) and referenced online to the left earlobe. Vertical and horizontal electrooculogram (EOG) will be recorded from four electrodes placed above and below the midpoint of the right eye (VEOG) and beside the outer canthi of the left and the right eye (HEOG). EEG AND EOG will be recorded between 0.05-100 Hz with a 50Hz notch filter. Data were sampled at a rate of 1,000 Hz. Following the advice of Hajcak, Weinberg, Macnamara, and Foti (2012), and Luck (2014), EEG and EOG will be re-referenced offline to a mastoid reference. Eye blinks will be removed using Scan 4.5’s ocular artefact removal method, which is based on Semlitsch, Anderer, Schuster, & Presslich (1986). Other artefacts (e.g., excessive eye movements recorded in EOG electrodes, bodily muscle) will be marked and removed from the recording following visual inspection. For resting state, passive viewing trials and FGNG trials separately, EEG will be processed as described below.

Alpha asymmetry during resting state and motivationally-relevant elicitation

In accordance with Ochner et al. (2009), EEG during resting state (eyes open and eyes closed recordings) and passive viewing will be epoched into 2-second segments. A Fast Fourier Transform will be carried out on all epochs to obtain measures of alpha oscillatory power (8-12 Hz range) in each condition (resting eyes open, resting eyes closed, passive viewing of food objects, passive viewing of non-food objects). After this step, the eyes open and closed alpha power will be averaged to obtain the mean resting state alpha power. Power values will be logtransformed to normalise data distribution. Alpha activity will only be investigated in frontal electrode sites F3/4. To assess the extent of frontal asymmetry for each participant in each condition, an asymmetry score will be calculated by taking the observed right-frontal alpha-band power at electrode site F4 and subtracting it by the equivalent power observed in left-frontal electrode site F3 (i.e., F4 – F3). It is important to remember that alpha-band power is traditionally viewed as negatively related to neural activation. Therefore, regarding asymmetry scores, a positive score will indicate right-greater-than-left frontal alpha and therefore left-greater-than-right neural activity in frontal cortex, indicating approach motivation. Alternatively, a negative asymmetry score will indicate left-greater-than-right alpha-band power, and therefore right-greater-than-left neural activity, indicating avoidance motivation.

ERPs in passive viewing and FGNG trials

In accordance with Lapenta et al. (2014), data will be low-pass filtered at 30 Hz. Each passive viewing trial will be epoched into segments starting 100 ms before - to 1000 ms after - stimulus onset, and each FGNG trial will be epoched into segments starting 100 ms before to 500 ms following stimulus onset. Each epoch will be baseline corrected using the 100 ms pre-stimulus and averaged for all trials within each condition (food vs. non-food items in passive viewing trials; food vs. non-food items associated with Go and No-Go responses, respectively, in FGNG trials). For passive viewing trials only, mean amplitudes during the 300 ms – 800 ms following stimulus onset will be used to assess LPP amplitudes at frontal electrodes F3/4 separately for food and non-food items. For FGNG trials only, the most negative value in the 150 ms to 340 ms time window after stimulus onset will be used to investigate peak N2 amplitudes at frontal electrodes Fz and FCz. In addition, the most positive values in the 250 ms – 500 ms time window will be used to assess peak P3a amplitudes at frontal electrodes Fz and FCz, for food and non-food items associated with Go or No-Go responses, respectively.

Proposed Analyses and Expected Results

Data preparation

In addition to asymmetry scores and ERPs described above, mean scores will be calculated for responses to the Adult Eating Behaviour Questionnaire approach scale, and the number of false flags per condition during the FGNG task (food No-Go and non-food No-Go).

Planned analysis

As the proposed experiment focuses around both behavioural approach motivation and impulsivity, the proposed analyses for each of these investigations are discussed in turn below:

Behavioural approach motivation

A pair of two-step hierarchical multiple regressions will be carried out to assess the predictive power of behavioural approach motivation (both self-reports and related neural correlates) on perceived object size. In one of these hierarchical multiple regressions, the scaled size of food objects in the Scaling Task will be the dependent variable. In the other hierarchical multiple regression, the scaled size of non-food objects in the Scaling Task will be the dependent variable. The reason for conducting a hierarchical multiple regression for each condition (scaled food and non-food objects) is to assess whether any changes in perceived object size are specific to food. Following Pitfall 1 outlined in Chapter 2 of this thesis (an overly confirmatory research strategy), if behavioural motivation is positively associated with the scaled size of both food and non-food objects, then it is likely that behavioural approach motivation does not affect eating behaviour through changes in perception of food size. This is because if both food and non-food objects are perceived as larger when a person has high behavioural approach motivation, then these effects would cancel each other out when perceiving objects within their environment. In both planned hierarchical multiple regressions, age and gender will be entered in the first step as controls. The reason for the inclusion of age and gender is that, as explained in Chapter 3 of this thesis, both factors have been shown to be significant predictors of BMI, and therefore may influence perception of food (and subsequent eating behaviours) similarly to behavioural motivation. Also, in both regressions, all predictor variables related to behavioural approach motivation will be entered in step 2. Specifically, these are the mean asymmetry scores calculated from frontal alpha power during resting state (resting eyes open and eyes closed averaged together) and motivationally-relevant elicitation (observed while passively viewing food or non-food items, respectively), means of self-reported behavioural approach motivation (as measured by the Adult Eating Behaviour Questionnaire), and mean amplitude of frontal LPPs (observed while passively viewing food or non-food items, respectively).

In line with the hypotheses of this proposal, it is expected that the outcome of the regressions will suggest that self-reports of behavioural approach motivation predict the scaled size of food objects in the Scaling Task. Specifically, it is expected that there will be a positive association between self-reported behavioural approach motivation and scaled size of food objects, such that those with greater self-reported behavioural approach motivation will perceive food items as larger (Hypothesis 1). It is also predicted that frontal alpha asymmetry will predict the scaled size of food objects in the Scaling Task. Specifically, it is expected that alpha asymmetry scores during resting states will be positively associated with the scaled size of food items, such that those with greater resting-state right-frontal alpha asymmetry (indicative of left-greater-than-right neural activation), will perceive food items as larger (Hypothesis 2). The same prediction is made in relation to asymmetry scores observed when participants undergo motivationally-relevant elicitation (passive viewing of food items; Hypothesis 3). Finally, it is expected that frontal LPPs observed when participants passively view food items will predict the scaled size of food items during the Scaling task. Specifically, it is expected that the mean amplitude of these frontal LPPs will be positively associated with the scaled size of food objects during the scaling task, such that those with greater mean frontal LPPs during the viewing of food images will perceive food items as larger (Hypothesis 4). Importantly, for all of these hypotheses, it should be noted none of these predictor variables should significantly predict the scaled size of non-food objects.

Impulsivity

A second pair of hierarchical multiple regressions will be carried out to assess the predictive power of impulsivity (both behavioural measures and related neural correlates) on perceived object size. In the first of these hierarchical multiple regressions, the scaled size of food objects during the Scaling Task will be the dependent variable. In the second hierarchical multiple regression, the scaled size of non-food objects in the Scaling Task will be the dependent variable. Again, both regressions will be carried out to assess whether any perceptual affects are specific to food items. For both hierarchical multiple regressions, age and gender will again be included in step 1 of the regression as control predictors. Subsequently, all predictor variables relevant to impulsivity will be entered at step 2. Specifically, the entered predictor variables will be mean false flag frequency and peak frontal N2 and P3a amplitudes observed during food No-Go trials or non-food No-Go trials, respectively.

It is expected that all impulsivity-related predictor variables will significantly predict the scaled size of food objects. Specifically, it is expected that frontal P3a amplitude will negatively predict the scaled size of food objects in the scaling task, in that those with smaller P3a amplitudes will perceive food objects as larger (Hypothesis 5). In addition, it is tentatively expected that frontal N2 activation observed during food No-Go trials will positively predict the scaled size of food objects during the scaling task, in that those with larger frontal N2 amplitudes will perceive food objects as larger (Hypothesis 6). Finally, it is expected that the behavioural measure of impulsivity (frequency of false flags in food No-Go trials) will positively predict scaled size of food objects during the scaling task, in that participants with more false flags during food No-Go trials will perceive food objects as larger (Hypothesis 7). Again, for these hypotheses, it is expected that no variables will predict the scaled size of non-food objects during the Scaling Task.

Discussion

The proposed research will be the first study to attempt to ascertain whether individual differences in psychological constructs related to eating behaviours (behavioural approach motivation and impulsivity), and their related neural correlates (frontal alpha asymmetry, LPP, N2 and P3a), represent an observable change in individuals' perception of food size. As before, food size perception is measured while avoiding the experimental pitfalls detailed in Chapter 2 and directly compared with non-food size perception.

Building on the results of Chapter 2 of this thesis, the proposed research will be the first to use EEG for an investigation of the Action-Specific and Attentional Accounts of object perception. This will be done by assessing the effects of behavioural motivation on perception. Due to the positive relationship between behavioural motivation and attentional bias asserted by Gable and Harmon-Jones (2010), it is expected that, following the Attentional Account described in Chapter 1 of this thesis, participants with increased behavioural approach motivation will perceive relatively larger food sizes compared to non-food objects of the same size. This is expected to occur because increased behavioural approach motivation is expected to lead to attentional narrowing, which in turn leads to increased food size perception. Whereas, because there is no known physical morphology associated with behavioural motivation and impulsivity, the Action-Specific Account would not expect these psychological constructs (or their related neural activations) to impact object perception.

Understanding the neural correlates of behavioural motivation and impulsivity, and the effects these neural activities may have on food size perception will add to the evidence within Chapter 2, which argues that food size perception is driven by attention free from action-specific influence (thus generating further support for the Attentional Account of object perception). This is because all the neural activities of interest within this study (except for N2) have been linked to attentional bias (Gable & Harmon-Jones, 2008; Ochner et al., 2009; McGeown & Davis, 2018; Sarlo et al., 2013; Polich, 2007). Further, determining whether psychological constructs associated with over-eating (such as behavioural approach motivation and impulsivity), and their respective neural correlates, lead to changes in perceived size of food provides an opportunity to test the efficacy of interventions on over-eating (such as tDCS modulation of brain activity) without the relying on self-reported eating behaviours.

The proposed research may also provide a perceptual explanation for why certain individuals may act more impulsively in response to food, and thus be at greater risk of over-eating than those with less impulsivity. Such a result would fit in with previous research which suggests that impulsive individuals consume more calories when eating larger units of food compared to the same food divided up into smaller units (van Kleef, Kavvouris, & van Trijp, 2014). Following the logic of the Attentional Account, this may explain over-eating in impulsive individuals. Specifically, food may be more likely to fill the visual field of an impulsive individual (due to food's relatively increased size) and therefore make it more difficult to inhibit the individual's automatic response to eat.

In addition, the proposed research shall provide a perceptual insight for clinicians who are currently attempting to reduce food-based impulsivity and over-eating by employing tDCS to alter neural response to food. This is important as it may be the case that such over-eating interventions are presently, and unknowingly, altering individuals' perception of their environment. Depending on the results of the present study, future research should also run the Scaling Task alongside over-eating interventions, such as tDCS, to assess whether perception of food object size changes alongside successful neural intervention on over-eating. The neural correlates discussed in this chapter could be used to validate the results of such a study by ensuring that the intervention (e.g., tDCS) was successful. Finally, due to the theoretical and practical similarities between behavioural approach motivation and impulsivity (described in Chapter 3), it is suggested that future research into neural interventions on over-eating also investigate neural correlates of behavioural approach motivation (such as resting-state and motivationally-relevant elicitation frontal alpha asymmetry, and frontal LPPs) alongside those of impulsivity (N2 and P3a). This is because, as well as theoretical proximity, behavioural approach motivation and impulsivity are also implicated in the frontal region of the brain. As such, it is possible that the previously successful neural interventions on over-eating may have been successful due their incidental (and unintended) moderation of behavioural approach motivation.

Importantly, for this study to contribute to the theoretical understanding of object perception, or the development/improvement of interventions of over-eating, it must be free of the methodological pitfalls outlined in Chapter 1. This has been achieved for the proposed study by using the method described in Chapter 2 as a template. The findings of this study will only be of importance if the perceived size of food and non-food objects are not affected in the same way. As such, the relationship between behavioural approach motivation and impulsivity (including their relative neural correlates) and the perceived size of non-food objects will also be assessed.

In summary, the proposed research is novel in assessing how behavioural motivation and impulsivity, in addition to their neural correlates, affect perception of food object size. This will be achieved by using the Scaling Task to track whether perception differs in line with these variables. The results of the proposed research will not only enhance understanding of the perceptual system as it relates to the processing of food and non-food objects but will also have ramifications for the accuracy and success of interventions aimed at limiting overeating in impulsive individuals.

Chapter 5

Effects of behavioural motivation and impulsivity on food size perception

Impact of COVID-19 Statement

Following the cancellation of the previous experiment (presented as a proposal in Chapter 4 of this thesis), the present research was conducted to assess the relationship between behavioural motivation and impulsivity, and the size individuals perceive food items to be. The present research had to be conducted online due to COVID-19 restrictions. In brief, it was not possible to conduct this research in-person due to risk of COVID-19 transmission. In addition, participant recruitment was challenging as, due to financial restrictions placed on research at the time of data collection, it was not possible to financially incentivise participants to complete the experiment. Therefore, the findings from this study should be taken with some caution and it is recommended that efforts should be made to replicate them in the laboratory.

Abstract

In addition to neural interventions to reduce over-eating, behavioural interventions also exist. In these interventions, a FGNG task (that measures inhibition in response to food) is often used to retrain an individual's automatic impulse to eat. However, as with neural interventions, it is presently not known whether such interventions affect an individual's perception of food size. Following the reasoning of the Attentional Account, as these interventions reduce impulsivity, and impulsivity is associated with an individual's attention, then it is suspected that such interventions may affect perception of object size. The present chapter is the first research to assess whether impulsivity is related to the perceived size of objects. Within this chapter, food-specific measures are employed, namely the Three Factor Eating Questionnaire (impulsivity), and FGNG task - in addition to the True-to-Size Scaling Task developed in Chapter 2. In addition to assessing impulsivity's potential impact on food size perception, this study is the first to investigate the previously reported relationship between self-reported and behavioural impulsivity within a food-specific context. The results suggest that food-specific measures of impulsivity have a similar relationship to that of their domain-general counterparts. However, no relationship between impulsivity and food size perception was observed. The outcomes of each measure were inspected, concluding that a lack of consistency in reports within the Scaling Task may explain why no relationship with impulsivity was observed. Considering this, the present chapter also explores actions to determine the validity of the Scaling Task as a measure of object size perception.

Introduction

It has been shown that a range of factors may influence the way that an individual sees their environment. For example, Saxton, McCarty, Caizley, McCarrick and Pollet (2020) demonstrated that appraisals of non-food objects (food objects were not included in their study) and bodies are more positive when individuals are hungry compared to when satiated. In addition to this, Proffitt and Linkenauger (2013) have asserted that an individual's perception of their environment may be affected by their ability to act. As such, size perception was selected for investigation in the present experiment as there is currently controversy as to how an individual's perception of their environment may be flexible. In Chapter 2 of this thesis, a method was designed to test whether such factors influence an individual's perception of their environment. This method, known as the Scaling Task, was designed to assess the size that objects were perceived as. This task improved on the method designed by Yellowlees, Roe, Walker and Ben-Tovim (1988) and avoided the infamous El Greco Fallacy (described in Chapter 2 of this thesis). In brief, the Action-Specific account (Proffitt & Linkenauger, 2013) suggests that an individual's perception of their environment may be penetrable and affected by their ability to interact with said environment. In counter to this, Collier (2018) argued that supposed action-specific effects on perception may actually reflect changes to an individual's judgement or evaluation of an object, rather than perceived spatial features (this is described in more detail in Chapter 1 of this thesis). Alternatively, the Attentional Account (also described in Chapter of this thesis) argues that an individual's perception is dependent on the breadth of attention given to objects within their visual field. In Chapter 2 of this thesis, a Scaling Task was designed to measure how participants perceived the physical size of food and non-food objects. This method was designed to assess participants’ perception of physical dimensions, rather than the participant’s judgement of said object. In that experiment, half of the participant’s fasted while half had recently eaten. Following the Action-Specific account, it was expected that – when fasting - participants would perceive food as relatively smaller than when satiated due to their increased capacity to eat. Whereas following the Attentional Account, it was expected that – when fasting - participants would perceive food as relatively larger than when satiated due to their increased attentional bias towards food. The results of Chapter 2 supported the Attentional Account by demonstrating that individuals perceive food items as relatively larger when fasting, compared to when satiated, suggesting that attentional biases rather than action-capacity affect participant’s perception of food size. It should also be noted that the methodological controls used in Chapter ensured perception of the physical dimensions of food were measured, and not judgement or evaluation. This result is important because it supports the results of Collier (2018) in demonstrating that perception of food size does not scale with the expectations of the Action-Specific Account. However, unlike Collier (2018), the results of Chapter 2 suggest that perception of food size may scale with the expectations of the Attentional Account.

