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Recalled and momentary virtual portions created of snacks predict actual intake under laboratory stress condition

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Abstract

Virtual portion tasks have been used to predict food intake in healthy individuals, severity of illness in individuals with anorexia nervosa, and weight loss in bariatric surgery patients. Whether portion creation in response to a recalled interpersonal stress ("recalled stress portions") could be used as a proxy for ad lib intake, after a stressor, remains untested, and the mechanism supporting this relationship is unclear. The present study's goals were: 1) to validate virtual portion tasks as proxies for actual food intake in a stressful context and 2) to test a causal pathway in which these virtual stress portions predict ad lib intake after stress. We proposed that this relationship is mediated by virtual portions created the moment after laboratory stress or rest manipulation

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(momentary portions), and before the participant actually ate food. At screening, 29 healthy undergraduate white women created virtual portions of eight snacks (apples, olives, potato chips, pretzels, caramel popcorn, milk chocolate) that they typically eat and also portions they recall eating in response to a stressful interpersonal situation. In addition, after a Trier Social Stress Test, or a rest period, on separate days in counterbalanced order, participants created ‘momentary’ virtual portions of the same snacks presented during screening, and then were given potato chips, mini golden Oreos, and M&Ms to eat. Recalled stress ($b = 0.07 \pm 0.02$, $p = 0.003$), and momentary stress ($b = 0.12 \pm 0.02$, $p = 0.00001$), portions of milk chocolate accounted for 29% and 51%, respectively, of the variance in ad lib stress intake of M&Ms. Typical ($b = 0.15 \pm 0.07$, $p = 0.03$), and momentary rest ($b = 0.21 \pm 0.06$, $p = 0.002$), portions of chips accounted for 16% and 31%, respectively, of the variance in ad lib rest intake of chips. The causal pathway from recalled stress portion to ad lib stress snack intake was completely mediated by momentary stress portion for milk chocolate and M&Ms ($\beta = 0.04 \pm 0.02$, $z = 2.4$, $p = 0.0154$). These findings illustrate the planning and recall components of eating in response to stress, but not necessarily under rest conditions. This recalled stress virtual portion paradigm has clinical and research value in that it can detect those who overconsume in response to stress.

1. Introduction

1.1 Utility of virtual portion estimation programming

Measurement of human food intake has proceeded slowly because the only precise measures have been on single meals in a laboratory setting. The advantage of the administration of virtual portion size tasks is that their predictive quality can be assessed across a variety of potentially eaten foods at the same moment in time. In research involving human ingestive behavior, virtual portion size paradigms have proven to be useful research tools for assessment of food intake controls. Jeff Brunstrom has introduced two psychometrics approaches to the measurement of expected satiety and portion size estimation.

The first approach used a *method of constant stimuli*, a psychophysics technique in which participants are shown a portion of food on a computer screen (virtual portion) and the size of that portion changes over a series of exposures in a single session [1]. The participant indicates whether the portion is bigger or smaller than a standard reference, such as the participant’s ‘typical portion size [1]. From these indications, a probit analysis is used to generate estimates, such as a person’s typical portion sizes or portions that would be needed to alleviate hunger between meals (expected satiety) [1]. To further demonstrate the utility of these estimations, Brunstrom et al found that typical portion size was predicted by gender, dietary behavior, and hunger [1]. To extend this beyond a student sample, Kissileff et al [2] compared adolescents with and without anorexia nervosa (AN). In addition to typical portion size, patients with AN estimated the maximum they could tolerate eating and reported tolerating smaller portions than healthy controls [2].

The second psychometric approach, *method of adjustment* [3], is a screen-based psychophysics technique in which participants are shown pictures of food portion on a computer screen, and they change the size of the portion displayed by pressing the left and right arrow keys on a keyboard, causing the portion to increase or decrease [3]. Brunstrom created these programs to measure: 1) “expected satiety”, with the prompt: “Imagine you are having this food for lunch TODAY. Look at the picture on the left. Now match the picture on the right so that both foods will leave you feeling FULL to the same extent (immediately after they have been eaten)”; and 2) “ideal portion”, with the prompt: “Imagine you are having this food for lunch TODAY. Select your IDEAL portion size” [3]. Brunstrom found that these tools were responsive in that large differences in expected satiety were detected across low- and high-calorie foods [3-5], and familiarity with a food was strongly associated with its expected satiety [5]. Laura Wilkinson found that both expected satiety and ideal portions were significant predictors of intake in healthy individuals and are thus proxies of intake [6]. In the same AN study previously mentioned [7], Herzog et al also explored elasticity in portion creation [7], that is, the magnitude of difference between a maximum tolerated portion (using *method of constant stimuli*) and typical portion sizes (using *method of adjustment*). They found that eating disorder scores predicted elasticity for high energy-dense (HiED), but not low energy-dense (LoED) foods [7]. Additionally, typical portions, ideal portions, and elasticity in patients with AN were smaller than in HC, which was a clinically useful demonstration [7]. Pleunie Hogenkamp et al. used these tasks and found that people who are sleep-deprived chose larger portions of snacks [8]. While examining portion control and healthy mindsets, Ralf Veit and colleagues found that these tasks detected sex differences and reductions in portion selection after a healthy mindset manipulation [9, 10].

Barbara Rolls suggested that “portion sizes are modifiable and should be further studied in connection with the prevention and treatment of obesity” [11]. Therefore, we extended these tasks to a bariatric surgery candidate sample and to age-, sex-, and race-matched controls, with our goal being to examine the influence of well-established factors (food properties, eating contexts, energy needs, bariatric surgery interventions) that influence the reliability and responsiveness of virtual portion creation tasks (VPCTs) [12]. We included typical and maximum tolerable eating context, that were previously used, and extended this to three additional eating contexts in which participants were instructed to indicate the amounts they would eat: to stay healthy, to feel comfortably satisfied, and if nothing was limiting them which we refer to here as ‘desire’ [12]. The decision to include these additional contexts was motivated by a concern to capture other meaningful portion responses that might reflect attitudes and mindsets associated with portion control and overconsumption that promotes weight gain. In healthy controls, we found that portions created in VPCTs are reliable over time and are influenced by food type, eating context, and changes in energy need [12]. We also found that ‘healthy’ and ‘desired’ portions predicted post-surgical weight loss [12].

1.2 Application of virtual portion creation tasks to stress paradigms

Forty-seven percent of an American representative sample was concerned with the amount of stress in their life and cope by engaging in maladaptive behaviors like eating for relief [13]. During stress, women overeat high-fat foods that they normally would avoid for health reasons to promote weight maintenance [14]. HiED foods are more palatable, and are therefore more rewarding or desired [3]. These foods are selected in larger portions [3]. The stress-induced drive for HiED foods could be contributing to the obesity epidemic [15]. Repeated stimulation of the reward pathways, through either stress-induced hypothalamic–

pituitary–adrenal stimulation, intake of highly palatable food, or both, may lead to neurobiological adaptations that promote the compulsive nature of overeating [16].

Because of the possible relationship between stress, stress-induced changes in energy intake, and body weight, we extended the VPCTs to include a prompt about portion creation in response to a recalled interpersonal stress situation (see 2.2.1 for more details). We found that, in the same bariatric patient cohort mentioned in 1.1, portions of milk chocolate created in response to these stressful situations positively predicted post-surgical weight loss, that is, the larger the portion, the higher the percent weight loss [17].

1.3 Present study

1.3.1 Objective—The overall objectives of this pilot study were: 1) to validate these virtual portion size tasks as proxies for actual food intake in a stress context, and 2) to test a causal pathway in which recalled stress portions predict ad lib intake after stress.

1.3.2 Aims

1.3.2.1 Aim 1.: The first aim was to assess the convergent and divergent validity of virtual portion creation on ad lib snack intake. In order to determine whether virtual portion creation could predict ad lib snack intake in eating contexts other than typical [6], in a laboratory setting, we compared virtual portion creation predictions of ad lib snack intake, and compared these predictions in stress and rest conditions. Changes in emotional state can influence eating and subsequent changes in intake, from baseline to heightened arousal, may be a trait. The hypothesis was that responses to VPCTs will reflect what one would actually consume under baseline and aroused (in this case being stress) conditions. Further, the magnitude of the strength of these relationships will be largest with foods that are the same in both the VPCTs and the ad lib test, and would decrease as: foods are more dissimilar, i.e. a highly-palatable sweet snack and a low-energy vegetable, and conditions or contexts are dissimilar, i.e. expected virtual intake under stress with actual ad lib intake after rest.

1.3.2.2 Aim 2.: The second aim was to appraise the convergent and predictive validity of recalled stress and typical VPCTs on VPCTs administered after an actual stress or rest, that is, to test whether momentary virtual portions, created in a laboratory setting, after rest or stress condition and at the time of eating, can be predicted from recalled virtual portions under similar theoretical conditions (typical and recalled stress, respectively). The hypothesis was that virtual portion creation is a stable exercise in that virtual portions should be relatively similar over time. Additionally, the magnitude of the strength of these relationships would be largest when the food and the context are the same, and would decrease as foods are more dissimilar, i.e. a highly-palatable sweet snack and a low-energy vegetable, and contexts are dissimilar, i.e. expected virtual intake under normal, non-stressed conditions with expected virtual intake after a laboratory stress manipulation.

1.3.2.3 Aim 3.: Expected satiety reflects aspects of the ‘utility’ value of a food, i.e., the expected benefits to the individual after it has been consumed [18]. Similar to expected satiety, there may be an ‘expected reward’ attached to foods, and during stress, this reward might be sought in order to cope [19]. The third aim was to test a causal pathway in which virtual portion sizes predict laboratory intake. This aim integrates evidence of three pathways from Aim 1 and Aim 2: 1) virtual portion creation under theoretical stress or rest condition → ad lib intake test after stress or rest; 2) virtual portion creation after stress or rest → ad lib intake test after stress or rest; and 3) virtual portion creation under theoretical stress or rest condition → virtual portion creation after stress or rest. The exploratory hypothesis is that, under stress, the relationship between a portion of food expected to provide reward or comfort to ameliorate negative stress state and eating that food in response to a real stress will be driven by how salient that portion is, which introduces a learning and memory component to this mechanism. Habitual behavior, in this case the behavior being eating in response to stress or absence of stress, is driven by stored information about the average immediate consequences of performing the action of eating [20]. We propose that, under each condition, the relationship between the stimulus (food) and subsequent response (pleasure of eating) is represented by decision-making aspect of virtual portion creation after stress or rest, in response to instruction that would prompt a participate to indicate what they would 'eat right now', which we call momentary. Further, these momentary portions influence the relationship between portions made under theoretical and actual conditions.

1.3.2.4 Auxiliary aims.: Alone, expected liking of food, actual liking of food [3, 6], and consumption frequency [21] are not consistent predictors of intake. However, one auxiliary aim was to confirm if liking (at screening as well as after actual consumption of snacks in the laboratory) and consumption frequency influence the size of the portions created in VPCTs and the amount consumed in the laboratory. The hypothesis was that liking and frequency are directly associated with, and drive the size of virtual and actual portions of food.

Additionally, Klatzkin et al [22] found that the interaction of perceived life stress (PLS) and negative affect (NA) predicted total ad lib snack intake, that is, higher stress-induced NA predicted greater snack intake for women with higher PLS [22]. Another auxiliary aim was to determine whether the PLS x NA interaction predicted ad lib intake of the individual snacks, with the hypothesis that PLS enhances the salience of NA as a trigger for stress-eating.

Further, to reduce biases that can be present when a participant is tested multiple times, the third auxiliary aim was to determine whether there were order effects on the tasks that were repeated over multiple test days.

1.3.3 Predictions—As mentioned, virtual portions that reflect expected satiety have been previously shown to predict intake in healthy individuals [6]. Therefore, virtual portions reflecting stress eating or normal consumption could also be useful proxies of laboratory-based measures of intake in these contexts, however because stress is known to influence intake of specific foods (e.g., Wardle and Gibson [23]), it follows that the extent to which a virtual portion predicts an actual portion may also be food specific. Overall, the following predictions (below and in Table 1 for reference) are to support predictive, convergent, and divergent validity, but more importantly, they are designed to address how responsive this instrument is to changes in pre-meal planning, food selection, portion creation, and snack consumption that are driven by alterations in state (stress or rest). The predictions below are indexed by the letter H followed by Arabic numerals for the main aims and lowercase Roman numerals for the auxiliary aims.

