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The effect of food anticipation on cognitive function- A replication study

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Abstract

Several lines of evidence indicate that glucose can enhance cognitive performance without being ingested. Previous research has found that the effect of food anticipation can boost cognitive resources in a testing environment [1]. This study was designed to replicate the findings utilizing the same population, examining the effect that food anticipation has on cognitive abilities among multiple weight groups. 182 students were included in this replication study. In order to accurately measure the results, the study randomized the order that food anticipation tasks and cognitive tests were performed. The results indicated that an anticipatory food reward effect enhanced the cognitive capabilities of individuals categorized by BMI as overweight and obese. Furthermore, this effect shifted the attention of these individuals toward lite food options as opposed to regular. Finally, this anticipatory food effect reduced emotional arousal regarding food for individuals in the obese BMI category. We replicated previous findings of increased cognitive resources in the presence of food anticipation prior to test taking. These findings add to the growing literature that the presence of food can boost cognitive resources in testing environments. Future studies should shift the focus away from weight as a driving factor in the results, and instead look at how socio-economic status (SES) and food insecurity may affect eye gaze behavior and the anticipatory reward effect associated with food cues.

Keywords: food anticipation effect, cognition, eye gaze behavior, weight, BMI, glucose

1. Introduction

Previous research has documented that resource scarcity in the form of time pressure, sleep deprivation, and high cognitive load can negatively impact cognitive performance [2-7]. Scarcity of any form can decrease the amount of cognitive resources for other functions, impacting daily life from impatient economic decisions to general financial concerns [15, 16]. However, these resources can be replenished through glucose supplementation [8]. It has been suggested that ingesting glucose before engaging in a difficult task can boost cognitive performance. For example, participants that consumed a glucose drink exhibited less intuitive, faulty decision-making than those that drank the placebo due to repletion of mental resources [17]. An alternative hypothesis for the effect of glucose suggests that glucose can enhance cognitive or physical performance even when it is not ingested. This enhancement occurs by activating brain regions associated with reward responses. Chambers et al. found that participants who rinsed their mouth with a glucose solution before engaging in physical performance showed an activated response in reward-related brain regions, including the anterior cingulate cortex and striatum [9]. Rowlatt et al. found that participants who rinsed their mouths with a carbohydrate solution showed significantly improved accuracy of skill-specific performance [10].

The current study investigated whether cognitive resources can be replenished by the simple act of anticipating food intake, prior to sensing or eating food. This question is important because it contributes to current understanding of the effects of food anticipation on cognitive ability. The results of this study could encourage further studies to investigate cognitive capabilities associated with low food levels or the relationship between decision-making and glucose levels. Furthermore, this study is the first to utilize eye tracking to examine the relationship between visual attention, cognitive function, and food-related decision making.

The hypothesis was tested by splitting participants into two conditions: the “anticipatory effect” and “no anticipatory effect” (control). In the anticipatory effect condition, participants completed a food choice task before taking a cognitive test. Conversely, in the control condition, participants were instructed to perform the cognitive test first in order to prevent any influence of food anticipation on the results. Next, participants were further divided into groups based on their BMI. The results demonstrated that overweight and obese participants that completed the food choice task prior to the cognitive test exhibited enhanced cognitive performance, demonstrating an anticipatory food reward effect. Additionally, eye tracking was used to monitor the eye movements of participants while they were shown pictures of food menus with lite or regular options. Finally, obese individuals displayed less arousal towards food and shifted their attention towards lite snacks.

2. Methods

Participants:

This experiment involved students from a large university in the United States. The participants were required to be at least 18 years of age and have no history of psychiatric or eating disorders or known food allergies. Participants also had to be willing to fast before the experiment and rank their hunger on a scale of 1 to 9 (1 = not at all, 9 = extremely hungry) before the experiment began.

Experimental Design:

There was a three-hour food deprivation period to allow for the body to revert to a natural hunger state. The participants were required to complete a cognitive test and a food choice task. Half of the participants completed the food choice task before the cognitive test in order to test the "anticipatory effect." The other half, considered the control group, performed the cognitive test before the food choice task. Therefore, participants are first broken down into two treatment conditions of anticipatory effect and no anticipatory effect. Within these, participants are separated further into three different BMI categories consisting of normal, overweight, and obese.

