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Poor sleep quality and stress differentially predict delay discounting for food, but not money, in college students

Olivia Law | **Erin B. Rasmussen**

Idaho State University, Pocatello, Idaho, USA

Correspondence
Erin B. Rasmussen, Department of Psychology, Stop 8112, Idaho State University, Pocatello, ID, USA.
Email: erinrasmussen@isu.edu

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Abstract

Early college is a time when eating habits change and subsequent weight gain may occur. Moreover, college students report higher stress levels and poorer sleep quality while enrolled in courses. This study investigated the extent to which stress and sleep quality in college students may be related to delay discounting (DD) for food—a psychological process in which immediate outcomes are preferred over larger, more delayed outcomes. College students ($N = 297$) completed the Food Choice Questionnaire (FCQ) and the Monetary Choice Questionnaire (MCQ)—measures of food and monetary DD, respectively. The Perceived Stress Scale (PSS), the Pittsburg Sleep Quality Index (PSQI), and measures of subjective hunger, substance use, and demographic variables were also administered. Perceived stress was related to poor sleep quality, alcohol use, substance use, and vaping. Analyses revealed that, when controlling for subjective hunger, perceived stress and poor sleep quality contributed unique variance to food DD, though in opposing directions. Perceived stress uniquely predicted preferences for immediate food, a phenomenon consistent with stress-induced urgent eating. Poor sleep quality uniquely predicted preferences for larger amounts of delayed food, a pattern consistent with eating later in the day. Stress and sleep quality, when controlling for substance use variables, were unrelated to monetary discounting. Stress and poor sleep quality, then, predict independent and opposing discounting processes in college students that are food-specific, as opposed to more general cross-commodity processes.

KEYWORDS
delay discounting, food, food choice questionnaire, monetary choice questionnaire, sleep quality, stress

1 | INTRODUCTION

It is well documented that the college years are a critical period of weight gain for young adults (Anderson et al., 2003; Cluskey & Grobe, 2009; de Vos et al., 2015; Lloyd-Richardson et al., 2009; see also meta-analysis Vella-Zarb & Elgar, 2009). This is especially the case during freshman year, when eating and exercise patterns change. Elevated stress levels in college students may also contribute to maladaptive eating patterns that increase weight gain (Groesz et al., 2017; Pelletier et al., 2016; Yau & Potenza, 2013; see review by Lyzwinski et al., 2018), as well as the probability of obesity (e.g., Sinha & Jastreboff, 2013; Yang et al., 2013; see also review by Tomiyama, 2019). One manner in which stress leads to overeating is by enhancing the urge to eat through increasing sensitivity to food reward, which occurs through the release of glucocorticoids (Adam & Epel, 2007; Fardet & Fève, 2014; Tomiyama, 2019). Indeed, a number of studies show that stress and negative affect can also contribute to the phenomenon of binge eating, which can reduce the impact of stress by lowering elevated cortisol levels (Gluck, 2006; Rosenbaum & White, 2015; Sulkowski et al., 2011; Wolff et al., 2000; see review by Naish et al., 2019).

Stress is also related to poor sleep quality (Åkerstedt et al., 2012; Geiker et al., 2017; Valerio et al., 2016). Aspects of poor sleep quality include feelings of tiredness after waking, an inability to fall asleep, and repetitive awakening at night (Buysse et al., 1989; Harvey et al., 2008). Poor sleep quality is problematic for a number of health-related reasons, but one issue is its association with weight gain and obesity; this too occurs in college students (Coughlin & Smith, 2014; Rahe et al., 2015; Sa et al., 2020; Taheri et al., 2004; Vargas et al., 2014; Wang et al., 2019; see also meta-analysis by Fatima et al., 2016). Poor sleep quality is linked to stress-related and appetite-related hormonal spikes that occur later in the day and into the evening after sleep restriction (Guyon et al., 2014; Joo et al., 2012; Leproult et al., 1997). Appetite and cravings for food, especially those with high-carbohydrate content, also increase with poor sleep quality (Spiegel et al., 2004). In studies that experimentally induce sleep deprivation, individuals who are sleep deprived for five consecutive nights eat an average of 550 additional calories more than those who are not sleep deprived (Markwald et al., 2013; Spaeth et al., 2013; Yeh & Brown, 2014), and these studies show that the general tendency is to eat later in the evening and at night (i.e., night eating). Indeed, the pattern with sleep deprivation (without stress) appears to be one in which less eating happens in the earlier part of the day and overeating occurs later in the day, as opposed to more urgent eating which is observed with the onset of stress.

1.1 | Delay discounting

While the associations among stress and sleep quality are associated, and they differentially predict differential eating patterns, it is unclear which psychological processes may be involved. One process that may be related to stress-related urgency in eating and sleep quality-related tendencies to eat larger amounts of food later in the day is delay discounting (DD). DD refers to a decline in the value of an outcome or reward as delay to its receipt increases (Ainslie, 1975; Johnson & Bickel, 2002; Madden & Bickel, 2010). While DD is regarded as a trait-like individual difference variable (see Odum, 2011a; Odum, 2011b), it is also sensitive to environmental state variables (see review by Rung & Madden, 2018).

