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Hungry for reward: How can neuroscience inform the development of treatment for Anorexia Nervosa?

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ABSTRACT

Dysfunctional reward from the pursuit of thinness presents a major challenge to recovery from Anorexia Nervosa (AN). We explore the neuroscientific basis of aberrant reward in AN, with the aim of generating novel hypotheses for translational investigation, and elucidate disease mechanisms to inform the development of targeted interventions. Relevant neuroimaging and behavioural studies are reviewed. These suggest that altered eating in AN may be a consequence of aberrant reward processing combined with exaggerated cognitive control. We consider evidence that such aberrant reward processing is reflected in the compulsive behaviours characterising AN, with substantial overlap in the neural circuits implicated in reward processing and compulsivity. Drawing on contemporary neuroscientific theories of substance dependence, processes underpinning the shift from the initially rewarding pursuit of thinness to extreme and compulsive weight control behaviours are discussed. It is suggested that in AN, weight loss behaviour begins as overtly rewarding, goal-directed and positively reinforced, but over time becomes habitual and increasingly negatively reinforced. Excessive habit formation is suggested as one underlying mechanism perpetuating compulsive behaviour. Ongoing research into the behavioural and neural basis of aberrant reward in AN is required to further elucidate mechanisms. We discuss clinical and transdiagnostic implications, and propose that future treatment innovation may benefit from the development of novel interventions targeting aberrant reward processing in AN.

Anorexia Nervosa (AN) is a severely debilitating psychiatric disorder of unknown aetiology characterised by the relentless and compulsive pursuit of self-starvation, leading to severe emaciation. There is clear evidence of biological influences and significant heritability (Boraska et al., 2014; Bulik et al., 2006), with a stereotypical presentation predominantly in females and a narrow range of onset (American Psychiatric Association, 2013). AN has low rates of full recovery and around 25% of individuals develop a chronic course (Berkman, Lohr, & Bulik, 2007) It ranks among the top 10 debilitating diseases of young women (Mathers, Vos, Stevenson, & Begg, 2000) and has the highest mortality rate of any psychiatric disorder (Arcelus, Mitchell, Wales, & Nielsen, 2011).

Sadly AN remains one of the most challenging of psychiatric disorders to treat, particularly in adults (Bulik, 2014). There is a paucity of evidence-based treatments, including no pharmacological treatment of benefit (McKnight & Park, 2010; Watson & Bulik, 2012) and no clearly recommended psychological treatment (National Institute for Health and Care Excellence, 2004). In the quest to develop novel interventions, there is increasing interest in the neurobiological factors underlying AN (Kaye, Fudge, & Paulus, 2009; Kaye et al., 2013). This paper describes recent research into the neuroscience of reward and compulsivity in AN, in order to generate novel hypotheses for translational investigations to elucidate disease mechanisms and inform the development of targeted interventions.

The problem of aberrant reward in AN

Individuals with AN experience perverse reward from the pursuit of thinness, and compulsively engage in extreme dietary restraint, often combined with over exercising. They describe self-starvation as providing a sense of power and achievement, and are perpetually preoccupied with control of eating, weight and shape (Cowdrey & Park, 2012; Cowdrey, Stewart, Roberts, & Park, 2013; Park, Dunn, & Barnard, 2011, 2012; Rawal, Park, & Williams, 2010; Rawal, Williams, & Park, 2011). This perversion of reward

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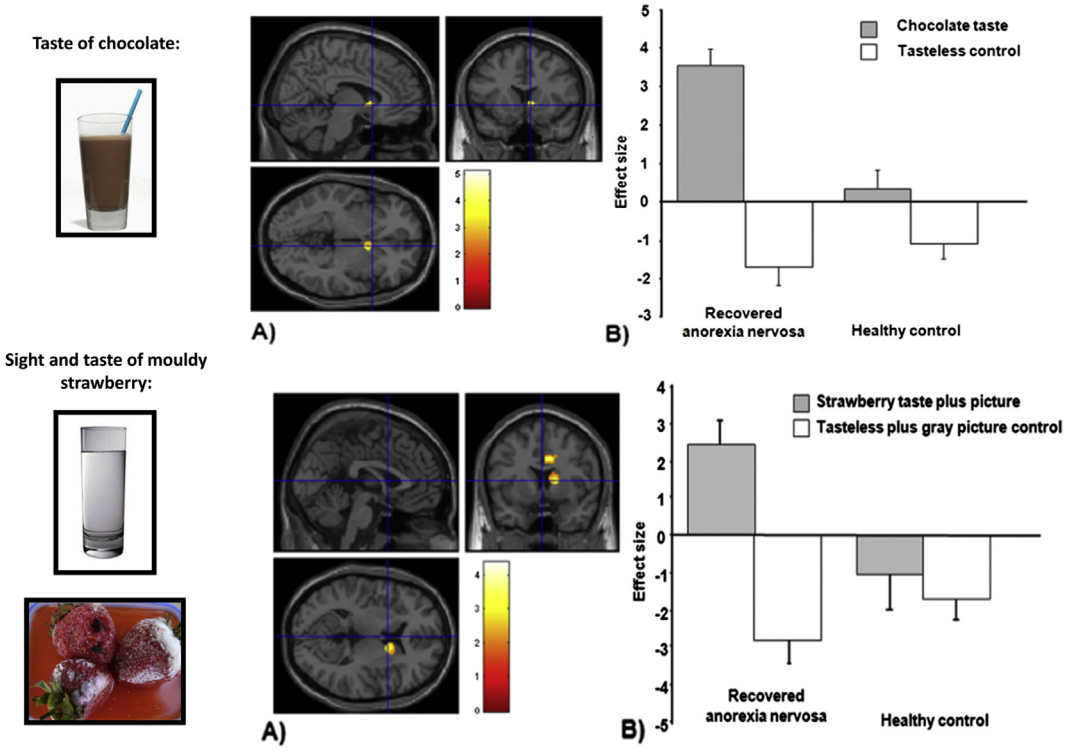