Tests:

The cognitive performance test consisted of twenty-four problems taken from the Raven's Progressive Matrices Test. This is a nonverbal test that consists of various geometric patterns with a missing piece that must be identified. Subjects were given sixteen minutes to complete twenty-four problems. In the food-choice test, participants were offered 20 binary choice sets. This set showed a snack and the "lite" version of the same snack (e.g. light or regular Yoplait vanilla yogurt). At the end of the test, participants drew a bingo ball labeled 1-20 and ate the corresponding snack of the number they chose. After the two tests, participants filled out surveys and their height and weight were recorded.

Data Collection:

The experimenters tracked eye movement during the food choice task. Total visit duration and pupil dilation was used to assess the temptation and emotional arousal of the participants. A Wilcoxon Rank-Sum test was then performed on the data. Our replication lacked the equipment to track eye movement.

3. Results

The actual performance of participants on the cognitive test are presented in Fig. 1. Accuracy was calculated by dividing the number of correct answers the participant earned by the total number of questions. Wilcoxon Rank Sum tests were utilized to replicate data analysis, which demonstrated a difference in the accuracies between treatment conditions across BMI categories. Individuals in the normal BMI category exhibit no significant difference in cognitive test performance across treatment conditions, so there is no evidence of an anticipatory food reward effect (Wilcoxon p-value = 0.240, T-Test p-value = 0.239). However, participants in the overweight and obese BMI categories demonstrate a statistical difference in scores according to the order in which they performed the experimental tasks (Wilcoxon p-value = 0.003, T-Test p-value = 0.004 for overweight, Wilcoxon p-value = 0.008, T-Test p-value = 0.012 for obese). Individuals that experienced an anticipatory effect by viewing slides of food before performing the Raven's Progressive Matrices Test possessed a higher proportion of total correct answers. This demonstrates that in those BMI categories, expecting consumption of a snack boosted their overall performance, which is a concept supported by prior studies suggesting obese individuals are more likely to benefit from food intake in a neurobiological way compared to lean individuals. Overall, the replicated result indicates the existence of an anticipatory reward effect regarding food and cognitive function in select BMI categories.