To determine DD with humans, participants are presented with a series of hypothetical choices between a smaller, sooner reward (i.e., \$40 now) versus a larger, more delayed reward (\$100 in 1 day). With this choice, for instance, most would choose the larger, delayed amount. With subsequent choices, the smaller, more immediate amount may be increased systematically (e.g., in \$10 increments) until the participant demonstrates a preference reversal for the smaller, more immediate amount, e.g., \$90 now may be chosen over the \$100 in a day. The indifference point resides between the values of the larger, later outcomes in the choices that flank the preference reversal (e.g., \$85 is the median between \$80 and \$90). This process is repeated for multiple delays that may range from 1 day to 360 days. Once indifference points (also called subjective values) are determined for multiple delays, they are plotted against delay as a DD curve. Subjective value plunges hyperbolically with delay (Mazur, 1987). Greater sensitivity to delay indicates steeper discounting and stronger preferences for smaller, sooner rewards. While this tendency has traditionally been called "impulsivity," there are compelling reasons to not use this term anymore and focus on discounting as an independent psychological process in which sensitivity to delay and preferences for smaller, sooner versus larger, delayed outcomes are seen as a characteristic of behavior or as a behavioral process in its own right (see Strickland & Johnson, 2021).

While DD, especially for monetary outcomes, has been studied largely as a behavioral characteristic of those with substance use disorders (e.g., Amlung, Vedelago, et al., 2016; MacKillop et al., 2011; Moody et al., 2016), it has also been applied to the study of metabolic health problems, such as weight gain and obesity. Obesity status predicts greater monetary DD across various measures (see Amlung, Petker, et al., 2016 for meta-analysis; Jarmolowicz et al., 2014; Lawyer et al., 2015; Weller et al., 2008). Moreover, studies on food DD, in which individuals choose between smaller, sooner versus larger, delayed bites of food show that obesity status also predicts steeper discounting with food-related outcomes (Boomhower et al., 2013; Hendrickson et al., 2015; Hendrickson & Rasmussen, 2013, 2017; Rasmussen et al., 2010; Rodriguez et al., 2021).

Some studies have reported on the relations of stress and sleep to DD but only with hypothetical monetary outcomes. In general, these studies show quite consistently that stress is associated with steeper monetary discounting (i.e., preference for immediate outcomes—see Fields et al., 2014, for meta-analysis; Malesza, 2019; Worthy et al., 2014; Xia et al., 2017). Research examining the relation between sleep quality and monetary DD, however, has produced somewhat mixed results. Curtis et al. (2018) found that shorter duration sleepers (>6 h/night) have steeper monetary discounting than longer duration (7–9 h/night) sleepers. However, Demos et al. (2016) and Libedensky et al. (2013) showed that experimentally induced sleep deprivation does not affect DD for money.

Though stress and sleep have independently been studied in relation to monetary DD, no study (to our knowledge) has examined these factors in relation to DD for food, which is important given the metabolic consequences of poor sleep quality and stress. Because weight gain and obesity have been shown to relate to food DD, sleep quality, and stress, there is substantial reason to believe that stress and sleep quality also may be related to food DD. The present study begins an examination of these relations. We hypothesized that, because of the relation between stress to more urgent eating patterns, high perceived stress would predict steeper food DD. Conversely, because poor sleep quality is associated with higher food intake later in the day (i.e., a lack of urgency in eating), we hypothesized that it would predict preferences for larger amounts of delayed food or lower DD.

2 | MATERIALS AND METHODS

2.1 | Participants

College students ($N = 297$) were recruited from lower division Idaho State University social sciences courses through the online participant management system SONA in which they received course bonus credit for study participation. An a priori power analysis for hierarchical linear regression, assuming up to five factors with an effect size of 0.07 (based on effect sizes for state factors influencing discounting—see Rung & Madden, 2018), an alpha of .05, and a power of 0.8, was conducted using G*Power. Based on this analysis, 274 participants were necessary to detect an effect. Eligible participants were ISU students who were 18 years or older and proficient in English. Exclusion criteria included endorsement of an eating disorder in the last 2 years and current pregnancy (potential variables that may affect food decisions).

2.2 | Measures

2.2.1 | Food Choice Questionnaire (FCQ)

The FCQ (α = .92; Hendrickson et al., 2015) is a validated measure of food DD that is based on the Monetary Choice Questionnaire (see below; Kirby & Maraković, 1996; Kirby et al., 1999). For the FCQ, a 5/8-in. cube is presented to a participant, and they are asked to imagine it as a single bite of their favorite food as they complete the measure. Participants are asked to make a series of 27 choices between a smaller number of bites immediately (i.e., nine bites now) versus a larger number of bites after a delay (i.e., 13 bites in 1 h). The delays span from 0.5 to 24 h. There are three magnitudes of bites (nine choice questions per magnitude): small (8–13 bites), medium (25–35 bites), and large (40–50 bites). Preferences toward the smaller, more immediate food outcome options result in higher discounting values.

