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# Changes in choice evoked brain activations after a weight loss intervention in adolescents

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ABSTRACT

This study was aimed to investigate if treatment-related success in weight loss (i.e., reductions of BMI and fat percentage) is linked to significant changes in choice evoked brain activity in adolescents with excess weight. Sixteen adolescents with excess weight (age range: 12–18; BMI range: 22–36) performed the Risky-Gains Task during functional Magnetic Resonance Imaging (fMRI) both before and after a 12-week weight loss intervention. Success in weight loss was selectively associated with increased activation in the anterior insula. We concluded that adolescents with the greatest increases in activation of the insula-related interoceptive neural circuitry also show greater reductions in BMI and fat mass.



## 1. Introduction

A quarter of the adolescent population in the United States and other developed countries are classified as 'obese', which places them at increased risk for premature mortality and physical morbidity in adulthood (Ogden, Carroll, Kit, & Flegal, 2014; Reilly & Kelly, 2011). Therefore, tackling obesity at an early stage of life, when obesity-related diseases are still preventable, remains a public health priority and, consequently, a major aim of Healthy People 2020 (Services, 2014). One key factor promoting obesity is the enormous pressure on maintaining energy balance provided by the modern food environment, wherein highly palatable yet unhealthy foods are abundant and proliferate (Zheng & Berthoud, 2007). In this context, a high burden is placed on the individual's ability to make healthy food choices (Rangel, 2013), particularly at a time when cognitive-emotional systems are still maturing and therefore, vulnerable to non-adaptive choices (Verdejo-Garcia et al., 2010). In line with this, longitudinal evidence has demonstrated an association between poor food choices and excess weight in adolescents (Te Morenga, Mallard, & Mann, 2013). Consequently, there is a need for more research into decision-making process underlying food choices in adolescence.

Risky decision-making, characterised by a tendency to select immediate, rewarding options despite the potential negative consequences, has been observed in adolescents with excess weight (Verdejo-Garcia et al., 2010). Further, studies investigating the neural mechanisms of such associations have utilised functional brain imaging and found that overweight and obese adolescents are characterised by alterations in their brain function including: (i) greater activation of the orbitofrontal cortex in response to food commercials (Rapuano, Huckins, Sargent, Heatherton, & Kelley, 2015), and during anticipation of risky decision-making (Delgado-Rico, Soriano-Mas, Verdejo-Roman, Rio-Valle, & Verdejo-Garcia, 2013); (ii) reduced activation of the lateral areas of the prefrontal cortex when attempting to inhibit prepotent responses to images of appetizing foods (Batterink, Yokum, & Stice, 2010); and (iii) reduced activation of the left anterior insula during anticipation of risky

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decision-making (Delgado-Rico et al., 2013). Further, growing evidence indicates that decision-making skills are associated with treatment success in weight loss interventions. For instance, overweight adults showing poorer decision-making skills are less able to lose weight and fat mass during a standard 12-week calorie-reduced intervention (Witbracht, Laugero, VanLoan, Adams, & Keim, 2012).

Longitudinal studies of brain activation during passive observation of food cues suggest that weight loss is associated with recovery of these brain alterations (Bruce et al., 2012). For instance, decreases in body mass index (BMI) after bariatric surgery are associated with diminished brain activation in the mesolimbic system, including the ventral striatum, putamen, and its cortical outputs such as the dorsomedial prefrontal cortex in response to high calorie food cues (Ochner et al., 2011). Moreover, increased brain activation in the anterior insula in response to high-calories food pictures pre-intervention predicts poor weight loss during treatment (Murdaugh, Cox, Cook, & Weller, 2012). There is recent evidence suggesting that brain alterations in obesity are sensitive to weight loss interventions that target enhancements in cognitive control (i.e., decision making) during rewarding stimuli in adolescents (Delgado-Rico et al., 2012; Kulendran et al., 2014). However, it remains unknown if the brain systems underlying risky decision-making recover after successful weight loss. This question is relevant as normalisation of brain activity during risky decision-making may be relevant to healthy food choices and weight loss.

In this study, we used functional magnetic resonance imaging to investigate if treatment-related success in weight loss (i.e., reductions of BMI and fat percentage) is associated with changes in brain activation during risky decision-making in adolescents with excess weight. Risky decision-making was challenged with the Risky-Gains Task (Paulus, Rogalsky, Simmons, Feinstein, & Stein, 2003), which has been shown to robustly activate the brain systems involved in reward-related risky choices (Delgado-Rico et al., 2013). We hypothesised that greater increases in anterior insula activation during anticipation of higher rewards (risky vs. safe choices) from pre-to post-treatment would be associated with more successful weight loss.

