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Individual differences in impulsivity and their relationship to a Western-style diet

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Abstract

In two studies we tested for a relationship between consumption of a Western-style diet, characterised by high intakes of saturated fat and added sugar, and individual differences in impulsivity. In Study 1, participants completed both a food frequency measure to assess diet and a measure of trait impulsivity. Greater trait impulsivity was associated with consumption of a Western-style diet in both men and women, independent of body mass index (BMI). Greater intake of sugar-sweetened beverages and take-away food were specifically linked to greater trait impulsivity. In Study 2 lean participants completed a laboratory-based impulsivity battery. Habitually consuming a Western-style diet was associated with greater trait self-report urgency and with more impulsive behaviour on a food delayed discounting task (DDT). Dietary relationships with trait sensation seeking, and performance on the Matching Familiar Figures Test, were moderated by gender. Dietary restraint, disinhibition, and hunger scores from the Three Factor Eating Questionnaire had only a small impact upon the relationship between a Western-style diet and impulsivity. These findings suggest that greater impulsivity is associated with consuming a Western-style diet, with possibly bidirectional causation.

Key words: Impulsivity; Western-style diet; Gender; Diet quality

1.0 Introduction

There are at least three reasons to suspect that a Western style diet - one rich in saturated fat and added sugar - may be associated with greater impulsivity and its converse, poorer self-control. The first is that pre-existing traits that dispose a person to choose immediate over delayed rewards could lead people to select easily available highly palatable foods over more healthful alternatives (Daniel, Stanton & Epstein, 2013; Keller & Siegrist, 2014; Houben, 2011). More healthful alternatives are likely to be harder to obtain, involve more preparation and provide less sensory pleasure. One line of research on self-control and diet, which is consistent with this view, has focussed on the probable long-term consequence of consuming palatable energy dense foods, namely elevated BMI (Schag et al., 2013). Consistent with expectations, studies in children, adolescents and adults have found that poorer self-control is indeed associated with greater BMI (e.g., Davis et al., 2010; Duckworth, Tsukayama & Geier, 2010; Francis & Susman, 2009; Houben, 2011; Murphy, Stojek & Mackillop, 2014; Nederkoorn et al., 2006).

A second line of research has started to explore more directly the relationship between diet and self-control in both obese and normal weight participants. Sproesser et al., (2011), had a sample of female adults (BMI range from 17 to 47) complete a general self-report measure of self-control as well as a food frequency questionnaire, the latter being used to create an index of diet quality. They found that poorer diet quality was associated with poorer self-control, but it is not clear whether this effect was mediated by BMI. Appelhans et al., (2012) had female overweight and obese adults complete a food diary and a delayed discounting task. Steeper discounting of delayed rewards was associated with greater reported energy intake from take-away and ready to eat meals. Scholten et al., (2014) studied obese and normal weight children and found a relationship between snack food consumption and self-reported disinhibition, however these effects were small, and were not evident in normal weight children when controlling for age, gender, ethnicity and socioeconomic status. As the Scholten et al., (2014) study suggests, diet quality-impulsivity relationships *may* reflect BMI-impulsivity relationships especially as poorer quality diets are likely to co-occur with greater BMI.

There is a third and quite different reason to suspect that a Western-style diet may be associated with poorer self-control. Animal studies have shown that consumption of diets rich in added sugar and/or saturated fat, result in adverse changes to the brain (e.g., Kanoski & Davidson, 2011). The most well documented effects concern the hippocampus, but a number of studies now suggest that impairments may also extend into prefrontal regions (e.g., Kanoski & Davidson, 2010; Kanoski et al., 2007). In humans, analogous brain regions support decision-making and the voluntary inhibition of behavior - self-control (e.g., Knoch & Fehr, 2007). Two human studies have now shown relationships between neuropsychological measures sensitive to hippocampal function and consumption of a Western-style diet, as measured by a food frequency questionnaire designed to assess variability in intake of saturated fat and added sugar (Francis & Stevenson, 2011; Brannigan, Stevenson & Francis, 2015). On this basis it seems plausible that as in animals, the human brain may also be adversely affected by consuming a diet rich in saturated fat and added sugar, and that this might include frontal regions involved in mediating self-control.

