# Breadth of Substance Use is Associated with the Selection of a Larger Food Portion Size via Elevated Impulsivity

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**Abstract**

Substance use is associated with altered or elevated food consumption and disordered eating. In the present study we examined whether breadth (variety) of drug use was associated with elevated portion size in a general population sample as it was in persons in recovery from substance use disorder. Furthermore, measures of emotional eating, impulsivity, food misuse, food craving were taken as possible mediators and reward responsiveness was examined as a potential moderator of this association. 444 adults (48.6% women, mean age of 47.8 years) completed an online study in which they were asked to make judgements of ideal portion size for 6 different foods using a validated online tool that allowed participants to adjust the portion size of images of foods. Ideal portion size has been identified as a strong predictor of actual consumption. Participants were also asked to report the number of substances used in the past and provide anthropometric information. The results confirmed that breadth of drug use was associated with selection of higher portion size. Reward responsiveness was not a moderator of this relationship. Of the tested mediators, only impulsivity mediated the association between breadth of drug use and portion size. The results show that impulsivity may underlie the association between eating and substance use.

Keywords: portion size, food intake, substance use, impulsiveness

## 1.0 Introduction

Substance use is associated with distinctive patterns of food preference and consumption. According to self-report, interviews, and diet record studies, people who use substances or have (or are in recovery from) substance use disorder (SUD) often experience higher food craving, elevated food consumption, nutrition disturbances, and, when in recovery, a significant increase in body weight [1], [2]. Most research in this area has focused on persons in recovery from SUD but there is evidence that these patterns are not limited to this population. Those who use substances at levels that do not meet the criteria for SUD often have functional impairment similar to those who do meet the criteria [3]. The present study examined the association between substance use and food portion size selection and the potential mediators of that relationship in a sample of the US general adult population.

While less research has examined eating behavior and nutrition in relation to casual or recreational drug use than in people in recovery from SUD, there is some evidence from interviews and diet records of an association. Cannabis, and nicotine use were associated with elevated fatty food consumption in adolescents [4], as was alcohol use [4]–[7]. Furthermore, eating disturbances may be more prevalent in those who engage in polysubstance use, defined as using more than one drug during a period of time, and the breadth (variety) of drug use across a time span of substance use [8]. Recreational polysubstance use is associated with poor nutritional choices [9] and greater high-fat food consumption than adolescent single-substance users or nonusers [4]. In an examination of the role of drug use in food consumption in a behavioral eating task in students without a SUD diagnosis, breadth of drug use, and not frequency of drug use, predicted higher energy consumption from a number of foods served in an afternoon snack taste test [10]. This increase in consumption was both directly associated with substance use and associated via elevated desire to eat the food, but not via increased pleasantness of the food, suggesting that breadth of drug use predicted consumption via wanting and not liking of food [10]. Breadth of drug use, more than the amount of substances used, has also been linked to eating behavior due to poor executive function. Low executive function is associated with general impulsive risk-taking and externalizing behavior, which is also associated with substance use (see [11]).

The work in this area is based, in part, on the results from studies of nutrition and body weight in those recovering from SUD and it appears that changes in eating are associated with a variety of drugs across classes. Elevated sweet food consumption or preferences for sweets has been reported in patients treated for opioid dependence [12], [13], alcohol dependence [14], [15], and cocaine dependence [16]. Changes in food selection and/or preference during recovery from SUD have also been reported for savory foods [17], [18]. Cocaine-dependent men [19] and adults in nicotine withdrawal [20] report elevated consumption of high-fat foods and carbohydrates.

As it was in students without SUD with real food consumption, breadth of drug use has been linked to food selection in online virtual meal scenarios in studies of persons in recovery from SUD. Higher food selection in those in SUD recovery was reported in two studies [21], [22]. In one, this relationship was mediated by breadth of drug use [22]. Furthermore, impulsivity mediated the relationship between breadth of drug use and food selection [22]. The results suggested that breadth of drug use may be more relevant than SUD diagnosis in the examination of how substance use may affect food choice and consumption [22]. The present study, thus, was designed to examine this mediation in a general population sample using an online tool that allowed participants to select the ideal portion of each food they would consume.

The connections between drug use and eating reported in the studies above may be due to shared neural mechanisms. There is a common central pathway for the liking and wanting of foods and drugs [23]–[25] and it is possible that unavailability of a substance or attempts to suppress craving for or consumption of one substance (in this case, drugs) can be expressed in misuse of another substance (i.e., food; see [1], [26], [27]. Emotion may be a mechanism. Stress, negative affect and emotional dysregulation are associated with substance use [28]–[30] and it is possible that eating may occur in this context. Emotional dysregulation is a link between emotional eating and substance use [31]–[34].

Impulsivity is also a potential mechanism for the relationship between substance use and food selection. Substance use, which is itself predicted by impulsivity, may increase impulsivity [35], [36]. Impulsivity, as measured by questionnaires, is a trait and traits are often perceived as being immutable. However, traits are not static across the lifespan; experiences can deepen the personality tendencies that lead people to engage in those actions [37] and traits such as impulsivity are themselves altered by lapses in impulse control [38]. Impulsivity is associated with breadth of drug use [39] and polysubstance use [40], [41]. Substance misuse is associated with food misuse ("food addiction"; FA) in many studies [42], [43], perhaps via substance replacement [44] or other mechanism.

