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The Relationship Between Sugar Intake and Neural Marker of Anxiety In Young Children

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THE RELATIONSHIP BETWEEN SUGAR INTAKE AND NEURAL MARKER OF ANXIETY IN YOUNG CHILDREN

By

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Introduction

Anxiety disorders affect about 1 in 5 adults in the United States population, making them the most common type of mental illness (Kessler et al., 2005). Additionally, 6.8 million adults suffer from General Anxiety Disorder, commonly abbreviated as GAD (Kessler et al., 2005). GAD is "excessive anxiety and worry (apprehensive expectation), occurring more days than not for at least 6 months, about a number of events or activities (such as work or school performance)" (American Psychiatric Association, 2013). The symptoms of GAD are: restlessness, being easily fatigued, irritability, difficulty concentrating, muscle tension, and sleep disturbance. But adults are not the only ones affected; anxiety disorders are the most frequently diagnosed psychopathology in children and adolescents as well (Beesdo et al., 2009). Anxiety has been a major research topic in clinical psychology for a long time. Prior studies have shown that most anxiety begins early in life and continues into adulthood. Therefore, understanding the trajectories that lead to anxiety as well as what can be done to treat and prevent anxiety is crucial.

Anxiety disorders can start early in development. Given this, there is substantial interest in identifying neural markers that may characterize trajectories that lead to anxious outcomes. One neural marker that has been studied extensively in relationship to anxiety is the error related negativity (ERN), which is a negative deflection that occurs about 50 milliseconds after an error is made on timed lab-based tasks. In over 40 studies, this neural maker has been found to be more negative in anxious adults (Moser, Moran, Schroder, Donnellan, & Yeung, 2013). Studies have also found that the ERN is enhanced in anxious children (Meyer, Weinberg, Klein, & Hajcak, 2012). Because of this, the ERN has been suggested as a neural biomarker for anxiety (Weinberg, Riesel, & Hajcak, 2012). Identifying neural markers, like the ERN, that develop

early on may aid in the implementation of early prevention of anxiety disorders. Prior evidence has emphasized the importance of early detection and treatment of anxiety disorders in the course of development. So, finding modifiable environmental factors that may impact neural markers of risk may provide evidence for new prevention and treatment approaches.

A body of research has been dedicated to exploring the relationship between food one consumes and one's mood. Specifically, many studies have explored links between sugar consumption and anxiety symptoms. Recent studies have found a connection between anxiety-like behavior and the genes involved in oxidative stress processing. Oxidative stress is the imbalance of high cellular levels of reactive oxygen and the ability of the body to detoxify it which can affect brain functioning. Souza et al. (2007) conducted a study where the goal was to explore the effect of a diet high in sucrose, a type of a carbohydrate that quickly turns to sugar, on anxiety-like behavior and brain oxidative status. In this study, there were two groups of rats; one group of ten rats received standard chow for four months and the other group of ten rats received the high palatable (HP) diet, which included high amounts of sucrose, for four months. The level of sucrose was the only difference in the rats' diet. Oxidative stress levels, metabolic factors, and behavior tests were assessed prior to as well as after the four months.

After the four months, both groups of rats were allowed to freely wander into a light compartment. The researchers found that the group of rats who were fed the HP diet were less likely to explore the light compartment ($p < 0.05$). This decreased tendency to explore the light compartment was interpreted as a marker of higher anxiety. In all, their data suggested that highly palatable diets may lead to an obese phenotype, which in turn increases oxidation in the frontal cortex and appears to increase anxiety-like behaviors in rats. Due to limitations, including the many brain systems involved in anxiety disorders that were not examined as well as the study

design, this study was not able to prove a causal relationship between HP diet and anxiety symptoms. Nonetheless, the results indicate a relationship between diet and anxiety.

To further reinforce this idea, many studies have demonstrated evidence for the idea that bingeing on sugar activates neural pathways associated with anxiety. In one experiment, Avena, Bocarsly, Rada, Kim, and Hoebel (2008) tested whether rats that binged on sucrose and then fasted would experience opiate-like withdrawal and increased anxiety-like behavior. They found that bingeing on sucrose followed by fasting created a state of increased anxiety and altered levels of nucleus accumbens dopamine and acetylcholine.

The experimental group of rats were given a diet of 10% sucrose solution and regular chow for 28 days. On day 28, the rats were deprived of sucrose for 36 hours. Afterward, the rats were placed on an elevated plus maze for 5 minutes. They found that this group of rats did indeed have an increase of anxiety-like behavior; which was determined by the decrease of time the experimental group of rats spent in the exposed arms of the elevated plus-maze (6% of the total time compared to the control group who spent 11% of the total time). In conclusion, long-term sugar bingeing can result in negative effects on behavioral and neurochemical alterations. This study is important to understand the correlation between large quantities of sugar consumption and modifiable behavior including anxiety-like symptoms.