The basic question we address in this manuscript is whether there is an association between consumption of a Western-style diet and greater impulsivity (and poorer self-control. To address this we report two studies. In Study 1 we examined diet-impulsivity relationships in a large student cohort. In Study 2 we conducted laboratory-based tests of impulsivity (and self-control) using lean participants recruited from Study 1. Four factors were considered to be important in determining diet-impulsivity relationships. The first concerned gender. Males and females were included in both studies because they differ on some but not all impulsivity tasks, with meta-analysis suggesting particularly large differences relating to risk taking (sensation seeking) and punishment sensitivity, and smaller differences on tasks related to effortful control (Cross, Copping and Campbell, 2011). In addition, men and women might also be expected to differ in their interest in healthy eating, their preoccupation with diet, and their body image, which might make self-control as it relates to food a far more pertinent issue for women than for men. For these reasons, we examined diet-impulsivity relationships for moderation by gender.

A second consideration concerned participant BMI, and whether this might drive diet-impulsivity relationships. In Study 1, we controlled for BMI in our analysis so as to determine if any diet-impulsivity relationship was sharing variance with a BMI-impulsivity relationship. In Study 2, all of our impulsivity tests were run on lean participants, allowing us to determine whether diet-impulsivity relationships could occur within such a group. If diet-impulsivity relationships emerge irrespective of BMI in Study 1, and in a lean group of participants in Study 2, this would suggest that diet-impulsivity relationships could occur independent of weight status.

A third consideration arose from previous studies of diet-behaviour relationships. In these studies the Restraint and Hunger dimensions of the Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985) were associated with consumption of a Western-style diet (Francis & Stevenson, 2011; Brannigan, Stevenson & Francis, 2015). A number of studies have found associations between measures of dietary restraint and impulsivity (Nederkoorn, Van Eijs & Jansen, 2004; Jansen et al., 2009), making this a potentially important variable to consider when concluding that diet may be related to impulsivity. Similarly, higher trait Hunger may predispose participants to engage in opportunistic eating, should food be available, making this component of the TFEQ also important to consider in the context of impulsive eating. Finally, other studies have suggested that disinhibition - also measured by the TFEQ - is also associated with impulsive behaviour (e.g., Leitch, Morgan & Yeomans, 2013). For these reasons, the impact of these three TFEQ scores on diet-impulsivity relationships was examined in Study 2.

A fourth consideration was the multifaceted nature of impulsivity (e.g., Duckworth & Kern, 2011) and the disagreement in the literature regarding its underlying dimensionality (e.g., Berg et al., 2015). This then requires some explanation of the tasks chosen in any study of this construct. One important distinction is between state and trait impulsivity, with most interest focussing on trait measures believed to reflect enduring individual differences. Two trait measures are particularly important in the literature and so both were included here. The first is the Barratt Impulsiveness Scale (BIS; Patton, Stanford & Barratt, 1995), which has been very widely used and has a factor structure that reflects a theoretically derived three-domain view of impulsivity (Motor, Inattention, Non-planning). A short-form of the BIS (Spinella, 2007) was employed in Study 1. The second trait measure is the Urgency, Premeditation, Perseverance and Sensation seeking (UPPS) scale (Whiteside & Lynam, 2001), which is empirically derived and has now become the predominant choice to assess trait impulsivity (e.g., Berg et al., 2015). This measure was used in Study 2.

A further important distinction is between self-report and behavioral measures of impulsivity, which are often only weakly correlated with each other and also have differing factor structures (e.g., Cyders & Coskunpinar, 2011). The behavioral measures, which were only used in Study 2, were all selected to represent tasks sensitive to reflection impulsivity (Kagan, 1966) - essentially acting without thinking. This included delayed discounting tasks, for both money and food, and a speed/accuracy task. This class of task was selected for two reasons. First, both the speed/accuracy task (Matching Familiar Figures Task; MFFT; Kagan, Lapidus & Moore, 1978) and the monetary Delayed Discounting Task (money DDT; Kirby & Marakovic, 1996) have previously been associated with pathological eating behavior (e.g., Braet et al., 2007; Davis et al., 2010; Epstein et al., 2014; Francis & Susman, 2009). Second, it seemed likely that this type of impulsivity would be linked to poor diet, such as for example, in choosing immediately available highly palatable foods without reflecting on their costs.