1.3.3.1 Virtual portions predict intake.: The following predictions support predictive and convergent validity. (H1) Recalled stress portions will positively predict ad lib stress intake for similarly matched HiED snacks. (H2) Typical portions will positively predict ad lib rest intake for similarly matched HiED snacks. (H3) Momentary stress portions will positively predict ad lib stress intake for similarly matched HiED snacks. (H4) Momentary rest portions will positively predict ad lib rest intake for similarly matched HiED snacks.

The following predictions support divergent validity. (H5) Recalled stress portions will not predict ad lib rest intake for similarly matched HiED snacks. (H6) Typical portions will not predict ad lib stress intake for similarly matched HiED snacks. (H7) Momentary stress portions will not predict ad lib rest intake for similarly matched HiED snacks. (H8) Momentary rest portions will not predict ad lib stress intake for similarly matched HiED snacks.

Additionally, as a negative control, specifically for energy density, we predicted that virtual portions of LoED snacks would not predict ad lib snack intake under any condition since all of the ad lib snacks were HiED (H9).

1.3.3.2 Recalled portions predict momentary portions.: Wilkinson et al found that expected satiety and ideal portion size not only predict intake separately, they are also highly correlated [6]. Therefore, we expected that (H14) recalled stress portions would positively predict momentary stress portions and (H15) typical portions would positively predict momentary rest portions. Since the snacks presented are the same in all virtual portion programs we used, we expected that H14 and H15 would be confirmed in all snacks.

1.3.3.3 Recalled portions predict intake through mediation by momentary portions.: We expected that (H16) recalled stress portions, specifically of HiED foods, which are more rewarding, would positively predict ad lib stress snack intake, and this prediction will be mediated [24] by their momentary stress portion. We also expected that (H17) typical portions of HiED foods would positively predict ad lib rest snack intake and this prediction would be mediated by their momentary rest portion.

1.3.3.4 Order effects on momentary portion creation and ad libitum snack intake.: The order in which participants undergo their stress or rest day will have no effect on their (H-i) momentary virtual portion creation or their (H-ii) ad lib intake for each snack.

1.3.3.5 Perceived life stress, negative affect, and intake.: (H-iii) PLS x NA interaction will positively predict ad lib intake for each snack, separately.

1.3.3.6 Liking and frequency correlate with virtual portion size.: (H-iv): Virtual expected liking, completed at screening, will positively predict liking after laboratory consumption of the same snack. (H-v) Virtual expected liking and (H-vi) consumption frequency (times/day) will positively predict virtual portion creation, for all eating contexts, of the same snack displayed.

1.3.3.7 Liking and frequency predict intake.: (H-vii) Virtual expected liking, (H-viii) consumption frequency, and liking after eating (H-ix) would positively predict ad lib stress and rest intake for similarly matched snacks.

1.3.3.8 Virtual portion by frequency interactions predict intake.: For the interaction of virtual portions and consumption frequency as stronger predictors of intake, we expected that the (H10) typical-by-frequency interaction and (H11) momentary rest-by-frequency interaction for milk chocolate and chips would be stronger predictors (compared to the virtual portions alone) of ad lib rest intake of M&Ms and chips, respectively. Similarly, we expected that the (H12) recalled stress-by-frequency interaction and (H13) momentary stress-by-frequency interaction for milk chocolate and chips would be stronger predictors (compared to the virtual portions alone) of ad lib rest intake of M&Ms and chips, respectively. The reasoning behind these predictions is that consumption frequency could moderate the relationship between virtual portion creation and ad lib intake, that is, it could be that the effect virtual portion creation on intake is different at different frequency "levels". While this set of analyses is not the focus of the report, they provide preliminary analyses for future projects.

2. Materials and methods

2.1 Participants

Female undergraduate students, between the ages of 18 and 22, responded to an advertisement for research investigating stress. Participants were told that the study was investigating stress physiology in college females. Women report eating greater amounts of food in response to stress than men, and because the relationship between stress and obesity is greater in women than men [25], only women were recruited for the study. Participants were excluded from study participation if they: 1) were currently in treatment for eating or weight problems; 2) were regular smokers; 3) were currently taking blood pressure, stimulant, or psychoactive medications; 4) self-reported current or prior cardiovascular disease, diabetes, or hypertension.

2.2 Screening

All screening measures were completed remotely by the participant on their own personal computer.

2.2.1 Virtual portion creation tasks completed at screening—The VPCTs used in this study employed *method of adjustment* [3, 12], in which the participant created virtual portions of foods on a computer monitor, in response to different eating contexts. This portion creation study was part of a larger stress study, and while the *method of constant stimuli* is likely more accurate, it requires many trials. We used the method of adjustment approach because it was less cumbersome, had proven to be valid for predicting intake [6], and we were able to assess a greater number of snacks in a shorter period. Participants pressed the arrow keys on a keyboard to decrease or increase the portion size of a food displayed on the screen [3]. In each trial, the foods were presented randomly as well as the starting picture.

2.2.1.1 Stimuli for virtual portion creation tasks.: The virtual snacks for the VPCTs were chosen to match the golden Oreos, potato chips, and M&Ms that were presented in the ad libitum intake test (explained in 2.6.2). Milk chocolate was similar to the M&Ms in the ad libitum intake test. Caramel popcorn was included as an alternative sweet HiED snack. Caramel popcorn was chosen as a replacement sweet HiED food due to its small unit size. Potato chips were the exact same in both the virtual portion task and the actual snack intake test, and pretzels were included as an alternative salty HiED snack. Apples (sweet LoED) and olives (salty LoED) were included as control foods since they were not as palatable as the sweet and salty HiED snacks and were not similar to the ad libitum intake test items.

2.2.1.2 Virtual portion creation instructions.: Participants were shown six snack foods (apples, olives, milk chocolate, caramel popcorn, pretzels, and potato chips) (Fig. 1), and were instructed to create virtual portions for two contexts: typical and stress. The typical context prompted participants to create virtual portions that they typically eat [12]. The prompt was: “Create the portion you might typically eat of this food”. The recalled interpersonal stress-eating context prompted participants to create virtual portions that they would eat in response to a recalled memory from a stressful interpersonal life event. The prompt was: “Recall yourself being in a situation that made you feel stressed and anxious from a relationship with family member, classmate, or co-worker. Create the portion of food you would eat in the situation you just recalled when you were stressed or anxious.”

2.3 Additional screening questionnaires

In addition to the aforementioned VPCTs, participants also indicated their liking (VAS) of these snacks (as well as the additional snacks used in the ad lib test) and how often they consumed them (times per day, week, month, or year). As part of the larger stress study [22], participants also completed preliminary screening questions aimed at assessing PLS and the exclusionary criteria described above, as well as measures closely tied to PLS: depressive symptoms, uncontrolled eating, emotional eating, cognitive restraint, and BMI [26-28].

2.4 Study design

If inclusionary criteria were met, participants were invited to schedule both of their laboratory sessions (rest and stress days). Each laboratory testing session began in the early evening (between 4:00-5:30 pm); study visits were scheduled for this time so that cortisol levels would be stable, rather than on a decline, which occurs in the earlier parts of the day. The order of rest and stress laboratory sessions was counterbalanced in a restricted randomized design. The average time between them was 6.5 ± 2 SD days. The rest day was identical to the stress day, with the exception that the stress testing was replaced with a rest period of the same length (Fig. 2). In order to standardize participant energy needs on the day of testing, participants refrained from: exercising strenuously; waking from sleep less than 2 h prior to the testing session; drinking more than a single caffeinated beverage in the morning; eating or drinking (except water) 2 h prior to the study; consuming any alcohol 12 h prior to the study; or taking any antihistamines, psychotropic medications, and neural stimulants. The experimenter confirmed that participants had followed all testing-day requirements. Participants were also encouraged to eat a snack before their 2 h fasting period to avoid excessive hunger.

2.5 Protocol

2.5.1 Stress day protocol—On the stress day, the research assistant placed a blood pressure cuff on the non-dominant arm of the participant. Next, participants completed questionnaires assessing their subjective well-being: stress intensity, positive and negative affect, hunger, and desire to eat. Participants then rested quietly for 10 min, during which time cardiovascular activity was assessed every 5 min. Cardiovascular measures comprised systolic blood pressure, diastolic blood pressure, and heart rate. HPA-axis activity was assessed immediately following baseline rest via salivary cortisol. Participants then underwent the Trier Social Stress Test (TSST). The TSST [29] is a stress test that reliably induces large and consistent cardiovascular responses. During pre-task instructions (5 min), the researcher informed the participants that they would be giving a speech that will be audio- and video-recorded for later analysis and would be followed by a serial subtraction task. Participants were then introduced to the selection committee composed of three research assistants wearing white laboratory coats who would be evaluating their speech. The researcher then asked participants to imagine that they were applying for their ideal job and to take 5 min to prepare their speech describing why they would be the ideal candidate for the position. Immediately following the preparation period, the selection committee returned to the testing room and asked the participants to deliver their speech. If the participant finished before 5 min, the committee responded in a standardized way by asking the participant to continue. If necessary, the committee asked prepared questions to ensure that participants spoke for the entire period. Finally, the researcher asked the participants to perform mental math for 5 min by serially subtracting 7 from 2000 aloud as quickly and accurately as possible. Their progress was monitored, and when an error was made, the experimenter told the participants to start over from the beginning. Immediately following the completion of the TSST, participants rated the intensity of their stress (VAS).

2.5.2 Rest day protocol—During the rest day, participants completed the same procedures as the stress day, but in lieu of the TSST, participants rested quietly while listening to classical music and were given the option to read any of 3–4 magazines about the city of Memphis. Similar to the stress day, immediately following rest, participants rated the intensity of their stress.

2.6 Description of tasks

2.6.1 "Momentary" virtual portion creation tasks.—Participants were administered VPCTs 6 min after their stress or rest period (Fig. 2) during their laboratory visits. Unlike the VPCTs completed at screening, these "momentary" VPCTs instructed participants to create portions of food (same foods used during screening) that they would like to eat right now [6]. Afterwards, participants were instructed to sit and rest quietly. During this time, both the 35 min post-stress or post-rest induction measures of salivary cortisol were taken.

2.6.2 Ad-libitum snack intake.—Fifteen minutes after completion of the momentary VPCTs, participants were given a tray containing three plastic containers with a pourable lid, each filled with a different snack food. Three bowls were provided in which to pour each of the three snack foods, so participants could serve themselves. Each plastic container was the same size and filled to the top with either M&Ms. (935g, 19.5 servings, 4684 kcal), mini golden Oreos (380g, 13 servings, 1834 kcal), or potato chips (110g, 4 servings, 629 kcal). These three foods were used in the main stress-eating study that also measured cortisol, perceived life stress, and negative affect [22]. Some of them had also had previously been used for a binge eating disorder and stress study conducted by Klatzkin et al [30].

Participants were told that the purpose of this part of the study was to determine the effect of liking or disliking certain foods on salivary function. Participants were asked to sample each snack food and then rate it (0-15 ordinal scale) on the taste dimensions of salty, sweet, and crunchy, as well as how much they liked the snack. Participants were then left alone for 15 min to select portions, consume these portions, and rate the snacks, and were free to move about the private testing room.

2.7 Data analysis and design

SAS9.4 software (SAS Institute, Inc., Cary, NC, USA) was used for all analyses. Descriptive statistics (means ± SEMs) were computed for demographic variables, screening variables (PLS scores, hunger, liking, and consumption frequency), NA scores, portion responses (g) for each context, and ad lib snack consumption after stress and rest. In order to determine normality of distributions, univariate analyses were executed on all variables.

2.7.1 Power—Based on the Hamm et al study [12] (which was powered by the effects in a Brunstrom et al study [1]), to have a power of at least 80%, 29 participants were needed to detect significant differences in portion creation. Based on the Wilkinson et al study [6], to have power of at least 80% for the predictions of intake from portion size, 30 participants were needed. Forty-two women were recruited and participated in the overall stress-eating study [22], in which these VPCTs were administered, however twelve participants did not successfully complete all virtual portion creation tasks and one participant, who did complete all tasks, was a major outlier on intake (greater than the third quartile plus 1.5 times the interquartile range) and was removed from analyses.

