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RESEARCH ARTICLE



Interoception and self-regulation of eating behaviors and weight status in college students

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ABSTRACT

Objective: To determine the associations between interoception, self-regulation, eating behaviors, and weight status among college students.

Participants: 229 female undergraduates, predominantly classified as Juniors (51.1%) and identified as Hispanic/Latinx (75%) with a mean age of 23.4 (SD = 6.3), were examined.

Methods: Cross-sectional data using baseline measures from a larger, longitudinal study, were examined. Confirmatory factor analyses and structural equation modeling were conducted to test hypotheses.

Results: Interoception was directly associated to self-regulation. Interoception and self-regulation were inversely associated with non-purposeful eating. Non-purposeful eating was directly associated with weight status.

Conclusion: This study provided empirical evidence on the associations between interoception, self-regulation, eating behaviors, and weight status. Our results support the need for programs that target college students' cognitive skills to reduce unhealthy eating behaviors and optimize weight status. Future interventions are needed to enhance interoception and self-regulation skills so that college students can be more purposeful in their eating habits.

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Introduction

Obesity rates have rapidly increased over the last few decades, as nearly 40% of adults are considered to have obesity in the United States.¹ Similarly, obesity rates among college students have continued to increase throughout recent years. In fact, obesity rates double as students move from adolescence to emerging adulthood and consistently increase further into adulthood.² Since college can be such an important time for the development of health habits, it is important to examine this time period to provide solutions for excess weight gain and disease prevention.^{3–5} While many studies of college students examine health behavior outcomes such as snacking habits, physical inactivity, and the role of the university setting, all of which can lead to weight gain, the current study focuses on the associations of cognitive factors including interoception and self-regulation, and their contributions toward healthy and maladaptive eating patterns that may influence weight gain in college students.^{6–9}

Interoception

Interoception is defined as the ability to detect the afferent processing of signals from multiple organ systems within the body.^{10,11} In theory, a person who is considered to have high interoceptive skills can effectively perceive if they are hungry or satiated by tuning into their internal gastric signals.¹²

Garfinkel et al (2015) defined “interoceptive sensibility” as the self-reported measure to detect and respond to the body's internal signaling.¹³ In this study, interoceptive sensibility serves as an umbrella term that is made up of two subcategories commonly measured *via* self-report: interoceptive awareness and interoceptive responsiveness.¹³ Oswald and colleagues formalized the distinctions of interoceptive awareness, described as the general ability to detect the internal sensations within the body and interoceptive responsiveness, as the subjective response after detection of the internal signaling.¹⁴ Interoception has been linked across a variety of studies to both conscious and non-conscious self-regulation.^{12,15}

Self-regulation

Self-regulation is defined as a multi-factorial construct that includes one's physiological, emotional, and attentional ability to regulate behavior.¹⁶ Self-regulation is considered an independent, regulatory process where individuals utilize cognitive skills to achieve desired behaviors.¹⁷ This regulatory process is supported by the awareness and responsiveness of an individual's body signals, where individuals with high interoception are more apt to regulate their needs in a healthful manner.¹⁸ Specifically in young adults, self-regulation

is often used to assess the capabilities of one's control regarding food choice decisions and behaviors that may affect weight status.^{19,20} Despite efforts, individuals with reduced self-control may experience impulsivity, increased responsiveness to cravings, and overeating episodes, which can lead to undesired weight gain over time.^{21–23} It is believed that both interoception and self-regulation are necessary regulatory processes to achieve optimal eating habits in college students.

Eating styles

Research has focused on distinguishing healthy and maladaptive eating behaviors to figure out their effects on obesity risk.^{21,24,25} However, solely focusing on healthy vs. maladaptive behaviors may not show the complete picture. Eating styles, defined based on conceptual models of eating, have been commonly studied to provide distinct characteristics between eating habits. Several scales have been developed to measure eating styles, which have been found to be related to weight regulation, including emotional, external, uncontrolled, cognitive restraint and intuitive eating.^{26–29} When defining these eating behavior styles, researchers examined participants' responsiveness to a variety of traits including restraint, disinhibition, hunger, external cues and dieting attitudes and behaviors. However, the extent to which eating styles are deliberate or purposeful was not defined and it is unclear how interoception and self-regulation may influence eating styles.

Eating behaviors and weight development

Some eating behaviors require higher amounts of interoception and self-regulation as individuals that exhibit these eating behaviors need to be more purposeful in their eating style. Purposeful eating behaviors, including cognitive restraint and intuitive eating styles, may be negatively correlated with body mass index (BMI). Some studies have shown that when cognitive restraint eaters obtain cognitive control, exhibiting high levels of self-regulation, they are more likely to make healthy food choices and maintain healthy weight status.^{29–31} Likewise, those with higher levels of intuitive eating were more apt to have reduced BMI.³²

Other eating behaviors seem to be exhibited as a response to external stimuli and may be related to reduced levels of interoception and/or self-regulation skills. Non-purposeful eating behaviors, including emotional, external, and uncontrolled eating, may provide long-term consequences through excessive weight gain, leading to obesity and obesity-related health risks. Previous research has shown that emotional eating may lead to weight gain due to the inability to maintain adequate self-regulatory skills when experiencing negative emotions.^{33,34} External eating was a significant predictor of eating in the absence of hunger and weight status.^{35,36} Finally, uncontrolled eating which is categorized as a full loss of self-regulation has been correlated with increased BMI.³⁷ Despite previous research on eating behaviors, this study aims to determine if eating behaviors can be categorized into purposeful and non-purposeful eating domains.

Classifying eating behaviors into these domains will allow us to examine the interplay between one's cognitive factors (interoception and self-regulation), purposeful and non-purposeful eating behaviors, and weight status in college students.

