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Fermented foods, neuroticism, and social anxiety: An interaction model

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ABSTRACT

Animal models and clinical trials in humans suggest that probiotics can have an anxiolytic effect. However, no studies have examined the relationship between probiotics and social anxiety. Here we employ a cross-sectional approach to determine whether consumption of fermented foods likely to contain probiotics interacts with neuroticism to predict social anxiety symptoms. A sample of young adults ($N=710$, 445 female) completed self-report measures of fermented food consumption, neuroticism, and social anxiety. An interaction model, controlling for demographics, general consumption of healthful foods, and exercise frequency, showed that exercise frequency, neuroticism, and fermented food consumption significantly and independently predicted social anxiety. Moreover, fermented food consumption also interacted with neuroticism in predicting social anxiety. Specifically, for those high in neuroticism, higher frequency of fermented food consumption was associated with fewer symptoms of social anxiety. Taken together with previous studies, the results suggest that fermented foods that contain probiotics may have a protective effect against social anxiety symptoms for those at higher genetic risk, as indexed by trait neuroticism. While additional research is necessary to determine the direction of causality, these results suggest that consumption of fermented foods that contain probiotics may serve as a low-risk intervention for reducing social anxiety.

1. Introduction

Social anxiety disorder (also known as social phobia) is the third most prevalent psychiatric disorder with lifetime prevalence estimates as high as 10.7% (Wittchen et al., 1999; Veale, 2003; Kessler et al., 2012). This disorder is defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) as the experience of significant distress or impairment that interferes with ordinary routine in social settings, at work or school, or during other everyday activities (American Psychiatric Association, 2013). As a result, social anxiety disorder can negatively affect many areas of life including dating, school, work, and family relations, with subthreshold social anxiety showing almost the same level of impairments in daily life (Wittchen et al., 2000).

Phobias have been shown to run in families (Hettema et al., 2001). Although it is not clear exactly what is inherited, vulnerability to social phobia is associated with fundamental personality traits such as neuroticism, defined as the general tendency to experience negative emotions such as nervousness, anger, envy, guilt, and depressed mood (Matthews and Deary, 1998). In fact, according to a recent large-scale twin study, genetic factors that influence individual variation in neuroticism appear to account almost entirely for the genetic vulnerability to social anxiety disorder (Bienvenu et al., 2007).

Although treatment for social anxiety disorder typically consists of cognitive-behavioral therapy or pharmacotherapy with selective serotonin reuptake inhibitors (Veale, 2003), more recently there has been increased interest in understanding how nutritional factors, such as probiotic intake, influence psychiatric disorders (Logan and Katzman, 2005; Forsythe et al., 2010; Dinan and Quigley, 2011; Bested et al., 2013a, 2013b, 2013c; Foster and Neufeld, 2013; Wall et al., 2014). Probiotics are defined as “live micro organisms, which, when administered in adequate amounts, confer a health benefit on the host” (FAO/WHO, 2001). Preclinical studies have demonstrated potential gut-brain pathways that allow gut microbiota to exert anxiolytic effects (see Mayer et al., 2014). For example, using mouse models Bravo et al. (2011) demonstrated that ingestion of the lactic acid bacteria *Lactobacillus rhamnosus* resulted in vagus nerve dependent anxiolytic behavioral effects and modulation of GABA receptor expression. Similarly, Bercik et al. 2010, 2011 have shown that probiotic treatment can minimize anxiety induced by gut inflammation and these anxiolytic effects were associated with changes in brain derived neurotrophic factor and dependent on the vagus nerve.

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A recent study in humans has shown that consumption of a fermented milk product containing a combination of probiotics (*Bifidobacterium animalis*, *Streptococcus thermophiles*, *Lactobacillus bulgaricus*, and *Lactococcus lactis*) can modulate brain activity (Tillisch et al., 2013). After four weeks of consuming the fermented milk product, there was a reduction in brain activity in a network of areas, including sensory, prefrontal, and limbic regions, while processing negative emotional faces. Importantly, a control group that ingested a non-fermented milk product showed no such changes in brain activity, suggesting that the probiotics in the fermented milk were responsible for the modulation in brain activity. This study demonstrates that fermented foods containing probiotics can alter how the human brain processes negative social stimuli.

Clinical trials have also demonstrated anxiolytic effects of probiotics in humans, but not specifically in those with social anxiety. In a study of patients with chronic fatigue syndrome, ingestion of *Lactobacillus casei* was associated with decreased scores on the Beck Anxiety Inventory (Rao et al., 2009). Similarly, adminstration of the prebiotic trans-galactooligosaccharide, which promotes the growth of indigenous beneficial gut bacteria such as Lactobacilli, resulted in decreased scores on the anxiety subscale of the Hospital Depression and Anxiety Scale (HADS-A) in patients with irritable bowel syndrome (Silk et al., 2009). Improvement in HADS-A scores has also been shown in healthy participants from the general population following ingestion of a probiotic formulation consisting of both *Lactobacillus helveticus* and *Bifidobacterium longum* (Messaoudi et al., 2011).