The present study was designed, in part, to examine the association between breadth of drug use and food selection in a general population sample. In addition, the use of a validated measure of food portion size allowed for an examination of the relationship between substance use and the ideal food portion size of different foods for participants [45]. The virtual buffet used in the studies above [21], [22] allowed selection of presented fixed portions of food but did not allow participants to indicate their desired portion size. The present study tested several hypotheses (registered https://osf.io/mr37z). We predicted that higher breadth of drug use would be associated with selection of larger portion size for both sweet and savory foods. Furthermore, potential mediators of the association between breadth of drug use and portion size were examined, namely food cravings, impulsivity, FA, and eating styles.

Finally, we tested the hypothesis that the relationship between breadth of drug use and portion size would be moderated by reward responsiveness. Disturbances in reward responsiveness have been implicated in both substance [46] [47] and FA [48]. In a study of people in SUD recovery and controls, reward responsiveness moderated the relationship between SUD recovery status and food image selection in a virtual buffet meal [21]. However, this finding was not replicated in a similar study [22].

## 2.0 Method

### 2.1 Participants

Complete questionnaires were provided by 216 women and 228 men (N = 444). Their mean age was 47.78 years (SEM = 0.82) with a mean BMI of 28.16 kg/m$^2$ (SEM = 0.40). The participants were grouped by BMI using the WHO criteria; 4.1% were classified as underweight (BMI < 18.5), 36.7% were recommended weight (BMI 18.5 to 24.9), 28.9% were classified as “overweight” (BMI 25.0 to 29.9) and 27.3% had a BMI greater than or equal to 30 kg/m$^2$. 4.3% (n=19) of the participants did not supply information to allow a BMI calculation. 12.6% of the participants reported that they had been diagnosed with SUD.

A sample creation service (Qualtrics, Provo, UT) was utilized to recruit participants who were paid a nominal amount to complete the study. Response quotas were used to create a sample that was representative of the U.S. adult population (target gender 50/50% and age ranges: 18-34 years, 30%; 35-54 years, 32%; and 55+ years, 38%). 219 people began but did not complete the survey. Persons who reported having a eating disorder diagnosis or a vegetarian or vegan diet were excluded. Due to the 50/50 quota for women and men, anyone who identified as non-binary was not included. Because of the nature of the food portion task, participants were informed that only a computer could be used to access the study (other devices were detected and prevented from access). Qualtrics employs several quality control procedures to ensure that the participants were actual people and responses with unusually short durations were assessed for exclusion. Participants in Qualtrics panels agree in advance to be contacted for research purposes.

### 2.2. Measures

#### 2.2.1 Breadth of Drug Use

Breadth of lifetime experience with different drugs was measured using a question from The Alcohol, Smoking and Substance Involvement Screening Test (ASSIST; World Health Organization). The question asks “In your life, which of the following substances have you ever used (non-medical use only)?” The drugs list contains 10 substances including (as worded on the questionnaire): tobacco products, alcohol, cannabis, cocaine, amphetamine-type stimulants, sedatives and sleeping pills (benzodiazepines), hallucinogens, inhalants, opioids, and “other” drugs. Participants are asked to respond either “yes” or “no” for each item which allowed for the computation of the total number of drugs ever previously used. Participants who responded “no” to all listed substances were scored “0”.

### 2.2.2. Food Ideal Portion Size

An online portion size task was utilized to measure ideal portion size; computerized ideal portion size tasks are validated estimates of food selection [49]. Details regarding the current online portion size task can be found in Embling et al. [45]. The foods were selected from a depository of food portion size photographs of U.K. foods [45] that would be recognizable to those in the U.S. An effort was made to represent a selection of foods (e.g., sweet and savory, high and low energy density). Six snack foods were presented: grapes (loose, green and red), veggie chips (assorted savory crunchy vegetable snacks), party mix (assorted savory crunchy grain-based snacks), sponge cake (described to participants as pound cake), chocolate brownie pieces (brownie bits), and colorful candies (Skittles).

For each food, participants were asked to interact with a slider bar that moves through a series of images such that it appears that the portion increases (movement to right) or decreases (movement to left) in an animated fashion. Participants were instructed to select their ideal portion size of each food independently of the other and not as part of a single eating episode (i.e., meal). Once the participant decided on their ideal portion size, they moved on to the next item in the survey. Ideal portion size was defined as the mean energy content (kcal) of the selected food portions [45] and was the dependent variable in regression analyses.

### 2.2.3. Reward Responsiveness

Sensitivity to reward was measured using the Reward Responsiveness Scale (RRS) [50]. The RRS contains 8 items which are scored on a 5-point Likert-type scale; the score is obtained by totaling the responses. Cronbach's alpha for this sample was .82.

### 2.2.4 Appetite

Participants were asked to use 100-point visual analog scales (VAS) to respond to the questions “How hungry do you feel right now?” and “How full do you feel right now?”.