As we wanted to maximise the likelihood of detecting relationships between diet and impulsivity, we needed to identify participants who regularly or rarely consumed a Western-style diet. Consequently, in Study 1, we surveyed a student cohort using a brief, reliable and validated food frequency measure that focuses on foods high in saturated fat and added sugar (Francis & Stevenson, 2013). This cohort also completed the BIS, allowing us to assess relationships between diet quality and trait impulsivity, moderation by gender, and the impact of BMI. In addition, we also examined relationships between individual food and drink items on the food frequency measure and trait impulsivity. Data from studies in adolescents suggests that sugar sweetened beverage consumption may be one food specific associate (Solnick & Hemenway, 2012), while consumption of convenience and take-away food – perhaps reflecting poor meal planning – may be another. In Study 2, we recruited a lean subset of participants from Study 1, to undertake in-depth impulsivity testing, examining moderation by gender and the impact of the TFEQ scales.

To summarise, we hypothesised that: (1) greater consumption of a Western-style diet would be associated with greater impulsivity across both trait and behavioral measures; (2) that hypothesis (1) would hold true irrespective of BMI; (3) that hypothesis (1) would be moderated by gender, with possibly stronger relationships evident in women and differences to men emerging on measures of risk taking; (4) that hypothesis (1) would hold true irrespective of differences in eating behaviour on the TFEQ; and (5) that easily available palatable foods (sugary drinks and fast food) would be the most likely to be associated with trait impulsivity.

2.0 Study 1

2.1 Method

2.1.1 Participants

Five hundred and seventy one participants completed a brief food frequency questionnaire, and the short form BIS, as well as demographic measures (country of birth, age, gender, height and weight). These 571 participants were composed of 190 males and 381 females, with a mean age of 19.8 years (SD = 4.6) and with a mean BMI of 22.2 (SD = 3.4). Eighty one percent of the sample was born in Australia, and there were no differences in the relationships between test variables when only Australian born participants were examined.

2.1.2 Procedure

Following approval from the Macquarie University Human Research Ethics Committee, all first year psychology students completed several questionnaire measures in class, presented in randomised order, which included the short form BIS, the food frequency measure and demographic measures. Each participant consented (or not) to make their data available to the researchers, and only data from consenting participants is reported. No incentives for completion of these questionnaires or for making available their data were provided.

The short form BIS has 15 items, each answered on a four-point category scale reflecting the frequency with which each behavior applies to the respondent. As well as a total score, facet scores reflecting Motor impulsivity (e.g., 'I act on impulse'), Inattention (e.g., 'I concentrate easily') and Non-planning (e.g., 'I plan tasks carefully') are calculated. The measure has good reliability and validity (Spinella, 2007).

Participants completed the 26-item dietary fat and sugar scale (DFS) to assess intake of foods rich in saturated fat and added sugar. DFS scores can range between 26 and 130, with higher scores indicating more frequent consumption of foods rich in saturated fat and added sugar. The DFS has established test-retest reliability and validity (see Francis & Stevenson, 2013), the latter indicated by significant positive correlations for saturated fat and added sugar intake, with nutrient data obtained from a 4-day diet diary and a validated Australian food frequency questionnaire. As in previous studies of student populations, we found substantial variability in consumption of a Western-style diet on this measure (see Figure 1).

2.1.3 Analysis

The main form of analysis was hierarchical linear regression, with the BIS and its facet scores serving as the DVs. In these regression models DFS (diet) score was entered first, followed by the centred interaction of DFS (diet) score and gender to determine if the diet-impulsivity relationship was moderated by gender (please note that it is only the interaction effect which is of interest here, and not the separate and *independent* main effect of gender – as with Study 2 – hence only the interaction effect is used in the model). In the third step, BMI was added to the model. For each regression step incremental F (F_{inc}) was calculated to test whether each model improved upon the preceding one. The final reported model in the text is the simplest significant step that excludes variables that do not explain any additional variance. Zero order and semi-partial correlations for each variable are reported in its accompanying table.