Fig. 1. Neural Response to sight and taste of rewarding and aversive food stimuli: Taste of chocolate: A) Shows significantly increased activation in the ventral striatum in women recovered from AN compared to controls. B) Shows the larger effect size of the increased activation in women recovered from AN compared to controls for the chocolate taste and tasteless control condition. Sight and taste of mouldy strawberries: A) Shows significantly increased activation in the caudate and anterior cingulate in recovered AN compared to controls. B) effect size of the increased activation in recovered AN compared to controls for the mouldy strawberry taste and picture, and the tasteless and grey picture control condition. Reproduced with permissions and adapted from : F.A. Cowdrey, R.J. Park, C.J. Harmer & C. McCabe, 2011, Biological Psychiatry, 70(8), pp.736–743.

becomes accentuated in line with starvation (Keys, Brozek, Henschel, Mickelsen, & Taylor, 1950; Park et al., 2011).

Qualitative reports from patients confirm that AN behaviour is associated with a rewarding sense of personal meaning: "My anorexia makes me feel special, different and safe: nothing else in my life gives me this sense" (Park et al., 2011, p. 423), but takes on a compulsive quality which is experienced as central to the illness and a major barrier to recovery:

"The compulsive nature of behaviour in eating disorders is what characterises them … if restriction/exercise weren't compulsive, anorexia would be easy to overcome because it would be a conscious choice to 'switch off' the thoughts and stop the behaviours. The problem is that behaviours become compulsive and so it becomes more difficult to not engage in them" – *Participant aged 21, 2 year history of restrictive AN* (Godier & Park, unpublished data).

The perversely rewarding nature of AN not only presents a major barrier to engaging patients in treatments which are experienced as highly aversive (Park et al., 2012) but also contributes to high treatment drop-out and relapse rates (Watson & Bulik, 2012).

What is known about the neural basis of aberrant reward in AN?

Neuroimaging studies in AN have demonstrated functional and structural abnormalities in areas of the brain known to be involved in reward processing (Kaye et al., 2009; Kaye et al., 2013). In particular, abnormalities have been found in the anterior cingulate (AC), involved in emotional evaluation and response selection, the orbitofrontal cortex (OFC), a key area linking food and other types of reward to hedonic experience (Berridge & Kringelbach, 2008) and the ventral striatum (VS), incorporating the nucleus accumbens (NAc). The VS is an area integral for coding the pleasure of a reward and also it's motivational salience-defined as the process through which a stimulus is converted from a neutral representation into an attractive and wanted incentive that a person will work to acquire (Berridge & Robinson, 1998). Neural circuits subserving these regions are also strongly implicated in compulsivity (Everitt & Robbins, 2005) and, as will be discussed below, are therefore potentially of transdiagnostic significance (Robbins, Gillan, Smith, de Wit, & Ersche, 2012).

The majority of neuroimaging studies in AN have investigated recovered subjects to avoid the confounds of starvation, but findings in recovered and ill subjects have been surprisingly similar (Frank et al., 2012; Kaye et al., 2013). It remains unclear whether parallels identified in reward circuitry are due to a scarring effect of starvation, or represent an underlying vulnerability (Cowdrey, Park, Harmer, & McCabe, 2011). Prospective longitudinal studies of individuals prior to illness onset are needed to clarify this issue. To illustrate exactly how regions of the brain involved in reward processing are different in those with a history of AN, the next section will briefly consider recent neuroimaging studies using symptom-provoking paradigms.

Aberrant food reward in AN: increased neural responsivity to rewarding and aversive stimuli

Our research in individuals recovered from AN was the first functional magnetic resonance imaging (fMRI) study to include the sight and taste of both rewarding and aversive food stimuli (Cowdrey et al., 2011) (See Fig. 1). Despite no self-reported differences, we found that compared to controls, individuals recovered from AN demonstrated heightened neural activation to both pleasurable food reward stimuli (liquid chocolate) in the putamen, an