### 2.2.5 Mediators

#### 2.2.5.1 Impulsivity

Impulsivity was measured by administration of the short UPPS-P Impulsive Behavior Scale (SUPPS-P) [51]. The UPPS-P measures 5 facets of impulsivity which are somewhat discrete psychological processes that lead to impulsive behaviors [52]. The score for the scale and for each subscale (facet) is obtained by summing responses. The 20-item short form assesses negative urgency, lack of premeditation, lack of perseverance, sensation seeking, and positive urgency. Reliability for the scale in this sample was .84.

#### 2.2.5.2 Eating Styles

Emotional eating, cognitive restraint of eating, and external eating (eating in the presence of external cues) were measured by the Dutch Eating Behavior Questionnaire (DEBQ) [53]. Reliability (Cronbach's alpha) was .93, .96, and .89 for restraint, emotional eating, and external eating respectively.

2.2.5.3 Food Craving

Food craving was assessed using the short form of the Food Craving Questionnaire-Trait-reduced (FCQT-r) [54]. Each of the 15 statements is rated on a 6-point Likert-type scale which is summed to produce a total score. For this sample, Cronbach's alpha was .96. A trait measure was used because transient changes in food craving were not of interest.

2.2.5.4 Food Misuse ("food addiction")

FA was measured by the Modified Yale Food Addiction Scale 2.0 (mYFAS2) which evaluates indications of "addiction" toward foods according to the DSM-5 criteria for substance use disorder [55]. The mYFAS2 has 13 dichotomous items (11 for FA symptoms and 2 for feelings of distress) and is scored by counting the number of diagnostic criteria that are met. In the present sample, reliability was good; Kuder–Richardson's alpha was 0.88. In regression analyses below, the mYFAS2 was entered as a continuous variable (i.e., number of symptoms).

2.3. Procedure

All procedures were approved by the Wagner College Psychology Department Human Experimentation Review Board (application SU22-4). Responses were obtained from adults who participated using the Qualtrics online survey tool. The sample size was determined so that we would be able to detect relatively small effect sizes with a power of .80 [56].

After providing consent, participants were screened for eating disorders and a vegan/vegetarian diet. They were then asked their gender identity and whether they were diagnosed with and, if yes, had been treated for a SUD. Participants were then asked to complete the ASSIST and VAS to assess hunger and fullness. The next phase of the survey involved test food images (foods were presented in random order in each task). Participants were first asked to rate their liking of, desire to eat, and familiarity with each food that would appear in the portion size task to allow removal of disliked or unfamiliar foods (none was removed). The second task asked them to identify the ideal portion size for each food after completing a practice task. When the food tasks were completed, the mediator and moderator questionnaires were presented in random order. Finally, participants were asked to provide their age and height and weight (for calculation of BMI). Participants were then debriefed as to the purpose of the study.

2.4 Data Analyses

All analyses were performed using IBM SPSS Statistics for Windows (Version 28.0. Armonk, New York). Correlations (2-tailed) among the psychological measures and with portion size and breadth of drug use were performed as well. Those mediators with statistically significant correlations with portion size were selected for the multiple regression analyses to determine which variables were unique predictors of portion size and standardized coefficients (ß) were reported. VIF was used to assess multicollinearity and residuals were checked for stochasticity in the regression analysis.

Conditional process analysis (moderated mediation analysis) was conducted using the PROCESS plug-in for SPSS (Model 4; release 4.2) [57] using 5000 percentile bootstrap confidence intervals to identify mediators. Model 15 was used in order to examine direct and indirect (via mediators) effects and interaction (with reward responsiveness) effects on portion size. Outcome-defining continuous variables were mean-centered. For all mediation analyses, hunger and fullness ratings were entered as covariates [45]. The unstandardized coefficients (b), confidence intervals (CI) and adjusted $R^2$ are reported. In these analyses, these coefficients describe how much mean portion size changes in kcal for each unit of change in the predictor. 95% confidence intervals are reported; an interval that does not include zero indicates a significant effect. Mediation analysis is inherently causal in its specification of a direction of association, but it is simply a way to describe and test possible causal relationships [58]. Because the design used in the present study is atemporal [59] and does not involve an experimental manipulation, causality cannot be determined even when the statistical method uses terminology suggesting causality [57].

## 3.0 Results

### 3.1 Descriptive Statistics

The energy (kcal) in the portion sizes selected were averaged to compute the mean ideal portion size [45]. Mean scores for the questionnaires and the mean portion sizes are reported in Table 1. Two participants did not indicate their ideal portion size for brownies; the missing values were replaced using the mean replacement method. The percentage of participants who reported having used each drug on the ASSIST is presented in Table 2. 17.3% of participants indicated that they had not used any of the drugs listed.

### 3.2 Regression Analysis

There were statistically significant positive correlations between breadth of drug use and FA, food craving, external eating and impulsivity. The energy from the mean ideal portion was positively correlated with breadth of drug use, FA, food craving, emotional eating, dietary restraint, external eating, and reward responsiveness (see Table 3a). Mean portion size was also positively correlated with the positive urgency, negative urgency, and sensation seeking facets of impulsivity (see Table 3b). The correlation between breadth of drug use and mean ideal portion size was small but positive and statistically significant, $r(442) = .11$, $p = .019$. Mean ideal portion size was not correlated with BMI, r(423) = -.001, p = .977, and was significantly negatively correlated with age, r(442) = -.269, p = .001. The mean portion size was correlated with hunger, r(442) = .335, p = .000, but not with fullness, r(442) = -.030, p = .522.