2.2.2 | Monetary Choice Questionnaire (MCQ)

The MCQ (α = .92; Kirby & Maraković, 1996; Kirby et al., 1999) is a well-established 27-item measure of DD for hypothetical monetary outcomes across three magnitudes: small ($25–$35), medium ($50–$60), and large ($75–$85). Like the FCQ, individuals are presented with choices between a smaller, immediately available amount of money (e.g., $54 now) versus a larger, delayed amount of money (e.g., $77 in 117 days). The delay range spans 1–360 days. Higher discounting values reflect preferences for small, immediate outcomes.

2.2.3 | Perceived Stress Scale (PSS)

Participants' subjective stress was measured through the PSS (α = .90; Cohen et al., 1983). The PSS is a 10-question, gold standard, self-report measure in which participants indicate how often they experienced different stressors in the last month using a scale rating (Cohen et al., 1983). Scores are reversed on the positive items; then, all scores are summed to get a total PSS score. Higher scores indicate greater amounts of perceived stress.

2.2.4 | Pittsburgh Sleep Quality Index (PSQI)

The PSQI (α = .83; Buysse et al., 1989) measures self-reported sleep quality through a composite of answers to sleep-related items that include factors such as sleep disturbances, amount of time spent asleep, and amount of time it takes to fall asleep. The PSQI consists of 19 questions, resulting in seven component scores (scores ranging from 0 to 3, with higher scores meaning greater sleep difficulty) based on seven areas of sleep quality problems. These scores are then summed to reach a total PSQI score, ranging from 0 to 21. Total scores were used in this study and higher scores indicate poorer sleep quality.

2.2.5 | Drug, alcohol, and nicotine use

As drug and alcohol use is associated with stress in college students and adults (Grunberg et al., 2011; Metzger et al., 2017; Park et al., 2004; Ratanasiripong et al., 2009; Sinha, 2008), these factors were measured as potential confounding variables. Self-reported drug use was determined using the Drug Abuse Screening Test (DAST-10) (Skinner, 1982); higher scores indicate greater drug use. Alcohol use was assessed through the Alcohol Use Disorders Identification Test (AUDIT-C), also a self-report measure, in which a score of 3 or greater indicates possible alcohol abuse (Bush et al., 1998). Nicotine use was also measured, as it is related to DD for food (e.g., Bickel et al., 1999). Smoking was also assessed through the Fagerstrom Test for Nicotine Dependence (FTND) (Heatherton et al., 1991). A modified version for assessing vaping habits was adapted from the original FTND.

2.2.6 | Demographic and biometric questionnaire

Demographic information, such as age, gender, ethnicity, religion, annual income, and employment status was gathered through a demographics questionnaire. Biometric information, including height and weight, was collected through self-report and used to calculate the BMI of each participant.

2.2.7 | Subjective Hunger Questionnaire (SHQ)

The SHQ is a self-report measure in which a visual analog scale of 0 to 100 is presented, and participants are asked to indicate their current subjective hunger level (Rasmussen et al., 2010). Participants were also asked to report how long ago (in hours) they last had a meal and snack. Subjective hunger has been associated with food DD (e.g., Rodriguez et al., 2021), so was measured as a potential confounding variable.

2.3 | Procedure

The study was approved by and conducted under the auspices of the Institutional Review Board for Idaho State University. After student participants signed up for the study, they were sent an online link to access the survey via Qualtrics. The participants first read and signed the informed consent form via electronic signature before completing the following measures on Qualtrics: SHQ, FCQ, MCQ, followed by the demographic questionnaires, the DAST, AUDIT-C, PSS, PSQI, and biometrics, including self-reported height and weight. The order of the FCQ, MCQ, and demographic questionnaires was counterbalanced across participants.

2.4 | Analyses

DD rates for the FCQ and MCQ for three magnitudes of food and money amount (small, medium, and large) were determined for each individual in the manner described by Hendrickson et al., 2015 and Kirby & Maraković, 1996, respectively). Briefly, predetermined discounting values associated with each question defined the range of an individual's estimated discounting rate within each of the three different magnitudes (e.g., small, medium, and large). Selection of the smaller reward or delayed reward narrowed the range of the estimated discounting rate for each participant. For example, on the question "Would you like 4 bites now or 8 bites after 5 hours?" the predetermined discounting value is 0.201. An individual with this discounting rate would be "indifferent" between the two rewards presented in the trial and would select either the smaller or the larger reward approximately 50% of the time. Thus, an individual with a discounting rate greater than 0.201 would select the smaller, sooner reward, while an individual with a discounting rate less than that value would select the larger, delayed outcome. The point at which the participant switches from the larger, delayed outcome to the smaller, more immediate outcome on the FCQ defines the upper and lower bounds of the range. The geometric mean is used to calculate the midpoint between these two bounds and represents the discounting value for that specific magnitude. While a single discounting rate was determined for each magnitude, an omnibus (overall) discounting value was determined by calculating the mean discounting value of all three magnitudes for each participant. See Hendrickson et al. (2015) and Kirby and Maraković (1996) for more information on scoring.

