

Sugar Content Impacts Mood but not Reward Valuation

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ABSTRACT: Due to the high frequency at which sugar is found in foods, adolescents can build addictive tendencies to sugar. The sweet compound is often associated with positive mindsets and memories. To collect data on how different sugar levels may impact mood, we administered surveys before and after female participants aged 14-17 consumed cookies of varying sugar content (8, 4, and 0 grams of sugar/cookie). In response to the question, "rate your current mood on a scale of 1-10," participants reported a significantly higher mood following consumption of the 8g and 4g cookies ($p=0.0001$ and $p=0.0013$, respectively) and a substantially lower mood following consumption of the 0g cookie ($p=0.0405$). Interestingly, sugar content did not affect how much participants reported they would pay for each cookie ($p=0.3842$). These results suggest that sugar content impacts mood; however, it did not significantly affect the value that participants placed on the reward of each cookie.

KEYWORDS: Behavioral and Social Sciences; Cognitive Psychology; Sugar; Mood; Reward.

■ Introduction

Sugar is often considered the ultimate attraction to adults and kids alike. Its sweetness creates irresistible goods and addictive treats. Children often reach for sweet products, lollipops, chocolate, and gummy candy because they satisfy their cravings.

Sugar increases the release of dopamine, a neurotransmitter that makes us feel pleasure. Sugar consumption activates the reward system in our brains, producing addictive behaviors like continuously wanting to ingest sugar because it makes people feel good. This reward system shapes eating patterns by promoting the repeated intake of high-sugar foods. Because sugar can cause feelings of reward and satiety, people often look to it to seek its effects. This reward partially leads people to seek foods with pleasant tastes and rewarding feelings.¹

A study showed the effects of the ingestion of sugar and a calorie-free substitute placebo to be the same.² Artificial sweeteners such as Splenda and Stevia have been shown to psychologically rewire our brains to believe our bodies are ingesting real sugar. It will be essential to investigate if the same holds true for various amounts of sugar in addition to sugar substitutes. Sugary snacks and sweet treats play a significant role in the lives of many, especially teenagers. We are interested to know more about how varying sugar contents impact mood and reward pathways.

In the present study, participants consumed a series of three chocolate chip cookies, all with varying amounts of added sugar: standard (8g sugar/cookie), low (4g sugar/cookie), and no sugar (0g sugar/cookie). Sugar refers to the white sugar that was added to the cookie dough. Each cookie, even the ones with zero added sugar, had some sugar due to the controlled number of chocolate chips placed on every cookie.

Participants then answered a series of questions regarding their mood before and after the consumption of each cookie. We hypothesized that the results of our surveys would show similar positive changes in mood before and after consum-

ing the cookies with standard sugar and low sugar. However, we predicted that the changes in mood before consuming the cookie with no sugar would be either negative or less favorable than the change with the other two cookies. Similar changes in mood before and after eating cookies of varying sugar contents could suggest that activation of the brain's reward pathways has a psychological and biological component.

■ Methods

Participant Recruitment and Screening:

With Horace Greeley High School Institutional Review Board (IRB) approval, female participant recruitment was completed via a paper flyer advertising the study at a youth summer camp. Males were not included in the study. Interested participants were then given a paper screening questionnaire that included demographic information such as age and sex and experimental safety questions such as allergies and food avoidance. Food avoidances were defined as any food that the participant extremely disliked or would not eat. This allowed us to make sure all participants would eat the cookies. Exclusion criteria included any participant who had food allergies (besides nuts because cookies were already nut-free) or food avoidances. Participants were not asked to follow a specific diet before the experiment, and all cookies were distributed and consumed at intervals described below beginning at 3:45 pm. Informed consent was obtained from all participants who met inclusion criteria before any experimental procedures.