Linear regression analysis was performed to identify which potential mediators make unique contributions to the energy from food portions. The analysis revealed a significant model, $R^2 = .21$; F(11, 432) = 11.86, p = .000, where all coefficients were positive but only impulsivity was a unique contributor, ß = .23; t = 4.21, p = .000. The standardized residuals scatterplot and the residual Q-Q plots indicated a normal distribution confirming that the regression was appropriate. Multicollinearity was low (all VIF < 3.0).

### 3.3 Conditional Process Analysis

Based on the results of the correlation analyses (and a multiple regression analysis confirming acceptably low multicollinearity), a moderated mediation model was tested in order to examine whether reward responsiveness moderated the mediation of the relationship between breadth of drug use and portion size by impulsivity. Hunger, fullness and age were entered as covariates. The model was statistically significant, F(8, 435) = 15.53, p = .000; $R^2 = 0.22$. Results indicated that impulsivity fully mediated the association between breadth of drug use and portion size at all values of reward responsiveness (see Figure 1). Hunger, fullness and age were significant covariates and the interactions of breadth of drug use and impulsivity were not significant (see Table 4a). The results indicate that, on average, each additional drug used is associated with selecting approximately 3.5 kcal more via elevated impulsivity across at the 16th, 50th, and 84th percentiles of reward responsiveness. The index of moderated mediation was not significant, coefficient = 0.007 (95% CI: -0.294 to 0.306).

#### 3.3.1 Reverse Mediation

While mediation analysis on its own cannot determine causality, the model tested is based on hypothetical direction of cause. An examination of “reverse causality” can be performed by reversing the predictor and mediation variables and the results can improve understanding of the relationships among the variables[60]. This analysis was performed here because it is possible that impulsivity could lead to higher breadth of drug use. The model for predicting portion size from impulsivity with breadth of drug use as a mediator was statistically significant but breadth of drug use did not mediate the relationship between impulsivity and portion size (see Table 4b for coefficients).

#### 3.3.2 Exploratory Examination of the Role of Gender

Independent groups t-tests (degrees of freedom adjusted for violation of variance equality assumption) showed that men (M = 409.17 kcal, SEM = 14.54) selected larger portion sizes than did women (M = 298.21 kcal, SEM = 13.30), t(440.32) = 5.63, p = .000. Men (M = 2.68, SEM = .15) reported a higher breadth of drug use than did women (M = 2.17, SEM = .14), t(438.81) =

2.53, p = .006. As would be expected, women had higher scores on emotional eating and dietary restraint and reported higher food craving. On the measures of impulsivity, men reported higher scores on positive urgency and sensation seeking. There was no statistically significant difference in BMI (see supplemental material).

In order to examine whether gender moderated the mediation by impulsivity of the association between breadth of drug use and average portion size, a conditional process analysis was conducted. The results indicated that gender did not moderate the mediation. Impulsivity fully mediated the relationship between breadth of drug use and portion size for both women and men (see supplemental material).

### 3.4 Exploration of Facets of Impulsivity

Conditional process analysis was conducted to determine which facet(s) of impulsivity explain the mediation of the link between breadth of drug use and portion size by impulsivity. The facets of UPPS-P which were significantly correlated with portion size were negative urgency, positive urgency, and sensation seeking (see Table 5). In a linear regression, positive urgency (ß = .26; t = 3.72, p = .000) and sensation seeking (ß = .19; t = 3.73, p=.000) were unique predictors of portion size, F(13,430) = 12.67; $R^2$ = .26.

The conditional process analysis revealed a significant model, F(10,433) = 16.26, p = .000; $R^2$ = .27. Only sensation seeking mediated the relationship between breadth of drug use and portion size. Furthermore, mediation occurred only at moderate ($50^{th}$ percentile) to high levels ($84^{th}$ percentile) of reward responsiveness. However, the index of moderated mediation included zero, coefficient = .183, 95%CI: -0.033 to 0.536 (see Table 6 for cofficients).

### 3.5 Examination of Individual Foods

Because some of the research examining the link between substance use and food selection suggests that drug use may be associated with elevated consumption of selective foods (e.g., sweet versus non-sweet), the association of drug use with each food was examined. All food portion sizes were positively correlated with FA, food craving, urgency and sensation seeking. All portions except grapes were positively correlated with external eating.

Conditional process analysis revealed that sensation seeking fully mediated the association between breadth of drug use and larger portions of brownies, cake, party mix, and veggie chips. Negative urgency fully mediated the association between breadth of drug use and smaller portion of grapes. There was a positive direct association between the selected portion size of Skittles and breadth of drug use but no significant mediation. Reward responsiveness was not a significant moderator in the mediation for any food (see supplemental material).