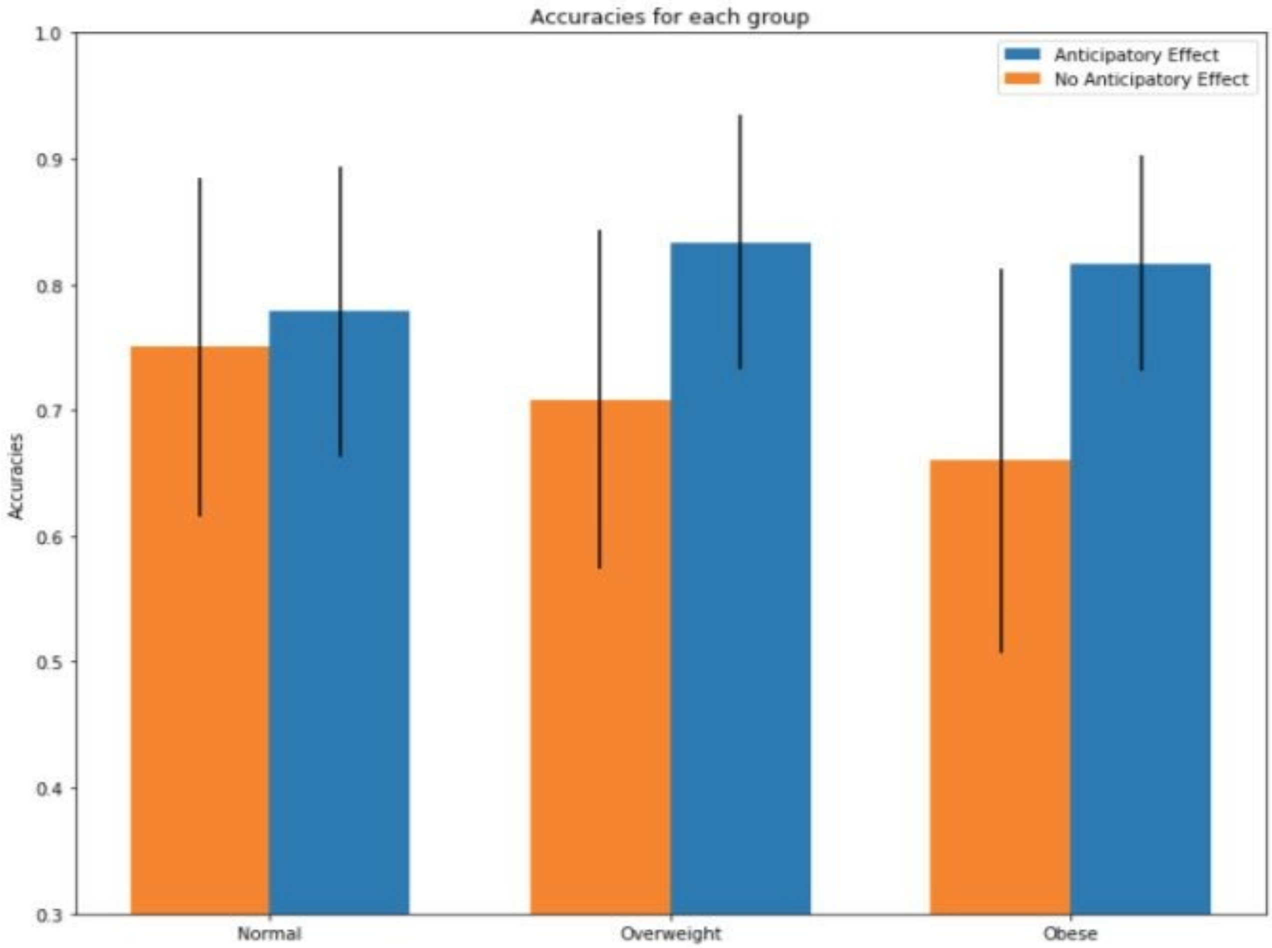

Fig. 1. Accuracy of scores on the cognitive replication test by treatment condition and BMI category. On the x-axis, BMI categories from left to right are normal, overweight, and obese. Accuracy is on the y-axis. The anticipatory effect is represented by blue, and no anticipatory effect is represented by orange. An anticipatory effect is demonstrated in participants of overweight and obese BMI categories, as they exhibit higher proportions of correct answers than participants in the control group.

The study's next results were generated by eye-tracking data. Although our replication study lacked the equipment to recreate these results, we were able to analyze their data set and generate graphs that confirmed their findings. As demonstrated in Fig. 2, there is evidence that the presence of an anticipatory food effect shifts the attention of overweight and obese individuals toward lite over regular snacks. Attention level was interpreted as “temptation,” and quantified as the difference in time visit duration in the regular versus the lite snacks. As described in the methods section, participants viewed slides with a regular and a lite version of the same snack during the food choice task. In Fig. 2, positive values on the y-axis signify that subjects spent more time looking at the lite snacks, while negative values mean that subjects spent a greater amount of time looking at regular snacks.

Wilcoxon Rank Sum tests were utilized again to replicate data analysis, which demonstrated a difference in attention level throughout the food choice task in overweight and obese participants as opposed to those of normal BMI. Specifically, individuals in the overweight and obese BMI categories in the *no anticipatory effect* condition spent a statistically significant amount of time focused on regular snacks, while those in the normal BMI category did not (Wilcoxon p-value = 0.709, T-Test p-value = 0.487 for normal). However, their attention shifts more toward lite snacks after experiencing an anticipatory effect (Wilcoxon p-value = 0.078, T-Test p-value = 0.140 for overweight, Wilcoxon p-value = 0.203, T-Test p-value = 0.171 for obese). Overall, our replication study confirms the result that an anticipatory effect has the ability to shift the attention, as measured by eye-tracking cues, of overweight and obese individuals from regular to lite food.

