Increased desire for food when fasted is associated with increased fMRI activation of the ventral striatum, insula and amygdala

A. P. Goldstone[1], C. Prechtl de Hernandez[1], K. Muhammed[1], G. Bell[1], G. Durighel[2], E. Hughes[2], A. D. Waldman[2,3], and J. D. Bell[1]
[1]Molecular Imaging Group, Imaging Sciences Department, MRC Clinical Sciences Centre, Hammersmith Hospital, Imperial College, London, United Kingdom,
[2]Robert Steiner MRI Unit, Imaging Sciences Department, MRC Clinical Sciences Centre, Hammersmith Hospital, Imperial College, London, United Kingdom,
[3]Department of Imaging, Charing Cross Hospital, Imperial College Healthcare NHS Trust, London, United Kingdom

Introduction

Using functional MRI, we examined how activity of brain regions previously implicated in reward, emotion and addiction varies with respect to nutritional state (fasted vs. fed) when viewing food pictures of different caloric density, and its variation with how appealing the foods are rated [1]. We hypothesised that picture ratings and preference for high-calorie foods would be suppressed when fed, which would be reflected by changes in regional brain activation [2,3].

Methods

18 right-handed, non-obese healthy volunteers (BMI 22.2 ± 0.5 kg/m^2, age range 19-36y, 8 male, 10 female) were studied on 2 separate mornings after an overnight fast (mean ± SEM 15.5 ± 0.3h) or when fed (1.2 ± 0.1h after breakfast, mean food intake 689 ± 55 kCal, 45 ± 4% of estimated resting energy expenditure). Subjects scored their appetite using visual analogue scales (scale 1-10). Functional MRI was performed while viewing pictures of (i) high- or (ii) low- calorie foods, (iii) non-food related household objects (x 54 pictures each) and (iv) blurred pictures (x 162 as baseline) in a block design (6 pictures per block, 2.5sec per picture, 0.5sec ISI) using a 3T Philips Intera MR scanner (EPI, TR 3sec, TE 30ms, 44 x 3.25mm slices, 2.5mm voxels). Subjects rated how 'appealing' they found each picture while being scanned (scale 1-5).

SPM5 (Wellcome Dept. of Imaging Neuroscience, UCL, UK) was used for pre-processing with motion and slice timing correction, normalisation to standard EPI MNI template, smoothing (8mm FWHM), and analysis using the GLM with random effects region of interest (ROI) analysis (ventral striatum, insula and amygdala) using a statistical threshold of FDR P<0.05 (MarsBar [4]).

Results

Visual Analogue Scales: 'Hunger' and 'pleasantness to eat' ratings were greater in the fasted compared to the fed state (P<0.001). *Picture Rating*: Both high- and low-calorie food pictures were rated as more appealing when fasted than when fed (P<0.001), and were more appealing than object pictures when fasted (P<0.001), but not when fed (P>0.7). High-calorie pictures were more appealing than low-calorie pictures when fasted (P=0.01), but not when fed (P=0.2). The difference in rating between high- vs. low-calorie pictures was correlated with 'hunger' and 'pleasantness to eat' when fed (r = +0.5, P=0.02), but not when fasted (P=1.0). *fMRI Activation*: There was significant activation of the ventral striatum, insula and amygdala when viewing high-calorie vs. object or high- vs. low-calorie pictures when fasted (Fig.1), but not when fed. The increased activation in these brain regions when fasted compared to when fed (P<0.05) mirrored the difference in rating for the pictures (P<0.001) (Fig.2). Furthermore, individual differences in ventral striatum activation when viewing high- vs. low-calorie pictures between fasted and fed states correlated with the individual differences in picture rating (r = +0.49, P<0.05).

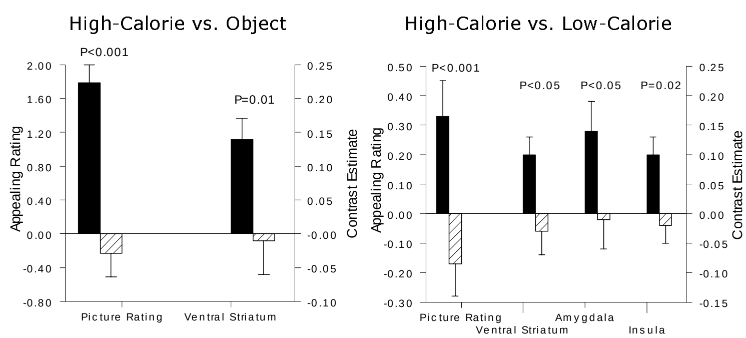

Figure 2. Difference in picture rating ('how appealing') and average ROI activation (contrast estimate) when viewing high-calorie vs. object (left graph) and high- vs. low-calorie (right graph) pictures when fasted (solid bar) or fed (hatched bar). Mean ± SEM, paired t-test (fasted vs. fed).

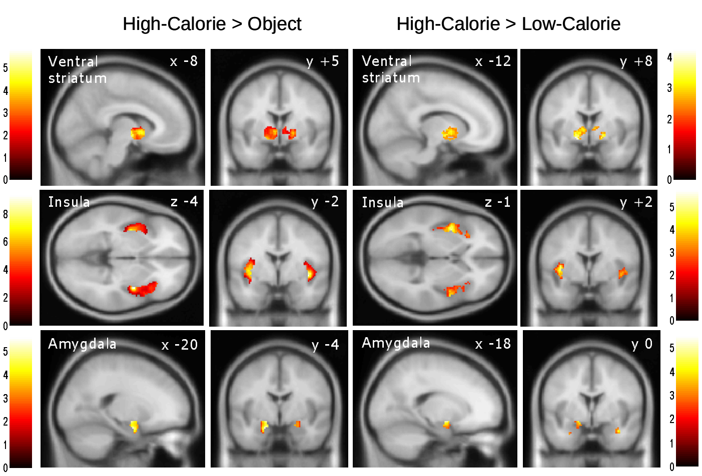

Figure 1. Statistical parametric maps of significant ROI activation (threshold FDR P<0.05) for high-calorie > object (left) and high-calorie > low-calorie (right) picture contrasts when fasted. x, y & z co-ordinates given in MNI space. Bars represent SPM (t) statistic.

Discussion

Increased hunger and desire for food, particularly high-calorie appealing foods, when fasted is associated with increased activation of the ventral striatum, insula and amygdala, brain regions involved in reward, craving and emotion [5-7]. Changes in gut and other appetite hormones when fasted or fed may be a mechanism by which such brain activity is modulated to alter human appetite [8,9].

References: [1] Berthould. Physiol Behav 91:486-98, 2007. [2] La Bar et al. Behav Neurosci 115:493-50, 2001. [3] Killgore et al. Neuroimage 19:1381-94, 2003. [4] Brett et al. Abstract HBM Sendai, Japan 2002. [5] Del Parigi et al. Ann NY Acad Sci 967:38-97, 2002. [6] Porubska et al. Neuroimage 32:1273-80, 2006. [7] Beaver et al. J Neurosci 26:5160-6, 2006. [8] Batterham et al. Nature 450:106-9, 2007. [9] Farooqi et al. Science 317:1355, 2007.