### 3.6 Exploratory Analysis removing Participants who reported SUD Diagnosis

In order to examine whether the association between breadth of drug use and portion size was driven only by the presence of persons who reported a SUD diagnosis, a number of additional analyses were conducted. Independent groups t-tests (degrees of freedom corrected for violaton of equal variance assumption) showed that persons who reported a SUD diagnosis ($n = 56$) reported a significantly higher mean number of drugs used ($M = 4.27$, $SEM = 0.41$) than did those who responded that they did not ($n = 388$; $M = 2.16$, $SEM = 2.16$), $t(61.07) = 5.05$, $p = .000$. Those reporting SUD selected larger portion size ($M = 466.18$ kcal, $SEM = 34.48$) than did those who did not ($M = 339.17$ kcal, $SEM = 10.34$), $t(65.27) = 3.53$, $p = .000$. Furthermore, they had significantly higher scores on emotional and external eating, negative and positive urgency, sensation seeking, food craving, and FA but no difference in BMI. The range of drugs selected from the list for both groups was the same (0 to 10). A zero for someone who reported SUD would not be expected but it is possible that they did not identify with any of the substances on the list provided or that they reported SUD in error. The correlation between breadth of drug use and mean ideal portion size was positive and nonsignificant for both those who reported having a SUD diagnosis, $r(54) = .04$, $p = .760$, and those who did not, $r(386) = .05$, $p = .289$.

In order to examine the role that SUD diagnosis might play in the results reported above (section 3.3), a conditional process analysis was conducted for only those participants who reported no SUD. The results indicated that the positive direct and indirect associations between breadth of drug use and mean portion size were not significant (see supplemental). However, the examination of individual foods revealed that there are significant associations between breadth of drug use and the portion sizes selected by the individuals who reported no SUD diagnosis. All food portion sizes were positively correlated with urgency and sensation seeking. All portions except grapes and veggie chips were positively correlated with external eating. FA and food craving were each positively correlated with portion size of brownies, Skittles and veggie chips (party mix was correlated only with food craving). Conditional process analysis showed that external eating fully mediated the association between breadth of drug use and larger portions of brownies and cake. Negative urgency fully mediated the link between breadth of drug use and smaller portions of grapes. There was no relationship between breadth of drug use and the portion sizes of the other foods (see supplemental material).

## 4.0 Discussion

The results of the present study show that, as expected, higher breadth of drug use was associated with the selection of a larger ideal food portion size. Furthermore, the results indicate that this association is mediated by impulsivity in the form of sensation seeking. The analysis of individual foods showed that mediation by impulsivity of the association between breadth of drug use and portion size occurred for both sweet and savory foods of varying energy density. Portion size was positively correlated with all mediators and, while breadth of drug use was associated with higher food craving, FA, and external eating scores, none of these were significant mediators of portion size. The results support the findings that breadth of drug use is associated with elevated food consumption [10] and selection of foods in a buffet scenario [22].

They are also consistent with the finding that impulsivity mediated the association between SUD recovery status and food selection [22]. However, reward responsiveness was not a moderator which is consistent with one study that showed that it did not moderate the association between SUD recovery status and food selection [22] but not with one that showed that it did [21].

In this study, the connection between the mean ideal potion size and breadth of drug use depends upon the presence of those particiants who reported having a SUD diagnosis. However, in those who do not report a SUD diagnosis, breadth of drug was associated with elevated portion size for cake and brownie bites, the two sweet energy dense food items, and smaller grape portion. Interestingly, for these participants, the association with larger portion was mediated by external eating and not sensation seeking. Those with substance use levels below the threshold for an SUD diagnosis should not be perceived as being free of substance-related problems. It has been suggested that substance use should be thought of in dimensional and not categorical terms [3], [61]. The degree of functional impairment from subthreshold disorder is almost equal to that of those who meet the full diagnosis [3]. In the present study, SUD status was gathered for descriptive purposes and is only known through self-report unlike in previous studies [21], [22]. It is possible that some participants were unaware that they meet SUD criteria or decided not to report it. The range of breadth of drug use was similar for both those who did and did not report SUD and was similar to breadth of substance use reported in other samples [21], [22]. Thus, the presence of persons reporting SUD may have increased the number of persons with high breadth of drug use without increasing the range of values.

This is the first study that we are aware of that examined ideal portion size in relation to substance use. The total amount of food (kcal) selected is similar to that in studies that did not allow participants to adjust portion size [21], [22]. Furthermore, it was impulsivity and not food craving, emotional eating, or FA that was the sole mediator of the relationship. In a prior study comparing those in SUD recovery and controls, it was the impulsivity facet lack of premeditation that mediated the association between SUD recovery status and food selection [22] and here, in a general population sample selecting portion size, the facet of impulsivity that mediated the relationship between breadth of drug use and portion size was sensation seeking. This difference in mediators may be due to differences in the populations that were sampled and the food task used.

Sensation seeking has been associated with non-clinical substance use [62]. While not typically described as an emotion-related facet of impulsivity, it has been linked to emotional arousal and an inability to regulate emotional arousal [63]. Sensation seeking appears driven largely by reinforcement; it correlates with increased frequency of substance use [64] and, therefore, may represent a general reliance on habits, an impaired balance between conditioned responses, and goal-directed aspects of behavior control [65]. Thus, the mediation here by this facet of impulsivity may be due to the much lower presence of people reporting SUD than in a previous study.