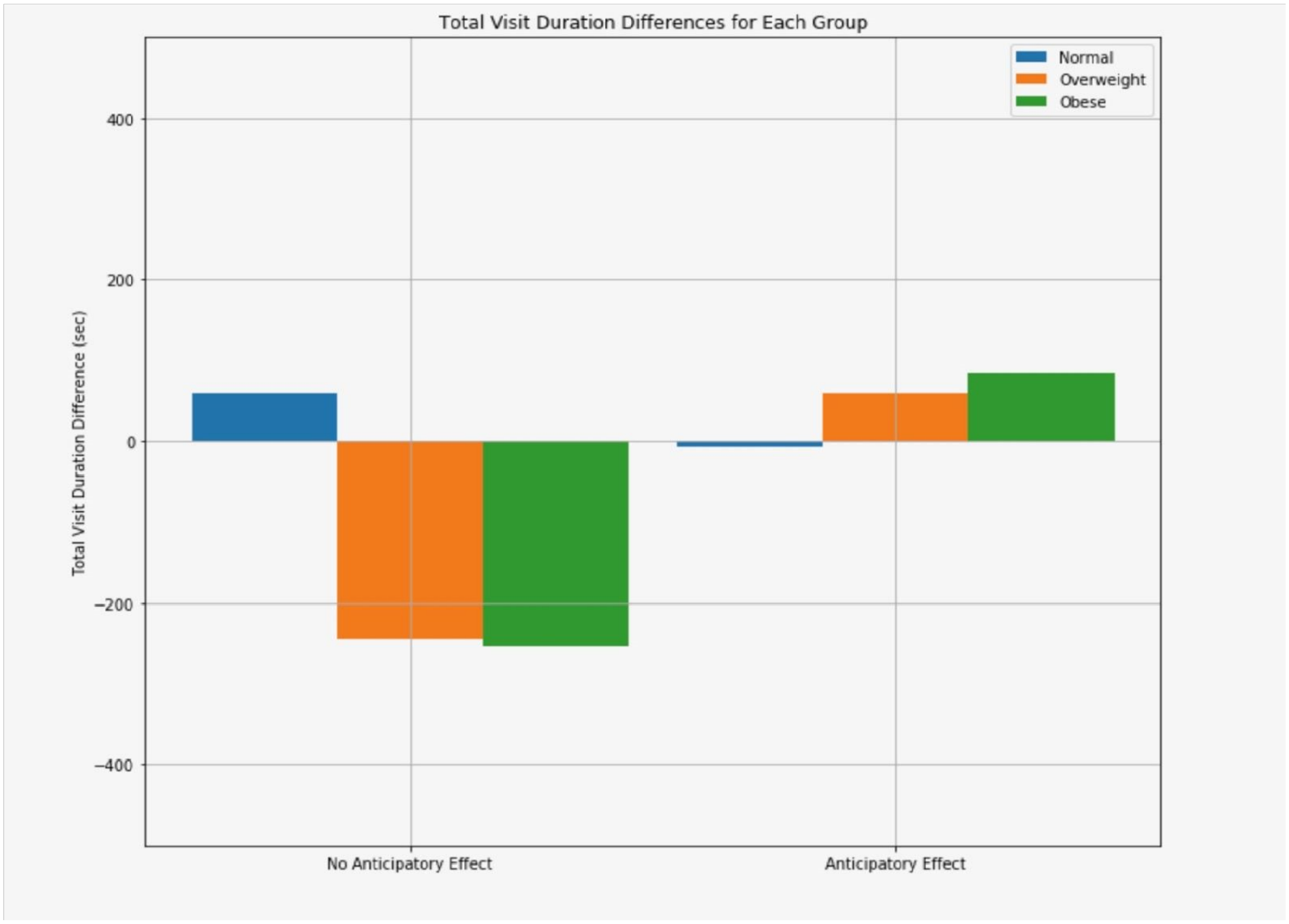

Fig. 2. Attention level toward food items in the replication food choice task by BMI category and treatment condition. The treatment conditions are on the x-axis, with no anticipatory effect on the left and anticipatory effect on the right. Total visit duration difference in seconds is on the y-axis. The BMI categories are differentiated by color, with normal represented by blue, overweight represented by orange, and obese represented by green. Participants in the overweight and obese BMI categories under the anticipatory effect paid more attention to "lite" snacks instead of their regular counterparts.