## 2. Methods and procedures

*Participants*

The sample was comprised of sixteen adolescents (age range: 12–18; mean age: 13.94; standard deviation: 1.65; twelve females; all right handed) with excess weight according to the criteria of the International Obesity Task Force (IOTF) (Cole & Lobstein, 2012). This is a subsample of participants from a previously published intervention study in which fMRI was conducted prior to and following the weight loss intervention (Delgado-Rico et al., 2012). The sample size of the present study was calculated to detect weight loss changes associated with the intervention. The present study introduces for the first time the longitudinal imaging component of this larger study.

Participants' socio-demographic characteristics, BMI, fat percentage and baseline blood-count based biochemical parameters are displayed in Table 1. A Whole Body Composition Monitor (TANITA SC-330) was used to obtain participant's BMI and fat percentage. Participants were recruited from the paediatrics and endocrinology services of the Hospital “Virgen de las Nieves” in Granada, Spain, and from schools located in the same geographical area. The inclusion criteria were as follows: (i) aged between 12 and 18 years old; (ii) BMI values falling within the intervals categorized as excess weight according to the IOTF (BMI percentile > 85th); (iii) absence of history or current evidence of neurological or psychiatric disorders, assessed by participants and parents interviews; (iv) absence of significant abnormalities on MRI (Magnetic Resonance Imaging) or any contraindications to MRI scanning (including claustrophobia and implanted ferromagnetic objects), and; (v) absence of history of brain injury involving loss of consciousness for longer than 5 min. All participants had normal or corrected-to-normal vision. The study was approved by the local Ethics Committee of the University of Granada. All participants and their parents were debriefed about study aims and detailed procedures. Participants signed an assent form certifying their voluntary participation and their parents signed a parental permission form authorizing the participation of their children in the study.

All participants partook in a 12-week multicomponent behavioural intervention, consisting of cognitive behavioural therapy, structured physical activity and dietary counselling (Delgado-Rico et al., 2012). Two fMRI sessions were conducted. Each fMRI scan took place at 6 pm and prior to this the participants had fasted for approximately 3 h. The first session was conducted within 11.88 days (SD = 10.22) prior to the start of the intervention and the other within 18.19 days (SD = 7.93) following completion of the treatment.

*fMRI task*

The Risky-Gains task described by Paulus et al. (2003) was utilised as the neuroimaging task of choice. In each trial, participants are presented with the numbers 20, 40 and 80 in a fixed order. The task requires the participant to acquire as many points as possible by choosing between safe (20 points) and risky (40, 80 points) options. Each number (20, 40 or 80) is presented on the screen for 1 s, and the participant is instructed to press a button while the selected number is on the screen in order to win the corresponding amount of points. If participants fail to press the button within the required time, a ‘too late’ message is displayed on the screen and they miss the points for that trial.

The first number in the sequence is always a safe choice. Participants are told that if they choose to press the button while the 20 is on the screen they would always receive 20 points. Moreover, participants are told that they have the option to wait and select one of the two subsequent choices (40 and 80); in that case they could win either 40 or 80 points, but that there would be a chance (i.e., the probability is uncertain) that these options lead to losses of 40 or 80 points, respectively. Thus, although the subject may gain more points per trial by waiting until the 40 or 80 choices appear on the screen, there is also a risk of losing 40 or 80 points. Points accumulate from trial to trial and the stake is shown at the top of the screen, being continuously updated. Participants received feedback immediately after making a response, so they could adapt their behaviour to the feedback received.

The task consisted of 96 trials, each trial lasting 5 s (total of 8:05 min). Fifty-four trials (56.25%) were non-punished trials, where participants could get as much as 80 points, while 24 trials (25%) were punished −40 and 18 trials (18.75%) were punished −80 trials. The expected value of the three options (20, 40 and 80) is the same (i.e., the penalties are set in a way that there is no advantage in selecting the 40 and 80 options). Therefore, there is no advantage in selecting the risky response (40 or 80) over the safe response (20).

*Inside scanner behavioural measures*

The primary behavioural performance measures were safe and risky rates (proportion of safe/risky election by total trials).

*Imaging data acquisition and pre-processing*

The subject's head was immobilised inside the MRI coil with