Biological Psychology 117 (2016) 108–116

Contents lists available at ScienceDirect

Biological Psychology

journal homepage: www.elsevier.com/locate/biopsycho

Supersize my brain: A cross-sectional voxel-based morphometry study on the association between self-reported dietary restraint and regional grey matter volumes

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ARTICLE INFO

Article history:
Received 9 June 2015
Received in revised form 2 March 2016
Accepted 14 March 2016
Available online 16 March 2016

Keywords:
Voxel-based morphometry
Dietary restraint
Grey matter volume

ABSTRACT

Restrained eaters do not eat less than their unrestrained counterparts. Proposed underlying mechanisms are that restrained eaters are more reward sensitive and that they have worse inhibitory control. Although fMRI studies assessed these mechanisms, it is unknown how brain anatomy relates to dietary restraint. Voxel-based morphometry was performed on anatomical scans from 155 normal-weight females to investigate how regional grey matter volume correlates with restraint. A positive correlation was found in several areas, including the parahippocampal gyrus, hippocampus, striatum and the amygdala (bilaterally, $p < 0.05$, corrected). A negative correlation was found in several areas, including the inferior frontal gyrus, superior frontal gyrus, supplementary motor area, middle cingulate cortex and precentral gyrus ($p < 0.05$, corrected). That higher restraint relates to higher grey matter volume in reward-related areas and lower grey matter volume in regions involved in inhibition, provides a neuroanatomical underpinning of theories relating restraint to increased reward sensitivity and reduced inhibitory capacity.

1. Introduction

Dietary restraint refers to the intentional and sustained restriction of food intake for the purposes of weight-loss or weight-maintenance (Herman & Mack, 1975a). However, in contrast to this formal definition of restrained eating there is ample evidence that self-reported restrained eaters, that is, people who score high on self-report scales of dietary restraint, do not eat less than their unrestrained counterparts (de Witt Huberts, Evers, & De Ridder, 2013; Stice, Fisher, & Lowe, 2004; Stice, Cooper, Schoeller, Tappe, & Lowe, 2007; Stice, Sysko, Roberto, & Allison, 2010). In fact, Herman & Mack (1975a) established in the seventies already that self-reported restrained eaters over- rather than under-consume. They also were the first to demonstrate that self-reported restrained eaters break their pattern of food restriction after receiving a preload of food. Many studies have replicated this preload-induced loss of dietary control, often denoted as ‘disinhibition effect’ since then, although null findings have also emerged (Knight & Boland, 1989; Lowe, 1993; Polivy, Heatherton, & Herman, 1988; Van Strien, 2000). Furthermore, self-reported restrained eaters are more likely to be overweight (Klesges, Isbell, & Klesges, 1992; Laessle, Tuschl, Kotthaus, & Pirke, 1989) and healthy weight self-reported restrained eaters/dieters might even be at increased risk for weight gain and future onset of binge-eating (French, Jeffery, & Wing, 1994; Klesges et al., 1992; Mann et al., 2007; Stice, Presnell, Shaw, & Rohde, 2004; Tanofsky-Kraff et al., 2006; Lowe, Doshi, Katterman, & Feig, 2013).

The evidence outlined above suggests that the self-reported status of being a restrained eater is a marker for someone’s intention rather than actual success in restricting food intake. It appears that healthy weight self-reported restrained eaters mainly diet to avoid weight gain instead of to lose weight (Chernyak & Lowe, 2010). Thus, self-reports of restraint in healthy weight individuals might rather signify perceived difficulties in maintaining current weight and dealing appropriately with everyday food temptations than their actual behavior (Lowe & Levine, 2005; de Ridder, Adriaanse, Evers, & Verkes, 2014). Explanations for the divergence between self-reported restrained eaters’ intention and behavior has been sought in two possible directions, namely that individuals high in self-reported restraint might have a reduced inhibitory con-

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http://dx.doi.org/10.1016/j.biopsycho.2016.03.007
0301-0511/

trol capacity, or an increased sensitivity to food reward (or both) (e.g., Nederkoorn, Van Eijs, & Jansen, 2004; Papies, Stroebe, & Aarts, 2007). Although it has repeatedly been shown that people high in self-reported dietary restraint are worse at inhibition (Houben & Jansen, 2014; Nederkoorn et al., 2004), at least one other studies found the opposite, namely that self-reported restrained eaters were better at inhibiting responses to food cues in a computer task than self-reported unrestrained eaters (Meule, Lukito, Vogele, & Kubler, 2011). More univocal support exists for the second proposition, that self-reported restrained eaters have an increased sensitivity to food rewards: individuals high (versus low) in self-reported restraint show greater salivary response to the sight and smell of food (Brunstrom, Yates, & Witcomb, 2004; Klajner, Herman, Polivy, & Chhabra, 1981; LeGoff & Spigelman, 1987), they report having stronger cravings for palatable foods (Gendall, Joyce, Sullivan, & Bulik, 1998; Polivy, Coleman, & Herman, 2005), they have a stronger implicit preference for palatable foods (Houben, Roefs, & Jansen, 2010; Houben, Roefs, & Jansen, 2012), are more likely to overeat in response to the smell, sight or thoughts of palatable food (Fedoroff, Polivy, & Herman, 2003; Fedoroff, Polivy, & Herman, 1997; Papies & Hamstra, 2010), and they have an attentional bias towards palatable energy-rich foods (Forestell, Lau, Gyurovski, Dickter, & Haque, 2012), especially when pre-exposed to palatable food cues (Papies, Stroebe, & Aarts, 2008), although null findings have also appeared (e.g., Werthmann et al., 2013).