Similar to these mentioned studies, in my honors thesis, I will be using data collected in Dr. Meyer's lab to examine whether sugar consumption correlates to anxiety symptoms and a neural biomarker for anxiety in children. The data I will use were collected through Electroencephalography (EEG) and self-report tasks. In the current study, 79 five- to seven-year-old children completed a series of computer games while on-going EEG was measured. The data in my honors thesis focuses on one game the children played called "aliengonogo." In this game,

the children were instructed to “shoot” an alien, by clicking the mouse, when the alien appeared on the screen. However, if an astronaut appeared on the screen, they were directed to not press anything and thus “save” the astronaut. Throughout the game EEG data were recorded. The children played the computer game without the parent in the room at first and later with the parent in the room sitting next to them; we counterbalanced the parent/experimenter condition. For the purpose of my Honors Thesis, we will examine both conditions. Along with the games played, the Screen for Child Anxiety Related Disorders (SCARED) was administered to parents to measure child anxiety symptoms. I will use the results from these surveys in order to assess the General Anxiety Disorder symptoms of the children. In addition to the SCARED questionnaire, parents also completed other self-report measures as part of the larger study. Another measure provided was the food survey, which included a list of multiple common foods like broccoli, bread, chicken, cookies, soda, etc. Parents were asked to report how many times their children ate each item within the past two weeks. The types of foods were listed vertically, and next to each type of food were bubble-in options that described how frequently their children consumed each food in the past two weeks.

In sum, a link between anxiety and sugar consumption has been identified across a range of studies. However, no previous study has examined whether sugar consumption relates to neural markers of risk for anxiety in humans. Furthermore, no previous study has examined the relationship between sugar consumption, anxiety, and neural markers of risk in young humans. Given that anxiety tends to begin early in life, identifying environmental factors that may impact risk markers early in development may provide novel avenues for intervention and prevention strategies.

In light of the idea that sugar intake may be related to anxiety, I wish to examine whether sugar intake in children may relate to a neural marker of risk for anxiety (i.e., the ERN). Additionally, I wish to examine to what extent sugar intake and the ERN may relate to GAD symptoms in children. To do this I examined the bivariate correlations between the sugar subscale and the ERN as well as the correlations between anxiety and ERN and anxiety and sugar. We also plan to control for variables that may influence these correlations such as socioeconomic status, parent's education, and children's age. We hypothesize that sugar consumption will relate to both an increased ERN, as well as increased GAD symptoms.

Methods

Participants

The overall study included 100 children between the ages of five and seven years old, who were recruited from the Tallahassee community. Of the 100 children, 79 children completed the EEG assessment. Children were only included in analyses if they had completed the EEG assessment. There was a total of 35 female and 42 male children ages 5 to 7 years old (average = 5.78, SD = .771.) Parents who participated in this study were on average 37.27 years old, SD = 6.496. Out of the participants, 7% identified as Hispanic or Latino, 6% as Asian, 18% as black, 67% as white, and 7% as other. 88% of the parents who participated in this study were female. Looking at social economic status, 3% of the participants reported making less than $10,000 per year, 7% reported making between $10,000-$25,000 per year, 9% reported making between $25,000-40,000 per year, 37% reported making $40,000-$75,000 a year, and $43,000 reported making more than $75,000 per year.

Protocol

When the families arrived for their lab visit, both the children and parents were consented and instructed by a research coordinator. The lab visit included a variety of behavioral and psychophysiological measures. During the lab visit, both the parents and children completed one self-report measure: the Screen for Child Anxiety Related Disorders (SCARED) while only the parents completed a food survey and only the children completed the go/no-go task with EEG.

Self-Report

The current study focuses on self-report measures that evaluate the child's anxiety symptoms. The SCARED scale screens for childhood anxiety disorders including general anxiety disorder, separation anxiety disorder, panic disorder and social phobia. It consists of 41 items that parallel the DSM-IV criteria for anxiety disorders. This measure has demonstrated good psychometric properties: "the total score and each of the 5 factors for both the child and parent SCARED demonstrated good internal consistency and discriminant validity (both between anxiety and depressive and disruptive disorders and within anxiety disorders)" (Birmaher, B., Brent, D. A., Chiappetta, L., Bridge, J., Monga, S., & Baugher, M. (1999). Both the parent and the children completed the SCARED scale. Parents also completed a questionnaire indicating foods their children had eaten. Parents were asked to report how many times their children ate each item within the past two weeks. The food survey was a straight forward measure that included different types of food such as broccoli, chicken, cookies, desserts, fruit juices, bread, and other foods. The scale went from never to 1-2 times to 3-4 times to more than 4 times.

