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Thirst interoception and its relationship to a Western-style diet

Mairead Brannigan, Richard J. Stevenson *, Heather Francis

Department of Psychology, Macquarie University, Sydney, NSW2109, Australia

HIGHLIGHTS

- Individual differences in interoception have been observed.
- The origin of these individual differences is poorly understood.
- We test if thirst-related interoception is related to a Western-style diet.
- Thirst interoception is poorer in those with a diet rich in fat and sugar.
- Several mechanisms are discussed to account for this association.

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ABSTRACT

Less sensitive interoception for hunger and fullness has been observed in people who consume a diet rich in saturated fat and added sugar. In this study we examined whether healthy young people who routinely consume such diets, also demonstrate less sensitive thirst interoception. Participants, varying primarily in diet, were made thirsty by consuming salted chips and later provided with *ad libitum* access to water, with thirst ratings obtained throughout. A self-report measure of interoceptive awareness was also included plus measures to determine eating habits, memory and executive function. A diet reported as richer in saturated fat and added sugar (an HFS diet) was associated both with less sensitive thirst interoception and with greater attention to somatic signs. Evidence of poorer hippocampal-sensitive learning and memory was also detected. Poorer sensitivity to interoceptive cues appears to be a reliable correlate of an HFS diet and its causal origins are discussed.
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1. Introduction

Interoception refers to the perception of stimuli originating within the body [6,17]. This has traditionally been studied using heart rate, with interoceptive sensitivity defined as the deviation of self-monitored heart rate from an electronically derived measure of actual heart rate (e.g., [27]). People reliably vary in how accurately they can monitor their heart rate, and this correlates with variation observed in other forms of interoception, including perceived exertion, satiation and the detection of hunger-related stomach contractions (e.g., [19]). Individual differences amongst the latter, including thirst, are particularly significant as they may impact upon energy balance. High levels of hunger and thirst may facilitate energy intake via food and sugar-laden drinks, while impaired satiation and heightened sensitivity to fatigue/exertion may make it hard to end a meal and initiate exercise. This is why understanding both the nature and origins of interoceptive variation is important. In the current study we examine whether a recently identified correlate of interoceptive variation in hunger and fullness – a Western-style diet rich in saturated fat and added sugar – extends to thirst.

Individual differences in interoception have not been extensively studied and there is only a limited literature exploring why such variation may occur. At least some individual differences may have a genetic origin. Evidence suggests that variations in undertaking exercise, and in the relationship between self-reported hunger and food intake, are both under partial genetic control (e.g., [3,20]). A further source of variation may arise experientially, during development [16]. It has been suggested that for hunger and satiety, focussing a child's attention on ‘cleaning their plate’ and regular meal times, may progressively dislocate the regulation of food intake away from interoceptive cues and towards potentially less reliable external cues (e.g., serving size). A variety of evidence has been amassed that parents who adopt ‘a clean plate’ strategy may be doing so at the expense of their child's ability to effectively utilise interoceptive cues for hunger and satiety (e.g., [1]). Other psychological sources of variation have also been identified. These include depression, which involves impaired interoception (e.g., [15,17]) and personality variables associated with an internal or external focus (e.g., [10]).

An additional source of variance relates to habitual diet. Cooling and Blundell [5] reported that participants who differed in the proportion of

* Corresponding author. Tel.: +61 2 98508098; fax: +61 2 98508062.
E-mail address: dick.stevenson@mq.edu.au (R.J. Stevenson).

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fat they consumed, also differed in their hunger/fullness ratings during a series of test meals. Those who reported eating a diet high in fat reported a greater base-rate of hunger (i.e., a greater desire to eat). In addition, on *ad libitum* meals that differed in energy density, habitual high fat consumers ate a fixed volume of food to achieve satiety, while the low fat consumers ate a fixed energy content. Whether these diet-related effects arise from genetic or experiential factors is not currently known. Francis and Stevenson [12]) examined the relationship between dietary intake of saturated fat and added sugar, and interoceptive sensitivity. On two test meals, healthy lean participants who habitually reported consuming a diet rich in saturated fat and added sugar (an HFS diet or a 'Western-style' diet) ate more food but showed similar shifts in hunger and fullness than participants who reported consuming a diet low in saturated fat and added sugar (an LFS diet). Thus to generate a one unit change in hunger and fullness required significantly greater energy intake in the HFS group than the LFS group, suggesting less interoceptive sensitivity for a given amount of food intake.

