Appetite 95 (2015) 44–57

Contents lists available at ScienceDirect

Appetite

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

Research review

Individual differences in the interoceptive states of hunger, fullness and thirst

Richard J. Stevenson [a,*], Mehmet Mahmut [a], Kieron Rooney [b]

[a] Department of Psychology, Macquarie University, Sydney, NSW 2109, Australia
[b] Discipline of Exercise and Sport Science, University of Sydney, Sydney, NSW 2006, Australia

ARTICLE INFO

Article history:
Received 16 October 2014
Received in revised form
5 May 2015
Accepted 11 June 2015
Available online 26 June 2015

Keywords:
Hunger
Fullness
Thirst
Interoception

ABSTRACT

Interoception is the ability to perceive internal bodily states. This involves the detection and awareness of static and changing afferent signals from the viscera, motivational states, affective reactions, and associated cognitions. We examined whether there are individual differences in any or all of these aspects of ingestion-related interoception and their possible causes. Individual variation in almost all aspects of interoception was documented for hunger, fullness and thirst – including how participants use, prioritise and integrate visceral, motivational, affective and cognitive information. Individual differences may arise from multiple causes, including genetic influences, developmental changes hypothesised to result from child feeding practices, and from conditions such as depression, anxiety, eating disorders and certain subtypes of obesity. A nutritionally poor diet, and dietary restraint, may also affect ingestion-related interoception. Finally, certain forms of brain injury, notably to the medial temporal lobes are associated with impaired ingestion-related interoception. We conclude by examining the practical and theoretical consequences of these individual differences.

1. Introduction

Interoception is the ability to perceive the internal state of the body (Craig, 2002; Sherrington, 1906; Vaitl, 1996). Sensory information from the viscera is transmitted via spinothalamic and vagal afferents to the anterior insular, somatosensory and orbitofrontal cortices (Critchley, Wiens, Rotshtein, Ohman, & Dolan, 2004; Khalsa, Rudrauf, Feinstein, & Tranel, 2009). These cortical centres support the perception of a range of states, including those generated by bodily organs (e.g., bowel, bladder, stomach, heart), the skin senses (e.g., cool, warm, touch, itch), internal chemoreceptors (e.g., air-hunger), and muscles and tendons (e.g., proprioceptive feedback, fatigue). The same cortical centres also contribute to the integrations of internal sensory information into drive states (e.g., pain, sex, hunger, thirst) and emotions (Harshaw, 2014).

It has been known for some time that individuals differ in their interoceptive abilities (e.g., Katkin, 1985; Monello & Mayer, 1967; Pennebaker, 1982; Schachter, 1968; Schandry, 1981; Stunkard, 1959). Presumably, such individual differences can be found for all interoceptive states, but there have been few previous examinations. One area where these individual differences may be particularly important concerns ingestive behaviour – the focus of this manuscript – and relatedly the short-term regulation of energy intake. While several interoceptive states may affect ingestive behaviour (e.g., body temperature, fatigue, stress, arousal), the most important are likely to be hunger, fullness and thirst (noting that drinking makes a significant contribution to energy intake; e.g., De Ruyter, Katan, Kuijper, Liem, & Olthof, 2013; De Ruyter, Olthof, Seidell, & Katan, 2012).

The importance of hunger, fullness and thirst to the study of ingestive behaviour can be seen in three ways. First, there is considerable scientific interest in these states, which is reflected in the space devoted to them – 13% of the book's content by pages – in Logue's (2004) introductory textbook to this field. Second, these states have a long history of academic attention from the Greek philosophers onwards (see Cofer & Appley, 1966). Third, lay people *believe* – rightly or wrongly – that hunger, fullness and thirst are key factors in regulating eating and drinking (e.g., Monello & Mayer, 1967; Mook, 1992; Phillips, Rolls, Leddingham, & Morton, 1984), making their role important to study. While thirst is distinct from hunger and fullness, the latter two are clearly related (Mattes, 2010). However, they are not identical, because as described further below

* Corresponding author.
E-mail address: dick.stevenson@mq.edu.au (R.J. Stevenson).

http://dx.doi.org/10.1016/j.appet.2015.06.008
0195-6663/

they are characterised by different visceral sensations, affective states and motivational consequences. It is for all of these reasons that we focus on individual differences in hunger, fullness and thirst – these being arguably the most relevant to ingestive behaviour and the short-term regulation of energy intake.

To study the nature of individual variation in these states, and to examine the putative causes of any variation, the manuscript is organised into four parts. The first examines the nature of each state, their measurement, basis in physiology, sensitivity to environmental influences, and relationship with behaviour. The second reviews individual differences within each state. The third examines causes of these individual differences, including genetic, developmental, experiential, health-related and cognitive mechanisms. Finally, we critically discuss the practical and theoretical implications of this literature.