Current study

We propose to extend the literature by reconceptualizing 5 of the most prominent eating styles within two new conceptual constructs, purposeful and non-purposeful eating domains. We define the term "purposeful eating" when someone makes a conscious decision to consume or not consume certain food items. Two eating styles might fit within the purposeful eating domain: cognitive restraint and intuitive eating styles. The cognitive restraint eating style, also referred as dietary restraint or restrained eating, is the deliberate restriction of food intake, often used in effort to lose weight, whereas intuitive eating is a novel, non-diet approach encompassed around mindfulness and awareness of hunger and satiety cues.^{38–40} Although both eating styles are vastly different from each other, they share a commonality of self-control, "eating for purpose", and require high interoception and self-regulation.^{20,41} In past research, cognitive restraint or intuitive eaters reported better self-regulation and healthy weight maintenance.^{20,42,43} Alternatively, we define "non-purposeful eating" domain behaviors as when individuals ignore or disregard internal signals guided by interoception and self-regulation and when individuals allow either emotion or external prompts to be the driving force to regulate eating behaviors, potentially leading to adverse dietary choices. We propose that the eating styles within the non-purposeful eating domain include external, emotional, and uncontrolled eating. External eating is described as consuming food after being stimulated by external temptations.³⁹ External eaters are more prone to eat foods that captivate the senses, such as the sight or smell of food.³⁹ Emotional eating is defined as eating in response to emotional cues as a strategy to cope with negative emotions.³⁹ Lastly, uncontrolled eating is described as the complete loss of control when eating, often leading to excessive overeating.²⁷ These non-purposeful eating domain behaviors are solely motivated by external factors which may underutilize self-regulation, and interoceptive awareness and responsiveness, however these relationships have yet to be observed.

Previous research has identified cognitive factors such as interoception and self-regulation may be important toward a college student's eating behavior and weight status. However, it remains unclear the extent to which these eating behaviors are influenced by one's awareness and decision-making. The current study will classify measures of interoceptive awareness and responsiveness to develop "interoceptive sensibility". We will also classify 5 eating styles onto a two-factor structure of purposeful and non-purposeful eating domains. This study will also examine the direct associations between interoception, self-regulation, purposeful and non-purposeful eating domains, and weight status in college students. We hypothesize that cognitive restraint and intuitive eating will

share observed similarities within the “purposeful” eating domain and that external, emotional, and uncontrolled eating styles will create the “non-purposeful” eating domain. We predict that the following associations will be observed: 1.) individuals with higher interoceptive sensibility will have greater levels of self-regulation (Figure 1a), 2.) those with increased cognitive skills (interoceptive sensibility and self-regulation) will exhibit more purposeful eating domain behaviors and classified with normal weight status (Figure 1b), 3.) conversely, those with decreased cognitive skills will demonstrate increased non-purposeful domain behaviors and classified with overweight/obese weight status (Figure 1b), and 4.) lastly, those with purposeful eating behaviors will more likely be classified with normal weight status, whereas, those with non-purposeful eating behaviors will more likely be classified with overweight/obese weight status (Figure 1c). In support of our hypotheses, we have developed a theoretical model to better understand the associations of interoception, self-regulation, eating domains and BMI (Figure 1).

Methods

Participant recruitment and procedures

This cross-sectional study utilized the baseline measures from a larger longitudinal research study. Participants ($n=229$) were recruited from a 4-year university located in the southern region of Florida. Participants were predominantly recruited through the university psychology research participation pool online system, SONA. Other recruitment methods included classroom announcements and recruitment flyers. Participants eligible for this study were non-nutrition major undergraduate college students, aged 18 years or older. Exclusion criteria included taking medications that suppress or increase appetite, previously diagnosed eating disorders or mood disorders, pregnant or planning to

become pregnant, student athletes and/or dietetic students. Interested students completed an online screening survey through Qualtrics to ensure their eligibility. Online informed consents were provided *via* Qualtrics to eligible students prior to the start of their initial survey. At baseline, participants completed a Qualtrics survey to provide self-reported demographic information, anthropometrics, and completed measures using validated questionnaires, which took approximately 30 min to complete. At the end of the research study, participants received a \$15 Amazon e-gift card as compensation. Males ($n=13$) were excluded post-hoc due to inadequate sampling. Study protocols were reviewed and approved by the university’s Institutional Review Board with an expedited review (IRB-20-0556).

Participant measures

Interoceptive awareness and responsiveness

Multidimensional Assessment of Interoceptive Awareness (MAIA) is a 32-item questionnaire that identifies eight components of interoceptive awareness.⁴⁴ Topics such as emotional awareness, self-regulation, and body listening scales are included to assess perceived levels of interoception (e.g., “I can pay attention to my breath without being distracted by things happening around me.”).⁴⁴ The measure is scored based on the average responses within each subscale using a Likert scale of 0 (never) to 5 (always). Five of the 8 subscales had high internal consistency and were utilized in the final model: Attention Regulation (7 items), Emotional Awareness (5 items), Self-regulation (4 items), Body Listening (3 items), and Trusting (3 items). Internal consistency, measured by Cronbach’s alpha (α), of the subscales ranged from 0.82-0.91, indicating adequate reliabilities in our sample. The MAIA has demonstrated good internal consistency (5 subscales: $\alpha=0.79-0.87$) and construct validity among predominantly female adult populations.^{44,45}