2.7.2 Data collection—Data were collected at Rhodes College (Memphis, TN), de-identified, and then transmitted by internet to Columbia University (New York, NY), where initial analyses were done, and further transferred to Mount Sinai Morningside Hospital (New York, NY), where analyses were completed and the manuscript was written.

2.7.3 Linear regressions and correlations—All linear regressions and correlations were held to Bonferroni correction for multiple comparisons dependent upon the *k* number of comparisons in a given set of analyses.

2.7.3.1 Liking, consumption frequency, and virtual portion creation: As an aside, since liking is administered at screening (expected liking) and after ad lib intake (actual liking), we wanted to determine if liking ratings were consistent between screening and test days (H-iv). Liking ratings made after eating in the lab were linearly regressed from virtual liking that the participants reported at screening.

To assess how much variance in virtual portion creation is explained by liking (VAS) and consumption frequency (times per day) (H-v & H-vi), all virtual portions were linearly regressed from liking ratings and consumption frequencies.

2.7.3.2 Liking, consumption frequency, and ad libitum snack intake: To determine how much variance in ad lib rest intake is explained by virtual liking and consumption frequency (times per day) (H-vii & H-viii), rest intakes were linearly regressed from liking ratings and consumption frequencies of the same snack. Additionally, to test if ad lib intake is associated with ratings of how much the participant liked what they tasted (H-ix), linear regressions of ad lib rest intake from respective liking ratings were performed. Using the same approach, we then explored responses and intakes in the stress condition.

While the main aims were focused on virtual portions and ad lib intakes, these regressions pertain to the auxiliary aims, and were performed to determine if liking and frequency should be included as statistical controls or covariates in future analyses, including virtual portion creation and ad lib intakes.

2.7.3.3 Predictions of ad libitum snack intake from virtual portions: To determine whether recalled virtual portion creation predicts ad lib snack intake (H1-H9) differentially for individual snacks, as opposed to their combination, intakes (g) of each snack item (mini golden Oreos, potato chips, and milk chocolate M&Ms) were linearly regressed from recalled (typical and stress) virtual portions (g) created of each of the six snack items. Additionally, snack intakes (g) of each item were linearly regressed from momentary virtual portions (g) created of each of the six snack items.

2.7.3.4 Predictions of ad libitum snack intake from interaction between virtual portion and frequency: To test whether the interaction, or product, of virtual portions created and consumption frequency predict intake (H10-H13), stress and rest intakes were linearly regressed from the product of portion size and frequency for all eating contexts (typical, recalled stress, and momentary).

2.7.3.5 Predicting momentary virtual portion creation from recalled virtual portion creation: In order to determine if momentary virtual portions created in a laboratory setting (H14 & H15), after stress or rest condition and at the time of eating, can be predicted by recalled virtual portions created under the same theoretical conditions (typical and recalled stress), momentary virtual portions were linearly regressed from typical and recalled stress portion sizes.

2.7.3.6 Correlations within and between eating contexts: In order to examine how: 1) portions of the same snack associate across different contexts and 2) portions of different snacks associate within the same context, linear regressions were performed across all virtual portions (momentary stress from recalled stress portions, momentary rest from typical portions, momentary stress from typical portions, and momentary rest from recalled stress portions).

2.7.4 Models of mediation—

Mediation analysis tests a hypothetical causal chain where a variable affects another variable and, in turn, that variable affects a third variable [24]. Mediators describe the how or why of a relationship between two variables and often describe the process through which an effect occurs [24]. To examine a potential causal pathway that explains the relationship between the recalled portion sizes (typical or recalled stress portions) and actual intake of food (H16 & H17), Hayes process macro [31] was used. The mediation model included intake as the outcome or dependent variable (y), recalled portion size as the predictor or independent variable (x), and momentary virtual portion size as the mediator (m). The total, direct, and indirect effects are presented. The direct effect is the effect of x on y without m, while the indirect effect is the path x to y through m. The total effect is the sum of the two. In full causal mediation, the direct effect should be non-significant.

Separate mediation analyses were performed for the stress and rest manipulations; we planned to do them on foods in which regressions of m from x, y from m, and y from x were significant.

2.7.5 Analyses of variance—

In order to determine whether order of test day (stress day then rest day or vice versa) had an effect on momentary portion size creation (H-i) and intake of snacks after stress or rest (H-ii), multiple one-way ANOVAs were performed. Momentary portion sizes, ad lib stress intake, and ad lib rest intake, of each snack, were the dependent variables, and order classification (stress-rest or rest-stress) was the independent variable.

In order to determine if the relationship between PLS x NA interaction and total intake [22] is maintained for each snack intake separately (H-iii), one-way ANOVAs were performed with ad lib stress intake for each of the three snacks as the dependent variable and PLS x NA interaction as the independent variable.

2.8 Ethics and regulatory approval

All participants were provided written informed consent prior to enrollment. These analyses are part of a larger stress study and was approved by the Institutional Review Board at Rhodes College (Memphis, TN). Participants received partial course credit for their time.

3. Results

3.1 Participant characteristics

Twenty-nine female college students completed screening, rest day, and stress day measures (see Table 2 for mean age, BMI, NA, and PLS scores). Pre-testing NA was no different between rest and stress days (mean difference = −0.76 ± 6.01 SD, t = −0.68, $P = 0.50$). NA significantly decreased after the rest period (mean difference = −2.55 ± 0.83 SE, t = 3.06, $P = 0.005$), on the rest day, and significantly increased after the stress period (mean difference = 4.17 ± 0.87, t = 4.82, $P < 0.0001$), on the stress day.

3.2 Ad libitum snack intake regressions

See Table 3 for virtual portion and ad lib snack intake means.

3.2.1 Recalled portions and ad libitum snack intake

3.2.1.1 Recalled stress portions and ad libitum stress snack intake

M&M and chip intake.: Recalled stress portions of chips (B = 0.10 ± 0.05, R^2 = 0.10) and milk chocolate (B = 0.08 ± 0.02, R^2 = 0.29) did not predict stress intake of M&Ms or chips, respectively (Bonferroni-corrected P > 0.001, Table 4, rows 1 & 10), which did not support H1. However, before Bonferroni-correction, recalled stress portions of milk chocolate, positively predicted ad lib stress intake of M&Ms (B = 0.54, P = 0.003, Fig. 3A, Table 4, row 10). Counter to the hypothesis that portions of olives and apples would not predict any ad lib intakes (H9), recalled stress portion of olives positively predicted ad lib stress intake of potato chips (B = 0.08 ± 0.02, R^2 = 0.42, Bonferroni-corrected P = 0.0002, Fig. 3C, Table 4, row 3). Recalled stress portions of apples did not predict ad lib stress intake of any snack item (slopes ranging from ⁻0.03-0.01, Bonferroni-corrected P > 0.001, Table 4, rows 2, 8, & 14), which confirmed H9.

Oreo intake.: Recalled stress portion sizes did not predict ad lib stress intake of Oreos (B ranging from ⁻0.22-⁻0.01, Bonferroni-corrected P > 0.001, Table 4, rows 13-18), though there was a negative trend between recalled stress portion of chips and ad lib stress intake (B = −0.22 ± 0.08, R^2 = 0.23, P = 0.01, Fig. 3B, Table 4, row 13).

Before Bonferroni correction, all intercepts were significant ($P \leq 0.05$, Table 4) except for milk chocolate (P = 0.06, Table 4, row 10). This indicates that, regardless of a significant slope, the average ad lib stress intake of each snack was significantly different from zero in most cases.

3.2.1.2 Convergent validity - Typical portions and ad libitum rest snack intake

M&M and chip intake.: Typical portions of chips (B = 0.15 ± 0.07, R^2 = 0.16) and milk chocolate (B = 0.02 ± 0.03, R^2 = 0.02) did not predict ad lib rest intake of M&Ms or chips, respectively (Bonferroni-corrected P > 0.001, Table 4, rows 1 & 10), which did not support H2. However, before Bonferroni-correction, typical portions of chips positively predicted ad lib rest intake of chips (P = 0.03, Fig. 3D, Table 4, row 1). However, other salty snacks predicted chips. Typical portions of olives predicted ad lib rest intake of potato chips (B = 0.08 ± 0.02, R^2 = 0.40, Bonferroni-corrected P = 0.0002, Fig. 3E, Table 4, row 3) and typical portions of pretzels predicted ad lib rest intake of potato chips before correction (B = 0.25 ± 0.82, R^2 = 0.28, P = 0.003, Fig. 3F, Table 4, row 5). Typical portions of apples did not predict ad lib rest intake of any snack item (B ranging from 0-0.70, Bonferroni-corrected P > 0.001, Table 4, rows 2, 8, & 14), which confirmed H9.

Oreo intake.: Typical portion sizes did not predict ad lib stress intake of Oreos (B ranging from 0.01-0.70, Bonferroni-corrected P > 0.001, Table 4, rows 13-18), however, there was a negative trend between typical portion of chips and ad lib rest intake (B = 0.47, R^2 = 0.22, P = 0.01, Fig. 3G, Table 4, row 13).

Before Bonferroni correction, all intercepts were significant ($P \leq 0.05$, Table 4) except for salty HiED snacks ($P > 0.05$, Table 4, rows 1 & 5). This indicates that, regardless of a significant slope, the average ad lib rest intake of each snack was significantly different from zero in most cases.

3.2.1.3 Divergent validity - recalled stress portions and ad libitum rest snack intake:

Recalled stress portions did not predict ad lib rest intake of any snack (*B* ranging from ⁻0.42-0.48, Bonferroni-corrected $P > 0.0004$, Supplemental Table 1, rows 19-24) which confirmed H5.

3.2.1.4 Divergent validity - typical portions and ad libitum stress snack intake:

Typical portions did not predict ad lib stress intake (*B* ranging from ⁻0.53-0.49, Bonferroni-corrected $P > 0.0004$, Supplemental Table 1, rows 13-14,16-18) except for olives, which positively predicted ad lib stress intake of chips ($B = 0.70$, Bonferroni-corrected $P \leq 0.0004$, Supplemental Table 1, row 15).

3.2.2 Momentary portions and ad libitum snack intake

3.2.2.1 Convergent validity - Momentary stress portions and ad libitum stress snack intake

M&M and chip intake.: Momentary stress portions of milk chocolate positively predicted ad lib stress intake of M&Ms ($B = 0.12 \pm 0.02$, $R^2 = 0.51$, Bonferroni-corrected $P = 0.00001$, Fig. 4A, Table 5, row 10), which confirmed H3. However, momentary stress portions of chips (before Bonferroni-correction, $P = 0.02$) did not significantly predict ad lib stress intake of chips ($B = 0.19 \pm 0.08$, $R^2 = 0.19$, Bonferroni-corrected $P > 0.001$, Fig. 4B, Table 5, row 1). Momentary stress portions of olives positively predicted ad lib stress intake of chips ($B = 0.09 \pm 0.02$, $R^2 = 0.35$, $P = 0.0008$, Fig. 4C. Table 5, row 3), and before Bonferroni correction, caramel popcorn positively predicted ad lib stress intake of chips ($B = 0.03 \pm 0.01$, $R^2 = 0.19$, $P = 0.02$, Fig. 4D, Table 5, row 6). Momentary stress portions of apples did not predict ad lib stress intake of any snack item (*B* ranging from ⁻0.01-0.04, Bonferroni-corrected $P > 0.001$, Table 5, rows 2, 8, & 14), which confirmed H9.

Oreo intake.: (*B* ranging from ⁻0.13-0.14, Bonferroni-corrected $P > 0.001$, Table 5, rows 13-18).