The current study sought to address several open questions regarding the anxiolytic effects of fermented foods that likely contain probiotics. No previous studies have examined the specific relationship between fermented food consumption and social anxiety. Furthermore, it is unclear how natural patterns of fermented food consumption relate to anxiety in humans because all existing studies are clinical trials in which consumption of probiotics was controlled. In addition, no studies have investigated whether consumption of fermented foods that likely contain probiotics can moderate the relationship between neuroticism, a known genetic risk factor for certain anxiety disorders, and anxiety symptoms. Thus, in the current study, a cross-sectional approach was undertaken to examine whether consumption of fermented foods that likely contain probiotics was related to social anxiety in a population of young adults, and if so, to explore whether consumption of fermented foods interacts with neuroticism to predict social phobia symptoms. If this in fact the case, we hypothsize that young adults who are high in neuroticism will demonstrate lower levels of social anxiety if their fermented food intake is high when compared to those with low intake.

2. Methods

2.1. Participants

Data were collected as part of mass testing for introductory psychology classes at a medium-size public liberal arts university in Virginia which counted for partial fulfillment of a course requirement. Surveys were completed electronically using Qualtrics software by 732 students. All participants provided informed electronic consent. The study protocol was approved by the Protections of Human Subjects Committee, and the investigation was carried out in accordance with the Declaration of Helsinki.

2.2. Measures

2.2.1. Social Phobia and Anxiety Inventory (SPAI-23)

The Social Phobia and Anxiety Inventory (SPAI-23) is a 23-item abbreviated inventory to assess social anxiety and agoraphobia symptoms (Roberson-Nay et al., 2007). Participants respond using a 5-point scale ranging from 0 (never) to 4 (always) to indicate how frequently they experience symptoms related to social phobia (16 items) and agoraphobia (7 items). The social anxiety SPAI-23 Difference Score, which reflects a "pure" measure of social anxiety, is obtained by summing up the responses for each subscale separately and then subtracting the agoraphobia score (Cronbach's alpha=0.90) from the social phobia score (Cronbach's alpha=0.95).

2.2.2. Big Five Personality Inventory

The 44-item Big Five Inventory assesses the personality traits extraversion, agreeableness, conscientiousness, openness, and neuroticism (John and Srivastava, 1999). Participants respond using a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree) to indicate how much a given characteristic applies to them. For the current study, the eight item neuroticism subscale was used (Cronbach's alpha=0.82).

2.2.3. Exercise frequency

Exercise frequency was assessed with a single item that asked: "how often do you exercise?" (see Appendix). Participants responded using a 4-point scale: 1 (never); 2 (1–3 times in the last month); 3 (1–3 times per week); and 4 (at least once per day). Scores were converted to monthly frequencies of 0, 2, 8, and 30.

2.2.4. Food frequency

To determine participants' consumption of foods, they were first asked to think of their food intake over the past 30 days (see Appendix). This was followed by a list of 10 items consisting of the following: 1.fruits and vegetables of all kinds, including fresh, canned, frozen, cooked, raw, and juices; 2. yogurt, 3. kefir, or food or beverages that contain yogurt; 4. soy milk, or foods or beverages that contain soy milk; 4. miso soup; 5. sauerkraut; 6. dark chocolate; 7. juices that contain microalgae; 8. pickles; 9. tempeh; and 10. kimchi. Participants were asked to indicate how often they consume each of the foods using the following 7-point scale: 1 (never); 2 (1–3 times in the past month); 3 (1–3 times per week); 4 (1–3 times per day); 5 (3–5 times per day); 6 (5–7 times per day); and 7 (more than 8 times per day). Scores were converted to monthly frequencies of 0, 2, 8, 60, 120, 180, and 240, respectively.

Given that the internal consistency of the nine fermented food items was high (Cronbach's alpha=0.89), a single score was derived as the mean per month consumption of the fermented food items.

2.3. Statistical analysis

Zero-order correlations between the SPAI-23 Difference Score and neuroticism, probiotics consumption, fruits and vegetable consumption, and exercise were calculated to examine bivariate relationships.

Before conducting the linear regression, the predictor variables were standardized (Dawson, 2014). Next, an interaction term was calculated by multiplying the standardized Neuroticism scores and the standardized IHS Fermented Food scores. A regression model was then constructed to predict the SPAI-23 Difference Score from Neuroticism, IHS Fermented Food, and their interaction (Neuroticism*IHS Fermented Food). Exercise frequency and fruit and vegetable consumption were controlled for statistically via inclusion in the model but were also examined as variables of interest. Age, sex, and race/ethnicity were also controlled for statistically via inclusion in the model.

3. Results

Of the 732 participants who completed the questionnaire, 22 were excluded due to missing data on key variables of interest, leaving a final sample size of 710 (445 female). These participants were between the ages of 18 and 38 years ($M=19.1$ years, S.D.=1.5). The sample was ethnically diverse (45% reported their race as Caucasian, 31% non-Caucasian, and 23% as multiracial).

Table 1
Means and distributions.

Measure	Mean	Median	S.D.	Range	Skewness	Kurtosis
SPAI difference score	19.47	18.00	10.36	−2.00–58.00	0.43	0.36
Neuroticism	23.77	24.00	6.32	8.00–40.00	0.09	−0.29
Fermented foods	9.91	2.37	24.51	0.00–240.00	6.48	51.65
IHS Fermented foods	0.86	0.69	0.57	0.00–2.68	0.65	−0.15
Fruits & vegetables	77.42	60.00	52.74	0.00–240.00	0.85	0.82
Exercise	12.70	8.00	11.12	0.00–30.00	0.79	−1.09

Note: Fermented foods, fruits & vegetables, and exercise are monthly frequencies; IHS Fermented Foods, inverse hyperbolic sine transformed fermented foods variable.