As this study was highly powered, we also computed zero order correlations between each short-form BIS total and facet score, and individual food items on the DFS to determine whether reported frequency of consumption of particular types of food or beverage were associated with trait impulsivity. On these tests, alpha was set at 0.002 for each impulsivity facet score, using a Bonferroni correction for multiple comparisons (i.e., 0.05/26).

2.2 Results and Discussion

Table 1 presents the outcome of the hierarchical regression analyses. DFS (diet) score was significantly associated with total BIS score, and with the Motor and Inattention facet scores, but not with the Non-planning facet. These relationships were not moderated by gender. The addition of BMI to the model improved fit for total BIS score (final model, $F(3,567) = 5.90$, $p < .001$, adjusted $R^2 = .03$) and for the Motor facet (final model, $F(3,567) = 10.04$, $p < .001$, adjusted $R^2 = .05$), but not for the Inattention facet (see Table 1 for the final model). The inclusion of BMI did not affect the magnitude of the various DFS (diet) score impulsivity relationships, indicating that a Western-style diet is associated with greater impulsivity irrespective of this variable. That BMI too was associated with greater impulsivity confirms previous reports of this type of association (e.g., Davis et al., 2010; Duckworth, Tsukayama & Geier, 2010; Francis & Susman, 2009; Houben, 2011; Murphy, Stojek & Mackillop, 2014; Nederkoorn et al., 2006).

Table 2 presents correlations between each individual food or drink item on the DFS and the BIS total and facet scores. Three general observations can be made about these results. First, higher frequency of use of take-away/fast-food tends to be correlated with greater impulsivity. Second, sugar sweetened beverage use is also associated with greater impulsivity, with the exception of milk-based products. Third, the Non-planning facet was not associated with more frequent consumption of any food or beverage item.

3.0 Study 2

3.1 Method

3.1.1 Participants

Participants from Study 1 (i.e., from the undergraduate psychology participant pool) whose scores fell below the lower (52) quartile and above the upper (71) quartile of the DFS were approached by telephone (only if they had consented to do so) and asked if they would like to participate in Study 2. The idea here was to maximise the spread of DFS scores, to ensure an adequate range for correlation.

Each prospective participant was then screened to confirm normal BMI, and to establish no current medical conditions that might interfere with diet and eating (e.g., eating related disorders, diabetes, chronic medical/psychiatric conditions). Using this approach, 56 participants were recruited and tested. In addition, a further two participants were obtained from advertisements placed around campus, followed by telephone administration of a subset of DFS items and the BMI/medical screening. From the total of 58 participants who completed testing, we excluded the data of two participants. One, on actual measurement of weight and height at the end of the study had a BMI below 17, and the other reported being currently medicated for Attention Deficit Hyperactivity Disorder. While the inclusion of these two participants does not alter the pattern or significance of the results, neither would have been recruited if this information had been known during screening. Participants either completed this study for course credit or for those recruited from advertisements received a small cash payment.

3.1.2 Materials

For the demographic questionnaire, participants recorded their age, gender, current medical conditions, prescription drugs, physical activity levels, and when they last ate and drank.

For the Dietary Fat and Sugar scale (DFS), see Study 1 for details.

The Three-Factor Eating questionnaire (TFEQ) is a 51-item instrument with good reliability and validity (Stunkard & Messick, 1985) and measures three dimensions of human eating behaviour: Restraint, Disinhibition and Hunger.

The Urgency, Premeditation, Perseverance and Sensation Seeking questionnaire (UPPS has established reliability and validity, and is a 45-item scale designed to assess four facets of impulsivity (Whiteside & Lynam, 2001; Whiteside et al., 2005): (1) Urgency, with lower scores indicating greater urgency to act; (2) Premeditation, with higher scores indicating little premeditation; (3) Perseverance, with higher scores indicating lack of perseverance; and (4) Sensation seeking, with lower scores indicating greater sensation seeking.