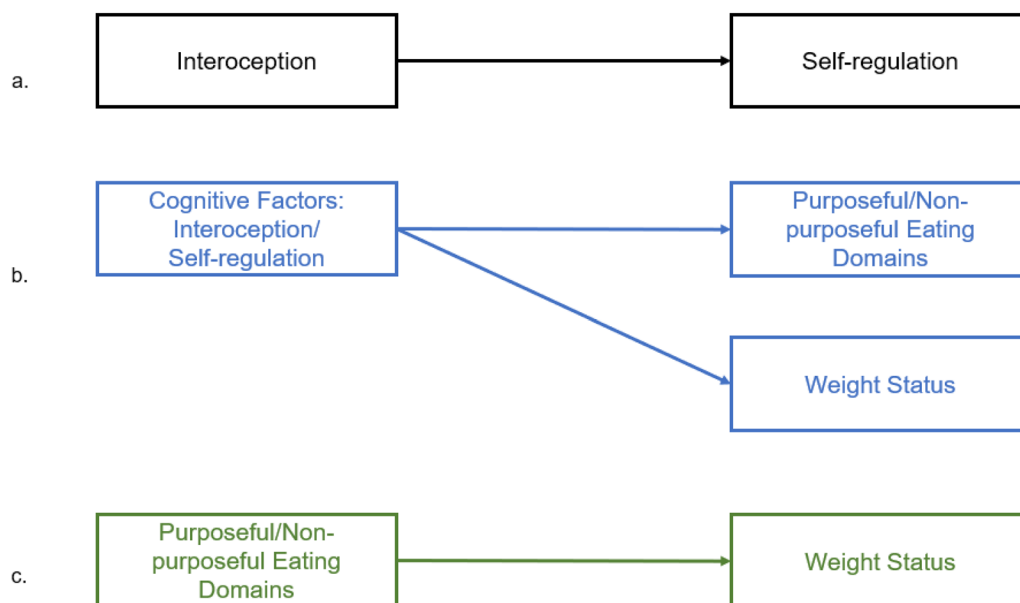


Figure 1. Theoretical model on the associations of cognitive factors, eating domains, and weight status.

Body Responsiveness Scale (BRS) is a 7-item scale that measures how a participant's internal sensations are appreciated and indicates the person's eagerness to respond to their internal cues, for example, "I 'listen' to my body to advise me about what to do".⁴⁶ BRS includes 2 subscales (Importance of Interoceptive Awareness-4 items; Perceived Disconnection-3 items) and measured on a 7-point Likert scale indicating 1 as 'not at all true' and 7 as 'always true of me'. Higher point scores are indicative of increased interoceptive responsiveness. Good construct validity and internal consistency ($\alpha=0.83$) was indicated in previous work with adult women (aged 18–87).⁴⁶ The internal consistency of BRS was $\alpha=0.75$ in our study sample.

Self-regulation

The Self-Regulation of Eating Behavior Questionnaire (SREBQ) is a validated questionnaire used to assess the participant's perceived self-regulation on one's own eating behaviors.⁴⁷ It is a 5-item questionnaire that assesses an individual's self-regulation capacity. Items are scored using a Likert scale using 1 (Never) to 5 (Always), e.g., "I'm good at resisting tempting food".⁴⁷ Good internal consistency ($\alpha=0.75$) and construct (concurrent, convergent and discriminant) validity was reported in the general adult (20–65 years) population.⁴⁷ The questionnaire's internal consistency for the total score was $\alpha=0.69$ in this study, indicating borderline consistency. However, in some cases, an internal consistency of ≥ 0.60 is considered acceptable.^{48,49}

Purposeful and non-purposeful eating domains

Dutch Eating Behavior Questionnaire (DEBQ) is a 33-item questionnaire that contains 3 subscales of emotional eating, external eating, and restrained eating.²⁷ The assessment indicates a person's eating behavior based on three main psychological theories.²⁷ For the purposes of this study, we only utilized the emotional eating (13 items) and external eating (10 items) subscales. Participants were asked questionnaire items such as "Do you have a desire to eat when you are disappointed?" and were scored on a Likert scale ranging from 1 (seldom) to 5 (very often). The DEBQ has good internal consistency and factorial validity.²⁷ Since its development, this questionnaire has been validated in several adult populations.^{50–52} In our sample, the DEBQ had a high internal consistency at $\alpha=0.95$ and 0.85 for emotional eating and external eating, respectively.

Three-factor Eating Questionnaire (TFEQ-R18) is an 18-item assessment that measures eating behavior concepts of cognitive restraint, uncontrolled and emotional eating.³⁹ Originating from obesity research, the questionnaire is set to identify eating behaviors that are deemed higher in overeating.³⁹ Only the cognitive restraint (6 items) and uncontrolled eating (9 items) subscales were utilized in the current study. Items such as "When I smell a delicious food, I find it very difficult to keep from eating, even if I have just finished a meal." were asked and scored using a four-point response scale, with higher scores indicative of increased patterns of the eating behavior. Good internal consistency (cognitive restraint $\alpha=0.76$ and uncontrolled $\alpha=0.86$) and construct

validity were demonstrated in Finnish young adults.³⁹ The TFEQ-R18 demonstrates a good internal consistency at $\alpha=0.89$ and 0.79 for uncontrolled eating and cognitive restraint eating in our sample, respectively.

Intuitive eating focuses on the individual's response to their body signaling such as their hunger and satiety cues.²⁸ The Intuitive Eating Scale-2 (IES-2) is a 23-item questionnaire that examines an individual's ability to respond to their hunger and satiety cues to determine when, what, and how much to eat.²⁸ The questionnaire is comprised of 4 subscales (Eating for Physical Rather Than Emotional-8 items; Unconditional Permission to Eat-6 items; Reliance on Hunger and Satiety Cues-6 items; Body-Food Choice Congruence-3 items) and scored using a Likert scale of 1 (strongly disagree) to 5 (strongly agree). The IES-2 construct validity and internal consistency was reported as good in college females.²⁸ In the current study, the scale had a Cronbach's alpha of 0.87 representing good internal consistency.