Data were analyzed using IBM SPSS Statistics. Pearson product–moment correlations were conducted first to determine potential associations of DD with perceived stress, sleep quality, and several other potential covariates such that they could be controlled in analyses. Because discounting values were positively skewed, they were log-transformed for all analyses (a common practice in discounting research) which normalized the distributions. Multivariate analyses of variance (MANOVAs) were conducted for the three magnitudes of food discounting and the three magnitudes of monetary discounting with perceived stress and sleep quality, as well as confounding variables (determined by correlations), as variables influencing discounting. Hierarchical regressions were conducted on omnibus DD for food (FCQ) and money (MCQ) by entering confounding variables in the first step and stress and sleep quality in the second step to examine any unique variance contributed by stress and sleep quality on discounting. An interaction term (stress X sleep quality) was also entered in the model in separate regressions to determine the extent to which the interaction of stress and sleep quality interacted to affect discounting processes, given that they are related to one another in the literature (see introduction). There were no missing data from the database; therefore, all 297 participants' data were used in the analysis.

3 | RESULTS

3.1 | Participant demographics

Participant characteristics are shown in Table 1. Most of the sample ($N = 297$) was white, female, and college aged. The average participant weight was slightly overweight with a mean of 75 kg (166 lb.) and a BMI of just over 26. Participants reported mean stress levels that were within the range of moderate stress (14–26; Cohen et al., 1983). The mean sleep quality was 7.43, which meets the criteria for a sleep disturbance or poorer sleep quality (criterion >5). Participants also reported moderate hunger with a mean of 31 on the SHQ, and a mean of 5.17 and 2.64 h since the last meal and snack, respectively. Mean scores for alcohol and drug use (AUDIT and DAST-10) were quite low (less than 2), as was endorsed cigarette and vape use.

TABLE 1 Demographic characteristics.

	Total ($N = 297$) Mean (S.E.)
Age (years)	21.67 (0.285)
Gender (percent female)	73.83%
%White[b]	75.8%
Weight (kg)	75.53 (1.248)
BMI (kg/m^2)	26.22 (0.391)
Perceived stress	20.08 (0.39)
Sleep quality	7.43 (0.20)
Subjective hunger (0–100)	31.09 (1.506)
Hours since the last meal	5.17 (0.279)
Hours since the last snack	2.64 (0.175)
Alcohol Use Disorders Identification Test–C (AUDIT-C)[a]	1.52 (0.118)
Drug Abuse Screening Test-10 (DAST-10)[b]	1.24 (0.159)
Endorsed cigarette use[c]	5.7%
Endorsed nicotine vape use[d]	13.8%

[a] $n = 190/297$ with scores of 0.
[b] $n = 245/297$ with scores of 0.
[c] $n = 283/297$ with scores of 0.
[d] $n = 260/297$ with scores of 0.

3.2 | Correlations

Pearson *r* correlations are shown in Table 2. Perceived stress was significantly correlated with poor sleep quality, alcohol use, drug use, and vaping. Alcohol use correlated significantly with drug use and vaping. Subjective hunger correlated with the medium, large, and omnibus magnitudes of the FCQ. Therefore, these factors were considered as co-variates in the analyses.

3.3 | Food DD

To first characterize food DD, the top of Figure 1 shows mean food DD values (log-transformed) across small, medium, and large magnitudes of bites, as well as omnibus DD. A repeated measures ANOVA across magnitude (not including omnibus) revealed a significant difference among the means, $F(1.653, 489.368) = 58.81$, $p < .001$; $\eta_p^2 = .21$), discounting decreased with magnitude. Post-hoc contrasts (Tukey HSD) revealed significant differences between small versus medium magnitudes, $F(1,296) = 55.61$, $p < .001$; $\eta_p^2 = .16$), small versus large magnitudes, $F(1,296) = 79.40$, $p < .001$; $\eta_p^2 = .21$, but no difference between medium versus large, $F(1,296) = 16.89$, $p = .054$, $\eta_p^2 = .05$. Thus, magnitude was considered in subsequent analyses.

A MANOVA was conducted with the three magnitudes of food discounting data as dependent variables and subjective hunger, perceived stress, and sleep quality as continuous variables related to discounting. There was an effect of subjective hunger on small $F(1,296) = 8.68$, $p = .003$; $\eta_p^2 = .029$), medium $F(1,296) = 91.65$, $p < .001$; $\eta_p^2 = .063$), and large magnitudes $F(1,296) = 11.65$, $p < .001$; $\eta_p^2 = .038$). There was also an effect of perceived stress on medium $F(1,296) = 4.45$, $p = .036$; $\eta_p^2 = .15$) and large magnitudes $F(1,296) = 7.42$, $p = .007$; $\eta_p^2 = .025$) of food discounting. Finally, there was an effect of sleep quality for medium $F(1,296) = 4.068$, $p = .045$; $\eta_p^2 = .014$) and large $F(1,296) = 4.958$ $p = .027$; $\eta_p^2 = .017$) magnitudes of food discounting. There were no statistically significant relations of stress or sleep quality on small magnitudes of food discounting.