3.2.2.2 Convergent validity - Momentary rest portions and ad libitum rest snack intake

M&M and chip intake.: Momentary rest portions of milk chocolate (before Bonferroni-correction, $P = 0.04$) did not predict ad lib rest intake of M&Ms ($B = 0.06 \pm 0.03$, $R^2 = 0.15$, Bonferroni-corrected $P > 0.001$, Fig. 4E, Table 5, row 10). Momentary rest portions of potato chips (before Bonferroni-correction, $P = 0.002$) did not predict ad lib rest intake of potato chips ($B = 0.21 \pm 0.06$, $R^2 = 0.31$, Bonferroni-corrected $P > 0.001$, Fig. 4F, Table 5, row 1). However, momentary rest portions of olives positively predicted ad lib rest intake of potato chips ($B = 0.07 \pm 0.02$, $R^2 = 0.35$, Bonferroni-corrected $P = 0.0008$, Fig. 4G, Table 5, row 3). Momentary rest portions of apples did not predict ad lib rest intake of any snack item

(*B* ranging from -0.03-0.01 Bonferroni-corrected $P > 0.001$, Table 5, rows 2, 8, & 14), which confirmed H9.

Oreo intake.: None of the momentary rest portions predicted ad lib rest intake of Oreos Bonferroni-corrected (*B* ranging from -0.08-0.13, $P > 0.001$, Table 5, rows 13-18).

3.2.2.3 Divergent validity - momentary stress portions and ad libitum rest snack intake: Momentary stress portions did not predict ad lib rest intake of any snack (*B* ranging from -0.22-0.50, Bonferroni-corrected $P > 0.0004$, Supplemental Table 1, rows 7-12) which confirmed H7.

3.2.2.4 Divergent validity - momentary rest portions and ad libitum stress snack intake: Momentary rest portions did not predict ad lib stress intake of any snack *(B* ranging from -0.25-0.49, Bonferroni-corrected $P > 0.0004$, Supplemental Table 1, rows 1-2,4-6), which confirmed H8, except for olives, which positively predicted ad lib stress intake of chips ($B = 0.62$, Bonferroni-corrected $P \leq 0.0004$, Supplemental Table 1, row 3).

3.2.3 Virtual portion regressions

3.2.3.1 Convergent validity - Momentary stress portions and recalled stress portions: Recalled stress portions positively predicted momentary stress portions of potato chips, apples, olive, and milk chocolate (*B* ranging from 0.36-0.70, R^2 ranging from 0.27-0.80, Bonferroni-corrected $P \leq 0.004$, Fig. 5A-D, Table 6, rows 1-4), which confirmed H14. However, recalled stress portions of pretzels ($B = 0.17 \pm 0.10$, $R^2 = 0.10$) and caramel popcorn ($B = 0.19 \pm 0.14$, $R^2 = 0.07$) did not predict momentary stress portions for the same snack (Bonferroni-corrected $P > 0.004$, Fig. 5E & F, Table 6, rows 5 & 6).

Before Bonferroni correction, all intercepts were significant ($P \leq 0.05$, Table 6) except for olives and milk chocolate ($P = 0.06$, Table 6, rows 3 & 4). This indicates that, regardless of a significant slope, the average momentary stress portion of most virtual snacks were significantly different from zero.

3.2.3.2 Convergent validity - Momentary rest portions and typical portions: Typical portions (Fig. 5H-M) positively predicted momentary rest portions for all snacks (*B* ranging from 0.45-1.08, R^2 ranging from 0.35-0.93, Bonferroni-corrected $P \leq 0.004$, Table 6, rows 2-5), except chips ($B = 0.44 \pm 0.17$, $R^2 = 0.21$, $P = 0.01$, Table 6, row 1) and caramel popcorn ($B = 0.44 \pm 0.17$, $R^2 = 0.21$, $P = 0.01$, Table 6, row 6). H15 was mostly confirmed.

Before Bonferroni correction, only intercepts for pretzels and caramel popcorn were significant ($P \leq 0.05$, Table 6, rows 5 & 6). This indicates that the average momentary rest portion of most virtual snacks were not significantly different from zero.

3.3 Mediation analyses

Mediation analyses were conducted on potato chips and milk chocolate, as they were the most closely matched snacks across all paradigms and had the strongest effects between recalled portion, momentary portion, and actual portion.

3.3.1 Stress mediation analysis—
The first model that was tested included recalled stress portion as the independent variable, ad lib stress intake as the dependent variable, and momentary stress portion as the mediator. H16 was confirmed, that is, the prediction of ad lib stress intake of M&Ms from recalled stress portion of milk chocolate was mediated by momentary stress portion of milk chocolate (direct effect: $B = 0.03 \pm 0.02$; $t = 1.44$; $P = 0.1614$, indirect effect: $\beta = 0.04 \pm 0.02$; $z = 2.4$; $P = 0.0154$; Fig. 6A). However, H16 was not confirmed with potato chips ($P > 0.05$, Fig. 6B).

3.3.2 Rest mediation analysis—
The second model that was tested included typical portion as the independent variable, ad lib rest intake as the dependent variable, and momentary rest portion as the mediator. H17 was not confirmed for milk chocolate ($P > 0.05$, Fig. 6C) or potato chips ($P > 0.05$, Fig. 6D), that is, the prediction of ad lib rest intake from typical portion was not mediated by momentary rest portion.

3.4 Auxiliary findings

Measures of central tendency for liking (both at screening and after eating) and consumption frequency are presented in Supplemental Table 2 & 3.

3.4.1 Regressions of liking after eating from virtual liking.—
Virtual expected liking positively predicted liking after stress eating for chips ($B = 0.60 \pm 0.14$, $R^2 = 0.39$, Bonferroni-corrected $P \leq 0.008$, Supplemental Table 4, rows 5 & 6), but not M&Ms ($B = 0.78 \pm 0.28$, $R^2 = 0.23$, Bonferroni-corrected $P > 0.008$, Supplemental Table 4, rows 1 & 2) or Oreos ($B = 0.16 \pm 0.21$, $R^2 = 0.02$, Bonferroni-corrected $P > 0.008$, Supplemental Table 4, rows 9 & 10). Virtual liking of chips ($B = 0.64 \pm 0.14$, $R^2 = 0.44$) and M&Ms ($B = 0.64 \pm 0.14$, $R^2 = 0.44$) positively predicted liking after rest eating for the same food (Bonferroni-corrected $P < 0.008$, Supplemental Table 4, rows 3,4,7, & 8), but this relationship wasn't significant for Oreos ($B = 0.24 \pm 0.19$, $R^2 = 0.05$, Bonferroni-corrected $P > 0.008$, Supplemental Table 4, rows 11 & 12). H-iv was confirmed in chips, partially confirmed in M&Ms, and was not supported in Oreos. All intercepts were significantly different from zero ($P \leq 0.05$) and ranged from 60-76 (Supplemental Table 4) out of a 100mm VAS scale; this is an illustration of mean liking ratings at significantly higher levels overall during the actual eating, regardless of condition, than for virtual expected liking.

3.4.2 Regressions of virtual portion size from liking and consumption frequency.—
Virtual liking positively predicted typical portions of all snacks *(B* ranging from 1.02-7.72, R^2 ranging from 0.28-0.46, Bonferroni-corrected $P < 0.002$, Supplemental Table 5, rows 1,2, 5-12) except apples ($B = 1.61 \pm 1.16$, $R^2 = 0.07$, Bonferroni-corrected $P > 0.002$, Supplemental Table 5, rows 3 & 4). Virtual liking positively predicted recalled stress portions for olives ($B = 2.43 \pm 0.63$, $R^2 = 0.35$, Bonferroni-corrected $P = 0.001$, Supplemental Table 5, rows 17 & 18), but not for any other snack (B ranging from 0.90-3.82, R^2 ranging from 0.05-0.16, Bonferroni-corrected $P < 0.002$, Supplemental Table 5, rows 13-16, 19-24). Virtual liking positively predicted momentary stress portions for the salty snacks (B ranging from 0.92-2.11, R^2 ranging from 0.26*0.44, Bonferroni-corrected $P \leq 0.002$, Supplemental Table 5, rows 25,26,29,30,33,34), but not the sweet snacks (B ranging from 1.17-4.56, R^2 ranging from 0.03-0.17, Bonferroni-corrected $P > 0.002$,

Supplemental Table 5, rows 27,27,31,32,35,36). Virtual liking of chips (B = 1.13 ± 0.32, R^2 = 0.31) and olives (B = 2.54 ± 0.54, R^2 = 0.45) positively predicted momentary rest portions of the same food (Bonferroni-corrected $P \leq 0.002$, Supplemental Table 5, rows 37,38,41,42), but not for any of the other snacks (B ranging from 0.82-3.28, R^2 ranging from 0.02-0.25, Bonferroni-corrected $P < 0.002$, Supplemental Table 5, rows 39,40,43-48). H-v was confirmed in chips and olives; partially confirmed in pretzels, caramel popcorn, and milk chocolate; and not supported in apples or the recalled stress-eating context.

Consumption frequency of chips (B = 61.13 ± 16.94, R^2 = 0.33) and olives (B = 556.06 ± 61.38, R^2 = 0.75) positively predicted typical portion size (Bonferroni-corrected $P \leq 0.002$, Supplemental Table 6, rows 1,2,5,6), but none of the other snacks did (B ranging from 70.5-1315.77, R^2 ranging from 0.08-0.16, Bonferroni-corrected $P > 0.002$, Supplemental Table 6, rows 3,4,7-12). Consumption frequency of olives positively predicted recalled stress portions (B = 491.59 ± 97.44, R^2 = 0.49, Bonferroni-corrected $P \leq 0.002$, Supplemental Table 6, rows 17 & 18) but not for any of the other snacks (B ranging from 31.28-1056.58, R^2 ranging from 0.05-0.09, Bonferroni-corrected $P > 0.002$, Supplemental Table 6, rows 13-16, 19-24). Consumption frequency positively predicted momentary stress portions for the salty snacks (B ranging from 49.64-459.24, R^2 ranging from 0.29-0.69, Bonferroni-corrected $P \leq 0.002$, Supplemental Table 6, rows 25,26,29,30,33,34), but not the sweet snacks (B ranging from 56.08-108.19, R^2 ranging from 0.001-0.09, Bonferroni-corrected $P > 0.002$, Supplemental Table 6, rows 27,28,31,32,35,36). Consumption frequency positively predicted momentary rest portions of olives (B = 585.79 ± 57.64, R^2 = 0.79, Bonferroni-corrected $P < 0.0001$, Supplemental Table 6, rows 41,42), but not for any of the other snacks (B ranging from $^-$164.20-110.14, R^2 ranging from 0.001-0.17, $P > 0.002$, Supplemental Table 6, rows 37-40, 43-48). H-vi was confirmed in olives, partially confirmed in chips, pretzels, and not supported in any of the sweet snacks. Consumption frequency appears to be strongest for salty snacks.

3.4.3 Regressions of intake from liking and frequency.

—Liking after eating, virtual liking, and consumption frequency did not predict ad lib intake for any snack or condition (B ranging from $^-$0.33-0.46, R^2 ranging from 0.004-0.26, Bonferroni-corrected $P >$ 0.008, Supplemental Table 7), with the exception of the positive prediction of rest intake of chips from frequency of chip consumption (B = 0.06 ± 0.02, R^2 = 0.26, P = 0.005, Supplemental Table 7, rows 21,22). Liking and frequency were not strong predictors, thus H-vii or H-viii were not supported.

3.4.4 Effects of stress-rest order on portion creation and ad libitum snack intake.

—Order of stress or rest day had no significant influence on momentary portion creation or ad lib snack intake for any of the snack items or for either condition (F-value ranging from 0.01-4.07, $P > 0.05$), which confirmed H-i and H-ii.

3.4.5 Effects of negative affect and perceived life stress on ad libitum snack intake.

—Klatzkin et al. reported that higher stress-induced NA predicted greater total snack intake for women with high PLS [31], however, in both conditions the NA x PLS interaction did not predict intake for any snack (potato chips, mini golden Oreos, and M&Ms) (Table 7, all Bonferroni-corrected P's > 0.008), which did not support H-iii. Therefore, the NA x PLS interaction was not included in subsequent analyses as this interaction did not explain a significant proportion of the variance in snack intake, with *B* ranging from 261.89-900.84 and R^2 ranging from 0.01-0.06 (Table 7).