The 21 trial monetary Delayed Discounting Task (DDT; Kirby & Marakovic, 1996) was used to calculate the number of immediate rewards selected and the parabolic discounting function. Each trial consisted of one smaller, immediate reward and one larger, delayed reward. Participants were asked to approach each trial as though it was the only choice they faced and then indicate which alternative they would prefer. The 21 trials were presented in the same fixed random order for each participant. Performance on this task is associated with self-reported impulsiveness (Kirby & Finch, 2010).

The version of Matching Familiar Figures Task (MFFT) used in this study was composed of 20 trials (Salkind & Nelson, 1980). On each trial, participants view six similar images and were asked to search through each one and choose as accurately as possible the one that matched the criterion image presented at the top of the computer screen. Participants were reminded there was no time limit, nor limit to the number of errors that could be made. The task assessed both the speed and accuracy of participant responses generating an error score and a response time score. These were then used to calculate an overall performance score - the 'iScore' (standard score of MFFT errors minus the standard score of MFFT time taken; Salkind & Wright, 1977). The MFFT has established validity and has been used before in exploring food-related impulsivity (e.g., Leitch, Morgan & Yeomans, 2013).

The 36 trial food Delayed Discounting Task (DDT) was developed for this study. Participants were instructed to make a series of hypothetical choices between a small portion of a less preferred food *now* versus a small portion of more preferred food following some delay (see Table 3). Less, moderately and highly preferred foods were used so that there was always a difference in preference between the immediate and delayed food. As individual preferences differ these were established prior to the food DDT using the Preference Task. On the Preference Task participants were asked to select their 10 most preferred and 10 least preferred foods from a list of 34 palatable sweet and savory snack items (see Table 4). Two less (selected at random from the bottom 10 foods), two moderately (selected at random from the middle 10 foods) and two highly (selected at random from the top 10 foods) preferred foods were then chosen to seed each participant's set of choices on the food DDT. This ensured that each administration of the food DDT used items customised to the participant's preferences. Each pairwise food choice was presented at six different time delays – 0, 1, 10, 30, 60 and 120 minutes. Trial order was fixed random, with instructions to treat each trial as a discrete choice.

3.1.3 Procedure

Twenty-four hours prior to the study participants received a text message reminding them to refrain from eating or drinking in the two hours preceding their test session. All participants reported complying with this instruction. On arrival participants were asked for their written consent, but with only a generic description of the aim - as approved by the Macquarie University Human Research Ethics Committee. Participants then completed the demographic questionnaire, the TFEQ, the UPPS, the monetary DDT, and the MFFT in that order. This was followed by the Food Preference test. Participants then filled in the DFS for a second time (the first time being when they completed the DFS for Study 1) and while they were doing so, the experimenter selected the foods to use in the Food DDT, which was completed next. Participant's height and weight was then measured. Finally, a debriefing interview was conducted to explain in more detail the purpose of the research.

3.1.4 Analysis

The main form of analysis was hierarchical linear regression, with each measures of impulsivity serving in turn as the DV (i.e., the four scales of the UPPS; the MFFT iScore; monetary DDT; food DDT). In these regression models DFS (diet) score was entered first, followed by the centred interaction of DFS (diet) score and gender, to determine if any diet-impulsivity relationships were moderated by gender. Finally, in the third step, the three TFEQ scores (restraint, disinhibition and hunger) were added to the model. For each step in the regression, incremental F was calculated to determine if the model was significantly improved by the addition of the new variable(s). The final reported model in the text is again the simplest significant model (i.e., the one that excludes variables that do not explain any additional variance). Zero order and semi-partial correlations for each variable are reported in the accompanying tables for each step in the regression.

3.2 Results

3.2.1 Dietary and demographic data

The distribution of participants' DFS diet scores completed on the day of testing are illustrated in Figure 2. The DFS has a theoretical range from 26 to 130 with participants here scoring between 33 and 94, with a mean of 59.8 (SD = 16.5). As most participants (54/56) were identified for recruitment based upon an earlier completion of the DFS (between 1-3 months prior to test), we were able to calculate reliability. While the zero order Pearson correlation was .91, indicating substantial similarity in the ordering of participant DFS scores across time, it is evident in Figure 2 (DFS score on the day of testing) that there was some regression to the mean (recall that participants were initially selected for this study based upon lower and upper quartile cut-offs).