After demonstrating that fasting (or indeed hunger) may affect an individual’s perception of food size, it is of interest to discern whether other bodily states or psychological constructs may have similar effects on perception – especially those which may contribute to over-eating. As explained in Chapter 4 of this thesis, impulsivity has been linked to over-eating (Atalayer, 2018). The previous chapter also outlined neural interventions, such as tDCS, which are used with the aim of decreasing an individual’s impulsivity to food and therefore subsequent over-eating

(Lapenta et al., 2014). While there is evidence that neural interventions are successful in reducing impulsivity and over-eating, Chapter 4 of this thesis asserted that little is known regarding how these neural manipulations affect an individual's cognition, or perception of object size. This is important because if a neural intervention was to decrease over-eating and the perceived size of food, it would provide clear evidence that interventions are successful because they reduce impulsivity and associated attentional re-allocation (Munk et al., 2020). As such, the Scaling Task could be used to further understand the psychological changes which may occur following successful neural interventions on over-eating. Such results would provide compelling evidence for the Attentional Account.

Impulsivity training, as an intervention on over-eating, also requires clarity as to how cognition and perception are affected. In impulsivity training an individual is taught to inhibit their automatic response towards a target. One example of impulsivity training in response to food was described by Houben and Jansen (2011), in which participants were taught to inhibit their response to chocolate during a Food Go/No-Go Task. In their experiment, the letters 'p' and 'f' were associated with Go/No-Go trials in which participants would have to press the spacebar (Go) or inhibit and press nothing (No-Go). These letters were presented randomly on-screen appearing over images of empty plates (neutral stimuli), chocolate (experimental stimuli) or other snacks such as nuts or crisps (filler stimuli). Participants were split into three separate groups. In their control group, all photo stimuli were associated with the go letter in half the trials and no-go in the other half. In another group, chocolate was always presented with the go letter. Finally, in their key experimental group, chocolate was always presented with the no-go letter. Following this Go/No-Go task participants were presented with an opportunity to eat chocolate (they were told this was a taste test to avoid demand characteristics). Their results demonstrated that chocolate consumption during the fake taste test was significantly lower in participants from the experimental group (presentation of chocolate always associated with no-go letter). Therefore, it could be argued that this intervention may also be an effective way of reducing impulsivity towards food and over-eating. However, similarly to the tDCS intervention described in Chapter 4, little is currently known about how training an individual's impulsivity affects an individual's cognition and perception. If impulsivity training decreases over-eating and the perceived size of food, it would provide clear evidence that training was successful because it reduced both impulsivity and subsequent associated attentional re-allocation towards food (Munk et al., 2020). Put simply, following impulsivity training, participants should perceive food items as relatively smaller due to a widened attentional breadth. This should in turn result in less false flags during food No-Go trials in a FGNG task and decreased over-eating. Such results would provide compelling evidence for the Attentional Account of object perception.

Before the Scaling Task can be used to assess whether impulsivity training has been successful, it must first be established whether or not there is a link between an individual's impulsivity and the size they perceive food objects to be. The present research intends to establish this connection by assessing the predictive power of impulsivity on reporting of object size during the Scaling Task. As the results of Chapter 3 suggest that food-specific survey measures of impulsivity are better at predicting health outcomes (i.e., BMI) than domain-general survey measures of impulsivity, the present study will only include food-specific measures of impulsivity. Specifically, the present study will include the food-specific survey measure of impulsivity used in Chapter 3 (Three Factor Eating Questionnaire R18; Karlsson, Persson, Sjöström, & Sullivan, 2000), and the food-specific behavioural measure of impulsivity outlined in Chapter 4 (Food Go/No-Go Task; FGNG; Allom et al., 2016).

In addition to food-specific impulsivity, food-specific behavioural approach motivation will also be examined in the present research. This is because Chapter 4 of this thesis outlined that, like impulsivity, behavioural approach motivation is also related to attentional bias. Therefore, according to the Attentional Account, behavioural approach motivation may also predict food size perception. Behavioural approach motivation’s inclusion in the present research provides an important control. Specifically, if behavioural approach motivation predicts the scaled size of food objects in the Scaling Task, then similar results should be observed when examining the relationship between impulsivity and food size perception. Alternatively, if it is observed that only one of either behavioural approach motivation or impulsivity predict the scaled size of food objects then it may suggest that food size perception is affected by an alternative mechanism to attentional bias.

Due to the link between behavioural approach motivation and attentional bias (described in Chapter 4 of this thesis), it is expected that (following the Attentional Account of object perception) scores in self-reports of behavioural approach motivation will predict the scaled size of food objects during the Scaling Task. Specifically, it is expected that there will be a positive relationship between self-reports of behavioural approach motivation and the scaled size of food items (hypothesis 1). Similarly, it is also predicted that impulsivity (both self-reports and the frequency of false flags during No-Go food trials) will predict the scaling of food objects in the Scaling Task. Specifically, it is expected that there will be a positive relationship between both scores in self-reports of impulsivity and the frequency of false flags during food No-Go trials, and the scaled size of food objects in the Scaling

Task (hypothesis 2). Importantly, for both of these hypotheses, it should be noted none of these predictor variables should significantly predict the scaled size of non-food objects.

In addition to the above, an exploratory investigation will be carried out to assess the differences between self-report and behavioural measures of impulsivity. Chapter 3 of this thesis outlined the potential impact of impulsivity on BMI (a health outcome related to over-eating), as measured by self-reports of food-specific impulsivity. This evidence may suggest that survey measures alone are sufficient to assess the impact of impulsivity on food size perception. However, the two intervention studies outlined above (Lapenta, et al., 2014; Houben & Jansen, 2011) demonstrate that an individual's impulsivity may be tracked and managed using FGNG tasks. This is important because Schag, Schönleber, Teufel, Zipfel, and Giel (2013) claim impulsive individuals only over-eat compared to controls in specific situations, such as following exposure to food. Together with the results of Chapter 3, this argument may suggest that results observed across measures of impulsivity may reflect distinct mechanisms contributing to impulsive behaviour. The existence of two distinct mechanisms of impulsivity is outlined by Hofmann et al.'s (2009) Dual Process Theory, which asserts that impulsivity is the outcome of two processes. One is the conscious pursuit of long-term goals, while the other is subconscious associations responsible for resisting (or not resisting) appealing stimuli. Fishbach and Shen (2014) further argue that these two processes act in tandem to produce or inhibit a behavioural outcome. The assertion that there are two distinct processes involved in impulsivity is supported by the findings of Wöstmann et al. (2013) who evidenced that some measures of behavioural impulsivity have poor test-retest validity. However, Allom, Panetta, Mullan, and Hagger (2016) argue that this lack of test-retest reliability is likely due to these tests measuring state impulsivity rather than a genuine lack of reliability. Therefore, conscious pursuit of long-term goals may represent trait impulsivity and is best measured by surveys, while the subconscious associations responsible for resisting tempting stimuli represents state impulsivity, best measured through behavioural tasks (Allom et al., 2016).

Duckworth & Kern (2011) performed a meta-analysis of 236 studies and found that the relationship between self-reported and behavioural impulsivity was small but positive. Rather than using them interchangeably, Sharma, Markon, and Clark (2014) argue that including both types of impulsivity measure may be beneficial when predicting the relationship between impulsivity and other variables. They argue that this allows researchers to assess what unique variance in a dependent variable is accounted for by each measure. This present experiment therefore also aims to assess the relationship between self-reports of food-specific (trait) impulsivity and food-specific behavioural (state) impulsivity. It is hypothesised that participants' self-reports will positively predict the frequency of false flags in response to food in No-Go trials (hypothesis 3), mirroring the relationship observed by Duckworth & Kern (2011). Again, none of these predictor variables should significantly predict the scaled size of non-food objects. While previous research has shown that there is only a small observable overlap between survey and behavioural measures of impulsivity, the relationship between food-specific measures of survey and behavioural impulsivity has never been examined. It is expected that the present study will observe stronger relationships for food-specific measures than observed in previous research investigating domain-general measures. If instead there is only a weak, or indeed no relationship between food-specific measures of self-reported and behavioural impulsivity, then this will be important for impulsivity training studies.

Impulsivity intervention studies should consider the use of self-report surveys to assess whether trait impulsivity is also affected by these interventions. This addition may be important to discern whether training interventions only affect implicit associations (state) impulsivity or have broader influences on the conscious pursuit of long-term goals (trait impulsivity).

Methodology

Participants

The present research recruited 79 participants (56 female) with a mean (standard deviation) age of 28.63 (10.56) years. Sample size was determined by power analysis in G*Power 3.1. A review of statistical power by Fitzner & Heckinger (2010) asserts that 90% statistical power is sufficient for clinical application. Therefore, a power level of 90% was selected for the present power analysis. The selected effect size was based on the analysis conducted in Chapter 3, in which BMI was predicted by food-specific behavioural approach motivation (present control measure) with an effect size of .33. The recruited participants for this experiment were all right handed, had no visual impairments, and at least corrected-to-normal vision. They were not currently following any diet, did not report any food allergies or intolerances, and had no history of eating disorders. In addition, participants did not have any other reasons for food restriction, such as medical conditions, vegetarianism etc., or religiously motivated restrictions.

Design

This study included four hierarchical multiple regressions. The first regression was conducted to test whether participant self-reports of behavioural approach motivation predicted the size participants perceive food to be. The second regression assessed whether self-reports of impulsivity, and a behavioural measure of impulsivity, can predict the size participants perceive food to be. The third and fourth regressions were similar to regressions 1 and 2 respectively, with the exception that they assessed the predictive power of behavioural motivation and impulsivity on the perceived size of non-food objects.

For these regressions, gender will first be included in the first step as a control. The reason for its inclusion is that there are differences in calorie consumption, eating styles, and body image pressures between genders – all of which affect eating behaviours and BMI (Rolls et al., 1991). As this study is investigated whether cognitive processes affect eating, it seems logical to include gender as a potential predictor of scaled food size – a difference in scaled food size between genders may help to explain why there are differences in calorie consumption and eating styles between males and females. Subsequently, self-reports of behavioural approach motivation were measured by mean scores on the Adult Eating Behaviour Questionnaire Approach Scale (Hunot et al., 2016). Self-reports of impulsivity were measured by mean scores on the Three Factor Eating Questionnaire R18 (Karlsson et al., 2000), while the behavioural measure of impulsivity was measured by mean frequency of false flags during No-Go trials in a Food Go/ No-Go task. Finally, the dependent variables of these regressions were mean accuracy error in millimetres during the scaling task when scaling food or non-food objects.

Materials

Surveys were used to measure food-specific motivation and impulsivity. Specifically, the Adult Eating Behaviour Questionnaire Approach Scale (Hunot et al., 2016) and Three Factor Eating Questionnaire R18 (Karlsson et al., 2000, respectively) were selected as, in Chapter 3 of this thesis, they were found to be more reliable compared to domain-general survey measures.

There were two tasks within the present study. The first was an online version of the True-to-Size scaling task developed in Chapter 2. The second was a Food Go/No-Go task based on the procedure of Lapenta et al., (2014) and Teslovich et al. (2014). The stimuli in these two tasks were the same. The food and non-food images used as stimuli in both tasks were taken from Blechert et al.,'s (2014) Food-Pics image database and Foroni et al.,'s (2013) Foodcast Research Image Database (FRIDa). 24 images were used as the stimuli in these tasks: 12 non-food and 12 food images. The food images were further grouped into foods that are healthy and sweet and those that are unhealthy and savoury. Healthy foods contain under 150 calories per 100 grams while unhealthy foods contained over 300 calories per 100g, similar to the categorisation used in Goldstone et al. (2009). These two subcategories were used because Chapter 2 found these images had the strongest effects on perception.

In both tasks, the longer axis of the images was displayed on the screen at a random 5 mm interval between 80 mm and 140 mm in size. The shorter axes maintained the image's original aspect ratio. As this experiment was conducted over the internet (and therefore likely on a variety of devices), the displayed size of images was calibrated on each machine so that the number of pixels on the participant's screen were accurately displayed at the required sizes consistently across devices.

Procedure

Participants were sent an e-mail containing a link to the online experiment and details of how to install Inquisit Web onto their computers. Participants completed a short demographics form detailing their gender. This was followed by the Adult Eating Behaviour Questionnaire Approach Scale and then the Three Factor Eating Questionnaire R18. Participants then completed the Scaling task, followed by the Food Go/No-Go task in one session. The procedure of each of these tasks is similar to that of the previous studies in this thesis but with some small amendments made for completing the study online. The procedure of each is described in turn below:

Scaling task

The screen was split into 4 invisible quadrants. Each trial commenced with a fixation point (ABC; Thaler et al., 2013) presented for 500ms in the centre of one of these 4 quadrants. This was then replaced by a blank white screen (inter-stimulus-interval) presented randomly for 500ms (+/- 200ms), followed by the presentation of either a food or non-food image in the location the fixation point was displayed. After the presentation of this image, a scaling cross was presented in the centre of the quadrant diagonal to that showing the on-screen image (as detailed in Chapter 2). Participants used the computer's arrow keys to change the dimensions of the scaling cross axes to match those of the on-screen object, at which point they pressed enter to submit their response. There was no time limit for this task and participants were instructed to scale items by only looking at the on-screen items rather than by using rulers, fingers, or other aids to measure object sizes. There was a total of 96 trials in the Scaling Task (48 for each image type; food vs non-food).

Food Go/No-Go Task

First a fixation point (ABC) appeared in the centre of the screen for 500 ms. Following this a blank white screen (inter-stimulus-interval) was displayed for 250 ms (+/- 100 ms). After this, an image of either food or non-food was presented for 500 ms, at which point there was another 250 ms (+/- 100 ms) blank screen before the beginning of the next trial. The subsequent trials began with the presentation of the next food or non-food image. Participants were instructed to press the spacebar with both hands as soon as a 'Go' stimulus was presented and inhibit this response for 'No-Go' stimuli. For example, participants pressed the spacebar when a food image was presented in blocks when food items were 'Go' stimuli, but did nothing when a non-food image was presented. Halfway through this task, Go and No-Go stimuli associations with food and non-food images were swapped. 25% of trials in this experiment were No-Go trials. A total of 1,728 trials were used in the FGNG task (864 for each image type; food vs non-food). Of these trials, 432 were No-Go trials (216 for each image type; food vs non-food). These trials were split into 12 blocks of 144 trials

Results

Participants' mean (standard deviation) score for each question in the Adult Eating Behaviour Questionnaire Approach Scale was 2.82 (.91), and the average score in the Three Factor Eating Questionnaire was 28.18 (16.99). Sapiro-Wilk tests revealed responses to these surveys were normally distributed, [W (72) = .976, p = .181] and [W (72) = .974, p = .137], respectively. However, the present study observed no significant relationship between responses in the Adult Eating Behaviour Questionnaire and the Three Factor Eating Questionnaire [r (70) = .006, p = .961]. This is in contradiction to the results of Chapter 3 (in which a very strong, and significant, positive relationship was observed), and Quilty and Oakman (2004). Although, it is not possible to determine why this may have occurred, the contradiction to Quilty and Oakman (2004) suggests that there may have been an issue with self-reports of behavioural approach motivation and impulsivity within the present study. As such, results within the present study regarding these surveys, and their ability to predict perception of food size, should be interpreted with caution.

In the FGNG task, the mean (standard deviation) of false flags observed was 4.53 (2.65) when attempting to inhibit response to non-food items, and 6.06 (3.21) when attempting to inhibit response to food items. A repeated-samples t-test revealed that participants committed significantly more false flags when attempting to inhibit response to food objects [t (71) = - 4.62]. This is consistent with previous FGNG research, such as Teslovich et al., (2014) which also suggest that participants are worse at inhibiting response to food, compared to non-food.

In the Scaling Task, the mean (standard deviation) error in reported object size report (in millimetres) was - 22.79 (5.47) for food objects and - 19.23 (5.41) for non-food objects. This is consistent with the results of Chapter 2 in suggesting that participants seem to under-report the size of objects, regardless of object type.

Behavioural approach motivation as a predictor of object size perception

The first two-step hierarchical multiple regression was carried out with mean accuracy error of scaled food size in millimetres as the dependent variable. Similarly to Chapter 3, age and gender were added into the regression at step 1 as controls. This is because, as explained in Chapter 3, age and gender have both been shown to affect BMI (İşeri & Arslan, 2009; Williams & Satariano, 2005; Kanter & Caballero, 2012) and were also included here as their effects on BMI may be driven by their potential effects on perception. Following this, behavioural approach motivation scores (Adult Eating Behaviour Questionnaire Approach Scale) was entered at step 2. The results of this regression can be seen in Table 1.

Table 1. Predictive ability of gender, and behavioural approach motivation on scaled size of food.

	Step 1			Step 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	.743	1.406	-.063	.753	1.416	.06
Adult Eating Approach				-.224	.723	-.04
F (df) for ΔR^2	= (1, 70) 0.578			= (2, 69) 0.339		
ΔR^2	.004			.001		
R^2	.004			.005		

Note. * p < .05, ** p < .01, *** p < .001

The above regression indicates that gender explained 0.04% of the variance in reported food object size in step 1, which was not significant [F (1, 70) = 0.279, p = .60]. In step 2, the added behavioural approach motivation scores accounted for a further 0.01% of the variance of reported food object size and did not contribute to the model to a significant extent [F (1, 69) = 0.186, p = .83]. With all three predictor variables included in the regression, none of the variables significantly predicted reported food object size. These three predictors together explained a mere 0.02% of the variation in reported food object size.

The second two-step hierarchical regression contained the same predictor variables in the same step order. However, in the current regression, the dependent variable was the mean accuracy error of scaled non-food size in millimetres. The results of this regression can be seen in Table 2.

Table 2. Predictive ability of gender and behavioural approach motivation on scaled size of non-food.