Weight status

Participant height and weights were self-reported *via* a Qualtrics online survey. Self-report of height and weights have been known to be underestimated (mean = 3.4 kg); however, correlations between self-report and measured height/weights resulted in all high correlations ($r>0.96$) and BMI category is often unchanged by this error.⁵³ Participants received a manual *via* email providing instructions to measure their height and weight using a tape measure and digital scale, respectively. Scale calibration (using a can of food) and repeated measurements were included in the manual to ensure accuracy in measurement. At each timepoint, participants were asked to weigh themselves, record their weight and provide self-report of weight while completing the other questionnaires. Calculations for BMI included the individual's baseline height and weight using the formula (weight (kg)/[height (m)]²).⁵⁴ Classifications for BMI calculated into 4 categories for demographic purposes using the Center for Disease Control guidelines: Underweight (BMI < 18.5), Healthy weight (18.5 – 24.5), Overweight (25.0 – 29.9), and Obesity (BMI ≥ 30.0).⁵⁴

Statistical analysis

Collected data were analyzed on SPSS Statistics v26.0 and SPSS AMOS v26.0. Both, one-factor and two-factor Confirmatory factor analyses (CFA) were used to examine the construct structure of interoceptive sensibility along with purposeful and non-purposeful eating domains. A 2-step Structural Equation Modeling (SEM) analysis was conducted.⁵⁵ A measurement model was utilized to assess constructive model fit between the proposed variables. Then, SEM was conducted to assess how self-regulation, purposeful and non-purposeful eating domains, and weight status are related to interoception. Given that our data was collected from a large sample size ($n>200$) and was examined for normality (skewness and kurtosis), maximum likelihood (ML) estimation, was performed when estimating the paths

of the diagram.⁵⁶ Participants with missing data and any detection of invalid data entry were removed from our initial sample. Abnormal response patterns and response time frames were utilized to determine invalid data.⁵⁷ To ensure that we have achieved sufficient power within our study, we conducted an ad hoc power analysis and sample size estimation using the “semtools” package in R software.^{58,59} The power/sample size function was based on a minimum achievable power (0.80), root mean squared error of approximation (RMSEA) (0.08), alpha (0.05), and the degrees of freedom from our specified model (85).⁶⁰ Based on this procedure an estimated 147 participants were needed to achieve minimum requirements. With our study sample of 229 participants, a power of 0.96 was calculated.

To determine SEM model fit, global fit statistics (e.g., chi-square, chi-square/degrees of freedom ratio, Comparative Fit Index (CFI), Tucker-Lewis Index (TLI) and RMSEA

statistics) and local fit statistics were employed to assess how well-fit the items are to the overall model. Chi-square statistics indicated any potential significant misfit in the model. However, as the current literature has indicated, the chi-square test is highly dependent on sample size where larger sample sizes often lead to a significant measure.⁶¹ Since our study consists of a large sample size, we utilized the chi-square/degrees of freedom ratio as the more accurate measure. This measure indicates a good model fit if the ratio is lower than the recommended value of 5.⁶¹ Both CFI and TLI testing are recommended when assessing the fit of a single model.^{59,61} CFI and TLI represents ‘goodness of fit’, where the >0.95 indicated excellent model fit.⁶² Values of CFI/TLI between 0.90-0.94 are also considered acceptable for model fit.^{61,63} Lastly, RMSEA is a measure of goodness of fit that suggests a value of 0.06 or below, however values up to 0.08 are considered acceptable and distinct cut-off’s at 0.10 are mediocre for model-fit criteria.^{59,62,64} For local fit statistics, standardized residuals were examined within the SEM model for any absolute value greater than 3, which would be indicative for a poor item fit to the overall model.⁶⁵

Table 1. Baseline participant demographic information.

		Sample	Percentage (%)
Race	Indigenous person or Native American	1	0.4
	Asian or Pacific Islander	6	2.6
	Black or African American	34	15
	White or Caucasian	126	55
	Other or Mixed	62	24
Ethnicity	Hispanic	172	75
	Non-Hispanic	57	25
Classification	Freshman	11	4.8
	Sophomore	38	17
	Junior	117	51
	Senior	63	28
BMI Category	Underweight	6	2.6
	Normal	125	55
	Overweight	60	26
	Obese	38	16
College Transfer	Started here	83	36
	Transferred	146	64
Major	Biological/Life Sciences	10	4.4
	Business	5	2.2
	Communication	2	0.9
	Education	1	0.4
	Engineering	1	0.4
	Health-related fields (nursing, physical therapy)	7	3.1
	Humanities	1	0.4
	Physical sciences (physics, chemistry)	1	0.4
	Pre-professional (pre-dental, pre-medical)	5	2.2
	Public administration	3	1.3
	Social sciences (anthropology, psychology)	150	66
	Visual and performing arts	1	0.4
	Other	11	4.8
Marital Status	Never Married	202	88
	Married	18	7.9
	Divorced	3	1.3
	Separated	6	2.6
Living location	On-campus housing	12	5.2
	Off-campus housing	217	95
Living arrangements	Living alone	14	6.1
	With other students	17	6.1
	My family (spouse or children)	35	14
	Parents	125	55
	Other relatives	7	3.0
	Other	7	3.0

Note: BMI: Body Mass Index.