In the current study we examine whether similar differences in habitual diet are related to another interoceptive state, thirst. Thirst is of interest for several reasons. First, there have been few studies of individual differences for this interoceptive state. What evidence is available suggests that some people consistently report higher levels of thirst than others [23], and that some individuals are more sensitive to consuming given volumes of fluid than others, an effect that may reflect sensitivity to stomach dilation [19]. Second, considerable amounts of energy may be consumed via drinking (i.e., sugar sweetened soft-drinks) making it important to understand whether/how thirst and oral-related sensations (i.e., mouth dryness) drive this avenue of consumption [9]. Third, much drinking is non-homeostatic, occurring at the same time as eating (e.g., [11]). Presumably this drinking is initiated by multiple cues, including context, base level of thirst, as well as sensitivity to oral sensations generated by eating, especially mouth dryness, which is the main visceral cue for thirst (e.g., [21,31]). Based upon the literature reviewed above, we would expect that both base level of thirst and sensitivity to visceral thirst-related cues (i.e., dry mouth) might also vary with habitual diet. In particular, an HFS diet should be associated with both a higher base rate of thirst and less sensitivity to oral cues normally associated with thirst. Furthermore, drinking should be less successful in remediating thirst in those who consume an HFS diet because they will be both less sensitive to their current thirst-related oral state (i.e., mouth dryness) and to their degree of stomach related dilation following any drinking.

To test these predictions, we recruited participants who differed principally in their consumption of saturated fat and added sugar using a validated dietary screening questionnaire [13]. The Dietary Fat and Free Sugar Questionnaire (DFS) assesses frequency of consumption of 26 foods and drinks that are high in saturated fat and/or added sugar. Participants reporting higher (i.e., an HFS diet) or lower (i.e., an LFS diet) scores on the DFS were then tested on a thirst-sensation induction procedure [4]. Participants were made to feel thirsty (i.e., enhanced oral dryness) by eating a portion of salted chips and then later in the study were given *ad libitum* access to water. Across the course of the study participants were repeatedly asked to judge their thirst. We assessed four key variables in relation to thirst interoception: (1) base level of thirst; (2) salt-thirst sensitivity – the change in thirst ratings observed after consuming the salted chips; (3) water-thirst sensitivity – the quantity of water needed to produce a one unit change in thirst ratings after drinking; and (4) predictability – the relationship between thirst ratings and later water intake. we hypothesised that an HFS diet would be associated with higher overall thirst ratings (i.e., greater base level thirst), and thirst ratings that were less sensitive to salt or fluid intake and less predictive of future water intake.

A number of other measures were also obtained, including biographic data, exercise habits and body mass index. These were collected so that we could identify variables that might confound any diet-related associations. We also employed two neuropsychological tests, one of hippocampal dependent learning and memory (logical memory percent retention; LMR) and another of executive function (digit span). In our previous study we found that tests of hippocampal-dependent learning and memory, but not executive function, were performed more poorly by those who reported consuming an HFS diet. Participants were also asked to complete the three-factor eating questionnaire (TFEQ; [35]), to check for certain correlations between diet (DFS score) and eating behaviour (restraint and hunger, but not disinhibition) also observed in our previous study [12]. Finally, we also included a general but indirect measure of interoceptive awareness (i.e., proneness to direct attention to somatic stimuli) the Pennebaker Inventory of Limbic Languidness (PILL; [25]), to test whether diet is associated with differences in focus on internal sensations.

2. Method

2.1. Participants

All consenting first-year psychology students completed the Dietary Fat and Free Sugar Questionnaire (DFS; [13]). We then approached all those with DFS scores below 52 (lowest 33%) and above 64 (highest 33%). Recruitment was supplemented by advertising on campus, with potential participants asked to complete a subset of DFS items on the phone (this resulted in three cases with full-scale DFS scores falling close to but outside of the original target range; see Results for details). Those whose DFS scores fell within the intended range were then given a brief medical screening interview. Those with a self-reported body mass index (BMI) outside of 18–25 (two participants on later weighing turned out to have BMIs of 25.5 and were included as their exclusion had no impact on the study outcomes) or with pre-existing medical or psychological conditions that could affect weight-maintenance, diet, thirst or performance on neuropsychological tests, were excluded. The research protocol was approved by the Macquarie University Human Research Ethics Committee.

3. Materials

3.1. Dietary assessment

The 26-item DFS was used to measure intake of foods high in saturated fat and/or added sugar. The questionnaire has established test–retest reliability and validity [13]. The latter was established by showing significant positive correlations of estimated intakes of saturated fat and added sugar from the DFS with estimates obtained both from a four-day diet-diary (Medical Research Council, Cambridge, UK) and from a pre-existing Australian food-frequency questionnaire (from the Commonwealth Scientific and Industrial Research Organisation).

3.2. Thirst manipulation

Participants consumed 19 g of chips, containing 0.28 g of salt, sufficient to induce a thirst-related dry mouth. Ratings of thirst were obtained on 15 cm visual analogue scales (anchors Not at all and Very), alongside measures of hunger, fullness, mood and arousal. Data from these other ratings are not reported, as they were included primarily to mask our focus on thirst. Towards the end of the study, participants were provided *ad libitum* access to refrigerated tap water, with the quantity drunk recorded after the study was complete.

3.3. TFEQ

This reliable and validated 51-item questionnaire, measures three cognitive dimensions of eating behaviour – restraint, disinhibition and hunger [35].

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