	Step 1			Step 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	.6793	1.392	0.058	.708	1.389	0.061
Adult Eating Approach				-0.828	0.709	-0.139
F (df) for ΔR^2	= (1, 70) 0.234			= (1, 69) 1.363		
ΔR^2	.003			.019		
R^2	.003			.023		

Note. * p < .05, ** p < .01, *** p < .001

Similar to the first regression, gender explained 0.3% of the variance in reported non-food object size in step 1, which was not significant [F (1, 70) = 0.234, p = .630]. In step 2, behavioural approach motivation accounted for a further 2% of the variance of reported non-food object size but did not contribute to the model to a significant extent [F (2, 69) = 0.868, p = .424]. As for food objects, none of the variables significantly predicted reported non-food object size and together only explained 2.3% of the variation in reported non-food object size.

The outcomes of these two regression analyses suggest that an individual's gender and self-report of behavioural approach motivation do not significantly predict the reported size of food or non-food objects in the Scaling Task.

Impulsivity as a predictor of object size perception

A third two-step hierarchical multiple regression was carried out with mean accuracy error of scaled food size in millimetres as the dependent variable. Again, gender was added into the regression at step 1 as controls. Following this, scores on the self-report measure of impulsivity (Three Factor Eating Questionnaire) and the number of Food No-Go False Flags were entered at step 2. The results of this regression can be seen in Table 3.

Table 3. Predictive ability of gender, Three Factor Eating, and Food No-Go False Flags on scaled food size.

	Step 1			Step 2		
Variable	**B**	**SE B**	**B**	**B**	**SE B**	**β**
Gender	0.74	1.41	0.06	0.80	1.47	0.07
Three Factor Eating				-0.1	0.4	-.03
Food No-Go False Flags				-0.08	0.22	-0.04
F (df) for ΔR^2	= (1, 70) 0.279			= (3, 68) 0.135		
ΔR^2	.004			.004		
R^2	.004			.008		

Note. * p < .05, ** p < .01, *** p < .001

The above regression indicates that gender explained 0.04% of the variance in reported food object size in step 1, which was not significant [F (1, 70) = 0.578, p = .60]. In step 2, scores on the Three Factor Eating Questionnaire and number of false flags during food No-Go trials were added. These accounted for a further 0.1% of the variance of reported food object size and did not significantly contribute to the model [F (3, 68) = 0.181, p = .909]. With all three predictor variables included in the regression, none of the variables significantly predicted reported food object size. These four predictors together explained 1% of the variation in reported food object size.

The fourth two-step hierarchical regression contained the same predictor variables as regression 3, included in the same step order. The dependent variable was mean accuracy error of scaled non-food size in millimetres. The results of this regression can be seen in Table 4.

Table 4. Predictive ability of gender, Three Factor Eating, and Non-Food No-Go False Flags on scaled non-food size.

	Step 1			Step 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	.67	1.39	.06	.24	1.44	.02
Three Factor Eating				.04	.04	.12
Non-Food No-Go False Flags				-.37	.25	-.18
F (df) for ΔR^2	= (1, 70) 0.234			= (3, 68) 1.214		
ΔR^2	.003			.034		
R^2	.003			.038		

Note. * p < .05, ** p < .01, *** p < .001

As before, gender explained 0.3% of the variance in reported non-food object size in step 1, which was not significant [F (1, 70) = 0.234, p = .63]. In step 2, Three Factor Eating Questionnaire scores and frequency of false-flags during non-food No-Go trials together accounted for a further 3.4% of the variance of reported non-food object size but did not contribute to the model to a significant extent [F (3, 68) = 0.888, p = .45]. With all four predictor variables included in the regression, none of the variables significantly predicted reported non-food object size. These four predictors together explained 4% of the variation in reported non-food object size.

The outcomes of these two regressions analyses suggest that an individual's age, gender, self-reports of - and behavioural - impulsivity do not significantly predict the reported size of food or non-food objects in the Scaling Task.

Self-report impulsivity as a predictor of behavioural impulsivity

Two final hierarchical multiple regressions were carried out with the frequency of false-flags during Food No-Go trials as the dependent variable. As in Chapter 3, age and gender were added into the regression at step 1 as controls because they affect BMI (İşeri & Arslan, 2009; Williams & Satariano, 2005; Kanter & Caballero, 2012) which may be driven by differences in inhibition. Following this, the self-report measure of impulsivity (Three Factor Eating Questionnaire scores) was entered at step 2. The results of this regression can be seen in Table 5.

Table 5. Predictive ability of gender, and Three Factor Eating on Food No-Go False Flags.

	Step 1			Step 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	-.44	.83	-.06	-.90	.82	.13
Three Factor Eating				.06	.02	.30*
F (df) for ΔR^2	= (1, 70) 0.29			= (1, 69) 6.38*		
ΔR^2	0.004			0.084		
R^2	0.004			0.088*		

Note. * p < .05, ** p < .01, *** p < .001

This regression indicated that gender explained 0.4% of the variance in Food No-Go False Flags Frequency in step 1, which was not significant [F (1, 70) = 0.29, p = .59]. In step 2, Three Factor Eating Questionnaire scores accounted for a further 8.4% of the variance in Food No-Go False-Flag Frequency and contributed to the model to a significant extent [F (2, 69) = 3.35, p = .04]. With all three predictor variables included in the regression, 8.8% of the variation in Food No-Go false flag frequency was explained but only the Three Factor Eating Questionnaire scores were a significant predictor of Food No-Go False Flag Frequency.

The outcome of this regression suggests that an individual's self-reported impulsivity, as measured by the Three Factor Eating Questionnaire, is indicative of their ability to inhibit responses to food during the FGNG task to a small yet significant extent, in that greater self-reported impulsivity is associated with a decreased ability to inhibit response to food items (as demonstrated by greater false flags).

The final regression carried out was the same as the previous one with the exception that frequency of false-flags during non-food No-Go trials was entered as the dependent variable. The results of this regression can be seen in Table 6.

Table 6. Predictive ability of age, gender, and Three Factor Eating on Non-Food No-Go False Flags.

	Step 1			Step 2		
Variable	**B**	**SE B**	**β**	**B**	**SE B**	**β**
Gender	-.35	.68	-.06	-.71	.68	.13
Three Factor Eating				.04	.02	.28
F (df) for Δ*R*^{2}	= (1, 70) 0.27			= (1, 69) 5.76		
ΔR^2	.004			.077		
R^2	.004			.08		

Note. * $p < .05$, ** $p < .01$, *** $p < .001$

This regression indicated that gender explained 0.4% of the variance in non-Food No-Go False Flags Frequency in step 1, which was significant [F (1, 70) = .267, p = .61]. In step 2, Three Factor Eating Questionnaire scores accounted for a further 7.7% of the variance in Non-Food No-Go False-Flag Frequency. Although the model was not significant at step 2 [F (2, 69) = 3.02, p = .60]. The two predictors together explained 8% of the variation in non-Food No-Go false-flag frequency. The outcome of this regression suggests that an individual’s age may be indicative of an individual’s ability to inhibit to response to non-food items during the FGNG task, in that ability to inhibit response to non-food decreases with age.

The above results suggest that neither behavioural approach motivation nor impulsivity (either self-reports or behavioural measures) predict the size participants perceive an object to be, regardless of whether or not it is food. In addition, it appears that self-reports of impulsivity only predict false flag frequency when inhibiting response to food objects. In addition, age was a predictor of false flags when inhibiting response to non-food objects.

Finally, although it was not possible to statistically compare performance in the Scaling Task in the present experiment with that of Chapter 2 (due to differences in the number/type of participants between experiments), it is important to look at the differences in accuracy between these experiments. For this, accuracy when scaling non-food items (non-fasting state) in Chapter 2 are compared to the non-food scaling accuracy in the present experiment. The mean (standard deviation) in Chapter 2 was [- 5.90 (11.37)] compared with [- 19.23 (5.41)] in the present experiment. The differences between these means suggest that participants were much more accurate during the in-lab compared to the online version of the Scaling Task. Interestingly, in addition to this difference in mean accuracy, participants accuracy was much less consistent in the in-person version of the Scaling Task. These observations suggest that there may be a considerable lack of consistency between the in-lab and online version of the Scaling Task. However, as no statistical test was possible, this observation should be considered with caution.

Discussion

The present experiment aimed to assess whether behavioural approach motivation and impulsivity impact an individual’s perception of food size. Results indicated that self-reports of behavioural motivation (Adult Eating Behaviour Questionnaire Approach Scale) did not predict an individual’s reporting of an object’s physical size. This result contradicts the first hypothesis, which predicted a positive relationship between self-reports of behavioural motivation and the size that food will be scaled to during the Scaling Task. This result suggests that the attentional biases caused by increased behavioural approach motivation (Gable and Harmon-Jones, 2008) may not affect the size that participant’s perceive food objects to be. In addition, the results of the present experiment demonstrated that neither self-reported impulsivity (Three Factor Eating Questionnaire) nor behavioural impulsivity (frequency of Food No-Go false flags) predicted an individual’s reporting of an object’s physical size. This result contradicts the second hypothesis, which predicted a positive relationship between self-reports of – and behavioural - impulsivity, and the size that food will be scaled to in the Scaling Task. This suggests that the attentional biases related to impulsivity (Munk, Schmidt & Hennig, 2020) may not affect the size that participants perceive food items to be. Importantly, for both of these hypotheses, none of these variables predicted the scaled size of non-food items either. Finally, it was observed that self-reports of (trait) impulsivity significantly positively predicted food-specific behavioural (state) impulsivity, mirroring the relationship observed by Duckworth & Kern (2011). This result supported the third hypothesis and suggests that as an individual’s self-reported (trait) impulsivity increases, the more difficulty the individual will have inhibiting response to food items (state impulsivity). These results, in addition to their implications are discussed in more detail throughout this discussion.

It was argued earlier in this chapter that behavioural approach motivation and impulsivity both have positive relationships with attentional biases towards food stimuli. It was also argued that these attentional biases would then, in turn, affect size perception (in accordance with the Attentional Account). The lack of relationships between behavioural motivation or impulsivity and scaled size of food objects suggests that perhaps the attentional bias (specifically narrowing of attentional breadth) caused by these psychological constructs does not affect the perceived size of food objects. However, as attentional bias was not measured in the present study, it is not possible to state with certainty that this is the case. Instead, it may be that the results of the present experiment imply that neither food-related impulsivity nor behavioural motivation incite narrowed attention toward food. If neither behavioural approach motivation nor impulsivity successfully incited attentional narrowing towards food items, then no relationship with the scaled size of food objects should be expected. Therefore, it is suggested that future studies be conducted to replicate the current research with the inclusion of a measure of attentional breadth, such as Navon figures (Gable and Harmon-Jones, 2010; described in Chapter 3 of this thesis). If such an experiment observed a relationship between behavioural approach motivation or impulsivity and narrowed attention, but not between behavioural approach motivation or impulsivity and scaled size of food objects, then it may be concluded with more certainty that attentional breadth does not affect the perceived size of food objects. Such an experiment would have implications for the Attentional Account and the ongoing debate as to whether perception is affected by cognition (Firestone & Scholl, 2016; Witt, 2017; Collier & Lawson, 2018; described in Chapter 1).

Alternatively, it may be the case that the null findings in the present experiment may be the result of using an online experimental design. However, since the FGNG task results were similar to those reported by Duckworth & Kern's (2011) meta-analysis, it may be that the current results reflect an issue with the reliability of the online versus in-lab versions of the Scaling Task specifically. The Scaling Task may yield more reliable findings when conducted under laboratory conditions in a soundproof booth (as in Chapter 2). Whereas, due to its online design, it was not possible to control the conditions under which participants completed the present experiment. This lack of control may have caused input from participants to be affected by disruptions in attention, such as differences in lighting conditions or the presence of other people (or pets) in the participants' environment. These potential distractions could have a large effect on the Scaling Task because, following the Attentional Account, the expected perceptual effects depend on a narrowing focus of attention. Although participants generally under-reported the size of objects in the Scaling Task (similarly to in Chapter 2), large differences in the accuracy of object Scaling exist between Chapter 2 and the present study. This was the case, even when only considering non-food objects which are not expected to be affected by perceptual effects of either fasting (as in Chapter 2) or behavioural motivation and impulsivity (as in the present experiment). Therefore, the considerable observed differences in both mean accuracy and consistency of reports (as measured by standard deviations) between these two experiments suggest that there may be a lack of reliability between the in-lab and online version of the Scaling Task – this may explain why none of the variables within this experiment predicted the scaled size of food items. As such, it would be appropriate to replicate the present study in its entirety under laboratory conditions to obtain greater certainty of the relationships between food size perception and measures of impulsivity and behavioural approach motivation. The results obtained in such a study may then be more informative as to why over-eating occurs frequently in the impulsive, as demonstrated by previous research (Schag, Schönleber, Teufel, Zipfel, & Giel, 2013; Loxton, 2018). In a laboratory study, it would also be possible to collect reaction time (RT) data, which was not recorded for the present experiment for either FGNG Task or the Scaling Task to limit the number of participants required to achieve sufficiently powered results during Covid-19 restrictions. It would also be of interest to expand this study to include measurements of neural correlates (like the project proposed in Chapter 4).

The results of the present experiment further demonstrate a weak but significant relationship between food-specific self-reported and behavioural impulsivity. This result is in line with those of Duckworth & Kern's (2011) meta-analysis and demonstrates that the weak relationship observed between self-reported and behavioural impulsivity persist within a domain-specific context. This weak relationship between self-reports and behavioural motivation also supports Hofmann et al.'s (2009) Dual Process Theory, suggesting there are two conceptually linked processes involved in the outcome of impulsive behaviour. As such, it is argued that experiments which assess the effectiveness of impulsivity interventions (such as Lapenta, 2014; Houben & Jansen, 2011) only currently assess changes to implicit associations which make up state impulsivity. It is therefore recommended that such intervention studies consider the addition of self-reports of impulsivity to observe any potential changes in the conscious pursuit of long-term goals that are argued to make up trait impulsivity. This is of importance, as developing methods of impulsivity intervention which affect both mechanisms of impulsivity in tandem may lead to more effective treatments for reducing over-eating.

The significant positive correlation between self-reported and behavioural food-specific impulsivity provides an insight into the lack of relationship observed between self-reported behavioural approach motivation and impulsivity. Specifically, it suggests that self-reports of behavioural approach motivation were not as expected (a strong positive association with self-reported impulsivity was expected, as observed in Chapter 3 and Quilty & Oakman, 2004). Although it is not clear why this inconsistency in self-reported behavioural approach motivation may have occurred between studies, it may further explain why self-reported behavioural motivation did not predict the scaled size of food in the present experiment. As such, the reliability of the Adult Eating Behaviour Questionnaire should be investigated before asserting that the narrowed attention caused by increased behavioural approach motivation (Gable and Harmon-Jones, 2008) does not affect the perceived size of food objects.

The FGNG Task in the current experiment also revealed that age was a significant predictor of false flag frequency during non-food No-Go trials, in that increases in age predicted increases in false flags. This result was unexpected for two reasons: Firstly, there does not appear to be any theoretical reason for this result only occurring during non-food No-Go trials. Secondly, this result contradicts previous research, which observed that older adults commit fewer false flags on Go/No-Go Tasks compared to younger counterparts (Maillet, Yu, Hasher, & Grady, 2020). This result therefore draws into question the validity of the results obtained from this online FGNG Task.

In conclusion, the present research provided evidence that the relationship between self-reports and behavioural measures of impulsivity are as similar in a food-specific context as they are in a domain-general context. Importantly, although the Scaling Task is a promising measure of object perception, replication is required before using it to investigate the relationships between behavioural approach motivation and impulsivity, and food size perception. Further research should investigate the reliability of The Scaling Task. Specifically, such research should ascertain whether the lack of relationship observed between behavioural approach motivation and impulsivity, and the scaled size of food items in the Scaling Task was due to the procedure’s online design. Due to these questions regarding the Scaling Task’s reliability, it is presently not possible to rule out the role of impulsivity and behavioural motivation in object size perception.

Chapter 6

Thesis discussion, limitations, and directions for future research

Abstract

This chapter restates the main aims of this thesis. In addition to the central findings of each experimental chapter, it discusses the novel nature of each experiment, and how this contributes to the understanding of whether visual perception is cognitively impenetrable. For example, this thesis contains the first method of measuring alleged top-down effects on perception whilst successfully avoiding previous methodological pitfalls. The discussion further includes an exploration of the limitations of this thesis, both theoretically and experimentally. For example, the current thesis considers only one element of the Action-Specific Account – namely physical morphology – and as such the potential effects of energy expenditure required to act (relative to current energy reserves) and task proficiency on visual perception cannot yet be ruled out. Finally, this discussion contains concrete recommendations for future research to improve the validity of studies into the perception of food, in addition to suggestions for future research with further implications for the field of food perception. For example, included are suggestions (with examples) of how future research can use the seven experimental controls outlined in Chapter 2 to avoid methodological pitfalls of perception research. In addition, future research is suggested to further investigate the impact of attention on perception. For example, a method is proposed to investigate whether the attentional effects on food size observed in this thesis were caused by a physically empty stomach (differences in physical morphology) or subjective feelings of hunger (differences in psychological state).

Discussion of findings

This thesis tested certain predictions of the Action-Specific Account of object perception, which claims that a person’s ability to act affects their perception of their environment (Proffitt & Linkenauger, 2013). The predictions of this account were tested against an Attentional Account of object perception (outlined in the introduction of this thesis) which predicts that changes in perception are driven by attentional breadth (as evidenced by Anton-Erxleben et al., 2007; Cole et al., 2014). To date, no published research has demonstrated support for either account while avoiding methodological flaws that provide alternative explanations for results (Firestone, 2013; Firestone and Scholl 2016). As such, developing a method to successfully compare these accounts was the central aim of this thesis.