Results

Participant demographics

At baseline, there were 229 female participants who completed the questionnaires. Participants were predominantly classified as Juniors (51%), majored in social sciences (including anthropology, economics, political science, psychology, sociology; 66%), identified as White Hispanics (75%), were never married (88%), lived off-campus (95%), and many lived with their parents (55%). Participants had a mean age of 23.4 (SD = 6.3) and mean BMI of 25.5 (SD = 5.5), which is classified as overweight. All participant demographic information is included in Table 1.

Correlations

Means, standard deviations and correlations between all the study variables can be found in Table 2. Student BMI was positively associated with emotional eating ($r=0.29$, $p<0.001$), uncontrolled eating ($r=0.17$, $p=0.01$), and cognitive restraint ($r=0.18$, $p=0.006$). Also, BMI was negatively associated with MAIA-Trusting ($r=-0.19$, $p=0.004$), BRS ($r=-0.16$, $p=0.02$), and self-regulation ($r=-0.17$, $p=0.01$).

SEM model analysis

Confirmatory factor Analyses (CFA) for eating domains and interoceptive sensibility

A 2-factor CFA was conducted based on our proposed theory that eating behaviors can be categorized as purposeful or non-purposeful eating domains. The model fit indices (Table 3) were examined, and an adequate model fit was considered. Most factor loadings were considered strong except for the cognitive restraint loading on the purposeful eating domain (Figure 2). However, a strong inverse

Table 2. Baseline correlation matrix with Means and standard deviations of cognitive skills, eating domains, and BMI.

Variables	Mean (SD)	1	2	3	4	5	6	7	8	9	10	11	12	13
1. MAIA-A	3.12 (0.87)	1	.30**	.51**	.49**	.45**	.41**	.24**	−0.17*	−0.10	−0.10	.07	.29**	−0.02
2. MAIA-E	3.85 (0.84)		1	.46**	.48**	.36**	.28**	.10	−0.02	.07	.03	.09	.07	−0.07
3. MAIA-SR	3.17 (1.08)			1	.65**	.56**	.52**	.23**	−0.16*	−0.05	−0.10	.07	.27**	−0.08
4. MAIA-B	2.94 (1.09)				1	.51**	.41**	.14*	−0.03	.02	.02	.04	.09	−0.05
5. MAIA-T	3.66 (1.14)					1	.65**	.40**	−0.27**	−0.09	−0.22**	−0.10	.41**	−0.19**
6. BRS	31.38 (7.86)						1	.57**	−0.42**	−0.24**	−0.38**	.00	.59**	−0.16*
7. SREBQ	3.19 (0.72)							1	−0.43**	−0.39**	−0.51**	.08	.46**	−0.17**
8. DEBQ-Em	35.24 (15.56)								1	.52**	.64**	.22**	−0.68**	.29**
9. DEBQ-E	31.94 (7.66)									1	.64**	.09	−0.35**	.11
10. TFEQ-U	19.62 (6.10)										1	.15*	−0.58**	.17*
11. TFEQ-C	14.60 (3.90)											1	−0.25**	.18**
12. IES	3.42 (0.63)												1	−0.25**
13. BMI	25.69 (5.47)													1

Note:

*Correlations significant at the 0.01 level (two-tailed).

**Correlations significant at the 0.05 level (two-tailed).

SD: Standard Deviation; MAIA-N: Multidimensional Assessment of Interoceptive Awareness-Noticing; MAIA-ND: Multidimensional Assessment of Interoceptive Awareness-Not Distracting; MAIA-NW: Multidimensional Assessment of Interoceptive Awareness-Not Worrying; MAIA-A: Multidimensional Assessment of Interoceptive Awareness-Attention Regulation; MAIA-E: Multidimensional Assessment of Interoceptive Awareness-Emotional Awareness; MAIA-SR: Multidimensional Assessment of Interoceptive Awareness-Self-Regulation; MAIA-B: Multidimensional Assessment of Interoceptive Awareness-Body Listening; MAIA-T: Multidimensional Assessment of Interoceptive Awareness-Trusting; BRS: Body Responsiveness Scale; DEBQ-Em: Dutch Eating Behavior Questionnaire-Emotional Eating; DEBQ-E: Dutch Eating Behavior Questionnaire-External Eating; TFEQ-U: Three-factor Eating Questionnaire-Uncontrolled Eating; TFEQ-C: Three-factor Eating Questionnaire-Cognitive Restraint Eating; IES: Intuitive Eating Scale; SREBQ: Self-Regulation of Eating Behavior Questionnaire; BMI: Body Mass Index.

Table 3. Model fit indices for all model analyses.

Model	Chi-Square	P-value	χ^2/df	CFI	TLI	RMSEA
Interoceptive Sensibility CFA	2.466	0.116	2.47	0.99	0.96	0.080
Eating Domains CFA	9.71	0.021	3.24	0.98	0.92	0.099
Measurement Model	78.57	<0.001	2.12	0.96	0.94	0.070
SEM Model	108.29	<0.001	2.30	0.95	0.90	0.076

Note: CFA: Confirmatory Factor Analysis; SEM: Structural Equation Modeling; χ^2/df : chi-square/degrees of freedom ratio; CFI: Comparative Fit Index; TLI: Tucker-Lewis Index; RMSEA: Root Mean Square Error of Approximation.

**Figure 2.** Confirmatory factor analysis for purposeful and non-purposeful eating domains.

association between cognitive restraint and intuitive eating were indicated within the factor analysis. All factor loadings are in Figure 2. R^2 correlations were examined and all the loadings excluding cognitive restraint were favorable. Overall, we decided to keep it in the model to signify the imposed duality within the purposeful eating domain.