3.4.6 Portion-by-frequency interaction and ad libitum snack intake.

—None of the portion-by-frequency interactions were significant predictors of M&M and Oreo intake (*B* ranging from $^{-}$0.43-0.76, R^2 ranging from 0.01-0.19, Bonferroni-corrected $P > 0.0007$, Supplemental Table 8, rows 1-48, 97-144), which did not support H10-13. However, there were several significant interactions that predicted chip intake. Typical x frequency and momentary rest x frequency interactions for chips and olives positively predicted rest intake of chips (*B* ranging from 0.10-0.20, R^2 ranging from 0.37-0.50, Bonferroni-corrected $P \leq 0.0007$, Supplemental Table 8, rows 49,50,53,54,73,74,77,78), which confirmed H10 and H11. Moreover, recalled stress x frequency interaction for olives, and momentary stress x frequency interaction for chips and olives, positively predicted stress intake of chips (*B* ranging from 0.11-0.18, R^2 ranging from 0.37-0.44, Bonferroni-corrected $P \leq 0.0007$, Supplemental Table 8, rows 65,66,85,86,89,90) which confirmed H12 and H13. As seen in the liking-portion and frequency-portion regressions, taste matters, that is, liking and frequency influence virtual and actual consumption when then food has salt taste.

4. Discussion

4.1 Overall validity

Virtual and actual portions exhibited convergent validity, in that correlations were significant for both food items with matched properties between matched items and contexts (recall stress – actual stress, typical – rest), and divergent validity, in that correlations were not significant for unmatched items and contexts (stress – typical, rest – stress). The mediation, through momentary portion creation, between virtual portion creation and ad lib intake, suggests that planning for the appropriate portion in the recalled scenario may be at work during ad lib stress intake. The causal pathway we proposed with recalled portions predicting actual portions through mediation by momentary portions was food-specific (milk chocolate, but no other snack) and condition-specific (stress, but not rest). These findings demonstrate that there is stability of this instrument, although it's for the stress condition, and suggest the possibility of pre-meal planning [3].

4.2 Convergent validity of virtual portions and ad libitum snack intake

The hypothesis that recalled stress portions would predict ad lib stress intake was not confirmed after very conservative multiple comparisons corrections; however, the percentages of variance accounted for, for matched foods, were small to medium in size (20% to 50%). The strongest effects were for chocolate and potato chips, however effects for chocolate were stronger than chips; there may be a higher preference for sweet HiED than salty HiED foods under stress that does not exist for rest. Other studies have shown similar findings when salty HiED and sweet HiED snack intakes were compared under stress and rest conditions. Grunberg & Straub found that high-stress women ate more sweet HiED food than low-stress women. Additionally, salty HiED food intake was lower than sweet HiED food intake in high-stress women, and salty HiED food intake did not differ between high-stress and low-stress women [32]. Additionally, Zellner et al and Habhab et al found that participants who were stressed ate more M&Ms than chips and these stressed participants ate more than their non-stressed counterparts. The stressed group also self-reported a preference for sweet HiED foods over salty HiED foods while the non-stressed group did not [14, 33].

Another unexpected finding was the negative trend (not significant after correction) between recalled stress portion of potato chips and mini golden Oreos, such that the people who recalled eating larger portions of chips when stressed also recalled consuming smaller portions of mini golden Oreos while stressed. Additionally, on average, mini golden Oreos were the preferred food, that is, under rest and stress, participants consumed more mini golden Oreos visa-vis M&Ms and chips. On stress and rest days, the percentage of total intake attributable to mini golden Oreos was inversely associated with that of chips as well (Supplemental figure 1). Our study included female participants and there may be a sex-specific, subconscious tradeoff between choosing sweet HiED snacks over salty HiED snacks when choosing foods to cope with in response to stress [25].

The prediction that typical portions would predict ad lib rest intake, which reflected the finding that expected satiety predicts subsequent intake [6], was not confirmed after very conservative multiple comparisons corrections and the effect sizes for matched foods were much lower than those for recalled stress portions and ad lib stress intakes. The strongest effect was for chips, which is a reversal of what was found for the recalled stress-ad lib stress intake regressions. This finding may give preliminary insight into what foods are typically eaten under non-stressful situations (e.g. snacking during entertainment) versus what foods are eaten under stress. Further, the foods may be utilized differently depending on the context, for example, chocolate is more efficient for coping with stress [33, 34] than potato chips are, while potato chips, a common side to a sandwich or a standalone snack, may be more commonly eaten during non-stress condition. Also pretzels, a HiED snack, trended towards being a significant predictor of rest intake of potato chips (significant before correction), but this relationship may be driven by a possible outlier (participant “s” in Fig. 3F). From these results, we suggest that these recalled stress VPCTs may be useful for milk chocolate intake predictions and typical VPCTs may be useful for potato chips. Given that the utility of VPCTs appears to depend on whether a food is routinely consumed in given context, we recommend that follow-up studies should consider a broader range of foods and contexts, in combination with a systematic analysis of the importance of using specific foods to assess specific contexts.

Unlike the recalled stress and typical predictions, the prediction that momentary stress portions would predict ad li b stress intake was confirmed for milk chocolate and trended towards significance in potato chips (significant before correction). The prediction that momentary rest portions would predict ad lib rest intake was not confirmed but potato chips trended towards significant as well (before correction) with a small effect size. The strength of these regressions demonstrates that proximity (time interval) between virtual portion creation and ad libitum consumption of actual snacks sharpens the precision of the prediction. While the slopes and intercepts of the regressions demonstrated that participants tend to grossly overestimate their stress and rest intake (an order of magnitude for sweet

HiED snacks and up to three times as much for salty HiED snacks), the relationship was still proportional and trended towards significance (significant before correction). Stress intake of potato chips was also predicted by momentary rest portions of caramel popcorn (before correction). The finding may be attributed to the fact that they are both HiED snack foods. Hence, it may be that participants who eat large quantities in response to stress and are doing so consistently across HiED snacks.

Virtual portions of apples (across all eating contexts – recalled stress, typical, momentary stress, and momentary rest) did not predict ad lib stress or rest intake, which is evidence that apples were a good negative control food to include in the present pilot study. Virtual portions of the other control food, olives, however, consistently predicted ad lib stress and rest intake of potato chips. Upon examination of the data, the distribution of virtual olive portions was bimodal, and olive portions were strongly associated with participant liking and consumption frequency of olives, therefore, unlike other foods, olive portion creation was more of a “yes or no” question and were not a control food, where apple distributions were continuous. As a possible replacement salty LoED control food, we suggest pickles, which may be a more familiar and higher consumed food item.

4.3 Divergent validity of virtual portions and ad libitum snack intake

Divergent validity is supported by the fact that most (97%) regressions of mismatched conditions (i.e. recalled stress portions and ad lib rest intake) and foods (i.e. apples and potato chips) were not significant. Portions of olives were significant predictors of chip intake (three of four olive predictions), but, as mentioned, they have a bimodal distribution so other analyses are needed to confirm the association and agreement between these two variables. Interestingly, virtual portions of chips were weak negative predictors of mini golden Oreo intake, which may reflect a specific relationship between these two foods in which people (healthy individuals in this case) consistently choose chips over Oreos when they are presented in the same eating event. Future studies should include Oreos in the VPCTs to see if this relationship exists M&Ms and mini golden Oreos are both sweet HiED, but have other properties that differ and could explain why M&M and chip intakes were directly proportional while mini golden Oreo and chip intake were inversely proportional.

4.4 Recalled versus momentary portion size creation

Wilkinson et al. found that expected satiety and ideal portion size were highly correlated (R = 0.596, $P < 0.001$) [6]. Similarly, in matched foods, typical portions predicted momentary rest portions and recalled stress portions predict momentary stress portions, with slopes ranging from 0.35-1.08 g/g and R^2 ranging from 0.28-0.93. The expected satiety-ideal portion associations were likely stronger in the Wilkinson et al. study [6] compared to the aforementioned findings because both measures were completed by participants in the same setting. Despite the fact that typical and momentary portion creation were not equal, they were still proportional, which may illustrate how virtual portion creation is somewhat consistent over time. Another interesting takeaway is that portion creation was more consistent over time for LoED snacks. One might propose that this is because they are the least liked but their liking is not similar (mean olive liking = 35.1, mean apple liking = 72.6).

This may be an illustration of how impervious LoED food consumption is to emotional state.

4.5 A causal pathway to predict stress intake

We proposed a causal pathway model in which virtual portions created in response to a recalled interpersonal stressor predict ad lib intake after stress through mediation by virtual portions created after stress and before ad lib intake (momentary). The idea was that prediction was driven by learning or planning, that is, eating food in response to stress is a learned coping mechanism. Specifically, when participants are eating ad lib after stress, they may remember (possibly subconsciously) the virtual portions they chose after recalled stress and just prior (after the TSST) and they use these remembered portions to plan how they will create and consume actual portions in the lab. Therefore, their actual food intake post-stress is a function of pre-meal planning from previous virtual portion creations, and expectations of reward, that would allow them to cope effectively. We also proposed the same causal pathway, but in non-stress conditions; we found that while the momentary component is important to the stress pathway, it may not play an essential role in planning and subsequent decision making during non-stress situations.

4.6 Advantages, limitations, and future directions

Virtual portion creation tasks have been used in different ways to predict a variety of outcomes. They are less cumbersome than laboratory intake studies that lack ecological validity, and that are limited because only one context can be addressed at a time. For the strongest regressions (significant before correction), virtual portions accounted for 16-42% of the variance in ad lib intake, so other factors that may explain the remaining variance in intake. Bobroff & Kissileff found that liking and intake correlated poorly between subjects, but strongly within subjects [35]. Additionally, in a study with healthy individuals, BMI, liking, restraint, hunger, fullness, and other factors did not predict intake [6], and liking, in the present study, was consistent over time, but was not a strong predictor under stress, but is under non-stress conditions. An interesting finding from this study, particularly the auxiliary results, was that salt taste had an effect on the strength of relationship across liking, consumption frequency, virtual portion creation, and ad lib intake. It may be that there is less of a perception that salt is bad, compared to sweet, therefore liking, frequency, portion creation, and ad lib intake are more tightly associated, where as one may like sweet taste but not frequently consume or plan to consume sweet-tasting items. Future studies, with a larger cohort, should include liking as a possible moderator when examining portion creation and intake under stress and non-stress conditions.

Additionally, the unit of measurement used in our analyses, grams, can limit interpretation; grams were used instead of kilocalories in order to limit the inflation of portion sizes for HiED foods when they are compared to LoED foods. In actuality, it may be area of the portion size that is a better unit as it would be the closest to mirror expected volume of food, which participants likely have in mind when selecting portions. Nevertheless, the significant predictions of intake from virtual portions hold potential clinical value in that it can be an indicator for a hyperphagic stress-induced eating profile. With an increasing emphasis on ‘personalized precision medicine’, the ability to detect those who overconsume in response to stress prior to a weight loss intervention could indicate when additional behavioral interventions are needed.

A limitation to this study is that stress was induced in two different ways (interpersonal for recalled, and social for ad lib), which might explain differences between virtual portion creation from recalled and virtual portion creation in the lab after the TSST. While Klatzkin et al reported increases in stress-related physiological markers such as systolic and diastolic blood pressure and heart rate [22], we do not know if an interpersonal stressor would elicit the same response and it is unclear if these markers are raised by recalling a stressful event. The intensity of stress may be important for the subsequent portion creation response but is a difficult control. An added complication is that some people eat in excess in response to stress, some don't change their eating habits in response to stress, and some eat less [28]; this may explain why there were no observable differences in the means of the snack items between rest and stress (separate snack means and total means). However, these effects could be moderated by the intensity of the stress and by food choices available [28]. There may be other foods that would capture different responses from those presented in this report. Moreover, there is variation in how one's genome [36] and epi-genome [37] affect stress response and subsequent eating in response to that stress.

No virtual portions positively predicted mini golden Oreo intake and a limitation to the study is that there were no cookie or biscuit products included in the VPCTs. We might have found even stronger relationships between recalled and momentary portions with ad lib intake. Future studies should include cookies or biscuits in VPCTs to determine if the relationships observed in M&Ms and chocolate, and chips, is reproduced with mini golden Oreos and cookie/biscuit products.