The relationship between sensation seeking and eating behavior is less clear. Sensation seeking has been reported either as unrelated to or as negatively associated with FA [66]–[68] and there are mixed patterns in association with eating disorders [69]. Few studies examine impulsivity in relation to casual substance use and non-clinical eating patterns. Furthermore, less is known about substance use beyond adolescence and early adulthood [70] and the present sample includes a substantial number of persons in middle age and later. The impulsive risk-taking and externalizing behavior characteristic of sensation seeking is associated with higher breadth of drug use via poor executive function [11]. Executive function is associated with self-regulation of eating behavior [71]. Sensation seeking may be uniquely associated with food selection in the context of substance use but we are unable to determine that here. Sensation seeking is associated with larger portion sizes in those who do not report a SUD diagnosis. However, in that case mediation occurs via external eating suggesting a different mechanism. The present study was not designed to examine these differences and the number of persons reporting SUD is small (and unconfirmed) compared to a national rate of 17.3% [72] but this finding warrants further investigation.

The link between substance use and eating may be explained by numerous factors. There is a substantial (if not complete) overlap in the neural networks associated with food and drug craving [25]. Furthermore, the connections between eating and drug use appear to be the result of complex interactions between genetics, childhood familial environment, and behavior. Links between the genetics of food preference and SUD risk have been reported in both humans and animal models [73]. For example, rodents bred to select for sweet taste preference ingest more of a number of habit-forming drugs and those bred selectively for alcohol consumption ingest more of sweet solutions [73]. Furthermore, impulsivity is linked to sweet taste-liking [74] and has additive effects with sweet preference on drug and food addiction [73]. In women (but not men), sweet taste is associated with stronger euphoric effects of amphetamine [75] and there is a link between familial history of alcohol use and heightened sweet taste-liking [76], [77].

In the present study, physiological mechanisms are not directly examined. However, a review of the literature suggests several possible explanations for the results reported here. Other studies report evidence of reciprocal interactions between genetics and past experience of trauma and neglect with (and among) neural reward circuitry, impulsivity, emotional regulation, substance use [78]. Elevated reward sensitivity and poor inhibitory control are associated, although whether and how they are causally linked is unclear [79]. Hyperactive neural responses in reward-related circuitry and blunting of response inhibition circuity are a risk for substance use [80], [81] and disordered eating [78]. Sensation seeking is associated with a heightened inclination to exhibit approach responses towards intense and novel stimuli [82]. Neurally, dopamine dysfunction such as highly reactive midbrain dopamine responses to reward-associated stimuli and elevated dopamine tone and low striatal D2 receptor density may be important contributors to higher sensation seeking [82] and impulsivity [83], [84]. Neural links between eating and drug use extend beyond dopamine. For example, orexin, a hypothalamic peptide transmitter linked to appetite, also underlies novelty-seeking and drug consumption in animals [85]. The results of the present study are consistent with the idea that breadth of drug use may be a contributor to and a result of impulsivity, emotional dysregulation, and dopamine dysfunction (reward sensitivity and poor inhibitory control) [78].

This study has several limitations. The cross sectional correlational nature of the study does not allow cause of portion size to be determined. While the total amount of energy in the selected foods is high, it is comparable to what is selected in studies of menus and restaurant choices (for discussion, see Nolan [21]). The amount of food selected for each food was selected without reference to the amount of other foods selected. The test foods presented to participants differed on a number of different attributes including energy density and likely perceived volume. A future study might consider systematically varying food attributes and examining the relationship between breadth of drug use and ideal portion size to understand generalisability of this effect. The participants were asked about lifetime use; the frequency of substance use and primary substances used may be important variables in the link between substance use and eating but neither was recorded in the present study. In the one previous study that examined it, breadth of drug use was but frequency of drug use was not associated with the amount of food consumed [10]. Finally, it is unclear whether the loss of the overall significant relationship between breadth of drug use and ideal portion size when those reporting a SUD diagnosis were removed from the analyses is due to loss of power associated with the removal of 12.6% of the sample or a specific contribution of this sub-sample to the relationship. A future study should consider exploring the relationship between breadth of drug use and ideal portion size in both communities with samples that deliver an appropriately powered mediation analysis.

Future studies on this topic should consider the role of which substances are used and in what combinations (see [86]). However, lifetime use of multiple substances may be more important in relationship to psychopathology than which drugs are used [87]. In the present study, there is likely substantial heterogeneity in substances used and in patterns of use. Studies of drug use frequently screen out polysubstance users but polysubstance use is common and screening it out may not produce generalizable results [88], [89]. It may be useful to track a group of participants as they enter recovery and progress over time as was done by Kolarzyk et al. [12].

The results of the present study suggest that higher breadth of drug use is associated with larger ideal food portion size. This result in a sample representing the general population is consistent with previous findings that suggest that substance use may impact eating regardless of SUD status. The results also suggest that substance use be considered in attempts to understand the link between addictive behaviors and food consumption and body weight.

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Figure 1

Moderated mediation model showing the mediation of the association between breadth of drug use and mean portion size by impulsivity. The coefficients are unstandardized betas (with p value).