A one-factor CFA was conducted to evaluate the model fit of interoceptive sensibility. Goodness of fit indicators indicated an acceptable model fit. All model fit indices are

found in Table 3. The CFA factor loadings were all considered favorable. All factor loadings can be found in Figure 3. Also, R^2 correlations were assessed to further understand any potential poor fit within the model. Most of the R^2 correlations indicated a strong explained variance to the data.

Measurement model

A 2-step process was utilized to confirm model fit in the SEM analysis. First, a measurement model was assessed by creating latent variables out of all the proposed model variables, then correlating them altogether to create a saturated model. From there, the model fit was assessed to determine good model fit in the SEM analysis (Table 3). This analysis provided sufficient evidence to move forward in examining the proposed SEM model.

Full SEM model parameter estimates

The analysis of the full SEM model was conducted after achieving good model fit in the measurement model (Table 3). The fit indices indicated an adequate model fit and similar statistical significance as the measurement model (Table 3). Local fit statistics were also assessed using the standardized residuals. There were no indications of poor fit between the items in the model (Table 4). Interoceptive sensibility was found to have a significant inverse association with the non-purposeful ($b = -0.22$, $p = 0.002$) eating domain, and a direct correlation with self-regulation ($b = 0.50$, $p < 0.001$) (Figure 4). Also, there was a marginally significant association between interoceptive sensibility and the purposeful eating domain ($b = -0.35$, $p = 0.055$). Self-regulation had significant inverse association with the non-purposeful ($b = -0.46$, $p < 0.001$) eating domain (Figure 4). Lastly, the non-purposeful eating domain had a positive, direct association with continuous BMI ($b = 0.29$, $p = 0.002$) (Figure 4). Table 5 indicates the path relationships, the study's proposed hypotheses, and whether it was supported/unsupported by our findings.

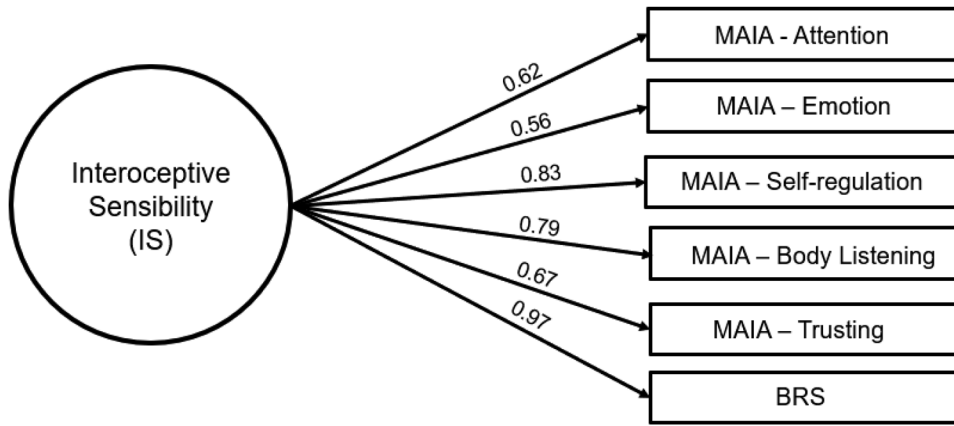


Figure 3. Confirmatory factor analysis for interoceptive sensibility.

Note: MAIA-Attention: Multidimensional Assessment of Interoceptive Awareness-Attention Regulation; MAIA-Emotion: Multidimensional Assessment of Interoceptive Awareness-Emotional Awareness; MAIA-Self-regulation: Multidimensional Assessment of Interoceptive Awareness-Self-Regulation; MAIA-Body Listening: Multidimensional Assessment of Interoceptive Awareness-Body Listening; MAIA-Trusting: Multidimensional Assessment of Interoceptive Awareness-Trusting; BRS: Body Responsiveness Scale

Table 4. Local fit estimators: Standardized residual covariances.

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. MAIA-A	.233												
2. MAIA-E	.825	.173											
3. MAIA-SR	.515	1.309	−0.056										
4. MAIA-B	.833	1.360	.321	.437									
5. MAIA-T	−0.022	.485	−0.142	−0.112	.000								
6. BRS	−0.038	−0.487	−0.162	−0.193	.077	.080							
7. SREBQ	−1.288	−1.578	−1.379	−0.806	.920	.726	.000						
8. DEBQ-Em	1.059	1.653	2.152	2.323	.033	−0.404	.632	.000					
9. DEBQ-E	−0.086	1.888	1.436	1.799	.216	−0.386	−1.155	.229	.000				
10. TFEQ-U	1.083	1.333	1.860	2.732	−0.467	−0.756	−0.850	−0.050	.000	.000			
11. TFEQ-C	2.177	1.005	2.203	2.446	1.025	2.544	1.237	.815	.092	.365	.000		
12. IES	−0.620	−1.336	−1.208	−2.076	.477	.497	.059	−0.120	.566	.207	−0.180	.000	
13. BMI	.455	.332	.768	.390	−0.438	−0.238	.068	.243	−0.227	−0.384	1.264	.055	.000

Note: MAIA-A: Multidimensional Assessment of Interoceptive Awareness-Attention Regulation; MAIA-E: Multidimensional Assessment of Interoceptive Awareness-Emotional Awareness; MAIA-SR: Multidimensional Assessment of Interoceptive Awareness-Self-Regulation; MAIA-B: Multidimensional Assessment of Interoceptive Awareness-Body Listening; MAIA-T: Multidimensional Assessment of Interoceptive Awareness-Trust; BRS: Body Responsiveness Scale; DEBQ-Em: Dutch Eating Behavior Questionnaire-Emotional Eating; DEBQ-E: Dutch Eating Behavior Questionnaire-External Eating; TFEQ-U: Three-factor Eating Questionnaire-Uncontrolled Eating; TFEQ-C: Three-factor Eating Questionnaire-Cognitive Restraint Eating; IES: Intuitive Eating Scale; SREBQ: Self-Regulation of Eating Behavior Questionnaire; BMI: Body Mass Index.