Survey:

A paper 5-question survey was used to assess participant mood and reward valuation before and after cookie consumption. To assess mood, respondents were asked to rate their mood and how much they wanted a cookie on a scale of 1-10, with 1 being the lowest and 10 being the highest. To assess reward valuation, respondents were asked to select how much they would be willing to pay for a cookie, turkey sandwich, and piece of pizza from a list of dollar amounts ranging from \$1.00 to \$10.00. Reward valuation was defined as how much money

the participants were willing to spend on each cookie before and after eating it. Questions regarding turkey sandwiches and pizza were designed to keep the experiment controlled. The purpose of the experiment was unrevealed.

Cookie Recipe:

Cookies were made in three batches according to sugar content. The following ingredients were combined in a large mixing bowl: 2 ¼ cups flour, 1 tsp baking soda, ½ tsp salt, two sticks softened butter, 2 tsp vanilla extract, two large eggs, and 303, 128, or 0 grams of sugar. The resulting dough was divided into 37, 32, or 30 equal portions resulting in approximately 8, 4, or 0 grams of sugar per cookie, respectively. Each cookie was topped with five semi-sweet chocolate chips. The cookies were baked until golden brown at 350 degrees Fahrenheit. The 8g cookies were individually packaged in a bag labeled A. The 4g cookies were individually packaged in a bag labeled B. The 0g cookies were individually packaged in a bag labeled C. One of each type of cookie was placed in a plastic container and labeled with participant IDs 1-24.

Experimental Timeline:

Before the start of the experiment, participants were not told the purpose of the experiment; however, they were informed that they would be consuming a set of cookies (unaware of their sugar contents) and then filling out a series of surveys. All participants completed the experiment at the same time but were spaced far apart and instructed that they could not speak or discuss each other's survey responses.

The experiment consisted of three segments: one for each type of cookie. During each segment, participants filled out the mood and reward valuation survey, ate the cookie, and then filled out the mood and reward valuation survey a second time. Participants drank a glass of water between each segment and waited 15 minutes. All participants consumed the cookies in order of decreasing sugar content. Upon completion of all three phases, participants were asked to reflect on their experience and state what they thought was the purpose of the experiment.

Statistical Analysis:

Paired t-tests were used to individually compare mood ratings on a scale of 1-10 before and after cookie consumption for each cookie group: 8g, 4g, and 0g sugar (Figure 1A). Ordinary one-way ANOVA with multiple comparisons was used to compare mood changes and reward valuation changes before and after cookie consumption between the 8g, 4g, and 0g cookie groups (Figure 1B, Figure 2). All analyses were completed using Prism 9.2.0 (GraphPad Software, LLC).

Results and Discussion

Participants:

Twenty-four female participants with an average age of 15.7 years (range 14-17) responded to the recruitment flyer. No participants met the exclusion criteria, and informed consent was obtained before any experimental procedures.

Sugar content significantly impacted mood: PuriScan Application Design:

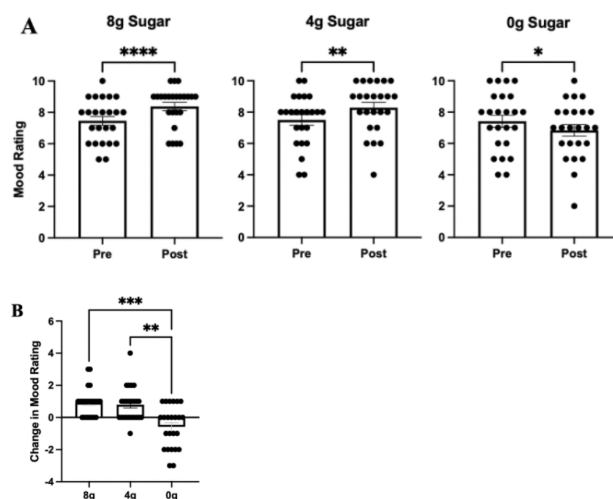


Figure 1: Sugar content impacts mood ratings. A) Survey responses asking participants to rate their mood on a scale of 1 to 10 before and after eating each of the three cookies. B) Change in mood score compared between the 8g, 4g, and 0g cookie groups.