Another limitation is that the VPCTs ask about snacks separately while in the actual ad lib snack consumption test, participants are presented with golden mini Oreos, M&Ms, and potato chips together and the amounts they consume of one snack likely effect the amount they will plan to consume of the other snacks. Future studies should include VPCTs that show multiple snacks at the same time. A possible approach would be to present one snack as the target portion that can be manipulated and the other two snacks as fixed portions. The fixed portions could be treated as preloads in a test meal situation and varied dependent on the eating context or research question being proposed. The idea would be to make the portion created closer to what would actually be happening in an actual eating situation with multiple snacks.

This study included women because they report eating greater amounts of food in response to stress than men [25] and while women have higher rates of obesity than men [38], studies of stress eating in men should still be conducted. Study participants were primarily White, non-Hispanic (86%), and because non-Whites report higher levels of stress [39], stress-eating studies with study populations of varying races and ethnicities are needed. Future studies should also include individual with obesity, of varying ages, with and without weight loss interventions, as obesity and prolonged life stress are comorbid [40] and interact to disturb the hypothalamic–pituitary–adrenal axis and metabolic feedback pathways that affect food consumption [41]. A study with individuals with obesity in particular would be useful to determine if the inverse relationship between portion creation of chips and consumption of mini golden Oreos is maintained, that is, to test if this observed trade off occurs in individuals of a normal BMI but perhaps not in those with obesity. This small study tested a simple causal pathway and should be reproduced with a larger n to increase power and test the same pathway as well as more complex, causal pathways including physiological stress markers like cortisol [28].

5. Conclusion

In conclusion, virtual portion tasks are useful tools in the study of eating behavior, whether it is predicting severity of an eating disorder, intake, or weight loss after bariatric surgery. The results presented from the current study further illustrate the research and clinical value of these tasks in that they predict intake under stress and sometimes rest conditions, and are relatively stable.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

This paper represents a response to the Society for Study of Ingestive Behavior, 2020, for a special issue in which senior and junior colleagues were invited to submit recent work from senior investigator’s laboratory, in place of reports usually presented at the annual meeting of the Society which did not occur in 2020, because of the COVID-19 pandemic. This report is also appropriate because it is the culmination of a collaboration among the investigators that was initiated at the SSIB meeting in Montreal, CA, in 2017. The data collection was carried out under the supervision of R. Klatzkin, at Rhodes College, and data analysis was conducted at Columbia University and the Icahn School of Medicine. The project was supported as part an investigation the used the same virtual portion size task in patients before after bariatric surgery (R01DK108643 Mechanisms Underlying Predictors of Success from Obesity Surgery, H.R. Kissileff, PI).

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ABBREVIATIONS

AN	anorexia nervosa
HC	healthy controls
HiED	high energy-dense
LoED	low energy-dense
VPCTs	virtual portion creation tasks
Ad lib	ad libitum
NA	negative affect
PLS	perceived life stress

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Highlights

- Portions, created virtually and in response to a recalled stress, predict intake
- Virtual portions created in response to an actual stress (momentary) predict intake
- Portions created in response to a recalled stress and an actual stress are similar
- This relationship is mediated by momentary portions because of learned coping
- Results are specific as pre-meal planning may be more important during coping for stress

Figure 1. Pictures of snacks

Pictures of the snacks shown in the virtual portion creation tasks and presented in the in-laboratory ad libitum snack buffet. Apples, olives, milk chocolate, caramel popcorn, pretzels were included in the virtual portion creation tasks. Golden Oreos and M&Ms were included in the in-laboratory ad libitum snack buffet. Potato chips was included in the virtual portion creation tasks and in-laboratory ad libitum snack buffet. Energy density (ED, kCal/g), and percent macronutrient composition of protein, carbohydrate, and fat are included below each item.

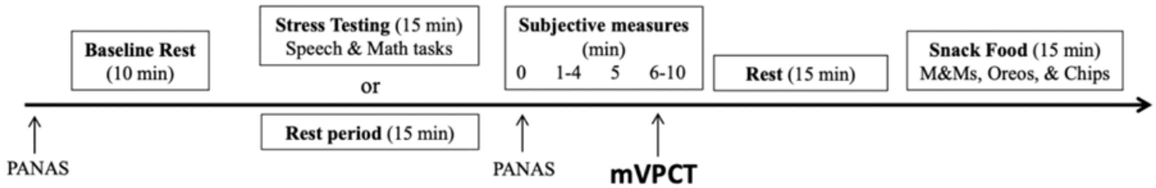

Figure 2. Laboratory protocol for stress or rest day

Study timeline of the laboratory protocol. PANAS, Positive and Negative Affect Schedule. mVPCT: momentary Virtual Portion Creation Task.

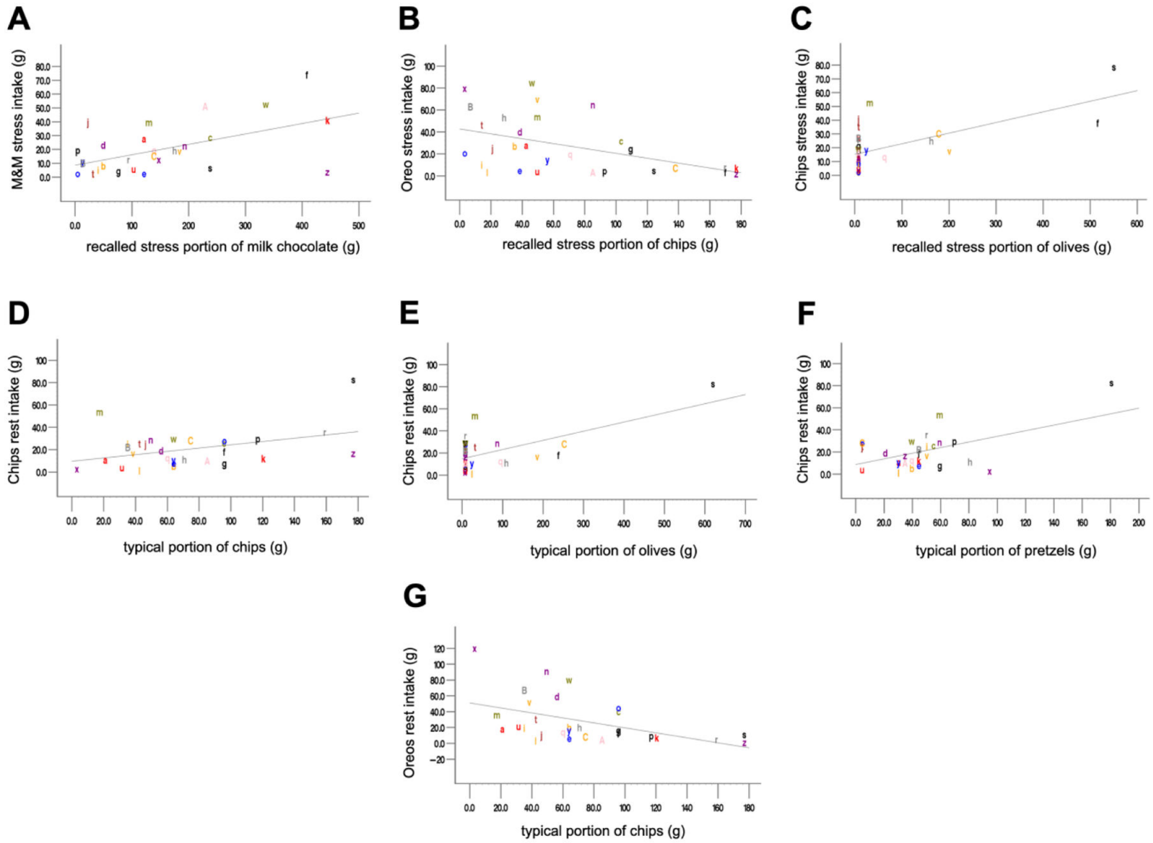

Figure 3. Regressions of intake from recalled portion size

Significant (before Bonferroni correction, $P < 0.05$) linear regressions of stress intake from recalled stress portions (A-C) and significant (before Bonferroni correction, $P < 0.05$) linear regressions of rest intake from typical portions (D-G) are shown for all participants ($N = 29$). *See* Table 3 for virtual portion and ad lib intake means and Table 5 regression statistics.

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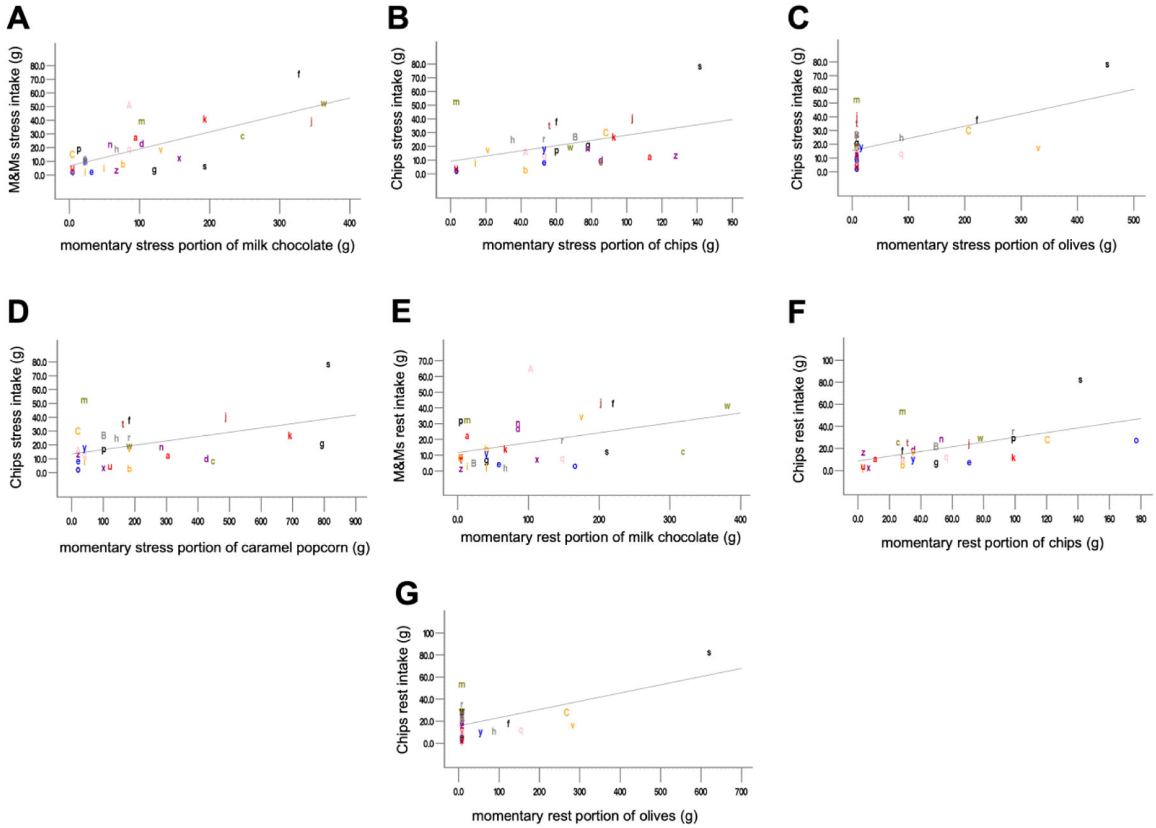

Figure 4. Regressions of intake from momentary portion size

Significant (before Bonferroni correction, $P < 0.05$) linear regressions of stress intake from momentary stress portions (A-D) and significant (before Bonferroni correction, $P < 0.05$) linear regressions of rest intake from momentary rest portions (E-G) are shown for all participants ($N = 29$). *See* Table 3 for virtual portion and ad lib intake means and Table 6 regression statistics.