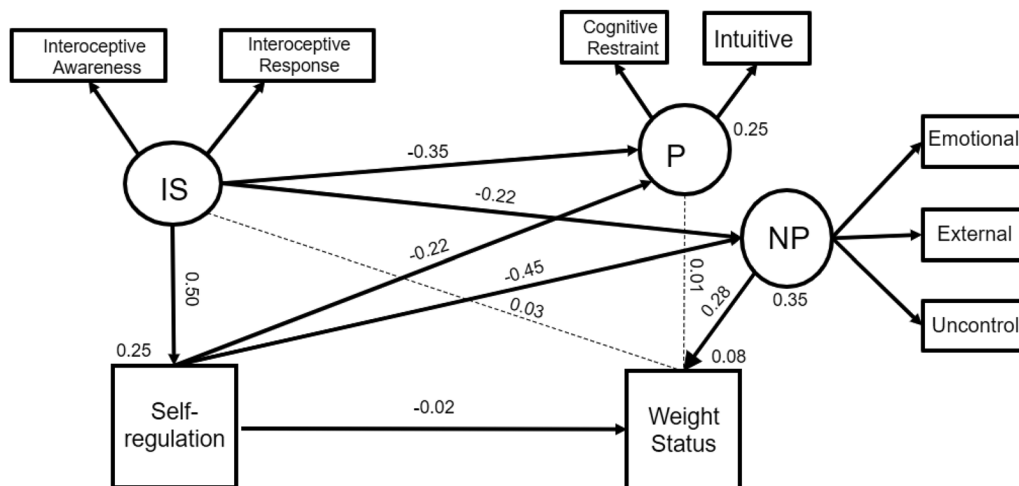


Figure 4. SEM model with standardized estimates on the associations of cognitive skills, eating domains, and BMI.

Note: IS= Interceptive Sensibility, P= Purposeful Eating, NP= Non-purposeful Eating.

Bolded lines indicate significant paths; Bolded dashed lines indicate marginally significant paths. Dashed lines indicate non-significant paths.

Table 5. SEM model path relationships and hypotheses.

Relationships	Standardized Regression Coefficients	P-value	Proposed Hypotheses	Hypothesis Supported
IS → Self-regulation	0.50	$p < 0.001$	Significant direct relationship	Supported
IS → Purposeful	-0.35	0.055	Significant direct relationship	Not Supported
IS → Non-purposeful	-0.22	0.002	Significant inverse relationship	Supported
IS → Weight Status	0.03	0.72	Significant inverse relationship	Not Supported
Self-regulation → Purposeful	-0.22	0.07	Significant direct relationship	Not Supported
Self-regulation → Non-purposeful	-0.45	$p < 0.001$	Significant inverse relationship	Supported
Self-regulation → Weight Status	-0.02	0.85	Significant inverse relationship	Not supported
Non-purposeful → Weight Status	0.28	0.002	Significant direct relationship	Supported
Purposeful → Weight Status	0.01	0.85	Significant inverse relationship	Not Supported

Note: SEM: Structural Equation Modeling; IS=Interoceptive Sensibility.

Discussion

Previous research has suggested that cognitive behaviors like interoception and self-regulation may impact college students' eating styles and weight. The current study further advances this area by defining and testing a two-factor structure of eating styles; purposeful and non-purposeful eating domains. The effects of interoception and self-regulation on eating domain and weight status in college students were examined. Significant differences between the two factors were found when eating behaviors were categorized into the purposeful and non-purposeful eating domains. SEM results indicated that participants with increased interoceptive sensibility had higher levels of self-regulation. Also, participants with increased cognitive factors of interoception and self-regulation were associated with reduced non-purposeful eating domain behaviors. Lastly, it was found that those with higher non-purposeful eating domain behaviors were more likely to report higher weight status.

The two-factor CFA presented distinct differences between the purposeful and non-purposeful eating domains. Emotional, external, and uncontrolled eating were found to have strong loadings onto the non-purposeful eating domain. These eating styles share a common "reactivity" toward external stimuli that, in turn, affect their food choices and consumption.^{37,66,67} Intuitive eating loaded significantly onto the purposeful eating domain. Intuitive eating has been popularized for its reliance on hunger and satiety cues, thus leading to more purposeful eating and lifestyle habits.⁶⁸ Cognitive restraint had an inverse relationship with intuitive eating but did not load strongly onto the purposeful eating domain. Although not strongly indicated, this finding revealed a potentially unique characteristic of cognitive restraint therefore, we chose to keep it included in the model. Cognitive restraint eaters are highly aware of their internal cues and position themselves to control their consumption regardless of their hunger and satiety levels.³⁹ Conceptually this behavior would categorize cognitive restraint eaters as purposeful, however, these eaters may later experience adverse eating habits due to the restrictive nature of the eating style.⁶⁹ The adverse pattern, called the disinhibition effect, where restricted eaters no longer practice restraint and often overeat as a result, may also explain why cognitive restraint was not factored strongly onto the purposeful eating domain.³⁶ Past literature has found distinct differences among those who were classified as successful vs.

unsuccessful cognitive restraint eaters.⁷⁰ When cognitive restraint is practiced successfully, adherence to one's dieting goal and increased resistance to tempting, high-calorie food was found, compared to those who were unsuccessful.^{42,71} In our study, results suggest that participants who reported cognitive restraint habits were both successful/unsuccessful eaters, thus resulting in the factor having an inverse relationship with intuitive eating and not factoring well onto the purposeful eating domain. Further investigation on the differences between successful/unsuccessful cognitive restraint eaters are needed to better understand the potential outcomes in relation to interoception, self-regulation and weight status in college students.