This chapter collates the key findings of each experiment conducted within this thesis, in addition to exploring what each study means for a theoretical understanding of object perception. This chapter also discusses the limitations of each experiment presented in this thesis, as well as directions for future research. Chapter 2 of this thesis presented a novel food-specific procedure for assessing the perceived size of food objects while controlling for experimental pitfalls. How these pitfalls are controlled, in addition to how they may be adapted for use in future research will be detailed within this discussion. In addition, this discussion will consider the potential impact of Chapter 3 on the food perception literature; namely, that food-specific surveys measuring behavioural motivation and impulsivity are better predictors of BMI than their domain-general counterparts. Finally, regarding the lack of a relationship between behavioural motivation and impulsivity, and perception of food size reported in Chapter 5, it is questioned whether the attentional effects observed in Chapter 2 apply to psychological constructs unrelated to physical morphology. The results of this thesis find more evidence for attentional - rather than action-specific - effects on object perception. However, it is encouraged that future research continue to test the Action-Specific and Attentional Accounts, as these may have ramifications for cognitive (im)penetrability of perception and understanding of how the mind is organized (Firestone and Scholl, 2016).

Demonstrating best practice for research into visual perception

The central aim of this thesis was to develop and present a novel measure for investigating top-down effects on perception while controlling for methodological pitfalls which may provide an alternative explanation for results (Firestone, 2013; Firestone & Scholl, 2016). A summary of each pitfall is discussed below, in addition to how each pitfall is controlled, why these controls are important to use, and how they may assist future research.

Pitfall 1: An overly confirmatory research strategy

Firestone and Scholl (2016) argued that a robust effect should be observed as both present when expected and absent when appropriate; the latter being referred to as a disconfirmatory finding. Unfortunately, research investigating top-down effects on perception often only seek to observe the presence of an effect and do not pursue disconfirmatory findings (Goldstone, 1995; Stefanucci & Geuss, 2009; van Koningsbruggen, Stroebe, Aarts, 2011; Milos et al., 2013; Witt, 2018). This is important because if a supposed perceptual effect is observed, even when it is not expected to, then this could suggest that either the results were caused by something other than perception (e.g., demand characteristics) or that the findings are not important for everyday perception and behaviours. An example of this in the context of food perception might be observing that both food and non-food items are perceived as larger after fasting. These effects would therefore have the same impact on everyday perception - rendering them unlikely to affect any food-specific behaviour like food choice or consumption. For this reason, disconfirmatory findings are important for the investigation of food size perception, and as such were included in Chapter 2. Participants in Chapter 2 scaled the size of non-food objects as well as food. The results demonstrated that participants only scaled food items as relatively larger after fasting – no perceptual effect on non-foods were observed. This disconfirmatory finding suggests that the observed attentional effects on the perceived size of food may be useful in everyday perception. Disconfirmatory findings can be incorporated into other research. For example, Cole et al. (2014) assessed participant's perceived distance to a cold drink on a hot day. Disconfirmatory findings could be added to this experiment by adding a condition in which participants report their distance from a hot coffee. In this instance they might expect that attentional effects on perceived distance to a desired cold drink may not be replicated when perceiving distance from hot coffee.

Pitfall 2: Perception versus judgement

It can be difficult to separate perception from related constructs – such as judgement. This is because some aspects of an object can be both perceived and judged (e.g., colour and size). For this reason, research sometimes mistakenly assesses judgement - or at least perception contaminated by judgement – rather than perception. This is commonly due to the use of centimeters (cm) for estimations, rather than scaled reporting of object size (e.g., van Koningsbruggen, 2011). The reason such estimations should be considered a measurement of judgement is because, unlike spatial properties, it is not possible for participants to perceive objects in cm. Instead, participants must judge the cm size of an objects based on the spatial features perceived. The difference between effects on perception and judgement are important, as both Action-Specific and Attentional Accounts expect effects on perception, and such perceptual effects could have ramifications for claims of cognitive impenetrability (Firestone and Scholl, 2016). To demonstrate the effect of judgement on reports of perception, Chapter 2 compared a novel scaling method against the cm estimations used in previous research. The results demonstrated that only the scaling method of reporting object size was able to detect differences between fasting and satiated conditions. Therefore, morphological state (empty stomach) did not influence judgement, but instead influenced perception via enhancing attention toward food (items that would restore homeostasis and achieve the participants' goal of satiation) but not non-food. It is suspected that judgement was not influenced because the same results were not observed when participants reported objects size in cm - suggesting that spatial features were influenced and reported only in the Scaling Task. This finding has implications for research investigating top-down effects on perception and provides a simple to adapt template for future research - even beyond food perception. For example, Witt (2009) investigated whether those experiencing chronic pain while walking perceived distances as further than controls - reported in feet and inches. Although it is entirely possible that their chronic pain participants judged the distances as further, the results of Chapter 2 suggest that it is unlikely that they actually perceived it as such. This is because, after controlling for judgement by employing the Scaling Task (opposed to the often used written/verbal estimates, similar to those used in Witt, 2009), no evidence in favour of the Action-Specific Account was observed. Instead, it was observed that only attentional changes have a significant effect on perception. For this reason, the lack of Action-Specific evidence in Chapter 2 suggests that Witt’s (2009) results were possibly the result of some form unintentional experimental bias. Therefore, it would be beneficial to replicate Witt’s (2009) experiment using a scaling method like that of Chapter 2 or Cole et al. (2014), rather than verbal reports. In such a replication, no difference between participant groups would be expected because, unlike making verbal or written estimations, the Scaling Task developed for this thesis does not appear to be affected the changes in judgement suspected to have been mistakenly reported by Witt (2009). However, this is not to say that all Scaling Tasks can be claimed to be free of the effects of judgement. In fact, Collier and Lawson (2017) have argued that many previous scaling tasks can be argued to be affected by judgement of non-visual features (such as expected ability to grasp an object when reaching to grasp; Linkenauger et al., 2011). However, unlike the Scaling Task presented in this thesis, these previous scaling tasks lack the methodological controls detailed in this thesis to rule out the potential contaminating effects of judgement on their results – thus falling to one of the seven main methodological pitfalls and fallacies specifically avoided in this thesis. For example, Linkenauger et al. (2011) used a type of scaling task for their participants to report the perceived dimensions of different sized blocks. Specifically, participants stated if the block was graspable before scaling the distance between to circles until their distance from each other matched the width of the presented block (target item). Their results were claimed to demonstrate that participants scaled graspable objects as smaller when they imagined grasping the target item with their dominant compared to their non-dominant hand, and as such, that perceived object size changes with ability to interact with it. However, Collier and Lawson (2017) argue that because participants were asked to report the graspability of the target item at the start of each trial participants reports of object size were potentially influenced by whether the object was judged as graspable (opposed to purely just the target item’s physical dimensions). This is not to say that reported object size using their scaling task was affected by judgement, only that it is not possible to rule out the potential contaminating effect of judgement on perceptual reports because it was not carefully controlled for in their study.

Pitfall 3: Demand and response bias

Orne (1962) demonstrated that when participants know the hypothesis of a study, they will attempt to conform to it. Durgin (2009) demonstrated that this is also the case when participants deduce a hypothesis. As such, researchers should attempt to disguise the hypothesis of their experiment where possible, for example using cover stories. However, as correctly pointed out by Firestone and Scholl (2016), it is not always possible to provide an adequate cover story for an experimental procedure. They suggest that in such situations, participants should be asked to identify what they believed to be the expected results. No cover story was given in Chapter 2, but following the completion of all tasks, participants were asked to indicate what they believed the hypotheses to be. Responses indicated that no participants were able to deduce the expected results. This is an important control, even in studies that do provide a cover story, as if participants correctly identify experimental hypotheses then demand characteristics cannot be ruled out as the cause of results. As such, it is advised that a cover story should be used where possible for research assessing perception. In addition, participants should still be asked report the suspected hypotheses at the end of the experiment, even when a cover story is employed. This would allow not only to discern whether data may have been influenced by demand characteristics but also inform whether the cover story is appropriate for use in future research.

Pitfall 4: Low-level differences

It is agreed that supposed top-down effects on perception could actually be caused by visual differences between stimuli (Firestone & Scholl, 2016; Witt, 2017). Chapter 2 provides a simple example of how to avoid this pitfall. Specifically, stimuli were the same when participants were hungry and when satiated. Even though stimuli were the same when satiated and fasting, significant differences in the perceived size of healthy sweet and unhealthy savoury foods were observed. This is an important finding because if only low-level differences are responsible for the results of previous research, then no difference between conditions should have been observed in Chapter 2. Simply, the fact that some food items were reported as significantly larger while fasting, compared to satiated, indicates that results were not caused by low-level differences between stimuli. Although, this example of consistent stimuli across conditions can be applied to many experiments, it is not always possible. In such situations, Firestone and Scholl (2016) suggest that including additional experimental conditions may rule out the effects of low-level visual differences between stimuli. Examples of appropriate extra conditions could include disrupting low-level features while maintaining high-level features – such as image scrambling (as in Cano, Class & Polich, 2009), or disrupting high-level features and maintaining low-level features, for example by image blurring (as in Firestone and Scholl, 2015a).

Pitfall 5: Peripheral attentional effects

Perception of an object’s size and distance has been reported to change based on the breadth of attention towards said object (2018; Cole, Riccio & Balcetis, 2014; Kirsch, Heitling & Kunde). Although, attention may be considered a top-down effect on perception, Firestone and Scholl (2016) argued that these should be considered as distinct from other top-down effects (such as action-specific effects) because they may not challenge the concept of cognitive impenetrability (Fodor, 1980; Pylyshyn, 1980). In addition, although action-specific and attentional effects may appear distinct and competing explanations of changes in perception, Witt (2017) argued that action-capacity may affect perception indirectly by driving shifts in attention. Kirsch, Kitzmann and Kunde (2021) claimed to have observed exactly that. However, their research did not account for situations in which the predictions of the Action-Specific Account and Attentional Account were opposed. In Chapter 2, the predictions of the Action-Specific and Attentional Accounts were opposed while fasting participants reported the size of food objects. It was observed that certain food types were reported as relatively larger while fasting compared to satiated. This result suggests that action-specific effects do not affect perception - not even indirectly by driving attention. Instead, it may be that previously reported action-specific effects are actually misattributed attentional effects. Future research could investigate this further by attempting to remove the overlap between Action-Specific predictions and those of alternative accounts – this could be done similarly to Chapter 2.

Pitfall 6: Memory and Recognition

Some research studies investigating top-down effects on perception are contaminated by memory effects. Cole, Riccio and Balcetis (2014) provide just one example of such research. It was argued earlier in this thesis that unless a participant can see both the object they are assessing and the means of reproduction simultaneously, then the observed effect cannot be purely perceptual. This is because if a participant must look away from the target to report its size/distance, then they must remember the size/distance they perceived. Chapter 2 of this thesis controlled for the contaminating effects of memory on perceptual reports of object size by ensuring that both the target item and the scaling cross were visible to participants at the same time. In addition, the contaminating effects of memory may explain the differences observed between the True-to-Size Scaling and Estimation Tasks in Chapter 2. Unlike the Scaling Task, the Estimation Task required participants to report the size of objects in cm. This is an issue because cm cannot be perceived in the same way as spatial properties. Specifically, the size of a single cm can only be recalled and applied to the perceived spatial properties of an object. Although there is no reason to believe that the memory of one participant group would differ systematically from another, it is clear how this lack of reliability could affect the results of studies which rely on these estimations (e.g., van Koningsbruggen et al., 2011; Forwood et al., 2015; Collier, 2018). For this reason, it is suggested that future research avoid cm (or similar) estimations in favour of a scaling method like that provided in Chapter 2 or Cole et al. (2014).

El Greco Fallacy

Effects on perception should not be observable if the target stimulus and means of replication are identical. In such circumstances, perceptual effects on the target item will also affect the method of replication – thus cancelling one another out (Firestone, 2013). One clear example of this El Greco Fallacy can be found in Yellowlees et al., (1988) who reported that those with Anorexia Nervosa perceived food items as larger than control participants. However, using their scaling task, participants reported food size by manipulating a photo of the target food. Therefore, according to the El Greco Fallacy, no difference should have been observed. This is because any perceptual effects that changed the perceived size of the target food would have also affected their means of replication (manipulated object) and cancelled each other out. As such, it is reasonable to argue that Yellowlees' results were caused by something other than differences in food size perception. Importantly, this does not mean that such differences do not exist, only that they should not be observable using Yellowlees et al.'s (1988) scaling procedure. Chapter 2 avoided this fallacy by simply replacing the scaling object with a cross (+). This method avoids the El Greco Fallacy because, due to the dissimilarity between the scaling cross and the objects being scaled, the expected changes in object size perception would not affect the scaling cross - thus meaning that perceptual effects were observable. This is a simple measure to employ in most research projects. However, it is also the most important because even if all the other measures except this one are followed, without this measure a study would only be able to observe experimental bias or some other artefact.

Action-specific scaling versus attentional breadth

It is obvious that perception impacts an individual's actions. For example, even anecdotally, visual perception is used to select the least icy path in the snow. However, this thesis suggests that the reverse is not the case - action does not affect perception. For example, it is unlikely that ability to travel across ice affects perception of the amount of ice on the path. This is in direct contrast to proponents of the Action-Specific Account (e.g., Proffitt & Linkenauger, 2013; Witt et al. 2009; Eves et al., 2014), who argue that an individual's ability to interact with their environment affects their perception. This thesis also found evidence to oppose the suggestion by Witt (2017) and Kirsch, Kitzmann and Kunde (2021) that an individual's action-capacity may affect their perception by changing the attention given to objects. Instead, the results from this thesis suggest that attention - independent of action capacity - influences the size that objects are perceived to be. Following Gable and Harmon-Jones' (2010) investigation into attentional bias and object perception, it is believed that attention affects perception of an object's size through attentional breath. Specifically, the narrower an individual's attention towards an object, the larger it is perceived to be, while wider attentional breadth leads to the object being perceived as smaller. In agreement with Firestone and Scholl (2016), this may not reflect a perceptual effect in the truest sense. The reason for this is that changes in perceived object size may occur due to small changes in visual input (such as shifts in the location of eye fixation) caused by attentional narrowing/widening. Research by Townsend and Courchesne (1994) could be used to argue that narrowed attention leads to small differences in visual input. In their experiment, patients with parietal cortex volume loss demonstrated narrower visual attention (and therefore perhaps a different visual input) to healthy controls. Interestingly, these patients were also significantly faster at responding to the appearance of objects within an attended space than controls. As such, it may be the case that patients were faster at responding to objects due to differences in visual input (fixation locations; caused by their narrowed attention). If these differences in visual input are also responsible for the perceptual effects predicted by the Action-Specific and Attentional accounts, then Firestone and Scholl (2016) would be correct to assert that these are not true perceptual effects. However, in line with Witt (2017), the question whether top-down effects on perception are direct or not, may be secondary to the proposal that cognition affects object perception. As such, although it is important to understand the organization of the mind, and whether top-down effects on perception are direct or indirect (and research should therefore continue to investigate this), it is important that this does not stop investigations into top-down effects on visual perception and subsequent behavioural outcomes. This is especially important when considering that changes in the way food is seen may affect eating behaviours (Gable and Harmon-Jones, 2010; Harmon-Jones & Allen, 1997; McGeown & Davis, 2018) and in turn lead to negative health outcomes, such as increased BMI. Investigating these top-down effects have the potential to benefit the development of interventions on harmful behaviours, regardless of whether the top-down effects are direct or indirect.

Domain-general and food-specific surveys as predictors of food-related health outcomes

Another aim of this thesis was to assess whether the attentional effects observed in Chapter 2 could be expanded to psychological states known to affect an individual’s attention – such as behavioural motivation and impulsivity (Gable & Harmon-Jones, 2010; Munk, Schmidt & Hennig, 2020), respectively. Impulsivity was of particular interest because, in addition to being related to a person's attention towards food (and therefore potentially their perception of food), interventions are being developed to reduce an individual's impulsivity and subsequent over-eating (e.g., Lapenta et al., 2014; Houben & Jansen, 2011; Tzavella et al., 2021, see Chapter 4 where these interventions are discussed in more detail). Behavioural motivation was also included because, in addition to being associated with attention given to food, it is very closely related to impulsivity while remaining a distinct construct (Quilty & Oakman, 2004). As such, it was suspected that behavioural motivation and impulsivity may cause over-eating by moderating the attention given to food and thus affecting the perceived size of food. If this were the case, then the Scaling Task presented in Chapter 2 could be used to track the efficacy of interventions on eating behaviours. For example, if impulsive individuals reported food items as smaller than before training started then perhaps the training was effective in more than simply reinforcing dieting goals.

However, before such an investigation was possible, the best measure for behavioural motivation and impulsivity had to be decided. This was an issue as many surveys assessing behavioural motivation and impulsivity are used interchangeably within the food perception literature (e.g., Castellanos et al., 2009; Halali, et al., 2020; Guzek, 2021; Gough, 2021). Despite this, there is no published comparison for their effectiveness in predicting health outcomes related to over-eating (e.g., increased BMI, Heart Disease, and Type 2 Diabetes). One way in which surveys measuring behavioural motivation and impulsivity differ is whether they target domain-general or domain-specific facets of their respective psychological constructs. Although it may seem obvious that food-specific measures will be better at predicting food-specific outcomes and behaviours, the lack of evidence for such a claim illustrates why research into food interactions employ domain-general and food-specific surveys interchangeably. For this reason, Chapter 3 of this thesis compared the effectiveness of domain-general surveys measuring behavioural motivation and impulsivity to their food-specific counterparts in predicting BMI.