To determine the unique variance contributed by perceived stress and sleep quality while controlling for subjective hunger, a hierarchical regression was conducted on omnibus food DD. In step one, subjective hunger was entered into the model and for step two, stress and sleep quality were added to the model. The models were both significant (see Table **3**). Subjective hunger accounted for a significant amount of variance in the first step. Sleep quality and perceived stress added unique significant variance to the model, and both were significant predictors of food DD. An additional hierarchical regression with a stress X sleep quality interaction term yielded no effects of an interaction. Additional hierarchical regressions were conducted to control for alcohol use, drug use, and vaping, as they were all correlated with sleep quality and stress. The model was not significant ($R^2 = .024$; $p = .068$), but vaping significantly predicted food DD in step one ($\beta = 0.148$, $t = 2.45$. $p = .015$), though this result is limited by the low number of people who reported vaping. In step two, both sleep quality ($\beta = -0.177$, $t = -2.715$, $p = .007$) and stress ($\beta = 2.164$, $t = 2.164$, $p = .031$) added unique significant variance to the model $\Delta R^2 = .03$) and both were significant predictors of food DD.

3.4 | Monetary discounting

The bottom of Figure 1 shows the means for monetary DD (log transformed) as a function of magnitude, as well as the omnibus DD value. There was an overall significant difference across magnitude, $F(1.966, 581.81) = 159.05$, $p < .001$, $\eta_p^2 = .35$, with lower magnitudes discounted more steeply than higher magnitudes. Post-hoc contrasts (Tukey HSD) revealed that small magnitude was discounted more steeply than medium magnitude, $F(1,296) = 76.38$, $p < .001$, $\eta_p^2 = .21$, and large magnitude, $F(1,296) = 783.54$, $p < .001$, $\eta_p^2 = .49$. Medium magnitude was discounted more steeply than large $F(1,296) = 93.9$, $p < .001$, $\eta_p^2 = .24$. Thus, magnitudes were considered in our analyses.

A MANOVA was conducted with the three magnitudes of monetary discounting data as dependent variables and alcohol use, drug use, vaping, stress, and sleep quality as continuous variables related to discounting. There were no effects of any of these variables on any of the three magnitudes of monetary discounting.

Table 4 shows hierarchical regression analyses for omnibus monetary DD. Omnibus monetary DD discounting values were correlated with alcohol use and drug use. When these variables were entered into the regression model as a first step, the model was significant, and drug use alone was a significant predictor of monetary DD. In the second step, when stress and sleep quality were added, the model was significant, and once again drug use alone (not stress or sleep quality) was a significant predictor of monetary DD. An additional regression with a stress X sleep quality interaction term was also not significantly related to monetary discounting.

4 | DISCUSSION

This study examined the extent to which perceived stress and sleep quality predicted food and monetary DD in college students. Before evaluating these relations, it was important to first characterize the DD data to ensure they were valid and consistent with trends in the literature. Food DD values were within the range of values from other studies (e.g., Hendrickson et al., 2015; Hendrickson & Rasmussen, 2017; Rodriguez et al., 2021). In addition, a magnitude effect was found, in which smaller magnitudes of food were discounted more steeply than larger, delayed outcomes. Money discounting showed similar trends, in terms of consistent values and a magnitude effect. These DD data also replicate previous literature on the magnitude effects of DD for food and money and provide a rationale to conduct analyses with different magnitudes of food (e.g., Green et al., 1994; Hendrickson et al., 2015; Kirby & Maraković, 1996; Rodriguez et al., 2021).

TABLE 2 Pearson product–moment correlations between small, medium, and large discounting rates for money and food.

Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.
1. FCQ small	-														
2. FCQ medium	.521***	-													
3. FCQ large	.337***	.752***	-												
4. FCQ Geomean	.663**	.913**	.819**												
5. MCQ small	.036	.160**	.150**	.159**											
6. MCQ medium	.044	.132*	.150**	.749***	.155**										
7. MCQ large	.021	.085	.096	.672***	.759***	.098									
8. MCQ Geomean	.022	.122*	.125*	.130*	.861**	.920**	.909**								
9. PSS	.077	.044	.075	.080	.122*	.081	.017	.067							
10. PSQI	−.067	−.131*	−.113	.058	.082	.028	.050	−.112	.461***						
11. DAST	.026	.22*	.063	.058	.140*	.126*	.115*	.128*	.152**	.134*					
12. AUDIT	−.203	−.062	−.066	−.046	.131*	.118*	.078	.115*	.124*	.143*	.312**				
13. BMI	.007	−.047	−.037	−.007	.050	.048	.079	.070	.110	.065	−.030	.095			
14. Subjective hunger	.095	.175***	.118*	.189**	.011	.007	.096	.044	.071	.017	−.029	.034	−.105		
15. Vaping	.069	.101	.061	.090	.095	.091	.081	.083	.172**	.223***	.221***	.258***	.010	.057	

Abbreviations: AUDIT, Alcohol Use Disorders Identification Test; DAST, Drug Abuse Screening Test; FCQ, Food Choice Questionnaire; MCQ, Money Choice Questionnaire; PSQI, Pittsburg Sleep Quality Index; PSS, Perceived Stress Scale.