Tasks and Materials

EEG was recorded while children completed a go/no-go task, which was developmentally appropriate. Children completed the task while the parent sat next to them and later while an experimenter sat next to them. The parent and experimenter conditions were counterbalanced.

The children were instructed to “shoot” aliens, by pressing the mouse button, as soon the alien appeared on the screen and “save” astronauts, by refraining from pressing the mouse button, when astronauts appeared on the screen. Stimuli consisted of an image that appeared on the screen for 500 ms. Children completed a total of 400 trials.

Psychophysiological recording and data analysis

Throughout the study, continuous EEG recordings were collected using an elastic cap and the ActiveTwo Biosemi system. Thirty-four electrodes were used as well as two electrodes on the left and right mastoids. Eye movements and eye blinks were recorded using four facial electrodes. Two electrodes located about 1 cm outside the outer edges of the right and left eyes were used to record horizontal eye movement. Vertical eye movements were recorded using two electrodes that were placed about 1 cm above and below the right eye.

EEG data were collected starting from 500 ms before the child’s response and up to 1,000 ms after the response. At the midline electrode, Cz, error-related brain activity was maximal and a difference score, which is the amount of errors minus the amount of correct responses, was calculated.

Statistical analyses were conducted using SPSS. Pearson correlations were used to examine the relationships between all study variables.

Results

Descriptive Data: Self-Report

In this study, the average sugar consumption among the participating children was 17.42 , SD = 3.12. For both the parent and child, none of the rates of sugar consumption related to gender. The parent’s age and child’s age did not relate to the child’s sugar consumption.

On the SCARED measure, the average score reported by parents was 53.78, SD = 9.397, while the average score reported by children was 67.03, SD = 19.370. There was no relation between the scores on the SCARED scale and the gender. The relationship between child age and total SCARED was at trend level (r= -.21, p=.06). GAD also relates to the child age where (r=-.22 p = .05).

Descriptive Data: ERN

There were 79 participants with useable alien go no go data. Throughout the study, children made on average 27.03, SD =16.489 errors in the parent condition. On average, children made 131.30, SD = 21.596 correct responses. The average accuracy rate for the children, while their parent was in the room, was 0.8329, SD = 0.8902. The average accuracy rate for the children, while the experimenter was in the room, was 0.8565, SD = 0. 08035.

Correlation Results

	Sugar consumption
Error related neural activity (ERN)	**-.30****
Child SCARED total	.13
Child SCARED panic	**.18[t]**
Child SCARED generalized anxiety	**.21***
Child SCARED separation anxiety	-.06
Child SCARED social anxiety	.01
Child SCARED school avoidance	.01
Parent SCARED total	.01
Parent SCARED panic	.02
Parent SCARED generalized anxiety	.03
Parent SCARED separation anxiety	.06
Parent SCARED social anxiety	-.05
Parent SCARED school avoidance	-.12

$^{t}p < .07$, * $p < .05$, **$p < .01$No

Table 1 Displayed are partial correlations when controlling for age

To examine the correlations between sugar consumption and the ERN while the parent was in the room, we conducted bivariate correlations. Results suggested there was a significant correlation between sugar consumption and ERN at CZ which was ($r = -.33$ $p = <.01$).

To examine the extent to which sugar consumption related to the Error Related Negativity (ERN) in both the parent and experiment condition, we performed a partial correlation while controlling for age. There was a moderate negative correlation between ERN and sugar consumption, which was statistically significant ($r = -.33$, $n = 79$, $p = .<01$); that is, the more negative the ERN of the child, the more sugar was found to be consumed by that child. A partial correlation was used to assess whether sugar consumption related to the children's report on the SCARED. Results suggested that there was a small positive correlation between the child SCARED panic symptom scale and sugar consumption, which was statistically significant ($r = .18$, $n = 79$, $p = .07$). A partial correlation was used to study the relationship of sugar consumption and child SCARED GAD. It was determined that there was a positive correlation between GAD symptoms and increases in sugar consumption, ($r = .21$, $n = 79$, $p = 0.5$). As can be seen in Table 1 both the ERN and the child report of GAD related to sugar consumption, such that children with a larger ERN consume more sugar, and children who report more GAD also consume more sugar.

As can be seen in Figure 1, there are both waveforms which include error, correct and the difference as well as topographical head maps which display error minus correct. As can be seen, children who consume more sugar have a larger ERN when compared to children who are low in sugar consumption. The grey line represents neural activity when the children make a correct

response in the Alien No Go task, the dotted line represents neural activity when the children made a mistake in the task, and the black line represents the difference between the two, that is, the bigger difference between the "correct" and "error" line, the higher the "difference" line. Overall, children with higher sugar consumption showed increased error-related neural activity. As can be seen in the topographical head maps, children high in sugar consumption display an increased ERN during the parent condition when compared to children who are low in sugar consumption.