The results of this chapter indicate that the food-specific measures (namely the Adult Eating Behaviour Questionnaire; Hunot et al., 2016; and the Three Factor Eating Questionnaire R18; Karlsson et al., 2000) were significantly better predictors of BMI than their domain-general counterparts (namely the BIS/BAS scales; Carver & White, 1994; and the Barratt Impulsiveness Scale; Patton et al., 1995). Specifically, the food-specific measures appeared to explain all the variance in BMI that the domain-general measures did and more. This finding has important implications for future food perception research, as it is now clear that research investigating food-based behavioural motivation and impulsivity should rely on food-specific measures to obtain maximal real-world applications. Put simply, it would be inappropriate to identify and recruit impulsive individuals for food research using a domain-general measure of impulsivity as such a survey would be a less effective indicator of impulsive eating than a food-specific survey.

The relationship between psychological constructs, attentional breadth, and perception of food size

After determining the best surveys for measuring behavioural motivation and impulsivity towards food, Chapter 4 presents an experiment for linking these psychological constructs, and their related neural activities, to food size perception.

Unfortunately, due to COVID-19 safety measures in the UK that prevented in-person experimentation, this study was cancelled shortly before data collection began and is presented as a research study plan only. Although it was not possible for this thesis, it is urged that researchers endeavor to conduct the proposed study in the future. The proposed study has the potential to improve the efficacy of interventions on over-eating by identifying novel links between manipulatable neural activity, psychological traits related to over-eating, and perception of food. For example, reports of food size during the Scaling Task (if related to neural activation and psychological constructs) could be used to track the success of over-eating interventions in a particular individual. This would improve the reliability of intervention studies, as such studies currently rely on self-reports of over-eating (which are susceptible to demand characteristics and inaccurate reporting; Dahle et al., 2021). Instead, Chapter 5 presented an online experiment aimed at assessing whether self-reports of behavioural motivation and impulsivity predicted the perceived size of food. It was expected that these psychological constructs would predict food size perception, as they were found to predict BMI in Chapter 3. Specifically, it was suggested earlier in this thesis that greater behavioural motivation and impulsivity may be responsible for increased BMI by causing an attentional bias towards certain food objects - resulting in foods looking larger, and in turn affecting food selection and consumption. The results of Chapter 5, however, indicate that neither self-reports of food-specific behavioural motivation and impulsivity - or a behavioural measure of impulsivity - were predictors of perceived size of food. It could therefore be concluded that behavioural motivation and impulsivity do not affect BMI and eating behaviour by driving the perceive size of food. This is not to say that they do not contribute to over-eating, only that the results of Chapter 5 suggest that behavioural motivation/impulsivity-based over-eating is not due to changes in perceived food size. Instead, it may be the case that these traits effect eating behaviours in an entirely post-perceptual fashion. For example, all individuals have an automatic response to consume perceived food, however this response may simply not be inhibited or challenged as effectively in those with high impulsivity/approach motivation (Booth, Spronk, Grol, & Fox, 2018).

The relationship between self-reported and behavioural impulsivity

The results of Chapter 5 also suggested that an individual's score in the Three Factor Eating Questionnaire (a food-specific survey measuring impulsivity) is indicative of an individual's ability to inhibit response to food during the Food Go/No-Go (FGNG) task (a behavioural measure of impulsivity). Importantly, this same relationship was not observed between responses in the Three Factor Eating Questionnaire and inhibition of non-food items during the FGNG. This is important because it suggests that the impulsivity measured by the Three Factor Eating Questionnaire is specific to food, and therefore may impact an individual's eating behaviours. This result is in line with Duckworth & Kern's (2011) meta-analysis and demonstrates that the weak relationship they observed between self-reports and behavioural impulsivity persist within a domain-specific context.

In addition, Chapter 5 also supports Hofmann et al.'s (2009) Dual Process Theory which suggests that two forms of impulsive processing produce behavioural outcomes. These are the conscious pursuit of long-term goals (trait impulsivity) and unconscious implicit associations between stimuli and action (state impulsivity). This has implications for research aimed at adjusting impulsivity to reduce food intake (such as Lapenta et al., 2014; Houben & Jansen, 2011). One example of such research of impulsivity training (e.g., Tzavella et al., 2021), in which responses to in a FGNG task (i.e., the implicit associations, or lack thereof, between food and inhibition) are retrained to reduce food intake. In essence, the results of Chapter 5 suggest that such FGNG training is only addressing one of the two mechanisms which make up impulsive behaviour. This may explain why Allom, Mullan and Hagger's (2016) meta-review concluded that impulsivity training reduces impulsivity and improves health behaviour immediately after training, but these effects do not persist over time. As such, it is suggested here that impulsivity training should also employ impulsivity surveys, such as the Three Factor Eating Questionnaire, to track the effects that impulsivity training may have on the conscious pursuit of long-term goals (trait impulsivity) across training sessions and beyond. This would be an important step towards developing an intervention that retrains both mechanisms of impulsive behaviour – thus leading to more effective, and potentially long-term, treatments for impulsive eating. An example of this type of intervention could involve combining impulsivity training with cognitive behavioural therapy (CBT). This would be effective as CBT is a technique which challenges an over-eating individual's innate goal to eat food and assists them in replacing it with a more helpful goal – achieved through mindfulness (Barry, Clarke, & Petry, 2009; Woolhouse, Knowles, & Crafti, 2012). If a study were to observe that self-reported impulsivity is reduced after CBT, then this would suggest that CBT successfully re-trains the goals measured by self-reported impulsivity. Following this, it would be of interest to combine CBT with previously discussed impulsivity training. Doing so would provide an approach to retraining impulsivity, which is more effective than impulsivity training alone, by targeting both goals (trait impulsivity) and implicit associations (state impulsivity) in tandem.

Limitations of this thesis

The work presented within this thesis is not without limitations. For example, Chapter 2 concludes that the perceived size of objects change based on the breadth of attention – narrower attention means objects perceived as larger, while broader attention means objects perceived as smaller. However, although it appears likely that narrower attentional breadth (and supposed centralisation of pupil fixations) causes objects to be perceived as larger, there may be another mechanism at play. Eye-tracking could be used to confirm whether healthy sweet and unhealthy savoury food items were reported as larger due to more centralised fixations after fasting compared to satiated. This would be important in confirming whether attention effects on perception occur by driving changes in fixation location. However, if a study successfully replicated the results of Chapter 2 but found no differences in eye-tracking data, then it may be the case that attention affects the perceived size of food items through a mechanism other than shifts in fixation location.

The results of Chapter 5 suggest that although there is a relationship between food-specific behavioural motivation and impulsivity, neither relate to the size food is scaled to. Due to the relationship between these psychological constructs and attentional bias outlined by previous research (Gable & Harmon-Jones, 2010; Munk, Schmidt & Hennig, 2020), the findings of Chapter 5 draw into question the validity of Chapter 2 which suggested that attentional bias causes changes in perceived food size. However, there are many reasons why the links between behavioural motivation and impulsivity, and food size perception were not reported in Chapter 5. For example, unlike Chapter 2, the testing conditions were less rigorous in Chapter 5. This is because the procedure in Chapter 5 was run online due to COVID-19 restrictions on in-person experimentation. As such, it was difficult to ensure that participants followed the instructions of this complex experiment, as they were unable to ask follow-up questions regarding the instructions and procedure. In addition, technical difficulties may have arisen due to participants using their own computing equipment. Finally, it was impossible to ensure that full attention was given to the task – this is of particular importance as the study investigated the effects of attention on object perception. As such, future research should assess the reliability of both online and in-person Scaling Tasks before ruling out attentional changes as a cause of altered perception of food size.

In addition to the experimental limitations discussed above, there are broader theoretical caveats which should also be addressed. Chapter 2 demonstrated no evidence for action-specific effects on the perception of object size. However, it must be highlighted that this work was conducted in the context of one section of Proffitt & Linkenauger's (2013) Action-Specific Account. Namely, the work of the present thesis centred around their argument that the physical state of one's body (morphology) can impact environmental perception. Although, Chapter 2 demonstrates that morphology does not cause action-specific effects on perception of object size, this does not mean that action-specific effects could not occur in other contexts. Proffitt and Linkenauger (2013) also argue that energetic expenditure and task proficiency impact object perception, and the current thesis does not investigate whether these effects occur in their respective contexts. As such, future research should investigate whether these factors (which are not related to morphology) impact perception in a way which could be explained by the Action-Specific Account. For example, Proffitt and Linkenauger (2013) argued that visual scaling occurs according to energy expenditure relative to current energy reserves (e.g., those who drink a sugary drink, and therefore have greater energy reserves, perceive hills as less steep; Schnall, Zadra, and Proffitt 2012). As required energy expenditure does not rely on morphology, but rather an implicit cognition aimed at maintaining a caloric surplus, the present thesis provides no information as to whether action-specific effects alter perception of physical tasks through this cognitive mechanism. Understanding whether cognition affects perception in this way has the potential to inform why obese individuals are less likely to exercise (Blair, 1993). Perhaps it is the case that obese individuals have a differing cognition which is more guarded against entering caloric deficit than normal weight controls – thus they perceive physical tasks as more demanding than controls and are more likely to avoid exercise when possible (Eves et al., 2014).

Questions remaining and directions for future research

This thesis has focused on addressing methodological issues which exist within the food perception literature. However, there are still many questions which remain – both regarding the results of this thesis and the broader literature. To that end, the following section contains a discussion of some of the questions which remain and suggests directions for future research. For example, it may be the case that behavioural motivation and impulsivity weren't significant predictors of food size in Chapter 5 because behavioural motivation and impulsivity are purely psychological construct that do not have known morphological states. This may suggest that physical morphology may be important in changing perception of object size. Consider the study presented in Chapter 2, where participants had both a physically empty or not empty stomach (differences in morphology) and reported feeling subjectively hungrier after fasting. In this situation, it is difficult to know whether it was the felt feeling of hunger or the morphology of the empty stomach which caused the observed perceptual change. If morphology is the cause, then proponents of the Action-Specific Account may assert that this requirement for an empty stomach (morphology) to evoke perceptual change may indicate that action-capacity is responsible for the observed perceptual differences. Although this may seem like a reasonable conclusion, such assertions would likely be mistaken. The reason for this is that Proffitt and Linkenauger (2013), while defining the Action-Specific Account, claimed that action-specific visual scaling occurs to produce effective action selection. This assertion is incongruent with the results of Chapter 2. The action-specific perceptual ruler used in food size perception would be the current capacity of one’s stomach. Following the logic of the Action-Specific Account, this perceptual ruler should scale the perceived size of food to promote increased caloric intake – because there is physically more space in the stomach when it is empty after fasting. As such, following the logic of the Action-Specific Account, foods should have been perceived as smaller after fasting – as this would make the individual likely to consume more calories than when satiated. However, the results of Chapter 2 suggest the opposite – participants reported food as relatively larger after fasting. If these results were caused by Action-Specific Scaling, then said scaling would be counter-intuitively promoting food consumption when participants have not been fasting. It is not clear how action-specific scaling such as this could be producing effective action. Therefore, although morphology may be important for changes in the perception of food objects (as would be expected by proponents of the Action-Specific Account), it is very unlikely that these changes are caused by action-specific scaling.

Although these results make it clear that action-specific scaling in the context of food size perception is unlikely, it does still leave questions as to whether the observed perceptual effects were caused by physical morphology or subjective feelings of hunger. Future research could assess the role of morphology in the perceived size of food items by teasing it apart from subjective feelings of hunger. This could be done by replicating the procedure of Chapter 2 with one small amendment. Specifically, one group (control) would complete the study procedure as in Chapter 2. A second group would do the same except for having their appetite suppressed during the fasting condition. This could be done by chewing sweetened gum, as doing so prior to food consumption has been demonstrated to significantly reduce feelings of hunger, food cravings and subsequent food consumption (Hetherington & Regan, 2011; Melanson & Kresge, 2017). In such an experiment, both groups will have empty stomachs after fasting, but the chewing gum group will have significantly lower subjective feelings of hunger. If the reported size of food is relatively larger after fasting, regardless of whether participants were chewing gum, then it may be that only physical morphology is responsible for causing changes in perception of food objects. Such a result would provide another potential explanation as to why no relationship of behavioural motivation and impulsivity with perceived food size was observed in Chapter 5 – because, unlike hunger, these psychological constructs have no known associated physical morphology.

As stated above, this thesis addresses only one of the factors suggested by the Action-Specific Account to influence a person's perception of their environment. Specifically, Chapter 2 suggests that an individual's physical state, or morphology, does not impact their perception of object size in a way explainable by the Action-Specific Account. However, there is still a need to investigate whether required energy expenditure (relative to current energy reserves) or task proficiency impact the way an object or environment is perceived. Fortunately, many of the controls presented in Chapter 2 could be applied to such investigations. For example, the novel Scaling Task could be used to assess whether golfing proficiency affects the perception of hole size, as claimed by Proffitt & Linkenauger (2013). In such an investigation, non-golfers would be asked to scale a cross to match the dimensions of a golf hole. Then half of the participants would spend a year practicing their putting while the other half have no practice. After this time, participants would again scale the size of the golf hole. The Action-Specific Account would expect those who practiced to perceive the hole as relatively larger – as their increased skill would lead to a more compact distribution of shots over multiple attempts (however, this would be difficult to separate from practice effects unrelated to skill, such as object familiarity). Investigations of this sort are essential for understanding the role of action-capacity on perception because it is presently unknown whether required energy expenditure or task proficiency affect perception - as the present thesis only considered morphology.

It was assumed in Chapter 2 that the observed effects on perception following a period of fasting may explain increased consumption in hungry individuals (e.g., Dalle Grave, 2020). Specifically, it is suggested in this thesis that participants perceive sweet healthy food and unhealthy savoury food as relatively larger when they are hungry (after fasting) and therefore more likely to select these foods for consumption. However, this was assumed and not tested in the current thesis. Future research should aim to replicate the effects on perception observed in Chapter 2 with the addition of a fake taste test (such as in Houben & Jansen, 2011). If successfully replicated - and participants eat more of these foods during a fake taste test after fasting than when satiated - then it can be argued that attentional narrowing causes changes in food perception and increases in food consumption.

Therefore, attempting to alter this automatic attentional narrowing may have implications for interventions on over-eating (Houben & Jansen, 2011; Lapenta et al., 2014). However, if the attentional effects on perception are successfully replicated - but no difference in eating between fasting and satiated states is observed during the fake taste tests - then the purpose of these perceptual effects in everyday perception must be drawn into question.

Although Chapter 2 indicates that certain foods may be perceived as relatively larger after fasting, it is not known why this attentional effect on perception was only observed when scaling healthy sweet and unhealthy savoury foods. Interestingly, many studies conducted into food perception and consumption (e.g., Liu et al., 2019; Ahn, Ham & Kim, 2019; To et al., 2019) use exclusively chocolate because it has been rated as the most tempting food item (Tan, Tan & Tan, 2021). However, despite this trend in experimental design, unhealthy sweet foods (which included chocolate) were not reported as relatively larger after participants had fasted in Chapter 2. There are multiple explanations for these results. Firstly, there may be an evolutionary purpose for only healthy sweet and unhealthy savoury foods being perceived as larger after fasting. Davis (2014) argues that hyper palatable foods, with their high levels of sugar, fat, and salt, compared to natural foods were evolutionarily advantageous. However, in a modern society, due to their availability, impact on reward sensors, and the lack of need for huge energy consumption, such foods are considered maladaptive, potentially addictive, and evolutionarily disadvantageous. With this, the question becomes why unhealthy sweet foods were not also significantly larger after fasting? Perhaps, although food groups were broken down into categories, these groups were still too broad. It is possible that chocolate was perceived as relatively larger after fasting but the other images in the unhealthy sweet category were not. Unfortunately, there were not enough trials for each stimulus image to make these comparisons in Chapter 2. This may be of interest for future research to investigate. Secondly, it is possible that chocolate (and perhaps all unhealthy sweet food), unlike other less hyper-palatable foods, appeared maximally tempting in both conditions, and therefore was not more tempting in the fasting condition. In such a situation, chocolate may evoke equal attentional narrowing across conditions – meaning no difference in reported size was observed. Evidence for this can be seen in Chapter 2 (Figure 4), in which unhealthy sweet foods are reported as the largest in both fasting and satiated conditions. This argument that hyper-palatable unhealthy sweet foods will be desired similarly (and therefore attended to as narrowly) when satiated or fasting conforms with the concept of sensory-specific satiety (Rolls, 1986). Sensory-specific satiety suggests that desire to eat a particular food decreases after consuming it (e.g., desire to eat pasta decreases after eating a portion of pasta) but will not decrease desire to eat a different food, regardless of satiety (e.g., desire to eat ice cream is not decreased after eating pasta). As unhealthy sweet foods (e.g., chocolate) rarely make up a full meal, it may be expected that participants find these foods as desirable (and therefore equally attention narrowing) while satiated as after fasting. Thirdly, unhealthy sweet foods may not have been reported as relatively larger after participants had fasted due to gut microbiota. The composition of an individual’s gut microbiota may drive their preference for food by inducing either: Cravings for certain foods or dysphoria in the individual until a particular food is consumed (Alcock, Maley & Aktipis, 2014). Alcock et al. (2014) suggest that these behaviours and preferences are induced to promote the prevalence of the microbiota already in the gut and limit the presence of alternative microbiota.

