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Research report

Reduced brain response to a sweet taste in Hispanic young adults

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ABSTRACT

Hispanics have an increased risk for metabolic disorders, which evidence suggests may be due to interactions between lifespan biological, genetic, and lifestyle factors. Studies show the diet of many U.S. Hispanic groups have high sugar consumption, which has been shown to influence future preference for and consumption of high-sugar foods, and is associated with increased risk for insulin-related disorders and obesity. Taste is a primary determinant of food preference and selection. Differences in neural response to taste have been associated with obesity. Understanding brain response to sweet taste stimuli in healthy Hispanic adults is an important first step in characterizing the potential neural mechanisms for this behavior. We used fMRI to examine brain activation during the hedonic evaluation of sucrose as a function of ethnicity in Hispanic and non-Hispanic young adults. Taste stimuli were administered orally while subjects were scanned at 3T. Data were analyzed with AFNI via 3dROIstats and 3dMEMA, a mixed effects multi-level analysis of whole brain activation. The Hispanic group had significantly lower ROI activation in the left amygdala and significantly lower whole brain activation in regions critical for reward processing, and hedonic evaluation (e.g. frontal, orbitofrontal, and anterior cingulate cortices) than the non-Hispanic group. Differences in processing of sweet tastes have important clinical and public health implications, especially considering increased risk of metabolic syndrome and cognitive decline in Hispanic populations. Future research to better understanding relationships between health risk and brain function in Hispanic populations is warranted to better conceptualize and develop interventions for these populations.

1. Introduction

Increased consumption of dietary sugars is a growing concern in the U.S., as it has been linked to an elevated risk for obesity, insulin resistance, diabetes, cardiovascular disease, and cognitive decline in older age (Elliott et al., 2002; Ferder et al., 2010; Fowler et al., 2008; James et al., 2011; Rippe and Angelopoulos, 2015; Stanhope, 2016). Dietary consumption of sugar has been found to be particularly prevalent among ethnic/racial minority populations, and recent studies in minority youth have reported links between greater consumption of dietary sugars and an increased association between cortisol and visceral adipose tissue (Gyllenhammer et al., 2014), a known risk factor for the development of fatty liver disease, insulin resistance, and Type 2 diabetes mellitus (T2DM; Sloboda et al., 2014). Indeed, several epidemiological studies have shown that Hispanic ethnic groups, have much greater risk for and prevalence of several metabolic conditions, including non-alcoholic fatty liver disease and T2DM (Schneiderman et al., 2014; Carrion et al., 2011; Goran, 2008). Importantly, these conditions have been associated with cognitive declines in older adults, and especially those from Hispanic backgrounds (Bangen et al., 2015; Blaum et al., 2007; Luchsinger et al., 2015; Zeki Al Hazzouri et al., 2013).

Recent neuroimaging and psychophysiological research suggests that differences in daily dietary sugar intake may have a neuro-biological basis. For example, animals studies have found significant effects of increased sugar consumption on neural pathways influencing subsequent food preference and consumption of high-calorie, sweet foods, such as hypothalamic networks important for homeostatic energy regulation and frontocortical-limbic networks important for reward processing (for a review see Murray et al., 2016).

Higher order processing of taste stimuli involves complex exchanges of information between the primary taste cortices

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(i.e. operculum and insular cortex) and higher order processing regions within the prefrontal, limbic, and medial temporal areas where the integration of affective, memory, and reward-based information occurs (Faurion et al., 1998; Haase et al., 2009; Jacobson et al., 2017; Kobayakawa et al., 1996; Verhagen et al., 2004; Veldhuizen et al., 2011). Among higher-order taste processing regions, the amygdala appears to be particularly important for affective and reward-based evaluations of gustatory stimuli due to extensive efferent and afferent connections with regions critical for primary taste processing, i.e. the insula, frontal operculum and Rolandic operculum. The amygdala is also known to be an important component of the fronto-temporal network responsible for the integration of affective, reward, and sensory information, and the determination of subsequent behavior. Moreover, amygdala response to consumption of sucrose has been directly associated with dietary intake of sugars (Rudenga and Small, 2012), as well as the evaluation of the pleasantness of taste stimuli (Green and Murphy, 2012). In particular, studies have shown that the *left* amygdala is activated in response to anticipation of glucose (O'Doherty et al., 2002), and to pictures of appetizing foods (Demos et al., 2011; Frankort et al., 2012).

Research suggests that brain response in this network may be lateralized in the context of affective and reward value-based judgments and decisions, and that left amygdala activation may be modulated by subjective experiences in association with cognitive and conscious affective evaluation. For example, studies have shown activation within the left amygdala among young adults in response to pictures of appetizing foods (Demos et al., 2011), and in sated, healthy weight participants during unbiased viewing of pictures of caloric food stimuli (Frankort et al., 2012). The amygdala, particularly in the left hemisphere, may also be especially susceptible to age-related changes. For example, research has found decreased connectivity in older adults between the left amygdala and frontal regions, including the OFC (Moriguchi et al., 2011). Thus, investigating ethnic differences in brain activation in these regions among young adults is critical to understanding their effects in aging populations.