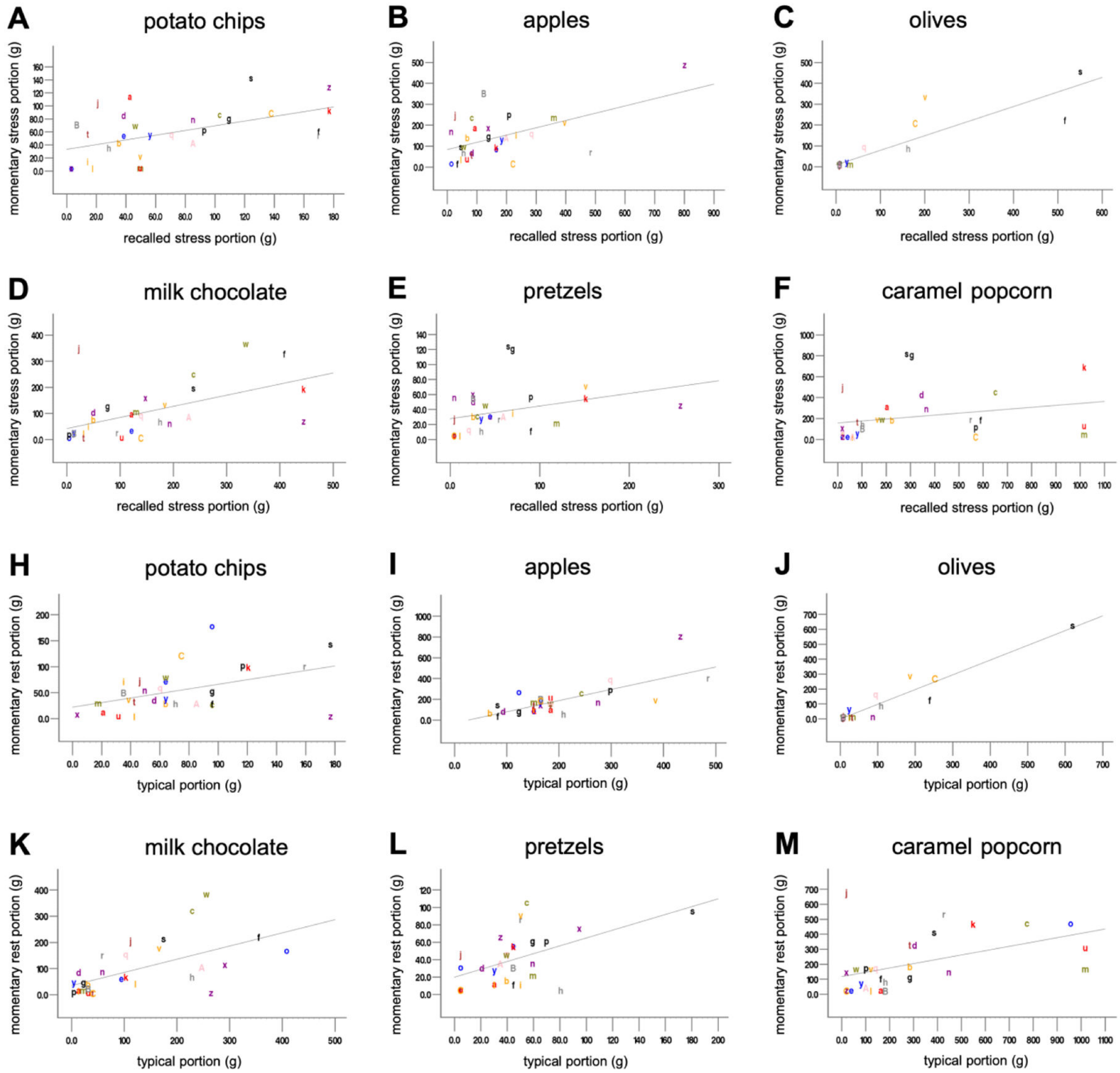

Figure 5. Regressions of momentary portion sizes from recalled portion sizes

Linear regressions of momentary stress portions from recalled stress portions of the same food (A-F) and linear regressions of momentary rest portions from recalled stress portions of the same food (H-M) are shown for all participants ($N = 29$). All regressions were significant ($P < 0.05$) except for momentary stress v. recalled stress regressions for pretzels (E) and caramel popcorn (F). *See* Table 3 for virtual portion means and Table 7 regression statistics.

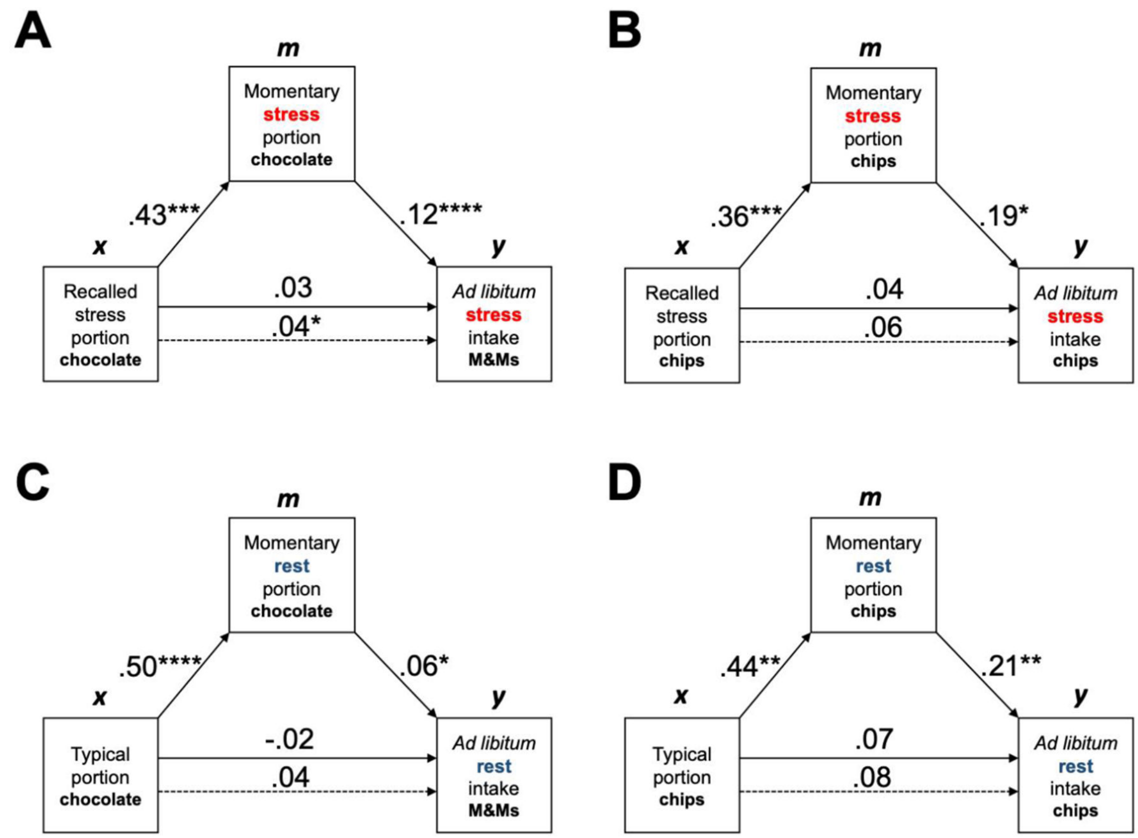

Figure 6. Mediation models

Four mediation analyses were conducted. ***x*** is an independent variable (recalled stress portion size in diagrams A & B, top row, and typical portion size in diagrams C & D, bottom row). ***y*** is a dependent variable (ad libitum stress intake in diagrams A & B and ad libitum rest intake in diagrams C & D). ***m*** is the proposed mediating variable (momentary stress portions in diagrams A & B and momentary rest portions in diagrams C & D). Diagrams A & C (left column) are mediation analyses done for milk chocolate (***x*** and ***m***) and M&Ms (**y**), while diagrams B & D (right column) are for potato chips (***x***, ***m***, and ***y***). In diagrams A-D, the coefficients on the solid arrows are unstandardized and the coefficients on dashed arrows are standardized (β). The solid arrow between ***x*** and ***y*** represents the direct effect of ***x*** on ***y***, while the dashed arrow represents the indirect effect of ***x*** on ***y as the path of x to y through m***. Both of these effects comprise the total effect of ***x*** on ***y***.

* $P \leq 0.05$

** $P \leq 0.01$

*** $P \leq 0.005$

**** $P \leq 0.001$

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Table 1

Predictions

H-i	The order in which participants undergo their stress or rest day will have no effect on their momentary portion size creation.
H-ii	The order in which participants undergo their stress or rest day will have no effect on intake
H-iii	Perceived life stress x negative affect interaction will positively predict ad lib intake for each snack, separately.
H-iv	Virtual expected liking, completed at screening, will positively correlate with liking after laboratory consumption of the same snack
H-v	Virtual expected liking will positively correlate with virtual portion creation, for all eating contexts, of the same snack displayed.
H-vi	Consumption frequency (times/day) will positively correlate with virtual portion creation, for all eating contexts, of the same snack displayed.
H-vii	Virtual expected liking and will positively predict ad lib stress and rest intake for snacks with similar taste and energy density
H-viii	Consumption frequency will positively predict ad lib stress and rest intake for snacks with similar taste and energy density
H1	Recalled stress portions will positively predict ad lib stress intake for snacks with similar taste and energy density
H2	Typical portions will positively predict ad lib rest intake for snacks with similar taste and energy density
H3	Momentary stress portions will positively predict ad lib stress intake for snacks with similar taste and energy density
H4	Momentary rest portions will positively predict ad lib rest intake for snacks with similar taste and energy density
H5	Recalled stress portions will not predict ad lib rest intake for any snack
H6	Typical portions will not predict ad lib stress intake for any snack
H7	Momentary stress portions will not predict ad lib rest intake for any snack
H8	Momentary rest portions will not predict ad lib stress intake for any snack
H9	As a negative energy control for energy density, virtual portions of low energy dense snacks will not predict ad lib snack intake of high energy dense snacks
H10	Typical-by-frequency interaction will be a stronger predictor (compared to the virtual portions alone) of ad lib rest intake for snacks with similar taste and energy density
H11	Momentary rest-by-frequency interaction will be a stronger predictor (compared to virtual portions alone) of ad lib rest intake for snacks with similar taste and energy density
H12	Recalled stress-by-frequency interaction will be a stronger predictor (compared to the virtual portions alone) of ad lib stress intake for snacks with similar taste and energy density
H13	Momentary stress-by-frequency interaction will be a stronger predictor (compared to virtual portions alone) of ad lib stress intake for snacks with similar taste and energy density
H14	Recalled stress portions will positively predict momentary stress portions of the same snack
H15	Typical portions will positively predict momentary rest portions of the same snack
H16	Recalled stress portions will positively predict ad lib stress snack intake, of the same or a similar snack, through complete mediation by momentary stress portion
H17	Typical portions will positively predict ad lib rest snack intake, of the same or a similar snack, through complete mediation by momentary rest portion

Table 2

Demographic data for study participants[1]

	Mean ± SEM
Age, y	19.23 ± 0.21
BMI, kg/m^2	22.28 ± 0.65
Perceived life stress score	17.90 ± 1.03
Rest day	
NA, pre-rest	15.21 ± 1.02
NA, post-rest	12.66 ± 0.70
NA difference	−2.55 ± 0.83[2]
Stress day	
NA, pre-stress	14.45 ± 0.67
NA, post-stress	18.62 ± 0.96
NA difference	4.17 ± 0.87[3]

[1] $N = 29$. Perceived life stress scores were collected at screening and range from zero to 40. Negative affect scores (NA), which range from 10 to 50, were collected prior to and after a stress or rest period. NA difference is the pre-test NA subtracted from the post-test NA.

[2] The decrease in NA on the rest day was significant ($t = 3.06$, $P = 0.005$).

[3] The increase in NA on the stress day was significant ($t = 4.82$, $P < 0.0001$).