Although it is not clear by which mechanisms this preference for food selection is driven by gut microbiota, it may explain why only some food types were perceived as relatively larger after fasting. Specifically, it may be the case that certain microbiota increases the likelihood that an individual will eat a particular food by narrowing their attention towards it. This in turn may then increase the food's perceived size - making it more salient and likely to be selected for consumption. In the context of Chapter 2, it is possible that – by chance – participants had larger levels of microbiota which promote a preference for healthy sweet and unhealthy savory foods. Future research could examine this possibility by assessing the dietary intake of each food type, and the microbiome of each participant (see Tang et al., 2020 for a review of procedures measuring the microbiome at an individual level) to determine whether the amount of a food type consumed prior to experimentation (and the composition of an individual's gut microbiota) predicts whether certain foods are reported as relatively larger while fasting. Studies comparing categories of food (opposed to food as one stimuli group) would be useful to inform future research into food perception because few studies have investigated differences across categories of food. Goldstone et al. (2009) provides one example in categorising food by caloric content, however few studies compare food in smaller categories, such as their nutritional content or taste – as in Chapter 2. Therefore, it is suggested that future research separate food stimuli into categories as there appears to be some differences in perception between food items.

The results of Chapter 2 may be important for virtual reality research, such as Woldegiorgis, Lin and Liang (2019) who showed that differences in facial morphology (such as interpupillary distance) have a significant effect on participants' perception of objects in virtual reality. Specifically, they showed that those with smaller interpupillary distances reported objects as larger than the object’s displayed size. Their results, which demonstrates that morphology also affects size perception in a virtual environment, suggests the results of Chapter 2 were not caused by assessing 2D representations of food. However, no published research has assessed food size perception in a 3D virtual environment. It was argued in this thesis that the observed differences in food size perception may impact food selection and consumption. As such, ascertaining whether the results observed in Chapter 2 persist within a virtual environment would have ramifications for virtual reality research on consumer selection (Waterlander, Scarpa, Lentz, & Steenhuis, 2011; van Herpen, van den Broek, van Trijp & Yu, 2016; Marty, Jones & Robinson, 2020). In said research, it is typical for an individual to explore a virtual supermarket and select the items they wish to buy from virtual shelves. Therefore, understanding whether the results of Chapter 2 can be replicated in virtual reality may explain why consumers make certain food choices in these experiments. For example, van Herpen et al., (2016) compared “purchasing” in a 3D virtual supermarket, 2D representations of supermarket shelves, and actual purchasing behaviour in a real shop. Their results demonstrated that purchasing behaviour in a virtual supermarket was more similar to real-world shopping than purchasing from 2D representations. Specifically, they observed that participant’s selections in a 3D virtual supermarket were more like real-world shopping in the number of products they “purchased”, and the location that items were selected from on shelves (e.g., when looking at shelves of milk, participants selected milk from more similar locations on the shelf) compared to when viewing 2D representations of shop shelves. The latter result implies a difference in attentional allocation between 3D and 2D environments (which may lead to differences in perception). Taken together, these results could imply that the differences in attention allocation (and subsequent perception) towards items between 3D environments and 2D representations is responsible for the differences in number of items purchased between these conditions. The Scaling Task could be used to expand on this virtual reality research; if it is observed that reported size of food is positively related to the amount of food purchased (or at least the amount of unhealthy food purchased), then the Scaling Task could be used to assess an individual's susceptibility towards potentially harmful behaviours (such as overbuying and consuming too much healthy food). This information could then, in turn, be used to develop an intervention aimed at reducing over purchasing of food items - similar to the neural and impulsivity interventions discussed in Chapter 5.

The results of Chapter 3 demonstrated that food-specific behavioural motivation and impulsivity are closely related constructs. The self-reports of food-specific behavioural motivation and impulsivity were weak-to-moderate but significant. Specifically, a positive correlation between food-specific approach motivation and impulsivity, and a negative correlation between food-specific avoidance motivation and impulsivity was observed. These observations support the assertion by previous research that behavioural motivation and impulsivity are related constructs (Quilty & Oakman, 2004). Furthermore, the cognitive mechanisms driving behavioural motivation and impulsivity appear to be conceptually similar. Hofmann et al.'s (2009) Dual Process Theory approach argues that impulsive behaviour is a combination of the unconscious implicit associations between stimuli and action (state impulsivity), and conscious pursuit of long-term goals (trait impulsivity). Similarly, behavioural approach motivation can be induced by presenting participants with food (Gable and

Harmon-Jones, 2010) and is also related to an individual's goal pursuit (Berkman & Lieberman, 2010). Interestingly, it could be argued that these two forms of behavioural motivation reflect state and trait behavioural approach motivation, respectively. Therefore, future research should beware the overlapping nature of behavioural motivation and impulsivity, as better understanding their relationship would have implications for research into altering impulsivity (such as Lapenta et al., 2014), and impulsivity training (such as Houben & Jansen, 2011). For example, it may be the case that impulsivity training is only effective at reducing food consumption when it also retrains an individual's behavioural approach motivation. At present, no published research has measured the effects that impulsivity training may have on behavioural motivation. Although assessing these two psychological constructs separately is difficult through behavioural means, neuroscientific approaches may provide a means of assessment. For example, a study may assess whether impulsivity training also reduces behavioural motivation by comparing the respective neural correlates both before and after training. In this instance it would be expected that cortical event-related potential components N2 and P3a - neural correlates of impulsivity - to be decreased and increased, respectively, after impulsivity regulation training. At the same time, incidental changes in behavioural approach motivation may be assessed by comparing resting state - and motivationally-relevant elicited - frontal alpha, and frontal LPPs before and after training. If training only reduces food consumption in those whose neural correlates of both impulsivity and behavioural motivation were affected, then such training may be made more effective by actively targeting behavioural motivation. Such research would be beneficial to creating effective training for reducing excessive food consumption, and potentially contribute to reducing obesity and accompanying physical and mental health problems.

Conclusion

In conclusion, this thesis described best practice for assessing food size perception, as well as how to apply this procedure to future research into top-down effects on perception. Importantly, this was achieved while avoiding methodological pitfalls, which have provided alternative explanations for the results of previous research. It was concluded that the Action-Specific account, which argues that perception of one’s environment changes based on action capacity, does not affect the perceived size of objects. Instead, attention towards objects changes size perception by affecting attentional breadth. In response to inconsistent survey selection across the food perception literature, this thesis also showed that food-specific surveys of behavioural motivation and impulsivity are better than their domain-general counterparts at predicting food-related health outcomes - namely BMI. As such, it is recommended that food-specific surveys should be used over domain-general surveys when investigating food perception or eating. This thesis also provides a proposed method of establishing the neural mechanisms involved in the perceived size of objects - by investigating the links between psychological constructs related to over-eating (behavioural approach motivation and impulsivity) and object size perception. Finally, this thesis indicates that individual differences in behavioural motivation and impulsivity do not predict perceived object size, at least not when measured online. Further investigation is required to determine whether this is because behavioural motivation and impulsivity are psychological constructs without known a physical morphology, or because the reported study was conducted in a less controlled environment outside the laboratory. Despite demonstrating that attention (independent of action-specific influences) affects perception, it is encouraged that future research continue to test the Action-Specific and Attentional Accounts. This is because both accounts may have ramifications for cognitive (im)penetrability of perception and understanding of how the mind is organized. Further, this thesis only investigated the role of physical morphology (and psychological traits related to over-eating) in assessing changes in perception. Therefore, it is possible that required energy expenditure (relative to energy reserves) or task proficiency may impact perception in a way not observed regarding morphology. In such instances, the procedure outlined in this thesis provides a template for research to investigate these facets of the Action-Specific Account as well as concrete directions for future research in this field.

References

Acock, A. C. (2005). *Working with missing values. Journal of Marriage and Family*, 67(4), 1012-1028.

Alcock, J., Maley, C. C., & Aktipis, C. A. (2014). Is eating behavior manipulated by the gastrointestinal microbiota? Evolutionary pressures and potential mechanisms. Bioessays, 36(10), 940-949.

Ahn, H. M., Ham, B. J., & Kim, S. H. (2019). A combined approach of high-frequency rTMS and food-inhibition association training reduces chocolate snack consumption. *Frontiers in Psychiatry, 10*, 815.

Allison, D. B., Kalinsky, L. B., & Gorman, B. S. (1992). A comparison of the psychometric properties of three measures of dietary restraint. *Psychological Assessment, 4*(3), 391.

Allom, V., Mullan, B., & Hagger, M. (2016). Does inhibitory control training improve health behaviour? A meta-analysis. *Health Psychology Review, 10*(2), 168-186.

Anton-Erxleben, K., Henrich, C., & Treue, S. (2007). Attention changes perceived size of moving visual patterns. *Journal of Vision, 7*(11), 5-5.

Atalayer, D. (2018). Link between Impulsivity and Overeating: Psychological and Neurobiological Perspectives. *Psikiyatride Güncel Yaklaşımlar, 10*(2), 121-137.

Attwood, A. S., O'Sullivan, H., Leonards, U., Mackintosh, B., & Munafò, M. R. (2008). Attentional bias training and cue reactivity in cigarette smokers. *Addiction, 103*(11), 1875-1882.

Balas, B., Auen, A., Thrash, J., & Lammers, S. (2020). Children's use of local and global visual features for material perception. *Journal of Vision, 20*(2), 10-10.

Balconi, M., Falbo, L., & Conte, V. A. (2012). BIS and BAS correlates with psychophysiological and cortical response systems during aversive and appetitive emotional stimuli processing. *Motivation and Emotion, 36*(2), 218-231.

Barry, D., Clarke, M., & Petry, N. M. (2009). Obesity and its relationship to addictions: is overeating a form of addictive behavior?. *American Journal on Addictions, 18*(6), 439-451.

Beaumont, J. D., Smith, N. C., Starr, D., Davis, D., Dalton, M., Nowicky, A., Russell, M., & Barwood, M. J. (2022). Modulating eating behavior with transcranial direct current stimulation (tDCS): A systematic literature review on the impact of eating behavior traits. *Obesity Reviews, 23*(2).

Bechara, A., Damasio, H., & Damasio, A. R. (2000). Emotion, decision making and the orbitofrontal cortex. *Cerebral Cortex, 10*(3), 295-307.

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discovery rate: a practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society: series B (Methodological), 57*(1), 289-300.

Berkman, E. T., & Lieberman, M. D. (2010). Approaching the bad and avoiding the good: Lateral prefrontal cortical asymmetry distinguishes between action and valence. *Journal of Cognitive Neuroscience, 22*(9), 1970-1979.

Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. Journal of experimental psychology: *Human Perception and Performance, 25*(4), 1076.

Blair, S. N. (1993). 1993 CH McCloy Research Lecture: physical activity, physical fitness, and health. *Research Quarterly for Exercise and Sport, 64*(4), 365-376.

Blechert, J., Goltsche, J. E., Herbert, B. M., & Wilhelm, F. H. (2014). Eat your troubles away: Electrocortical and experiential correlates of food image processing are related to emotional eating style and emotional state. *Biological Psychology, 96*, 94-101.

Blechert, J., Meule, A., Busch, N. A., & Ohla, K. (2014). Food-pics: an image database for experimental research on eating and appetite. *Frontiers in Psychology, 5*, 617.

Booth, C., Spronk, D., Grol, M., & Fox, E. (2018). Uncontrolled eating in adolescents: The role of impulsivity and automatic approach bias for food. *Appetite, 120*, 636-643.

Borg, G. A. (1982). Psychological bases of physical exertion. *Medicine and Science in Sports and Exercise, 14*(5), 377-81.

Brosch, T., Pourtois, G., Sander, D., & Vuilleumier, P. (2011). Additive effects of emotional, endogenous, and exogenous attention: behavioral and electrophysiological evidence. *Neuropsychologia, 49*(7), 1779-1787.

Brindal, E., & Golley, S. (2021). How can different psychological and behavioural constructs be used to personalise weight management? Development of the diet styles. *Appetite, 164*, 105272.

Caiani, S. Z., & Ferretti, G. (2017). Semantic and pragmatic integration in vision for action. *Consciousness and Cognition, 48*, 40-54.

Calitri, R., Pothos, E. M., Tapper, K., Brunstrom, J. M., & Rogers, P. J. (2010). Cognitive biases to healthy and unhealthy food words predict change in BMI. *Obesity, 18*(12), 2282-2287.

Cano, M. E., Class, Q. A., & Polich, J. (2009). Affective valence, stimulus attributes, and P300: color vs. black/white and normal vs. scrambled images. *International Journal of Psychophysiology, 71*(1), 17-24.

Carver, C. S., & White, T. L. (1994). Behavioral inhibition, behavioral activation, and affective responses to impending reward and punishment: the BIS/BAS scales. *Journal of Personality and Social Psychology, 67*(2), 319.

Castellanos, E. H., Charboneau, E., Dietrich, M. S., Park, S., Bradley, B. P., Mogg, K., & Cowan, R. L. (2009). Obese adults have visual attention bias for food cue images: evidence for altered reward system function. *International Journal of Obesity, 33*(9), 1063-1073.

Cañal-Bruland, R., & Van Der Kamp, J. (2015). Embodied perception: A proposal to reconcile affordance and spatial perception*. i-Perception, 6*(2), 63-66.

Cano, M. E., Class, Q. A., & Polich, J. (2009). Affective valence, stimulus attributes, and P300: color vs. black/white and normal vs. scrambled images. *International Journal of Psychophysiology, 71*(1), 17-24.

Ceylan, M., Z Aydinoglu, N., & G Morwitz, V. (2020). Embarrassed By Calories: Joint Effect of Calorie Posting and Social Context. *ACR North American Advances, 48*, 266-268.

Chen, Z., Veling, H., Dijksterhuis, A., & Holland, R. W. (2018). Do impulsive individuals benefit more from food go/no-go training? Testing the role of inhibition capacity in the no-go devaluation effect. *Appetite, 124*, 99-110.

Chen, L., Wu, B., Qiao, C., & Liu, D. Q. (2020). Resting EEG in alpha band predicts individual differences in visual size perception. *Brain and Cognition, 145*.

Chokron, S., & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research, 10*(1-2), 45-49.

Chuang, C. W. I., Sussman, S., Stone, M. D., Pang, R. D., Chou, C. P., Leventhal, A. M., & Kirkpatrick, M. G. (2017). Impulsivity and history of behavioral addictions are associated with drug use in adolescents. *Addictive Behaviors, 74*, 41-47.

Coan, J. A., & Allen, J. J. (2003). Frontal EEG asymmetry and the behavioral activation and inhibition systems. *Psychophysiology, 40*(1), 106-114.

Collier, E. S. (2018). The illusion of action-specific scaling effects: action capacity does not directly influence spatial perception, The University of Liverpool

Collier, E. S., & Lawson, R. (2017). Does grasping capacity influence object size estimates? It depends on the context. *Attention, Perception, & Psychophysics, 79*(7), 2117-2131

Collier, E. S., & Lawson, R. (2018). Getting a grasp on action-specific scaling: A response to Witt (2017). *Psychonomic Bulletin & Review*, 1-11.

Cole, S., Riccio, M., & Balcetis, E. (2014). Focused and fired up: Narrowed attention produces perceived proximity and increases goal-relevant action. *Motivation and Emotion, 38*(6), 815-822.

Cortina, J. M. (1993). What is coefficient alpha? An examination of theory and applications. *Journal of Applied Psychology, 78*(1), 98.

Cunningham, W. A., Espinet, S. D., DeYoung, C. G., & Zelazo, P. D. (2005). Attitudes to the right-and left: frontal ERP asymmetries associated with stimulus valence and processing goals. *NeuroImage, 28*(4), 827-834.

Cyders, M. A., Littlefield, A. K., Coffey, S., & Karyadi, K. A. (2014). Examination of a short English version of the UPPS-P Impulsive Behavior Scale. *Addictive Behaviors, 39*(9), 1372-1376.

Dahle, J. H., Ostendorf, D. M., Zaman, A., Pan, Z., Melanson, E. L., & Catenacci, V. A. (2021). Underreporting of energy intake in weight loss maintainers. *The American Journal of Clinical Nutrition*.

Dalle Grave, R. (2020). Regular eating, not intermittent fasting, is the best strategy for a healthy eating control. *Italian Journal of Eating Disorders and Obesity.*

Davis, C. (2014). Evolutionary and neuropsychological perspectives on addictive behaviors and addictive substances: relevance to the “food addiction” construct. *Substance Abuse and Rehabilitation, 5*, 129.

Davis, C., Patte, K., Levitan, R., Reid, C., Tweed, S., & Curtis, C. (2007). From motivation to behaviour: a model of reward sensitivity, overeating, and food preferences in the risk profile for obesity. *Appetite, 48*(1), 12-19.

de Haas, B., Schwarzkopf, D. S., & Rees, G. (2016). Attention and multisensory modulation argue against total encapsulation. *Behavioral and Brain Sciences*.

de Lauzon, B., Romon, M., Deschamps, V., Lafay, L., Borys, J., Karlsson, J., Ducimetière, P., Charles, M.A. (2004) The Three-Factor Eating Questionnaire-R18 is able to distinguish among different eating patterns in a general population. *The Journal of Nutrition, 134*(9), 2372-2380.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience, 18*(1), 193-222.