The amygdala has been shown to function as an important part of the motivation and saliency network, which, in part, serves to evaluate the relevance of stimuli and direct adaptive and value-based behaviors. This network also includes regions within the orbitofrontal and cingulate cortices, as well as the insula, which share numerous efferent and afferent connections with the amygdala. This network has been implicated in motivated behaviors, in particular those involved in appetite and eating (Menon and Uddin, 2010).

Research has reported that the amygdala has been shown to selectively respond to salient, need-based and rewarding stimuli. For example, studies have shown increases in amygdala activation as a function of thirst, and in response to pictures of beverages relative to control pictures during the state of thirst (Becker et al., 2015; de Araujo et al., 2003a); Wagner et al., 2006; Saker et al., 2014). Amygdala response has also been shown to be modulated by hunger state, with a number of studies reporting selective activation to food pictures, but not non-food pictures (e.g., tools), during the state of hunger, but not when sated (LaBar et al., 2001; Mohanty et al., 2008), and to high calorie over low-calorie food pictures during hunger (Goldstone et al., 2009). The amygdala also maintains extensive connections with hypothalamus, autonomic-visceral pathways, as well as the sensory-association cortex, and accordingly, has been theorized to represent a "gateway" connecting visceral signals with sensory information from the ventral stream (LaBar et al., 2001).

Notably, recent work suggests that there may be genetically-based ethnic differences in taste perception, with one study reporting that Hispanic males rated magnitude estimates of sucrose from whole mouth tasting higher in intensity than non Hispanic white males (Williams et al., 2016). In addition, Hispanic populations show differences in brain response to *visual* food cues. For example, positive associations between abdominal fat and reward response to pictures of high calorie food have been reported in Hispanic females (Luo et al., 2013), and negative associations have been reported between insulin sensitivity and brain response to high calorie versus non-calorie food images in regions important for reward (e.g., striatum, orbitofrontal cortex), and primary taste processing (e.g., insula) in Hispanic children with diabetes (Adam et al., 2015). However, there have been no specific studies to date investigating differences in brain response to *tastes*, and specifically *sweet taste,* in Hispanic adults. Studies examining such relationships in Hispanic adults are needed in order to better characterize the neural response to sweet taste as such research may help elucidate factors underlying increased risk for diabetes and other insulin related dysfunction in vulnerable Hispanic populations. Thus, the current study aimed to examine differences in fMRI activation between Hispanic and non-Hispanic young adults in response to a sweet taste (sucrose). To best isolate activation related to higher order taste processing, an event-related fMRI paradigm was used to measure whole brain activation while participants rated the pleasantness of sucrose.

We hypothesized significantly lower activation in Hispanic relative to non-Hispanics participants in the left amygdala in a region of interest analysis. We further hypothesized that whole brain analysis would demonstrate significantly lower activation in regions that are involved in processing hedonic aspects of taste in Hispanic relative to non-Hispanic participants.

2. Results

2.1. Demographics and the Three Factor Eating Questionnaire (TFEQ)

Independent samples t-tests were conducted to test for group differences in age, taste threshold, BMI, and the total scores for each of the three scales of the TFEQ (e.g. Impulsivity, Cognitive Restraint of Eating, and Locus of Hunger). No differences were found between Hispanic and non-Hispanic young adults in any of the demographic variables or on TFEQ scales 1 or 2 ($p > 0.05$; see Table 1). Significant group differences were found on TFEQ scale 3, hunger, with the Hispanic group having significantly lower ratings for locus of hunger than the non-Hispanic group, $t\ (24) = 3.66$, $p = 0.001$. The hunger scale of the TFEQ measures an individual's susceptibility to hunger based on a variety of internal (e.g., rumbling from the stomach) and external (e.g., smelling "a juicy steak") stimuli. It includes questions regarding feelings of hunger and its behavioral consequences (e.g. "I am always hungry so it is hard for me to stop eating before I finish the food on my plate.") (Stunkard and Messick, 1985).

2.2. Psychophysical measures of hunger and pleasantness

To determine whether there were significant effects of ethnic group on hunger and pleasantness ratings, independent samples t-tests were conducted with ethnic group as the independent variable and pre-scan hunger and sucrose pleasantness ratings as the dependent variables. No significant effects of ethnic group on pre-scan ratings of hunger ($p = 0.924$) or sucrose pleasantness ($p = 0.294$) were found (see Table 1 for means and standard errors).

2.3. Functional neuroimaging

2.3.1. Region of interest (ROI) analyses

To investigate the effect of ethnic group on left amygdala activation, a univariate ANOVA was conducted with ethnic group as