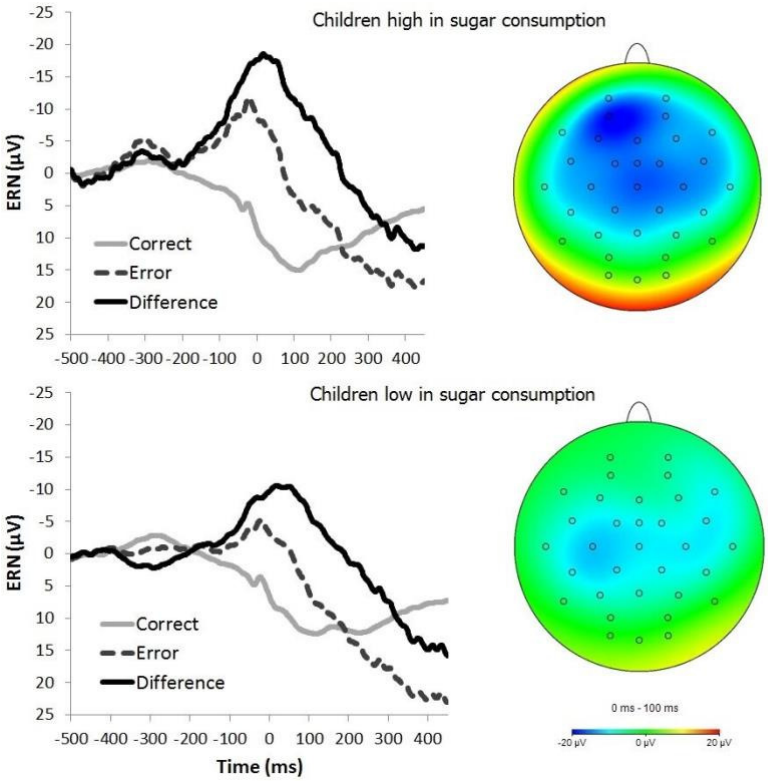

Figure 1 Head Maps and Line Graphs portraying levels of ERN in children with high sugar consumption and children with low sugar consumption

Discussion

This work is novel because we examine the relationship between a neural marker of risk for anxiety and sugar consumption in young children. Sugar consumption was significantly correlated to the magnitude of the ERN, meaning that sugar consumption may be a modifiable

factor that contributes to a neural marker of risk for anxiety in children. Previous work indicates that anxiety and ERN are related. Results from the current study show that children's sugar consumption was both related to increased results of panic and GAD on the SCARED.

The current study was conducted in young children (ages 5-7). We focused on young children because understanding the trajectories that lead to anxiety could help with early intervention and treatment, especially with such a modifiable factor like sugar consumption. Since there is a possibility that anxiety and ERN are more easily shaped at a young age, these results could aid in the promotion of decreasing overall sugar consumption which could aid in the prevention of psychopathology. Future work could consider other modifiable environmental variables that could lead to a decrease in anxiety and ERN.

Previous work has shown that an increased ERN during childhood is correlated with a risk for anxiety disorders (McDermott, Perez-Edgar et al., 2009; Meyer, Hajcak et al., 2015; Meyer, Nelson et al., Under Review). It is possible that sugar consumption shaping the ERN in childhood is also related to greater risk for anxiety disorders. Being able to intervene from a young age with an environmental factor that is negatively modifying a neural marker for anxiety could be extremely helpful.

The limitations of this study include the fact that sugar consumption was recorded by the parents. This could be unreliable as the parent does not account for the sugar the child consumes while not around them. There could also be self-report bias where the parent feels as if the amount of sugar their child consumes is embarrassing and therefore recorded a decreased amount. Another limitation of this study is that it is entirely correlational; future work could use random assignment to further examine the impact sugar may have on the ERN.

The study was not able to answer exactly what type of sugar (e.g., fructose, sucrose, or high fructose corn syrup) was correlated with an increase in ERN. Meaning we did not differentiate between naturally occurring sugar found in things such as fruit and high fructose corn syrup which is an artificial additive in many foods. Analyzing the type of sugar involved in the correlation between sugar consumption and ERN could be useful as it would aid with the preventions of decreasing sugar consumption to lessen the risk for anxiety. Future research could be conducted to further understand the correlation between sugar consumption and the shaping of ERN as this could positively impact the treatment or prevention of anxiety disorders.

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