Participants were asked to rate their moods on a scale from 1 to 10 before and after consuming each of the three cookies. The cookie with 8g of sugar resulted in a statistically significant increase in mood ($p < 0.0001$). The cookie with 4g of sugar also resulted in a statistically significant increase in mood ($p = 0.0011$). Like the cookie with 8g of sugar, the cookie with 4g of sugar produced a positive increase in mood from before to after cookie consumption. Unlike the first two cookies, the cookie with 0g of sugar significantly decreased mood from before to after cookie consumption ($p = 0.0250$) (Figure 1A).

While the 8g and 4g cookies both resulted in a significant increase in mood, this change was similar among the two groups ($p = 0.7528$). However, the shift in mood seen in both the 8g and 4g groups was significantly different from the change seen in the 0g group ($p = 0.004$, $p = 0.0051$, respectively) (Figure 1B). One participant resulted in a significant outlier, possibly due to eating less of the cookies or a biological factor that impacted their taste, and was excluded from the analysis. This data suggests that sugar content affects mood.

Sugar content did not impact the value of the reward:

Before and after consuming each cookie, participants were asked how much they were willing to pay for a chocolate chip cookie. Responses included less than \$1.00, \$1.00-\$10.00, and more than \$10.00. Despite the varying sugar contents (8g, 4g, and 0g of sugar) in the different cookies, the value participants placed on the reward did not change significantly after consuming each of the three cookies ($p = 0.3842$) (Figure 2). The data from this section of the survey generated a p-value of 0.3842, indicating that the results were not statistically significant. The results showed that data could have been strongly produced due to chance. This data suggests that sugar content does not impact the value participants place on the reward, as defined by the amount of money one would spend on a chocolate chip cookie.

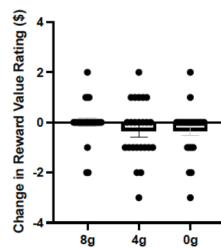


Figure 2: Sugar content does not impact reward valuation. Participants' responses to the amount of money they would spend on a cookie before and after the consumption of the cookie with 8g of sugar, 4g of sugar, and 0g of sugar.

Participant assessment of the study:

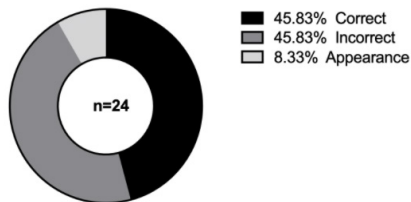


Figure 3: Participant assessment of study purpose. Short answer survey responses about the participants' impression of the purpose of the study, coded as correct, incorrect, or about cookie appearance.

After consuming all three cookies and completing the assessment surveys, participants were instructed to debrief on their experience with the study. In this debrief, participants were asked what they believed the purpose of the experiment was. Before the experiment, participants were only aware that they would be eating cookies and filling out the survey; no one was told the intent of the experiment. Of the 24 participants in the study, 11 (45.83%) correctly guessed that the objective of the experiment was to see how different levels of sugar impacted mood. Secondly, 11 participants (45.83%) provided an incorrect assessment of the study and could not identify the purpose of the experiment. These responses ranged from hunger cues to "the impact a piece of food can have on you." Interestingly, 2 participants (8.33%) noticed that the three groups of cookies looked different and believed the purpose of the experiment had something to do with how the appearance of various cookies impact people's moods and thoughts about the cookies after consumption (Figure 3).

Discussion

Sugar is quite an addictive substance. It has a draw. Adolescents especially are drawn to the sweet taste sugar brings to all types of food. A reason why sugar is so obsessive is because of how it makes people feel. Glucose (sugar) not only improves attention, speed of processing, and memory, but it is linked to affective mood changes. Elevated blood glucose levels contribute to increased mental energy. In other words, eating more sugar will lead to a more positive mental state.³ Our experiment produced similar findings when positive mood increases were seen after participants consumed cookies with 8g of sugar and 4g of sugar.