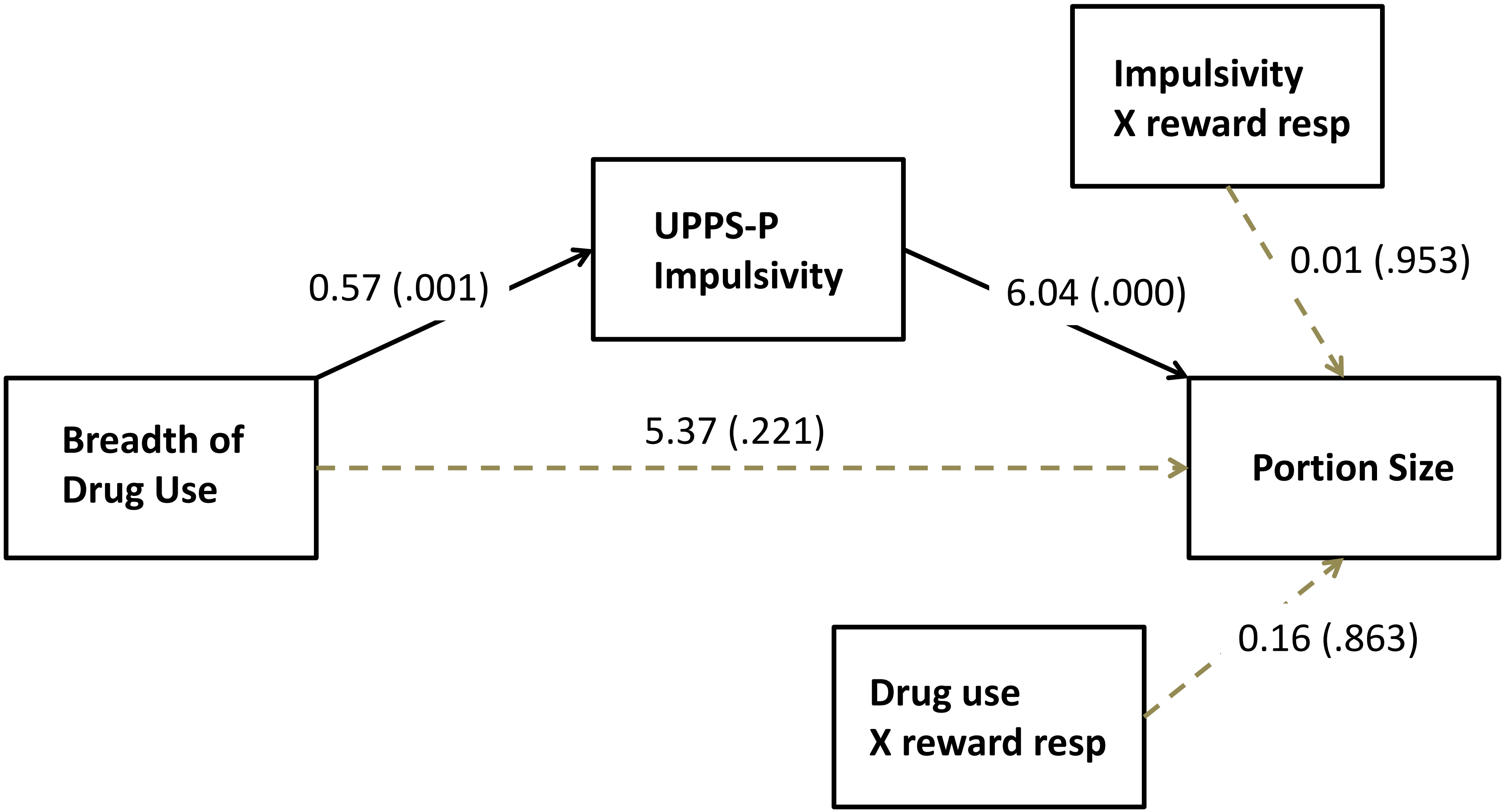
Impulsivity
X reward resp
UPPS-P
Impulsivity
0.57 (.001)
6.04 (.000)
0.01 (.953)
Breadth of
Drug Use
5.37 (.221)
Portion Size
0.16 (.863)
Drug use
X reward resp

Table 1: Mean scores on predictor, criterion, moderator and mediator variables.

| Measure | Mean | SEM |
|---|---|---|
| UPPS-P | | |
| Lack of Perseverance | 6.92 | 0.09 |
| Lack of Premeditation | 6.59 | 0.09 |
| Sensation seeking | 9.16 | 0.15 |
| Negative Urgency | 9.17 | 0.15 |
| Positive Urgency | 8.12 | 0.15 |
| UPPS-P Total | 39.96 | 0.42 |
| FCQ-Tr | 37.39 | 0.79 |
| DEBQ | | |
| Emotional Eating | 2.28 | 0.05 |
| Dietary Restraint | 2.64 | 0.04 |
| External Eating | 3.19 | 0.03 |
| mYFAS2 | 1.61 | 0.12 |
| RRS | 25.60 | 0.22 |
| Drugs Used | 2.43 | 0.10 |
| Portions (kcal) | | |
| Brownie bites | 400.00 | 15.60 |
| Grapes | 326.54 | 11.53 |
| Party mix | 303.79 | 13.00 |
| Pound cake | 538.04 | 14.46 |
| Skittles | 298.86 | 14.47 |
| Veggie chips | 263.90 | 13.28 |
| Total | 2129.32 | 61.28 |

Abbreviations: FCQ-Tr, Food Craving Questionnaire; DEBQ, Dutch Eating Behavior Questionnaire; RRS, Reward Responsiveness Scale; mYFAS2, modified Yale Food Addiction Scale 2

Table 2. Percentage of participants who indicated they had used each drug during their lifetime.