Elevated levels of interoception were associated with higher self-regulation scores. This association has been only briefly explored in recent years, however, past literature indicates that the cognitive influences of interoception can affect one's active decision-making when attempting to self-regulate.^{18,72,73} Researchers have used objective measures of interoception and found that individuals with increased interoceptive skills were inherently more precise when following body cues and were able to better regulate themselves based on their hunger and satiety levels.⁷⁴ College students who practiced theory-based mindfulness approaches (including self-awareness and attention control) in a short-term intervention were found to gain significantly higher self-regulation scores.^{75,76} However, in the college environment where palatable food choices are steadily abundant, long-term maintenance of effective interoception and self-regulation skills may be difficult. Future longitudinal studies are needed to further explain the mechanisms of interoception and self-regulation and its long-term effects on the college lifestyle.

Both interoception and self-regulation were inversely correlated with the non-purposeful eating domain. This finding was supportive of our hypotheses as it is suggested that emotional, external, and uncontrolled eating styles all share a sense of high reactivity to environmental stimuli (i.e. emotional reactions, the sight or smell of food). A recent study found that college students with increased interoception reported reduced levels of emotional, external, and uncontrolled eating behaviors.²⁹ Specifically, among female college students, food consumption was more affected by reactivity to emotions, compared to male counterparts.²⁹ These results were similar to previous studies that found higher levels of eating self-regulation were related to reduced incidences of maladaptive eating styles such as emotional and uncontrolled

eating.^{77,78} More recently, the incorporation of cognitive skills such as interoception and self-regulation has been utilized as a useful strategy in dietary interventions among college students.^{19,79–81} In fact, first-year college students with higher self-regulation skills were more prone to maintaining a healthy diet and optimal weight management throughout their college careers.⁸²

Lastly, it was found that non-purposeful eating had a significant direct association with BMI. Again, this confirmed our hypothesis as it was presumed that those who scored higher on the non-purposeful eating domain behaviors would be classified with overweight/obesity. Previous literature in college students has found that higher scores of emotional eating were positively related to BMI and other anthropometric measures.⁸³ In fact, a previous study found that the impact of emotional dysregulation on emotional eating was related to increased BMI in young adults.⁸⁴ Additionally, shared traits of the non-purposeful eating domain such as impulsivity, reward sensitivity and reactivity were positively correlated with reported higher college student weight status.⁸⁵ Our research utilizing the proposed eating domains may serve as an important resource to target the domain's specific traits and behaviors to promote healthy eating habits and optimal weight maintenance among college students.

Although this study provided empirical information on the related topics, there are a few limitations that should be addressed. First, this study utilizes cross-sectional data which does not allow the researchers to examine causality or long-term effects. Also, although it was not our intention, this study was female-only due to insufficient recruitment of male participants ($n=13$). The lack of male representation limits the generalizability of the study and does not provide the needed knowledge of the male perspective regarding cognitive behaviors, eating styles and weight status. Associations may differ within the male population as it has in similar previous research studies.^{29,86,87}

Additionally, our study population was predominantly Hispanic (75%) which can create potential issues when attempting to generalize to the general college student population. The social and cultural experiences surrounding eating behaviors may differ when compared to other ethnicities. Past research has shown that this population is considered the most at-risk for obesity and obesity-related issues.⁸⁸ However, it is acknowledged that the differences in eating behaviors in the Hispanic community have been ineffectively studied since it has often been only compared to the 'American' or western diet which may pose an inaccurate consideration of a healthy diet. Also, it is important to note that undergraduate students were predominantly recruited from the psychology software tool, called SONA. This led to approximately 66% of students categorized into the social sciences major (ie. psychology). Student's health perception knowledge may have led to biased responses and does not allow for generalizability to all college students. Lastly, all the measures utilized in this study were self-reported by the participant which may also lead to potential inaccuracies in data. However, all self-reported measures were previously validated in the college student population. Even with the

limitations of the study, there were also significant strengths. We employed 2 sets of CFAs and a 2-step SEM model analysis to validate our hypotheses. Furthermore, we were able to utilize those eating styles to identify two eating domains: purposeful and non-purposeful to further explain the associations between college student cognitive skills, eating behaviors, and weight status.

Implications for research and practice

Overall, this research study provided empirical evidence on the associations between interoception, self-regulation, purposeful and non-purposeful eating domains, and weight status in college students. These findings support the continued effort to examine college students' behaviors and their associated risk for obesity. In an environment where palatable food is abundant, development of strong internal regulation is warranted. We found that interoception was directly associated with self-regulation. Furthermore, both cognitive skills, interoception and self-regulation, were inversely correlated to non-purposeful eating domain behaviors. These findings identify the importance of focusing education efforts on the recognition and enhancement of cognitive skills to reduce unhealthy eating habits in college students. Future interventions can be curated to focus on educating college students to not only rely on their physical cues to increase internal awareness and responsiveness (interoceptive sensibility), but also provide the skills to self-regulate and make active decisions to be more purposeful in their eating habits. By creating interventions based on interoception and self-regulation, researchers may be hopeful to improve several health behaviors at once due to their perceived relationship with physical activity and mental health in college students.^{89,90}

Conflict of interest disclosure

The authors have no conflicts of interest to report. The authors confirm that the research presented in this article met the ethical guidelines, including adherence to the legal requirements, of the United States of America and received approval from the Institutional Review Board of Florida International University.

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