Finally, another metric of eye-tracking was utilized to measure emotional arousal of participants throughout the food choice task. Average pupil size was measured across treatment conditions and BMI category, as exhibited by Fig. 3. For normal and overweight participants, no significant differences were found in pupil size in response to the visual food choice test stimuli (Wilcoxon p-value = 0.691, T-Test p-value = 0.689 for overweight, Wilcoxon p-value = 0.554, T-Test p-value = 0.263 for normal). However, average pupil size was lower for obese subjects in the anticipatory effect condition (Wilcoxon p-value = 0.139, T-Test p-value = 0.058). This signifies that obese individuals that are anticipating food display less emotional arousal toward the food than normal or overweight individuals. In this case, our replicated findings match that of the original study.

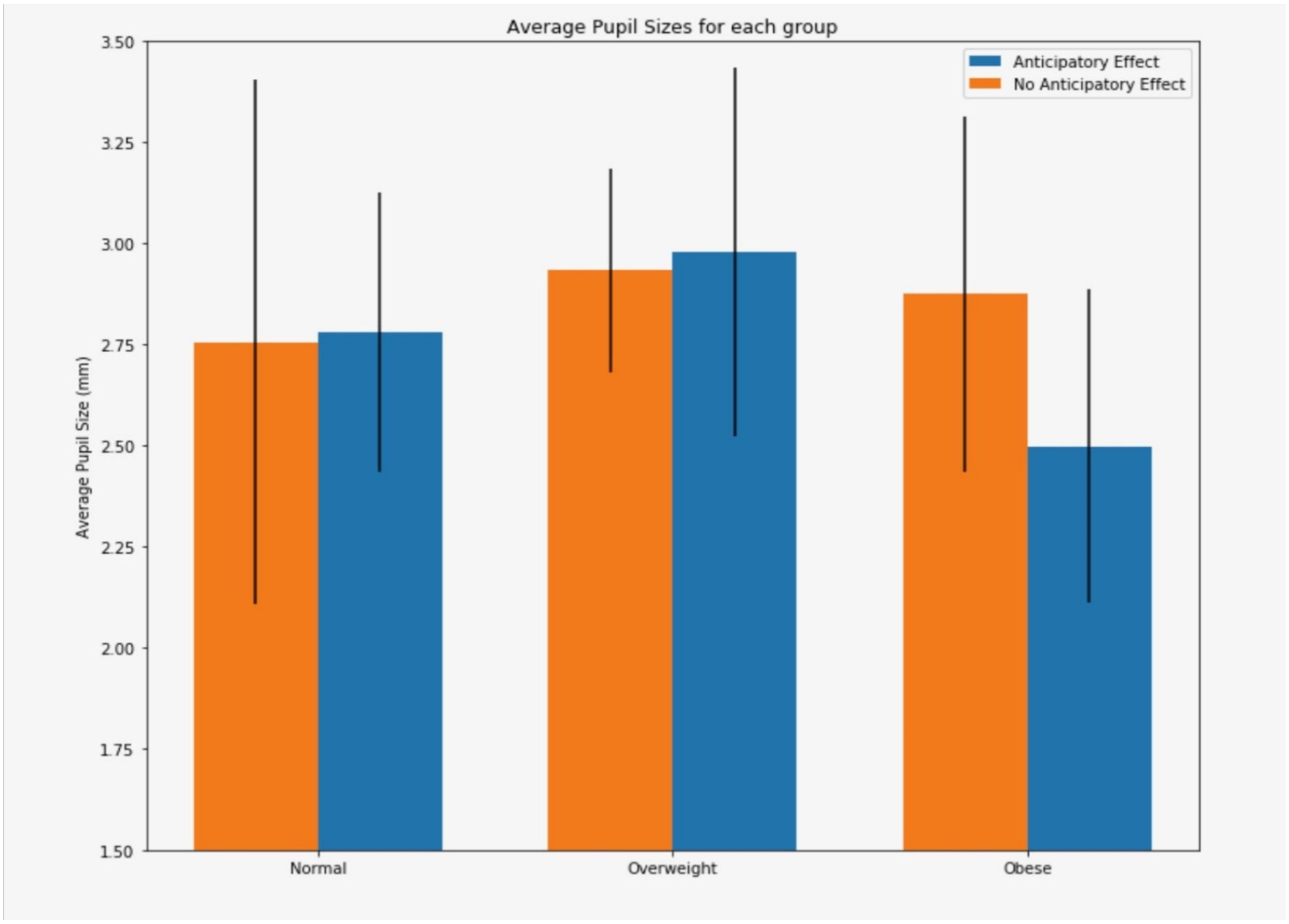

Fig. 3. Average pupil size during the replication food choice task by treatment condition and BMI category. On the x-axis, BMI categories from left to right are normal, overweight, and obese. Average pupil size in millimeters is on the y-axis. The anticipatory effect is represented by blue, and no anticipatory effect is represented by orange. Participants in the obese BMI category under the anticipatory effect exhibited lower average pupil size, indicating less emotional arousal regarding food.

To conclude, our replication of the original study's data analysis produced consistent results, but some numeric values differed. The dataset of the original study contained missing data, so the way in which we created equal sample sizes to allow for the Wilcoxon Rank Sum

Tests may have been different from their method. Overall, despite these slight inconsistencies, all three of the replicated results confirm the original findings.

4. Discussion

The main hypothesis of this study was that subjects that perform the food choice task before the cognitive test will experience an anticipatory food reward effect, exhibited by an enhancement of cognitive ability. However, there are certain limitations to the current study. First, the sample of normal weight participants used in the original study included participants with a BMI that is nationally categorized as underweight. This information was not mentioned in the analysis of the original study and could possibly have a significant effect on the results. Specifically, this could impact the results by strengthening the non-anticipatory effect found in normal weight participants because of the larger distribution created by combining both normal weight and underweight participants. Thus, future studies involving participants across different BMI categories should separate participants with a BMI under 18.5 (underweight) from individuals with a BMI of 18.5-24.9 (normal weight) to ensure that the results are not overrepresented and to verify if there is a possible relation between food anticipation and being underweight. Another limitation includes the low sample size for both obese and overweight participants. Additional research should evaluate the results using larger sample sizes in order to get a more accurate representation of the effects of food anticipation on participants across BMI categories.

We suggest that future studies focused on weight should categorize individuals into groups of average BMI (normal), and above average BMI (overweight and obese) to eliminate a negative connotation associated with the categories of normal weight, overweight, and obese. Furthermore, future studies should signify the socioeconomic impact of food scarcity on cognitive abilities, pushing the results further than numbers. Although there is not a large body of literature on the association between food insecurity, weight, and cognitive functioning, a correlation has been repeatedly established between low socioeconomic status (SES) and high BMI in high-income countries among women [11]. It has been hypothesized that the correlation between obesity and food insecurity stems from the idea that individuals should store more fat when they receive cues that food is uncertain [12]. When access to food is insecure, storing fat in the short run may help buffer against potential future food insecurity. Interestingly, another study looking at the relationship between food insecurity and SES in older men found that low-income, food-insecure men had lower odds of being overweight or obese compared to low-income, food-secure men [13]. Thus, instead of seeking evidence for a distinct reward system in obese and overweight individuals, we recommend that future studies look at how SES and food insecurity might impact cognitive abilities in testing environments.

5. Conclusion

In this study, we replicated the finding of increased cognitive functioning in the presence of food anticipation. Specifically, we found that obese and overweight individuals in the food anticipation condition experienced a significant increase in cognitive functioning. Furthermore, an anticipatory effect caused overweight and obese individuals to shift their attention toward lite over regular snacks. Finally, measured by average pupil size, obese participants in the anticipatory condition displayed less emotional arousal regarding food. This replication further strengthens the notion that the simple act of anticipating food consumption is as effective as other methods of restoring mental resources, including rest, glucose rinsing, and positive mood.

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