Dickinson, A., & McClinchy, J. (2011). I would be embarrassed for you to see what I eat: Older people rejecting the visual?. *Gerontologist*.

Duckworth, A. L., & Kern, M. L. (2011). A meta-analysis of the convergent validity of self-control measures. *Journal of Research in {ersonality, 45*(3), 259-268.

Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review, 16*(5), 964-969.

Egeth, H. E., & Yantis, S. (1997). Visual attention: Control, representation, and time course. *Annual Review of Psychology, 48*(1), 269-297.

Eves, F. F., Thorpe, S. K., Lewis, A., & Taylor-Covill, G. A. (2014). Does perceived steepness deter stair climbing when an alternative is available?. *Psychonomic Bulletin & Review, 21*(3), 637-644.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A. G. (2009). Statistical power analyses using G* Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods, 41*(4), 1149-1160.

Firestone, C. (2013). How “paternalistic” is spatial perception? Why wearing a heavy backpack doesn’t—and couldn’t—make hills look steeper. *Perspectives on Psychological Science, 8*(4), 455-473.

Firestone, C., & Scholl, B. J. (2014). “Top-down” effects where none should be found: The El Greco fallacy in perception research. *Psychological Science, 25*(1), 38-46.

Firestone, C., & Scholl, B. J. (2016). Cognition does not affect perception: Evaluating the evidence for “top-down” effects. *Behavioral and Brain Sciences, 39*.

Fishbach, A., & Shen, L. (2014). The explicit and implicit ways of overcoming temptation*. Dual Process Theories in the Social Mind*, 454-467.

Fitzner, K., & Heckinger, E. (2010). Sample size calculation and power analysis: a quick review. *The Diabetes Educator, 36*(5), 701-707.

Fock, K. M., & Khoo, J. (2013). Diet and exercise in management of obesity and overweight. *Journal of Gastroenterology and Hepatology, 28*, 59-63.

Fodor, J. A. (1983). *The Modularity of Mind*. MIT press.

Folstein, J. R., & Van Petten, C. (2008). Influence of cognitive control and mismatch on the N2 component of the ERP: a review. *Psychophysiology, 45*(1), 152-170.

Forcano, L., Castellano, M., Cuenca-Royo, A., Goday-Arno, A., Pastor, A., Langohr, K., ... & de la Torre, R. (2020). Prefrontal Cortex Neuromodulation Enhances Frontal Asymmetry and Reduces Caloric Intake in Patients with Morbid Obesity. *Obesity, 28*(4), 696-705.

Foroni, F., Pergola, G., Argiris, G., & Rumiati, R. I. (2013). The FoodCast research image database (FRIDa). *Frontiers in Human Neuroscience, 7*, 51.

Fox, S., & Hammond, S. (2017). Investigating the multivariate relationship between impulsivity and psychopathy using canonical correlation analysis. *Personality and Individual Differences, 111*, 187-192.

Franz, V. H., Gegenfurtner, K. R., Buelthoff, H. H., & Fahle, M. (2000). Grasping visual illusions: No evidence for a dissociation between perception and action. *Psychological Science, 11* (1), 20-25.

Franz, V. H. (2001). Action does not resist visual illusions. *Trends in Cognitive Sciences, 5* (11), 457-459.

Gable, P. A., & Harmon-Jones, E. (2008). Approach-motivated positive affect reduces breadth of attention. *Psychological Science, 19*(5), 476-482.

Gable, P. A., & Harmon-Jones, E. (2010). Late positive potential to appetitive stimuli and local attentional bias. *Emotion, 10*(3), 441.

Gajewski, P. D., & Falkenstein, M. (2013). Effects of task complexity on ERP components in Go/Nogo tasks. *International Journal of Psychophysiology, 87*(3), 273-278.

Galin, D., Ornstein, R., Herron, J., & Johnstone, J. (1982). Sex and handedness differences in EEG measures of hemispheric specialization. *Brain and Language, 16*(1), 19-55.

George, D., & Mallery, P. (2003). *SPSS for Windows—Step by Step: A Simple Guide and Reference. 11.0 Update* (4th ed.). Boston, MA: Allyn & Bacon.

Gibson, J. J. (2014). The theory of affordances (1979). *In The People, Place, and Space Reader* (pp. 90-94). Routledge.

Goldstone, R. L. (1995). Effects of categorization on color perception. *Psychological Science, 6*(5), 298-304.

Goldstone, A. P., Prechtl de Hernandez, C. G., Beaver, J. D., Muhammed, K., Croese, C., Bell, G., ... & Bell, J. D. (2009). Fasting biases brain reward systems towards high-calorie foods. *European Journal of Neuroscience, 30*(8), 1625-1635.

Goodale, M. A., Milner, A. D., Jakobson, L. S., & Carey, D. P. (1991). A neurological dissociation between perceiving objects and grasping them. *Nature, 349*(6305), 154-156.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences, 15*(1), 20-25.

Goodale, M., & Wolf, M. (2009). In D. Dedrick, & L. Trick (Eds.), *Computation, Cognition, and Pylyshyn* (pp. 101 – 137). Cambridge, Massachusetts: MIT Press.

Gough, T., Christiansen, P., Rose, A. K., & Hardman, C. A. (2021). The effect of alcohol on food-related attentional bias, food reward and intake: Two experimental studies. *Appetite, 162*, 105173.

Gregory, R. L. (1970). *The intelligent Eye*. New York: McGraw-Hill.

Guerrieri, R., Nederkoorn, C., Stankiewicz, K., Alberts, H., Geschwind, N., Martijn, C., & Jansen, A. (2007). The influence of trait and induced state impulsivity on food intake in normal-weight healthy women. *Appetite, 49*(1), 66-73.

Guzek, D., Skolmowska, D., & Głąbska, D. (2021). Associations between Food Preferences, Food Approach, and Food Avoidance in a Polish Adolescents' COVID-19 Experience (PLACE-19) Study Population. *Nutrients, 13*(7), 2427.

Hajcak, G., Weinberg, A., MacNamara, A., & Foti, D. (2012). *ERPs and the study of emotion*. In S. J. Luck & E. S. Kappenman (Eds.), The Oxford handbook of event-related potential components (pp. 441–472). Oxford University Press.

Halali, F., Lapveteläinen, A., Karhunen, L., & Kantanen, T. (2020). Eating behavior tendencies among Finnish adults in relation to previous weight loss attempts. *Appetite, 150*, 104650.

Harmon-Jones, E., & Allen, J. J. (1997). Behavioral activation sensitivity and resting frontal EEG asymmetry: Covariation of putative indicators related to risk for mood disorders. *Journal of Abnormal Psychology, 106*(1), 159.

Harmon-Jones, E., & Gable, P. A. (2018). On the role of asymmetric frontal cortical activity in approach and withdrawal motivation: An updated review of the evidence. *Psychophysiology, 55*(1).

Hetherington, M. M., & Regan, M. F. (2011). Effects of chewing gum on short-term appetite regulation in moderately restrained eaters. *Appetite, 57*(2), 475-482.

Hofmann, W., Friese, M., & Strack, F. (2009). Impulse and self-control from a dual-systems perspective. *Perspectives on Psychological Science, 4*(2), 162-176.

Houben, K., & Jansen, A. (2011). Training inhibitory control. A recipe for resisting sweet temptations. *Appetite, 56*(2), 345-349.

Hsieh, P. J., Vul, E., & Kanwisher, N. (2010). Recognition alters the spatial pattern of FMRI activation in early retinotopic cortex. *Journal of Neurophysiology, 103*(3), 1501-1507.

Huang, L., & Lu, J. (2016). The impact of package color and the nutrition content labels on the perception of food healthiness and purchase intention. *Journal of Food Products Marketing, 22*(2), 191-218.

Hunot, C., Fildes, A., Croker, H., Llewellyn, C. H., Wardle, J., & Beeken, R. J. (2016). Appetitive traits and relationships with BMI in adults: Development of the Adult Eating Behaviour Questionnaire. *Appetite, 105*, 356-363.

Huster, R. J., Enriquez-Geppert, S., Lavallee, C. F., Falkenstein, M., & Herrmann, C. S. (2013). Electroencephalography of response inhibition tasks: functional networks and cognitive contributions. *International Journal of Psychophysiology, 87*(3), 217-233.

İşeri, A., & Arslan, N. (2009). Obesity in adults in Turkey: age and regional effects. The European *Journal of Public Health, 19*(1), 91-94.

Ishak, S., Adolph, K. E., & Lin, G. C. (2008). Perceiving affordances for fitting through apertures. *Journal of Experimental Psychology: Human Perception and Performance, 34*(6), 1501.

Jeannerod, M., Decety, J., & Michel, F. (1994). Impairment of grasping movements following a bilateral posterior parietal lesion. *Neuropsychologia, 32*(4), 369-380.

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics, 43*(4), 346-354.

Kanter, R., & Caballero, B. (2012). Global gender disparities in obesity: a review. *Advances in Nutrition, 3*(4), 491-498.

Kantono, K., Hamid, N., Shepherd, D., Yoo, M. J., Carr, B. T., & Grazioli, G. (2016). The effect of background music on food pleasantness ratings. *Psychology of Music, 44*(5), 1111-1125.

Karlsson, J., Persson, L. O., Sjöström, L., & Sullivan, M. (2000). Psychometric properties and factor structure of the Three-Factor Eating Questionnaire (TFEQ) in obese men and women. Results from the Swedish Obese Subjects (SOS) study. *International journal of obesity, 24*(12), 1715-1725.

Kirsch, W., Heitling, B., & Kunde, W. (2018). Changes in the size of attentional focus modulate the apparent object's size. *Vision Research, 153*, 82-90.

Kirsch, W., Kitzmann, T., & Kunde, W. (2021). Action affects perception through modulation of attention. *Attention, Perception, & Psychophysics*, 1-11.

Kissileff, H. R., Brunstrom, J. M., Tesser, R., Bellace, D., Berthod, S., Thornton, J. C., & Halmi, K. (2016). Computerized measurement of anticipated anxiety from eating increasing portions of food in adolescents with and without anorexia nervosa: Pilot studies. *Appetite, 97*, 160-168.

Krause, B., & Cohen Kadosh, R. (2014). Not all brains are created equal: the relevance of individual differences in responsiveness to transcranial electrical stimulation. *Frontiers in Systems Neuroscience, 8*, 25.

Króliczak, G., Heard, P., Goodale, M. A., & Gregory, R. L. (2006). Dissociation of perception and action unmasked by the hollow-face illusion. *Brain Research, 1080*(1), 9-16.

Lambert, K. G., Neal, T., Noyes, J., Parker, C., & Worrel, P. (1991). Food-related stimuli increase desire to eat in hungry and satiated human subjects. *Current Psychology, 10*(4), 297-303.

Lapenta, O. M., Di Sierve, K., de Macedo, E. C., Fregni, F., & Boggio, P. S. (2014). Transcranial direct current stimulation modulates ERP-indexed inhibitory control and reduces food consumption. *Appetite, 83*, 42-48.

Lee, M. D., & Wagenmakers, E. J. (2014). *Bayesian cognitive modeling: A practical course*. Cambridge university press.

Lin, Q., Rieser, J. J., & Bodenheimer, B. (2013). Stepping off a ledge in an HMD-based immersive virtual environment. *In Proceedings of the ACM Symposium on Applied Perception*. 107-110).

Littel, M., Euser, A. S., Munafò, M. R., & Franken, I. H. (2012). Electrophysiological indices of biased cognitive processing of substance-related cues: a meta-analysis. *Neuroscience & Biobehavioral Reviews, 36*(8), 1803-1816.

Little, R. J. (1988). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association, 83*(404), 1198-1202.

Lloyd, E. C., & Steinglass, J. E. (2018). What can food-image tasks teach us about anorexia nervosa? A systematic review. *Journal of Eating Disorders, 6*(1), 31.

Loxton, N. J. (2018). The role of reward sensitivity and impulsivity in overeating and food addiction. *Current Addiction Reports, 5*(2), 212-222.

Luck, S. J. (2005). *Ten simple rules for designing ERP experiments. Event-related Potentials: A Methods Handbook*, MIT Press.

Luck, S. J. (2014). *An introduction to the event-related potential technique*. MIT press.

Liu, Y., Zhao, J., Zhang, X., Gao, X., Xu, W., & Chen, H. (2019). Overweight adults are more impulsive than normal weight adults: Evidence from ERPs during a chocolate-related delayed discounting task. *Neuropsychologia, 133*, 107181.

Maillet, D., Yu, L., Hasher, L., & Grady, C. L. (2020). Age-related differences in the impact of mind-wandering and visual distraction on performance in a go/no-go task. *Psychology and Aging, 35*(5), 627.

Maneiro, L., Gómez-Fraguela, J. A., Cutrín, O., & Romero, E. (2017). Impulsivity traits as correlates of antisocial behaviour in adolescents. *Personality and Individual Differences, 104*, 417-422.

Martin, L. E., Holsen, L. M., Chambers, R. J., Bruce, A. S., Brooks, W. M., Zarcone, J. R., Butler, M. G., & Savage, C. R. (2010). Neural mechanisms associated with food motivation in obese and healthy weight adults. *Obesity, 18*(2), 254-260.

Marty, L., Jones, A., & Robinson, E. (2020). Socioeconomic position and the impact of increasing availability of lower energy meals vs. menu energy labelling on food choice: two randomized controlled trials in a virtual fast-food restaurant. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), 1-11.

Massicotte, E., Deschênes, S. M., & Jackson, P. L. (2019). Food craving predicts the consumption of highly palatable food but not bland food. *Eating and Weight Disorders-Studies on Anorexia, Bulimia and Obesity*, 1-12.

May, C. N., Juergensen, J., & Demaree, H. A. (2016). Yum, cake!: How reward sensitivity relates to automatic approach motivation for dessert food images. *Personality and Individual Differences, 90*, 265-268.

McGeown, L., & Davis, R. (2018). Frontal EEG asymmetry moderates the association between attentional bias towards food and body mass index. *Biological Psychology, 136*, 151-160.

Melanson, K. J., & Kresge, D. L. (2017). Chewing gum decreases energy intake at lunch following a controlled breakfast. *Appetite, 118*, 1-7.

Milner, A. D., & Goodale, M. A. (1995). *The visual brain in action*. Oxford, England: Oxford University Press.

Milos, G., Kuenzli, C., Soelch, C. M., Schumacher, S., Moergeli, H., & Mueller-Pfeiffer, C. (2013). How much should I eat? Estimation of meal portions in anorexia nervosa. *Appetite, 63*, 42-47.

Munk, A. J., Schmidt, N. M., & Hennig, J. (2020). Motivational salience, impulsivity and testosterone in free cycling women: An ERP-Study. *Personality and Individual Differences, 160*, 109902.

Nederkoorn, C., Braet, C., Van Eijs, Y., Tanghe, A., & Jansen, A. (2006). Why obese children cannot resist food: the role of impulsivity. *Eating Behaviors, 7*(4), 315-322.

Nichelle, P. G., Almeida, C. C., Camey, S. A., Garmus, L. M., Elias, V., Marchioni, D. M., da Silva, D. G., Ocke, M. C., Slimani, N., Fisberg, R. M., & Crispim, S. P. (2019). Subjects' Perception in Quantifying Printed and Digital Photos of Food Portions. *Nutrients, 11*(3), 501.

Nichols, A. L., & Maner, J. K. (2008). The good-subject effect: Investigating participant demand characteristics. *The Journal of General Psychology, 135*(2), 151-166.

Nijs, I. M., Franken, I. H., & Muris, P. (2008). Food cue-elicited brain potentials in obese and healthy-weight individuals. *Eating Behaviors, 9*(4), 462-470.

Ochner, C. N., Green, D., van Steenburgh, J. J., Kounios, J., & Lowe, M. R. (2009). Asymmetric prefrontal cortex activation in relation to markers of overeating in obese humans. *Appetite, 53*(1), 44-49.

Ogilvie, R., & Carruthers, P. (2016). Opening up vision: The case against encapsulation. *Review of Philosophy and Psychology, 7*(4), 721-742.

Orne, M. T. (1962). On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. *American Psychologist, 17*(11), 776.

Pacheco-Colón, I., Lopez-Quintero, C., Coxe, S., Limia, J. M., Pulido, W., Granja, K., & Gonzalez, R. (2021). Risky decision-making as an antecedent or consequence of adolescent cannabis use: findings from a 2-year longitudinal study. *Addiction*.

Patla, A. E., & Goodale, M. A. (1996). Obstacle avoidance during locomotion is unaffected in a patient with visual form agnosia. *NeuroReport, 8*(1), 165-168.

Patton, J. H., Stanford, M. S., & Barratt, E. S. (1995). Factor structure of the Barratt impulsiveness scale. *Journal of Clinical Psychology, 51*(6), 768-774.

Perenin, M. T., & Vighetto, A. (1988). Optic ataxia: A specific disruption in visuomotor mechanisms: I. Different aspects of the deficit in reaching for objects. *Brain, 111*(3), 643-674.

Philbeck, J. W., & Witt, J. K. (2015). Action-specific influences on perception and postperceptual processes: Present controversies and future directions. *Psychological Bulletin, 141*(6), 1120.

Piqueras-Fiszman, B., Alcaide, J., Roura, E., & Spence, C. (2012). Is it the plate or is it the food? Assessing the influence of the color (black or white) and shape of the plate on the perception of the food placed on it. *Food Quality and Preference, 24*(1), 205-208.

Polich, J. (2007). Updating P300: an integrative theory of P3a and P3b. *Clinical Neurophysiology, 118*(10), 2128-2148.