In addition to the impact various sugar contents had on mood, we were interested to learn more about reward valuation. The information available to consumers can be associated with feelings of reward. In one study, when a food was labeled

"Rich and Delicious," there was increased activity in the orbitofrontal cortex (OFC) and ventral striatum (VS), areas of the brain associated with emotion and reward-linked behavior, respectively. This indicates that when people had reason to believe that a product was "good" and pleasurable, they placed a higher reward on it.⁴ This could explain some of the findings in our experiment. Participants may not have set higher rewards on the cookies with more sugar because they were not informed about the sugar content in the cookies. We hypothesize that if participants were informed of the cookie's sugar contents, they would be more likely to place a greater value on the cookie with the most sugar.

Our experiment was carried out without a problem, and the participants were engaged throughout each step. After collecting all the data, we zoomed in on the questions regarding mood and reward valuation for further analysis. The data shows that sugar content significantly impacts mood. The cookie with 8g of sugar and the cookie with 4g of sugar both produced a positive increase in mood from before to after each cookie was consumed. However, the cookie with 0g of sugar produced a slight decrease in mood from before to after consumption. In reference to mood valuation, sugar content did not impact the value participants placed on the reward. Reward, in this case, was defined as the amount of money a participant would spend on a chocolate chip cookie. Our results support our hypothesis before the experimental procedure that the standard sugar and low sugar cookie will show similar mood changes. In contrast, to be true, the no-sugar cookie will show a negative or less positive change in mood.

It can be inferred from these results that some of the positive mood change that occurred due to the cookie with 8g of sugar and the cookie with 4g of sugar was psychological because two cookies, with two different amounts of sugar, produced similar positive change in mood. This suggests that we can consume sweet treats with lower amounts of sugar and still feel the same satisfaction as they would have if we consumed a cookie with a larger amount of sugar. This could potentially provide a partial solution to sugar addiction, which can lead to obesity, a problem in many adolescents. Additionally, the results reveal that participants indirectly detected the difference between the cookies with sugar and those without sugar, indicated by the positive mood changes in Cookie A and B and the negative mood change from Cookie C.

It can also be inferred that because participants reported more positive mood changes in cookies with sugar than without and the value placed on the reward did not change between the cookies, the cookies with sugar didn't increase mood enough to affect how much participants would spend on the desired cookie. Suppose the mood increases from before and after consumption of the cookies with sugar were higher. In that case, it is possible that the reward valuation would have increased from before to after the consumption of these cookies because people would have been 'happier' with the cookies and would have therefore been willing to spend more to eat them.

More, other factors that could have influenced results are the caloric density of the cookies. The cookies with 8 g of sugar had a greater caloric density, and from research, we know that rich,

dense foods can often present feelings of pleasure and satisfaction. The different chemical structures of the cookies due to the different amounts of sugar could contribute to different cookie textures, which could affect study results. It should also be acknowledged that the results could have been affected by a lack of controls and factors like being full after consuming various cookies and that everyone ate the cookies in the same amount and order. If the experiment was repeated, some participants could consume the cookies in order of increasing sugar content, and some could consume one three times instead of each of the three cookies once. This could help decrease error, increase control, and explain the experiment's effects.

Because our study was limited to female participants, extending the analysis to male participants would be an appropriate next step to test for sex differences in the responses to varying sugar contents in cookies. Additionally, we believe another critical next step would be to monitor brain scans and measure how activity in brain regions associated with reward and pleasure changes in the presence of different sugar contents.

■ Conclusion

Our experiment was conducted to see the effects of different sugar content on mood and reward valuation. Altered sugar content resulted in positive changes in mood in the cookies with 8g of sugar and 4g of sugar and a negative shift in mood in the cookie with 0g of sugar. Interestingly, altered sugar content did not impact reward valuation, as measured by how much participants were willing to spend on each cookie. However, our categories of cookie values (less than \$1.00, \$1.00-\$10.00, and more than \$10.00) could have affected these results as it's unlikely an individual would spend \$10.00 on a singular cookie. Overall, the results of our study are significant because they indicate that different amounts of sugar can have different effects on mood, and we may be able to derive similar amounts of pleasure from products with fewer amounts of sugar. As a result, healthier products could replace full-sugar items.

■ Acknowledgments

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