2. The nature of hunger, fullness and thirst

2.1. The characteristics of hunger

Hunger may have three components (Faith, Kermanshah, & Kissileff, 2002; Murray & Vickers, 2009): (1) visceral sensations located in the abdomen (and in particular the stomach); (2) affective states relating to food and eating, which *may* be decomposed into liking (hedonic reaction to the stimulus) and wanting (desire for the stimulus; see Finlayson & Dalton, 2012; Havermans, 2011, for different perspectives); and (3) cognitions relating to food, hunger and eating. Additional visceral and cognitive states have also been noted, including physical weakness, dizziness, anxiety and headache, and for cognition, thoughts of food, irritability and lack of concentration (Murray & Vickers, 2009). All three components increase in intensity under conditions of food deprivation (Keys, 1946). One piece of evidence favouring discrete hunger components can be seen in gastrectomized patients (e.g., Kamiji, Troncon, Suen, & de Oliveira, 2009). They report broadly normal hunger and fullness states in the absence of a stomach, indicating the significant contribution of the motivational/affective and cognitive components to hunger. Another piece of evidence comes from reductions in liking that occur for foods eaten within a meal (sensory specific satiety; Rolls et al., 1981), allowing sweet foods to be enjoyed even after a filling savoury meal. This suggests that affective change can occur independently of visceral sensation.

The physiological and environmental correlates of hunger are well studied. Physiologically, transient changes in blood glucose (indicative of short-term energy needs), increases in plasma grehlin and motilin (which can initiate stomach contractions), as well as leptin (indicative of long-term energy needs), are all are associated with increased hunger (e.g., Campfield, Smith, Rotenbaum, & Hirsch, 1996; Janssen et al., 2011). Diet related factors (i.e., energy content, macronutrient content, fibre and glycemic index) are also important determinants in how filling a meal is, and thus its capacity to reduce hunger (e.g., Kirkmeyer & Mattes, 2000). A large number of environmental factors can affect reports of hunger, including the passage of time since the last meal, the approach of a meal-time, the sight and smell of food, and the degree to which it is liked (e.g., Herman, Ostovich & Polivy, 1993; Hill, Magson, & Blundell, 1984; Johnson, 2013). Indeed, palatability may be especially important in driving food intake and enhancing hunger (Yeomans, 1996).

Hunger, as a subjective state, is measured by asking participants to judge its degree of presence using some form of scale (De Graaf, 1993). Related measures are also collected in some studies, including desire to eat, appetite for a meal and prospective food consumption (e.g., Flint, Raben, Blundell, & Astrup, 2000). Hunger ratings are reliable both when made immediately (correlation between successive measurements made an hour apart; Stratton et al., 1998) and after several days when tested under similar conditions (i.e., time of testing and energy intakes matched; Flint et al., 2000; Raben, Tagliabue, & Astrup, 1995). However, there is still considerable variability, either resulting from individual differences or noise, as average coefficients of reliability are quite large. Under a similar fasted state, a repeated rating of hunger recorded on a 100 point scale would likely fall within ±28 points of the first rating (Flint et al., 2000).

Validity can be established in several ways (De Graaf, 1993), the most frequent being whether hunger ratings are predictive of eating and/or the quantity of food consumed. Hunger ratings reliably decrease over the course of experimental meals (e.g., Hill et al., 1984). In the lab, hunger ratings obtained both before (2–6 h) and immediately prior to an *ad libitum* meal are significant predictors of the amount of food consumed at that meal (e.g., Drapeau et al., 2007; Parker, Ludher, Loon, Horowitz, & Chapman, 2004a, 2004b). In more naturalistic diary studies a broader range of findings have emerged: (1) while all studies observe positive relationships between pre-meal hunger ratings and amount subsequently consumed, this association can be weak (e.g., McKiernan, Houchins, & Mattes, 2008; Drapeau et al., 2007) and it is weaker still when examined at the individual level (Mattes, 1990); (2) many meals are consumed when participants report *not being* hungry, and many meals are *not eaten* when they report being hungry (e.g., Mattes, 1990; Tuomisto, Tuomisto, Hetherington, & Lappalainen, 1998); and (3) in a study that included modelling stomach content based upon food diary data, De Castro and Elmore (1988), found that hunger ratings were a better predictor of food intake at a subsequent meal, than stomach content.

2.2. The characteristics of fullness

Feelings of fullness during eating and after eating have a number of common features. After a typical meal participants report visceral, affective and cognitive components to fullness (Murray & Vickers, 2009). This involves feelings of stomach fullness, feeling of being re-energized with no thoughts of food, a lack of desire to consume more food and a liking for the stomach-related feeling. When participants were asked to describe how they would feel after a heavy meal, they noted unpleasant abdominal bloating, negative cognitions and a markedly reduced desire to eat.

Perceptions of fullness can be affected by several factors. Environmentally, these include apparent portion size, attention to the food during eating, the number of people eating, and by the variety of food available (e.g., Mittal, Stevenson, Oaten, & Miller, 2011; Rolls et al., 1981; Wansink, Painter, & North, 2005). For example, when visual cues to the amount of food eaten are manipulated, average fullness ratings are the same as for participants who have eaten a visually identical but physically smaller quantity of food (Wansink et al., 2005). Variety is a particularly important influence on consumption (Johnson & Wardle, 2014). As one food is consumed, liking for that food wanes – sensory specific satiety (Rolls et al., 1981) and this is an important psychological contributor to meal termination (Hetherington, 1996). If multiple foods are available, this process occurs separately for each food, allowing potentially more to be consumed (Rolls et al., 1981). More general reductions in food liking may occur post-ingestively – alliesthesia (Cabanac, 1971) – reducing the desire to eat.

Physiologically, visceral fullness sensations derive from mechanoreceptors located in the stomach that are linked to the brain via the vagus and splanchnic nerves (Janssen et al., 2011; Klatt et al., 1997; Lee, Vos, Janssens, & Tack, 2004). Following the cessation of eating, sensations of fullness may be governed by the rate of gastric emptying, which is inversely proportional to the energy content of