Popien, A., Frayn, M., von Ranson, K. M., & Sears, C. R. (2015). Eye gaze tracking reveals heightened attention to food in adults with binge eating when viewing images of real-world scenes. *Appetite, 91*, 233-240.

Proffitt, D. R. (2008). An action-specific approach to spatial perception. *Embodiment, Rgo-space, and Action*, 179-202.

Linkenauger, S. A., Witt, J. K., & Proffitt, D. R. (2011). Taking a hands-on approach: apparent grasping ability scales the perception of object size. *Journal of Experimental Psychology: Human Perception and Performance, 37*(5), 1432.

Proffitt, D. R., & Linkenauger, S. A. (2013). Perception viewed as a phenotypic expression. *Action science: Foundations of an Emerging Discipline*, 171.

Pylyshyn, Z. W. (1980). Cognitive representation and the process-architecture distinction: Cognitive representation and the process-architecture distinction. *Behavioral and Brain Sciences, 3*(1), 154-169.

Pylyshyn, Z. (1999). Is vision continuous with cognition?: The case for cognitive impenetrability of visual perception. *Behavioral and Brain Sciences, 22*(3), 341-365.

Quilty, L. C., & Oakman, J. M. (2004). The assessment of behavioural activation—the relationship between impulsivity and behavioural activation. *Personality and Individual Differences, 37*(2), 429-442.

Raaijmakers, Q. A. (1999). Effectiveness of different missing data treatments in surveys with Likert-type data: Introducing the relative mean substitution approach. *Educational and Psychological Measurement, 59*(5), 725-748.

Ralph-Nearman, C., Achee, M., Lapidus, R., Stewart, J. L., & Filik, R. (2019). A systematic and methodological review of attentional biases in eating disorders: Food, body, and perfectionism. *Brain and Behavior, 9*(12).

Ratner, B. (2009). The correlation coefficient: Its values range between+ 1/− 1, or do they?. *Journal of Targeting, Measurement and Analysis for Marketing, 17*(2), 139-142.

Rauss, K., Schwartz, S., & Pourtois, G. (2011). Top-down effects on early visual processing in humans: A predictive coding framework. *Neuroscience & Biobehavioral Reviews, 35*(5), 1237-1253.

Rolls, B. J. (1986). Sensory-specific satiety. *Nutrition Reviews (USA), 44*(3), 93-101.

Rydkjaer, J., Jepsen, J. M., Pagsberg, A. K., Fagerlund, B., Glenthøj, B. Y., & Oranje, B. (2017). Mismatch negativity and P3a amplitude in young adolescents with first-episode psychosis: a comparison with ADHD. *Psychological Medicine, 47*(2), 377.

Sainani, K. L. (2015). Dealing with missing data. *PM&R, 7*(9), 990-994.

Sänger, J. (2019). Can't take my eyes off you–How task irrelevant pictures of food influence attentional selection. *Appetite, 133*, 313-323.

Sarlo, M., Übel, S., Leutgeb, V., & Schienle, A. (2013). Cognitive reappraisal fails when attempting to reduce the appetitive value of food: an ERP study. *Biological Psychology, 94*(3), 507-512.

Saxton, T. K., McCarty, K., Caizley, J., McCarrick, D., & Pollet, T. V. (2020). Hungry people prefer larger bodies and objects: The importance of testing boundary effects. *British Journal of Psychology, 111*(3), 492-507.

Schag, K., Schönleber, J., Teufel, M., Zipfel, S., & Giel, K. E. (2013). Food-related impulsivity in obesity and Binge Eating Disorder–a systematic review. *Obesity Reviews, 14*(6), 477-495.

Schmidt, J., & Martin, A. (2015). Neurofeedback reduces overeating episodes in female restrained eaters: A randomized controlled pilot-study*. Applied Psychophysiology and Biofeedback, 40*(4), 283-295.

Schnall, S., Zadra, J. R., & Proffitt, D. R. (2010). Direct evidence for the economy of action: Glucose and the perception of geographical slant. *Perception, 39*(4), 464-482.

Sekuler, R., & Sekuler, A. B. R Lau (1997)" Sound alters visual motion perception. *Nature, 385*(6614), 308.

Semlitsch, H. V., Anderer, P., Schuster, P., & Presslich, O. (1986). A solution for reliable and valid reduction of ocular artifacts, applied to the P300 ERP. *Psychophysiology, 23*(6), 695-703.

Sharma, L., Markon, K. E., & Clark, L. A. (2014). Toward a theory of distinct types of “impulsive” behaviors: a meta-analysis of self-report and behavioral measures. *Psychological Bulletin, 140*(2), 374.

Smith, E. E., Reznik, S. J., Stewart, J. L., & Allen, J. J. (2017). Assessing and conceptualizing frontal EEG asymmetry: An updated primer on recording, processing, analyzing, and interpreting frontal alpha asymmetry. *International Journal of Psychophysiology, 111*, 98-114.

Smith, K. E., Lavender, J. M., Leventhal, A. M., & Mason, T. B. (2021). Facets of Impulsivity in Relation to Diet Quality and Physical Activity in Adolescence. *International Journal of Environmental Research and Public Health, 18*(2), 613.

Spieker, E. A. (2013). *Retraining Attentional Bias to Unhealthy Food Cues*. Uniformed Services University Of The Health Sciences. Bethesda: United States.

Stasi, A., Songa, G., Mauri, M., Ciceri, A., Diotallevi, F., Nardone, G., & Russo, V. (2018). Neuromarketing empirical approaches and food choice: A systematic review. *Food Research International, 108*, 650-664.

Stefanucci, J. K., & Geuss, M. N. (2009). Big people, little world: The body influences size perception. *Perception, 38*(12), 1782-1795.

Stice, E., Palmrose, C. A., & Burger, K. S. (2015). Elevated BMI and male sex are associated with greater underreporting of caloric intake as assessed by doubly labeled water. *The Journal of Nutrition, 145*(10), 2412-2418.

Stockburger, J., Schmälzle, R., Flaisch, T., Bublatzky, F., & Schupp, H. T. (2009). The impact of hunger on food cue processing: an event-related brain potential study. *Neuroimage, 47*(4), 1819-1829.

Stormark, K. M., & Torkildsen, Ø. (2004). Selective processing of linguistic and pictorial food stimuli in females with anorexia and bulimia nervosa. *Eating Behaviors, 5*(1), 27-33.

Stroebe, W., Mensink, W., Aarts, H., Schut, H., & Kruglanski, A. W. (2008). Why dieters fail: Testing the goal conflict model of eating. *Journal of Experimental Social Psychology, 44*(1), 26-36.

Sugovic, M., Turk, P., & Witt, J. K. (2016). Perceived distance and obesity: It's what you weigh, not what you think. *Acta Psychologica, 165*, 1-8.

Tan, S. T., Tan, S. S., & Tan, C. X. (2021). Screen time-based sedentary behaviour, eating regulation and weight status of university students during the COVID-19 lockdown. *Nutrition & Food Science*.

Tang, Q., Jin, G., Wang, G., Liu, T., Liu, X., Wang, B., & Cao, H. (2020). Current sampling methods for gut microbiota: a call for more precise devices. *Frontiers in Cellular and Infection Microbiology, 10*, 151.

Tanofsky-Kraff, M., Ranzenhofer, L. M., Yanovski, S. Z., Schvey, N. A., Faith, M., Gustafson, J., & Yanovski, J. A. (2008). Psychometric properties of a new questionnaire to assess eating in the absence of hunger in children and adolescents. *Appetite, 51*(1), 148-155.

Teslovich, T., Freidl, E. K., Kostro, K., Weigel, J., Davidow, J. Y., Riddle, M. C., & Casey, B. J. (2014). Probing behavioral responses to food: development of a food-specific go/No-Go task. *Psychiatry Research, 219*(1), 166-170.

Thaler, L., Schütz, A. C., Goodale, M. A., & Gegenfurtner, K. R. (2013). What is the best fixation target? The effect of target shape on stability of fixational eye movements. *Vision Research, 76*, 31-42.

To, C., Falcone, M., Loughead, J., Logue-Chamberlain, E., Hamilton, R., Kable, J., ... & Ashare, R. L. (2018). Got chocolate? bilateral prefrontal cortex stimulation augments chocolate consumption. *Appetite, 131*, 28-35.

Townsend, J., & Courchesne, E. (1994). Parietal damage and narrow “spotlight” spatial attention. *Journal of Cognitive Neuroscience, 6*(3), 220-232.

Tzavella, L., Lawrence, N. S., Button, K. S., Hart, E. A., Holmes, N. M., Houghton, K., ... & Adams, R. C. (2021). Effects of go/no-go training on food-related action tendencies, liking and choice. *Royal Society Open Science, 8*(8).

Ungerleider, L.G., & Mishkin, M., (1982). In D. J. Ingle, M. A. Goodale, & R. J. Mansfield (Eds.), *Analysis of Visual Behaviour* (pp. 549 - 586). Cambridge, Massachusetts: MIT Press.

van Herpen, E., van den Broek, E., van Trijp, H. C., & Yu, T. (2016). Can a virtual supermarket bring realism into the lab? Comparing shopping behavior using virtual and pictorial store representations to behavior in a physical store. *Appetite, 107*, 196-207.

van Kleef, E., Kavvouris, C., & van Trijp, H. C. (2014). The unit size effect of indulgent food: How eating smaller sized items signals impulsivity and makes consumers eat less. *Psychology & Health, 29*(9), 1081-1103.

van Koningsbruggen, G. M., Stroebe, W., & Aarts, H. (2011). Through the eyes of dieters: Biased size perception of food following tempting food primes. *Journal of Experimental Social Psychology, 47*(2), 293-299.

van Strien, T., Frijters, J. E., Bergers, G. P., & Defares, P. B. (1986). The Dutch Eating Behavior Questionnaire (DEBQ) for assessment of restrained, emotional, and external eating behavior. *International Journal of Eating Disorders, 5*(2), 295-315.

Vuilleumier, P. (2005). How brains beware: neural mechanisms of emotional attention. *Trends in Cognitive Sciences, 9*(12), 585-594.

Swanston, M. T., & Wade, N. J. (2013). Visual perception: An introduction. *Psychology Press*.

Ward, E. J., & Scholl, B. J. (2015). Inattentional blindness reflects limitations on perception, not memory: Evidence from repeated failures of awareness. *Psychonomic Bulletin & Review, 22*(3), 722-727.

Waterlander, W. E., Scarpa, M., Lentz, D., & Steenhuis, I. H. (2011). The virtual supermarket: an innovative research tool to study consumer food purchasing behaviour. *BMC Public Health, 11*(1), 1-10.

Watson, T. D., & Garvey, K. T. (2013). Neurocognitive correlates of processing food-related stimuli in a Go/No-Go paradigm. *Appetite, 71*, 40-47.

Werthmann, J., Jansen, A., & Roefs, A. (2015). Worry or craving? A selective review of evidence for food-related attention biases in obese individuals, eating-disorder patients, restrained eaters and healthy samples. *Proceedings of the Nutrition Society, 74*(2), 99-114.

Williams, P. T., & Satariano, W. A. (2005). Relationships of age and weekly running distance to BMI and circumferences in 41, 582 physically active women. *Obesity Research, 13*(8), 1370-1380.

Witt, J. K. (2017). A role for control in an action-specific effect on perception. *Journal of Experimental Psychology: Human Perception and Performance, 43*(10), 1791.

Witt, J. K. (2017). Action potential influences spatial perception: Evidence for genuine top-down effects on perception. *Psychonomic Bulletin & Review, 24*(4), 999-1021.

Witt, J. K., Proffitt, D. R., & Epstein, W. (2005). Tool use affects perceived distance, but only when you intend to use it. *Journal of experimental psychology: Human Perception and Performance, 31*(5), 880.

Witt, J. K., & Dorsch, T. E. (2009). Kicking to bigger uprights: Field goal kicking performance influences perceived size. *Perception, 38*(9), 1328-1340.

Witt, J. K., Proffitt, D. R., & Epstein, W. (2004). Perceiving distance: A role of effort and intent. *Perception, 33*(5), 577-590.

Witt, J. K., Sugovic, M., Tenhundfeld, N. T., & King, Z. R. (2016). An action-specific effect on perception that avoids all pitfalls*. Behavioral and Brain Sciences, 39*.

Witt, J. K. (2017). A role for control in an action-specific effect on perception. *Journal of Experimental Psychology: Human Perception and Performance, 43*(10), 1791.

Witt, J. K. (2017). Action potential influences spatial perception: Evidence for genuine top-down effects on perception. *Psychonomic Bulletin & Review, 24*(4), 999-1021.

Woldegiorgis, B. H., Lin, C. J., & Liang, W. Z. (2019). Impact of parallax and interpupillary distance on size judgment performances of virtual objects in stereoscopic displays. *Ergonomics, 62*(1), 76-87.

Wolz, I., Sauvaget, A., Granero, R., Mestre-Bach, G., Baño, M., Martín-Romera, V., ... & Fernández-Aranda, F. (2017). Subjective craving and event-related brain response to olfactory and visual chocolate cues in binge-eating and healthy individuals. *Scientific Reports, 7*(1), 1-10.

Woolhouse, H., Knowles, A., & Crafti, N. (2012). Adding mindfulness to CBT programs for binge eating: a mixed-methods evaluation. *Eating Disorders, 20*(4), 321-339.

Wöstmann, N. M., Aichert, D. S., Costa, A., Rubia, K., Möller, H. J., & Ettinger, U. (2013). Reliability and plasticity of response inhibition and interference control. *Brain and Cognition, 81*(1), 82-94.

Yellowlees, P. M., Roe, M., Walker, M. K., & Ben-Tovim, D. I. (1988). Abnormal perception of food size in anorexia nervosa. *British Medical Journal (Clinical Research Ed), 296*(6638), 1689-1690.

Zhou, Q., Hagemann, G., Fafard, D., Stavness, I., & Fels, S. (2019). An Evaluation of Depth and Size Perception on a Spherical Fish Tank Virtual Reality Display. *IEEE Transactions on Visualization and Computer Graphics, 25*(5), 2040 – 2049.

Zoltak, M. J., Veling, H., Chen, Z., & Holland, R. W. (2018). Attention! Can choices for low value food over high value food be trained?. *Appetite, 124*, 124-132.

Appendix

Each participant’s reported hypothesis guess for the experiment in Chapter 2.

Participant Number	**Reported suspected Hypothesis**	**Guessed Hypothesis?**
1	“Unsure”.	No. No guess supplied.
2	“I don’t know”.	No. No guess supplied.
3	“Perceived object size will change relative to appetite”.	No. The hypotheses concerned food objects being perceived as larger or smaller while fasting compared to non-food object – not objects in general.
4	“Perception of size changes being on an empty stomach versus just eating”.	No. The hypotheses concerned food objects being perceived as larger or smaller while fasting compared to non-food object – not objects in general.
5	“Actual size estimation difference between accuracy of first part [fasted] and second part of the study [satiated]”.	No. It was hypothesised that there would be no difference in satiation conditions in the Actual Size Estimation Task.
6	“People change their view due to if they were eaten or not”.	No. First it is unclear if they are referring to size perception. Although, if they are, the hypotheses concerned food objects being perceived as larger or smaller while fasting compared to non-food object – not objects in general. Also, no food was actually eaten in this study.
7	“I don’t know”.	No. No guess supplied.
8	“Hunger will impact size perception – I don’t know how though”.	No. The hypotheses concerned food objects being perceived as larger or smaller while fasting compared to non-food object – not objects in general.

9	“If we are hungry, maybe we over-estimate the size of food and inedible objects”.	No. It was predicted that only food objects would differ significantly.
10	“Brain functions differently with or without food”.	No. There was no prediction regarding brain functions or neural activity.
11	“Higher estimations when hungry”.	No. It was hypothesised that only scaled food size would be significantly different following fasting. No difference in estimations was predicted.
12	“Hunger change how we perceive size?”.	No. It was hypothesised that fasting would only effect the size that food items are perceived to be.
13	“You will perform better in activities if you eat breakfast or not”.	No. The hypotheses concerned food objects being perceived as larger or smaller while fasting – not general accuracy regardless of object type.
14	“In estimation task, people will over-estimate the size of objects when hungry”.	No. The hypotheses predicted no significant difference in food objects between satiety conditions in the estimation task.
15	“Visual perception will be affected by a person’s hunger”.	No. The hypotheses concerned food objects (but not non-food objects) being perceived as larger or smaller while fasting – not objects in general.
16	“Results will demonstrate how objective and realistic a person is”.	No. The hypotheses concerned food objects (but not non-food objects) being perceived as larger or smaller while fasting – not objects in general.
17	“Food consumption of food at certain times of day would affect view of items”.	No. The hypotheses concerned food objects (but not non-food objects) being perceived as larger or smaller while fasting – not objects in general.

18	“If eating affect size; no breakfast you might find people under-estimate size”.	No. The hypotheses concerned food objects (but not non-food objects) being perceived as larger or smaller while fasting – not objects in general.
19	“We will see how we perceive food size”.	No. The hypotheses concerned food objects (but not non-food objects) being perceived as larger or smaller while fasting – not objects in general.
20	“People will view things differently depending on how hungry they are”.	No. The hypotheses concerned food objects (but not non-food objects) being perceived as larger or smaller while fasting – not objects in general.

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“I’m just getting started, it’s true that I dare,

This isn’t the end, you ain’t seen nothing yet”

Sea Girls, ‘Ready For More’ on ‘Open Up Your Head’ (2020).