*p < .05, **p < .01, and ***p < .001.

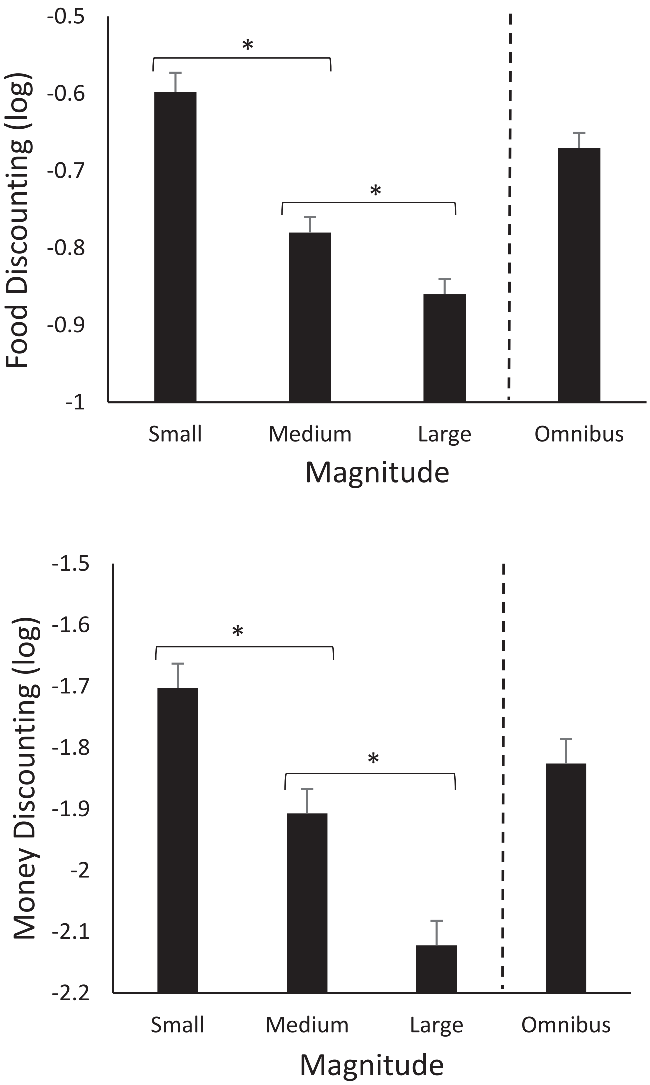

FIGURE 1 Means (log) for food (top) and monetary (bottom) discounting values as a function of small, medium, and large magnitudes of bites and dollar amount, respectively.

4.1 | Food discounting

Correlations revealed that subjective hunger was positively related to the omnibus, small, medium, and large magnitudes of food DD and replicated other studies (Hendrickson & Rasmussen, 2017; Rodriguez et al., 2021). Perceived stress and poor sleep quality were significantly related, also replicating other studies (e.g., Almojali et al., 2017; Charles et al., 2011; Mesquita & Reimão, 2010). Though limited by the low number of participants endorsing the use of these substances, alcohol, illicit drugs, and vaping were positively correlated with stress and poor sleep quality, supporting other research (e.g., Grunberg et al., 2011; Metzger et al., 2017; Park et al., 2004; Ratanasiripong et al., 2009; Sinha, 2008; Wilson et al., 2022). As such, these variables were statistically controlled as covariates in the analyses.

Perceived stress significantly predicted steeper discounting for food, or greater preference for smaller, sooner food outcomes. This effect was magnitude-dependent and occurred for medium and large, but not small, magnitudes of food. Therefore, the variance contributed by stress on food DD was dependent on moderate to higher magnitude bites of food (25–50 bites) over smaller magnitudes (8–13 bites). Additionally, when subjective hunger was controlled, perceived stress contributed unique variance to omnibus DD values.

This is the first study to our knowledge that specifically found significant relations between stress and DD for food and that higher stress levels are associated with preferences for immediately available food, especially when the magnitudes of food are higher. This preference for more immediate food may reflect a tendency to urgently reduce the impact of stress by eating, possibly supporting the relation between eating, obesity, and stress in the literature (e.g., Torres & Nowson, 2007; Xiao et al., 2013; Yang et al., 2013). The research on binge eating also may be relevant here, as a preference for immediately available food-related outcomes is a property of binge eating. Therefore, our results also may extend to research on urgent eating involved in stress-related binge eating (Gluck, 2006; Rosenbaum & White, 2015; Sulkowski et al., 2011; see review by Naish et al., 2019), though more research on this population may be necessary. It is important to point out, however, that the relation between stress and food discounting found in this study was correlational and not causal. Therefore, to understand if stress *causes* shifts to more immediate food rewards, an experiment in which stress is manipulated would be required.