Table 3 -

Means of virtual portions created and actual amounts consumed in laboratory[1]

	Virtual portions				Ad libitum intake	
	Recalled stress portion	**Typical portion**	**Momentary stress portion**	**Momentary rest portion**	**After stress**	**After rest**
Food	**Mean (g) ± SEM**	**Mean (g) ± SEM**	**Mean (g) ± SEM**	**Mean (g) ± SEM**	**Mean (g) ± SEM**	**Mean (g) ± SEM**
Caramel popcorn	292.3 ± 57.7	280.1 ± 54.8	207.5 ± 42.1	194.0 ± 33.5		
Hershey Kisses	141.0 ± 23.7	118.3 ± 21.2	100.9 ± 19.0	93.5 ± 17.9		
M&Ms					19.0 ± 3.3	21.5 ± 4.8
Mini Oreos					27.3 ± 4.6	27.9 ± 5.3
Potato chips	69.1 ± 10.0	71.5 ± 8.1	57.1 ± 7.0	53.6 ± 7.8	20.4 ± 3.0	20.2 ± 3.0
Pretzels	53.5 ± 10.2	44.8 ± 6.2	36.2 ± 5.5	39.8 ± 5.3		
Apples	164.4 ± 30.7	193.6 ± 18.4	138.8 ± 19.2	180.9 ± 26.5		
Olives	63.6 ± 25.3	62.0 ± 23.0	53.1 ± 19.7	59.4 ± 23.5		

[1]Values are mean portion sizes (in grams) ± SEM for all study participants ($N = 29$). Mean total amount eaten after stress is 22.3 ± 2.2g and mean total amount eaten after rest is 22.1 ± 2.4g.

Table 4 -

Statistics for regressions of ad libitum snack intakes from recalled portions[1]

			Ad lib stress intake v. Recalled stress					Ad lib rest intake v. Typical				
	Ad lib snack	**Virtual snack**	**Slope ± SE**	**Slope P**	**Intercept**	**Intercept P**	**R^2**	**Slope ± SE**	**Slope P**	**Intercept**	**Intercept P**	**R^2**
1	Potato chips	Potato chips	0.10 ± 0.05	0.09	13.43	0.01	0.10	0.15 ± 0.07	0.03*	9.62	0.10	0.16
2		Apple slices	0.00 ± 0.02	0.92	20.51	0.0001	0.0004	0.00 ± 0.03	0.99	20.31	0.01	0.000004
3		Olives	0.08 ± 0.02	**0.0002***	15.11	0.000005	0.42	0.08 ± 0.02	**0.0002***	14.95	0.000008	0.40
4		Milk chocolate	0.03 ± 0.02	0.26	16.11	0.002	0.05	0.00 ± 0.03	0.96	20.08	0.0002	0.0001
5		Pretzels	0.05 ± 0.06	0.43	17.73	0.0004	0.02	0.25 ± 0.08	0.003*	8.71	0.06	0.28
6		Caramel popcorn	0.01 ± 0.01	0.20	16.30	0.0007	0.06	0.02 ± 0.01	0.15	15.94	0.0007	0.08
7	M&Ms	Potato chips	0.10 ± 0.06	0.12	12.83	0.02	0.09	−0.02 ± 0.07	0.81	18.94	0.003	0.002
8		Apple slices	−0.02 ± 0.02	0.40	22.42	0.00008	0.03	0.00 ± 0.03	0.90	16.91	0.02	0.0006
9		Olives	0.04 ± 0.02	0.15	17.20	0.00007	0.07	0.00 ± 0.02	0.93	17.54	0.00002	0.0003
10		Milk chocolate	0.08 ± 0.02	0.003*	8.51	0.06	0.29	0.02 ± 0.03	0.47	15.31	0.002	0.02
11		Pretzels	0.04 ± 0.06	0.47	17.12	0.001	0.02	−0.03 ± 0.09	0.76	18.94	0.001	0.003
12		Caramel popcorn	0.02 ± 0.01	0.10	14.12	0.004	0.10	0.00 ± 0.01	0.67	18.96	0.0001	0.01
13	Oreos	Potato chips	−0.22 ± 0.08	0.01*	42.66	0.000002	0.23	0.01 ± 0.11	0.01*	50.96	0.00001	0.22
14		Apple slices	−0.03 ± 0.03	0.36	31.71	0.00008	0.03	0.70 ± 0.06	0.70	32.57	0.01	0.01
15		Olives	−0.03 ± 0.04	0.40	29.16	0.000009	0.03	0.51 ± 0.04	0.51	30.11	0.00005	0.02
16		Milk chocolate	−0.01 ± 0.04	0.87	28.17	0.0008	0.001	0.32 ± 0.05	0.32	22.18	0.01	0.04
17		Pretzels	−0.07 ± 0.09	0.41	31.09	0.00009	0.02	0.50 ± 0.16	0.50	23.19	0.02	0.02
18		Caramel popcorn	−0.01 ± 0.02	0.40	31.18	0.00008	0.03	0.69 ± 0.02	0.69	26.06	0.002	0.01

[1] *N* = 29. Linear regressions of ad libitum snack intake under stress condition from recalled stress portion, and ad libitum snack intake under rest condition from typical portion, were performed. P-values were held to Bonferroni correction (k = 36, $P \leq 0.001$) and significant values are **bolded**. Ad lib, ad libitum. SE, standard error of the slope.

* Uncorrected $P < 0.05$

Table 5 -

Statistics for regressions of ad libitum snack intakes from momentary portions[1]

	Condition		Ad lib stress intake v. Momentary stress					Ad lib rest intake v. Momentary rest				
	Ad lib snack	Virtual snack	Slope ± SE	Slope P	Intercept	Intercept P	R^2	Slope ± SE	Slope P	Intercept	Intercept P	R^2
1	Potato chip	Potato chips intake	0.19 ± 0.08	0.02 *	9.10	0.10	0.19	0.21 ± 0.06	0.002 *	8.74	0.05	0.31
2		Apple slices	0.00 ± 0.03	0.98	20.28	0.0008	0.00002	0.01 ± 0.02	0.63	18.28	0.001	0.01
3		Olives	0.09 ± 0.02	**0.0008** *	15.28	0.00001	0.35	0.07 ± 0.02	**0.0008** *	15.68	0.000007	0.35
4		Milk chocolate	0.05 ± 0.03	0.08	14.65	0.002	0.11	0.05 ± 0.03	0.14	15.68	0.001	0.08
5		Pretzels	0.18 ± 0.10	0.09	13.52	0.01	0.11	0.17 ± 0.10	0.12	13.59	0.01	0.09
6		Caramel popcorn	0.03 ± 0.01	0.02 *	13.48	0.002	0.19	0.03 ± 0.02	0.06	13.9	0.004	0.12
7	M&M intake	Potato chips	0.06 ± 0.09	0.48	15.74	0.02	0.02	−0.02 ± 0.07	0.76	18.88	0.0007	0.003
8		Apple slices	−0.01 ± 0.03	0.76	20.93	0.001	0.003	−0.02 ± 0.02	0.34	21.39	0.0002	0.03
9		Olives	0.01 ± 0.03	0.71	18.87	0.00004	0.01	0.00 ± 0.02	0.88	17.91	0.00001	0.001
10		Milk chocolate	0.12 ± 0.02	**0.00001** *	6.56	0.07	0.51	0.06 ± 0.03	0.04 *	11.61	0.01	0.15
11		Pretzels	−0.07 ± 0.11	0.54	22.17	0.0004	0.01	0.03 ± 0.10	0.77	16.47	0.004	0.003
12		Caramel popcorn	0.01 ± 0.01	0.57	17.69	0.0008	0.01	0.01 ± 0.02	0.55	15.65	0.002	0.01
13	Oreo intake	Potato chips	−0.13 ± 0.13	0.34	34.52	0.0006	0.03	−0.08 ± 0.13	0.53	32.67	0.001	0.01
14		Apple slices	0.04 ± 0.05	0.35	20.97	0.02	0.03	−0.03 ± 0.04	0.41	34.15	0.0007	0.03
15		Olives	−0.01 ± 0.05	0.75	27.99	0.00002	0.004	−0.03 ± 0.04	0.45	30.21	0.00004	0.02
16		Milk chocolate	0.06 ± 0.05	0.22	21.09	0.004	0.06	0.08 ± 0.06	0.15	20.28	0.01	0.07
17		Pretzels	0.14 ± 0.16	0.41	22.18	0.01	0.03	0.13 ± 0.19	0.50	22.99	0.02	0.02

Condition		Ad lib stress intake v. Momentary stress					Ad lib rest intake v. Momentary rest				
Ad lib snack	**Virtual snack**	**Slope ± SE**	**Slope P**	**Intercept**	**Intercept P**	**R^2**	**Slope ± SE**	**Slope P**	**Intercept**	**Intercept P**	**R^2**
18	Caramel popcorn	0.00 ± 0.02	0.92	27.66	0.0003	0.0004	0.00 ± 0.03	0.93	28.73	0.002	0.0003

[1] *N* = 29. Linear regressions of ad libitum snack intake under stress condition from momentary stress portion, and ad libitum snack intake under rest condition from momentary rest portion, were performed. P-values were held to Bonferroni correction (k = 36, $P \leq 0.001$) and significant values are **bolded**. Ad lib, ad libitum. SE, standard error of the slope.

[*] Uncorrected $P < 0.05$

Table 6 -

Statistics for regressions of momentary portions from recalled portions[1]

		Momentary stress v. Recalled stress					Momentary rest v. Typical				
	Snack	**Slope ± SE**	**Slope P**	**Intercept**	**Intercept P**	**R^2**	**Slope ± SE**	**Slope P**	**Intercept**	**Intercept P**	**R^2**
1	Potato chips	0.36 ± 0.11	**0.004** *	33.25	0.003	0.27	0.44 ± 0.17	0.01 *	22.23	0.13	0.21
2	Apple slices	0.35 ± 0.10	**0.002** *	83.11	0.002	0.31	1.08 ± 0.19	**0.000005** *	−28.66	0.50	0.55
3	Olives	0.70 ± 0.07	<**0.000005** *	8.77	0.40	0.80	0.99 ± 0.05	<**0.000005** *	−1.94	0.80	0.93
4	Milk chocolate	0.43 ± 0.13	**0.003** *	42.28	0.11	0.28	0.50 ± 0.13	**0.0007** *	34.93	0.12	0.35
5	Pretzels	0.17 ± 0.10	0.09	27.84	0.001	0.10	0.45 ± 0.14	**0.004** *	19.71	0.02	0.27
6	Caramel popcorn	0.19 ± 0.14	0.18	156.85	0.01	0.07	0.29 ± 0.10	0.01 *	116.42	0.01	0.23

[1] *N* = 29. Linear regressions of momentary portions made under stress from recalled stress, and momentary portions made under rest from typical portions, were performed. P-values were held to Bonferroni correction (k = 12, $P \leq 0.004$) and significant values are bolded. Ad lib, ad libitum. SE, standard error of the slope.

* Uncorrected $P < 0.05$

Table 7 -

Statistics from analyses of covariance[1]

	Condition	Food	R^2	Parameter	MS	Est ± SEM	t	p
1	Rest	Potato chips	0.04	Intercept	315.96	21.80 ± 3.40	6.41	<0.0001
2				Interaction	274.27	0.03 ± 0.03	1.07	0.29
3		M&Ms	0.03	Intercept	249.08	16.30 ± 3.32	4.90	<0.0001
4				Interaction	261.89	−0.03 ± 0.03	−0.98	0.34
5		Oreos	0.01	Intercept	198.05	29.44 ± 6.17	4.77	<0.0001
6				Interaction	900.84	0.03 ± 0.06	0.47	0.64
7	Stress	Potato chips	0.01	Intercept	98.86	21.74 ± 4.12	5.27	<0.0001
8				Interaction	286.34	−0.02 ± 0.03	−0.59	0.56
9		M&Ms	0.06	Intercept	586.27	15.70 ± 4.36	3.60	0.001
10				Interaction	319.52	0.05 ± 0.04	1.35	0.19
11		Oreos	0.01	Intercept	16.36	27.85 ± 6.42	4.34	0.0002
12				Interaction	693.20	−0.01 ± 0.05	−0.15	0.88

[1]Analyses of covariance performed for all snack foods separately. Dependent variable was intake and independent variable was the interaction between negative affect and perceived life stress score (see Table 1 for descriptive stats for negative affect and perceived life stress score). P-values for slopes were held to Bonferroni correction ($k = 6$, $P \leq 0.008$). $N = 29$. MS, mean square. Est, estimate (for intercept or slope of negative affect x perceived life stress interaction). SEM, standard error of the estimate.