| Drug | % |
|---|---|
| Alcohol | 76.7 |
| Tobacco | 49.3 |
| Cannabis | 40.0 |
| Amphetamine | 14.0 |
| Sedatives | 14.9 |
| Hallucinogens | 12.7 |
| Cocaine | 12.2 |
| Opiates | 12.2 |
| Inhalants | 5.8 |
| Other | 31.3 |

Table 3: Pearson correlations among measures and mean ideal portion size (MP) and breadth of drug use (BoDU). Significant coefficients are in bold (N = 444).

| | | BoDU | mYFAS2 | FCQ-Tr | DEBQ-E | DEBQ-R | DEBQ-X | RRS | UPPS |
|---|---|---|---|---|---|---|---|---|---|
| MP (kcal) | *r* | **0.110** | **0.297** | **0.279** | **0.219** | **0.096** | **0.239** | **0.102** | **0.386** |
| | *p* | **0.020** | **0.000** | **0.000** | **0.000** | **0.043** | **0.000** | **0.032** | **0.000** |
| BoDU | *r* | | **0.123** | **0.115** | 0.062 | -0.001 | **0.228** | -0.027 | **0.157** |
| | *p* | | **0.010** | **0.015** | 0.191 | 0.985 | **0.000** | 0.573 | **0.000** |

Abbreviations: mYFAS2, modified Yale Food Addiction Scale 2; FCQ-Tr, Food Craving Questionnaire; DEBQ-E, emotional eating; DEBQ-R, dietary restraint; DEBQ-X, external eating; RRS, Reward Responsiveness Scale

Table 4a. Conditional process analysis (moderated-mediation) model for the relationship between breadth of drug use and portion size. Coefficients are unstandardized betas indicating change in kcal.

| Direct Effect | | | |
|---|---|---|---|
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 4.64 | -6.25 | 15.53 |
| 50 | 5.43 | -3.33 | 14.19 |
| 84 | 6.07 | -6.61 | 18.75 |
| Indirect Effect via impulsivity | | | |
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 3.43 | 0.88 | 6.62 |
| 50 | 3.47 | 1.16 | 6.20 |
| 84 | 3.49 | 1.04 | 6.64 |
| Covariates | | | |
| Hunger | 1.94 | 1.21 | 2.64 |
| Fullness | 0.94 | 0.20 | 1.68 |

Table 4b. Conditional process analysis (reversed moderated-mediation) model for the relationship between impulsivity and portion size. Coefficients are unstandardized betas indicating change in kcal.

| Direct Effect | | | |
|---|---|---|---|
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 5.98 | 2.97 | 8.99 |
| 50 | 6.04 | 3.66 | 8.42 |
| 84 | 6.09 | 3.00 | 9.19 |
| Indirect Effect via BoDU | | | |
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 0.21 | -0.32 | 0.75 |
| 50 | 0.24 | -0.19 | 0.73 |
| 84 | 0.27 | -0.37 | 0.98 |

Abbreviations: RRS, Reward Responsiveness Scale; BoDU, breadth of drug use; LLCI, lower limit of confidence interval; ULCI, upper limit of confidence interval.

Table 5: Pearson correlations among UPPS-P facets of impulsivity, mean portion size (MP) and breadth of drug use (BoDU). Significant coefficients are in bold.

| | | UPPS | | | | |
|---|---|---|---|---|---|---|
| | | NU | Pers | Prem | SS | PU |
| MP (kcal) | *r* | **0.298** | -0.056 | -0.007 | **0.394** | **0.420** |
| | *p* | **0.000** | 0.241 | 0.879 | **0.000** | **0.000** |
| BoDU | *r* | **0.165** | 0.017 | 0.081 | **0.108** | **0.102** |
| | *p* | **0.000** | 0.729 | 0.088 | **0.023** | **0.031** |

Abbreviations: NU, negative urgency; Pers, lack of perseverance; Prem, lack of premeditation; SS, senstation seeking; PU, positive urgency

Table 6: Conditional process analysis for the mediation of breadth of drug use and total portion size by composite positive urgency and sensation seeking score (moderated by reward responsiveness). Coefficients are unstandardized betas indicating change in kcal.

| Direct Effect | | | |
|---|---|---|---|
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 5.25 | -5.41 | 15.91 |
| 50 | 5.26 | -3.16 | 13.68 |
| 84 | 5.27 | -6.96 | 17.49 |
| **Indirect Effect via PU** | | | |
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 1.99 | -0.03 | 4.95 |
| 50 | 1.80 | -0.27 | 4.12 |
| 84 | 1.64 | -0.05 | 4.18 |
| **Indirect Effect via SS** | | | |
| RRS Percentile | Coefficient | LLCI | ULCI |
| 15 | 0.84 | -0.77 | 2.91 |
| 50 | 1.76 | 0.20 | 3.86 |
| 84 | 2.49 | 0.28 | 5.45 |
| **Covariates** | | | |
| Hunger | 1.53 | 0.82 | 2.23 |
| Fullness | 0.67 | -0.06 | 1.40 |

Abbreviations: RRS, Reward Responsiveness Scale; BoDU, breadth of drug use; SS, sensation seeking; PU, positive urgency; LLCI, lower limit of confidence interval; ULCI, upper limit of confidence interval.