Poor sleep quality also predicted food discounting for medium and large magnitudes but not for small magnitudes of food. In other words, poor sleep quality predicted preferences for the larger, later rewards for medium and large food magnitudes. After controlling for subjective hunger, poor sleep quality added unique variance to food discounting. The relation between sleep quality and food discounting is also a novel finding. This result, plus a lack of interaction of stress and sleep quality on food discounting, suggests that stress and sleep quality, while correlated, appear to uniquely and independently predict opposing food DD patterns.

We did not detect a relation between obesity and food DD or monetary DD in the current study. One reason for this may be that weight and height were self-reported in this study; therefore, weight may have been underestimated. Moreover, this was a younger adult sample (college students) which had a lower range of BMI values compared to other studies reporting obesity effects. When comparing these data to other studies with food discounting, the age and BMI ranges are wider with other research (e.g., see Rodriguez et al., 2021 in which the mean BMI was 29.8, the high end of the overweight category), making it more likely to detect effects with more extreme values. Future studies should look specifically at samples that have a larger range of BMI scores, or perhaps compare stress, sleep quality, and food discounting in samples with obesity or eating disorders to determine the extent to which more extreme variation in eating patterns relates to these variables.

4.2 | Monetary DD

Consistent with other studies (e.g., Johnson et al., 2007; Yi et al., 2010), drug and alcohol use correlated significantly with

TABLE 3 Linear regression coefficients for FCQ omnibus.

Variable	b (SE)	β	t	R^2	ΔR^2	p
Step one						
				.062		<.001**
(constant)	−0.865 (0.035)		−24.551			<.001
Subjective hunger	0.004 (0.001)	.248	4.398			<.001**
Step two						
				.084	.022	<.001**
(constant)	−0.924 (0.076)		−12.088			<.001
Subjective hunger	0.007 (0.030)	.014	0.229			<.001**
Sleep quality	0.009 (.004)	.150	2.381			.031*
Perceived stress	−0.016 (.007)	−.137	−2.168			.05*

*p < .05, and **p < .001.

TABLE 4 Linear regression coefficients for MCQ omnibus.

Variable	b (SE)	β	t	R^2	ΔR^2	p
Step one						
				.037		.004*
(constant)	−1.913 (0.049)		−39.124			<.001
Alcohol use	0.028 (0.020)	.083	1.378			.169
Drug use	0.037 (0.015)	.149	2.477			.014*
Step two						
				.048	.012	.006*
(constant)	−2.122 (0.126)		−16.843			<.001
Alcohol use	0.025 (0.020)	.074	1.225			.222
Drug use	0.033 (0.015)	.136	2.239			.026*
Sleep quality	−0.001 (0.013)	−.003	−0.051			.960
Perceived stress	0.011 (0.006)	.111	1.711			.088

*p < .05, and **p < .001.

monetary DD variables across the range of magnitudes, though the base rate in the sample was low. In the MANOVA, there were no effects of these variables on monetary discounting. When controlling for them in the hierarchical regression, drug use was a significant predictor for omnibus monetary discounting. These data, though limited, may replicate that drug use predicts steep DD for money (see reviews by Reynolds, 2006; Carroll et al., 2010). When controlling for drug and alcohol use, sleep quality and stress did not predict omnibus monetary DD. Therefore, there was no consistent association of sleep quality or stress with monetary DD.

There is conflicting evidence in terms of the relations between stress and sleep quality to monetary DD. On one hand, a number of studies have found significant relations between stress and monetary DD (Fields et al., 2014; Worthy et al., 2014; Xia et al., 2017) and sleep quality and monetary DD (Curtis et al., 2018; Reynolds & Schiffbauer, 2004). Of note, in a meta-analysis by Fields et al. (2014), money discounting was found to have a positive association with stress across 16 published articles. The articles included in this meta-analysis measured monetary DD through a wide range of measures related to "impulsivity" such as the MCQ (which was used in the current study), delay of gratification, and the forced choice task. Measures of stress also differed in this meta-analysis, with many studies measuring cortisol and others using self-report measures such as the PSS. Conversely, like the findings of the current study, there are studies that show little or no relation between these variables (Demos et al., 2016; Libedensky et al., 2013). While our study adds to the current body of literature by finding no relations between stress and sleep quality with monetary DD, details in the measures of DD and stress may be better defined and parsed to better understand the mixed results.

The observation that sleep quality and stress consistently predicted food, but not monetary DD, shows specificity to commodity as opposed to more general discounting processes. There are potential reasons for these food-specific effects. One possibility is a potential domain effect. Domain effects refer to the extent to which some commodities are discounted more steeply than others. For example, a number of studies show food is discounted more steeply than money (e.g., Duckworth et al., 2010; Odum & Rainaud, 2003). Factors such as non-fungibility (inability to exchange a commodity for another, equally valued commodity) and perishability also influence how steeply a person discounts a commodity (Holt et al., 2016). Food tends to be a less fungible and more perishable commodity, which may help explain why it is discounted more steeply than money, which is more fungible and less perishable. One reason, then, why a domain effect was found in the present study could be due to generally higher discounting values for food than money.