Functional neuroimaging studies suggest that restrained eaters' behaviorally apparent increased reward response to foods is also reflected in an increased responsiveness of their brain's reward circuitry during both viewing and tasting food (Burger & Stice, 2011; Coletta et al., 2009; Demos, Kelley, & Heatherton, 2011; Wagner, Boswell, Kelley, & Heatherton, 2012): Burger and Stice (2011) found that participants who were higher in self-reported dietary restraint had stronger activation in the right orbitofrontal cortex (OFC) in response to tasting a milkshake. Coletta et al. (2009) showed that the normal drop in rewarding value of food after eating was not observed in self-reported restrained eaters. Instead, when self-reported restrained eaters were sated (compared to hungry) they had stronger activation in brain areas involved in hunger and reward (OFC, insula) in response to food pictures (Coletta et al., 2009). Furthermore, when women high in self-reported restraint consumed a milkshake as preload (compared to water) they showed greater activation in the dorsal striatum in response to pictures of appetizing foods (Demos et al., 2011). Combined, these results suggest that restrained eaters have an increased response in reward related brain regions upon viewing and tasting food, particularly when they are in a sated state.

Although the evidence outlined above suggests that self-reported restrained eaters have altered functional brain responses to food, less is known about the role of more stable – anatomical – brain characteristics in restrained eating, such as regional grey matter volume. Regional differences in grey matter volume can provide valuable information about normal and abnormal neuroanatomy, and have been linked to individual differences in general personality traits (DeYoung et al., 2010). It is generally thought that a greater volume of a specific brain structure may signify greater power to carry out specific functions associated with that structure (DeYoung et al., 2010).

To our knowledge, only one earlier study investigated the relation between dietary restraint and regional grey matter volume (Brooks et al., 2011). This study was primarily set up to investigate grey matter volume in two subtypes of anorexia patients and reported no significant relation between dietary restraint scores and regional brain volumes in their healthy control group. However, because variations in brain structure associated with personality characteristics in the healthy range are relatively small, their null-finding might be explained by the low number of healthy control subjects (n = 21). Studies on the structural basis of personality characteristics usually include much higher numbers of participants (i.e., 100 subjects or more: DeYoung et al., 2010; Fuentes et al., 2012). In the present study, we aimed to investigate how regional brain volume covaries with level of self-reported dietary restraint in a large population of normal weight females. Investigating this is relevant because it yields insights into the brain characteristics of a population at risk for developing problematic eating behaviors and becoming overweight.

Building on the findings from functional neuroscience studies described above, we hypothesized that regional grey matter volume in brain regions involved in food reward and inhibitory control correlate with level of dietary restraint.

Relating food-related and personality related concepts to anatomical features of the brain can potentially reveal common underlying components and any neural substrates. Such an approach may provide new insights into how eating behavior and different cognitive functions are related to each other and which regions underlie those functions. By identifying the brain regions where grey matter volume covaries with personality or eating behavior, we can build brain-based theories of personality and eating behavior. Knowing how brain differences relate to the expression of different traits and behaviors opens directions for future research in both brain structure and eating behavior.

2. Materials and methods

2.1. Ethics statement

Data used for the analyses in this article was taken from studies that were approved by the Medical Ethical Committee of either the University Medical Center Utrecht or of Wageningen University. All subjects provided written informed consent.

2.2. Participants

The sample consisted of 155 females with a healthy weight (mean age ± SD: 22.9 ± 4.0, range: 18–40; mean Body Mass Index (BMI) ± SD: 21.5 ± 1.7, range: 18.1–25.2), who participated in seven earlier unrelated studies in our and affiliated labs (six published studies (Charbonnier, van der Laan, Viergever, & Smeets, 2015; Griffioen-Roose et al., 2014; Smeets, Kroese, Evers, & De Ridder, 2013; van der Laan, De Ridder, Viergever, & Smeets, 2012; van der Laan, De Ridder, Charbonnier, Viergever, & Smeets, 2014; van Rijn, de Graaf, & Smeets, 2015) and one study in preparation). Self-reported length and height (to calculate BMI) were acquired during the screening phase of the study they participated in. Participant selection for the current study was limited to young adult women because they generally score higher on restraint and because of known gender differences as well in reasons for dieting as in brain anatomy and function (Cahill, 2006; Luders, Gaser, Narr, & Toga, 2009; Neumark-Sztainer, Sherwood, French, & Jeffery, 1999; Pingitore, Spring, & Garfield, 1997). All participants were right-handed, non-smokers and had a stable weight (did not gain or lose > 5 kg in the past 6 months). All participants were healthy, i.e., they reported having no eating disorder and no neurological, metabolic, endocrine or gastrointestinal disorders. Furthermore, none of the participants had a food allergy or followed a medically prescribed diet. Participants were recruited with posters and flyers at the University Medical Center Utrecht or at Wageningen University and Research centre in The Netherlands.

2.3. Dietary restraint measurement

The restrained eating scale of the Dutch Eating Behavior Questionnaire (Van Strien, Frijters, Bergers, & Defares, 1986) was used