There is another possibility, though. Other studies show that some manipulations affect discounting for some outcomes more than others due to metabolic factors. Mindful eating, a process of objectively describing interoceptive and exteroceptive stimuli involved in eating, has been shown to affect food discounting, but not money discounting, in experimental studies with humans (Hendrickson & Rasmussen, 2013; Hendrickson & Rasmussen, 2017; Rasmussen et al., 2022). Because stress and sleep quality also have been shown to affect physiological and metabolic processes related to food intake (Spiegel et al., 2004; Van der Valk et al., 2018), it is possible that food discounting may be more sensitive than money to stress and sleep quality. For example, stress (e.g., increases in cortisol) may increase hunger signals (e.g., ghrelin) or decrease satiety signals (e.g., insulin or leptin), such that more immediate food outcomes are valued. Future research should examine these physiological correlates with stress- and sleep-quality-related food discounting.

Despite the robust and consistent relations of stress and sleep quality to differing magnitudes of food discounting, there were some limitations to the current study. First, the study was cross-sectional and correlational. Stress and sleep quality were not experimentally manipulated to determine the effects on discounting. Therefore, it is unclear what the direction of causality is or if other extraneous variables affecting stress and sleep quality explain these results. This research, however, represents a first step toward understanding the relations among stress, sleep, and food DD; future studies might include an experimental manipulation of stress or sleep quality to help determine the direction of causality. Another limitation of the study was the sample. Though the sample size of this study was adequately powered and had moderate levels of stress and poorer sleep quality, the sample was quite homogenous. Most of the sample was white and female. A more diverse sample that includes stronger variance in gender, ethnicity, race, and socioeconomic status could give more representative information on the relations between sleep quality, stress, and food discounting.

Additionally, the study was conducted online, as opposed to in-person. Some research suggests that online studies may be more likely to generate less valid data; this is especially the case recently with crowd-sourced data with Mechanical Turk and the presence of bots in data collection (Hauser et al., 2022; Moss et al., 2021; Pozzar et al., 2020). However, participants in this study were not crowd-sourced; indeed, they were recruited from a local university through an online software that not only verified their student status and course, but participants also entered the study through this same database. Moreover, the characterization and replication of the food and money discounting data with other studies (see Figure 1) increases confidence in the data for the study.

Finally, the effect sizes in this study were small. To contextualize this, a brief discussion of discounting as a trait versus state is necessary. Odum (2011a, 2011b) characterized DD as a trait in terms of high test–retest variability, in which testing for discounting at two or more time points predicts relatively robust effect sizes. Moreover, cross-commodity discounting (e.g., money vs. food) is strongly correlated within individuals (see Odum et al., 2020), also supporting trait-like behavior. However, state variables such as framing and priming, have also been shown to consistently alter discounting processes, though the effect sizes are smaller (see meta-analysis by Rung & Madden, 2018). While the effect sizes of stress and sleep quality for food discounting in the current study were indeed smaller, they were within the range of other variables that have been shown to affect discounting, including subjective hunger, age (Lee & Rasmussen, 2021), and experimental manipulations of mindful eating (Hendrickson & Rasmussen, 2013; Hendrickson & Rasmussen, 2017; Rasmussen et al., 2022). Therefore, while most of the variation in DD is trait-like, variables such as stress and sleep quality, as well as other factors, may shift discounting processes in a smaller manner, though these small shifts across time may result in long-term health problems. More research on how the accumulation of small shifts in discounting may affect long-term health problems is necessary, given that discounting is regarded as a trans-disease process involved in health problems such as obesity and substance use disorders (Bickel et al., 2019).

5 | CONCLUSION

In summary, stress and sleep quality had unique and opposing relations with food DD. Perceived stress was associated with greater preferences for more immediate food outcomes (i.e., urgency in eating). Poor sleep quality predicted greater preferences for larger but more delayed food outcomes (non-urgency but tendencies to prefer more food later). Both types of patterns have implications for potential weight gain and obesity. A sleep-deprived person who is not stressed can be at risk for eating more food in a delayed manner (perhaps later in the day); a stressed person who is not sleep-deprived may be at risk for more urgent, impulsive eating. A person who is both stressed and sleep-deprived can be at risk for both types of patterns (see, for example, Tzischinsky et al., 2021). A next step for this study, then, may be to follow undergraduates across their college years to determine if stress and sleep quality predict weight gain or obesity by graduation or post-graduation. Another option is to examine these relations in populations that experience even higher levels of chronic stress or sleep deprivation to determine the extent to which food discounting also impacts obesity status or actual eating patterns, a behavior that was not measured in the current study. By also understanding the relation between these variables to physiological processes that may alter preferences for food, we can understand the factors that may affect food-related behaviors related to stress and sleep deprivation, such as impulsive eating, overeating, night eating, binge eating, and obesity. From this, targeted preventions, interventions, and treatment plans can be designed for at-risk students, as well as others who experience higher stress levels and poorer sleep quality.

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DATA AVAILABILITY STATEMENT

Data for this study can be found at this link: https://data.mendeley.com/datasets/pk8t5ghxht/1. Code for variables embedded in the document and data have been de-identified.

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