Participants had a mean age of 19.5 (SD = 2.3; range 18-28), a mean BMI of 21.5 (SD = 1.6; range 19-25) and exercised for a mean of 3.9 hours per week (SD = 3.0; range 0-14). DFS score was not significantly associated with age, BMI or weekly amount of exercise. Of the 56 participants, 23 were male, and the mean dietary fat and sugar score obtained from the DFS was not significantly different between men (M = 63.9, SD = 14.9) and women (M = 57.2, SD = 17.3). Participants' age, BMI and weekly amount of exercise did not differ by gender, although there was a trend for men to have larger BMI's than women ($t = 1.90$).

3.2.2 UPPS impulsivity questionnaire

Hierarchical regression analyses for the UPPS scales are presented in Table 5.

For the Premeditation facet (M = 22.0, SD = 5.1, range 11-33; e.g., 'My thinking is usually careful and purposeful') there was no significant model.

For the Urgency facet (M = 30.1, SD = 6.8, range = 12-44; e.g., 'I have trouble controlling my impulses'), there was a significant negative association with DFS (diet) score, which was not moderated by gender. The addition of the three TFEQ scale scores further improved the model, although no specific TFEQ scale was independently predictive (final model,

$F(5,50) = 4.26$, $p < .005$, adjusted $R^2 = .23$). Participants who reported being more impulsive (low scores) reported diets higher in saturated fat and added sugar.

While there was no overall association between the Sensation seeking facet (M = 23.9, SD = 6.9, range = 12-38; e.g., 'I'll try anything once') and DFS (diet) score, this relationship was moderated by gender (final model, $F(2,53) = 5.83$, $p < .005$, adjusted $R^2 = .13$). In men, sensation seekers (low scores) were significantly more likely to report diets rich in saturated fat and added sugar ($r(23) = -.48$). In contrast, female sensation seekers (low scores) were significantly more likely to report diets lower in saturated fat and added sugar ($r(33) = .39$).

Finally, for the Perseverance facet (M = 20.3, SD = 4.6, range = 12-32; e.g., 'I'll finish what I start'), there was no significant model.

3.2.3 MFFT

The outcome of the hierarchical regression for the MFFT iScores is presented in Table 6. The relationship with DFS (diet) score was significantly moderated by gender (final model, $F(2,53) = 4.58$, $p < .02$, adjusted $R^2 = .12$). For women, poorer speed/accuracy trade-off was significantly associated with diets richer in saturated fat and added sugar ($r(33) = -.40$). In men, there was no significant relationship.

3.2.4 Monetary DDT

As the derived parabolic discounting function and the number of immediate choices was highly correlated ($r(56) = 0.90$, $p < 0.001$), we chose to report just the latter variable as it is more readily interpretable (i.e., higher values indicate more immediate choices). Participants made a mean of 10.6/21 (SD = 5.1) immediate choices. Hierarchical regression (see Table 6) revealed no relationship with DFS (diet) score and no moderation by gender, however there was a significant improvement in the model when the TFEQ scores were added (final model, $F(5,50) = 2.60$, $p < .05$, adjusted $R^2 = .13$). Higher disinhibition scores were positively associated with a greater number of immediate choices, and higher dietary restraint was (marginally) negatively associated with fewer immediate choices.

3.2.5 Food DDT

Participants were instructed to make a series of hypothetical choices between a small portion of either a less or moderately preferred food *now* versus a small portion of either a moderately or highly preferred food after varying delays (see Table 3 for choices). We used a different approach to the money DDT to measure discounting, as preliminary analysis indicated that delay interval was an important factor in the relationship between their choice on this test and their habitual diet. Consequently, we fitted a line to each participant's data (excluding the zero interval), namely their number of immediate choices at each delay interval. The mean slope coefficient was positive ($M = 0.02$, $SD = 0.01$), and significantly differed from a mu of zero indicating that choices tended to shift from the delayed more preferred food at short intervals to the immediately available but less preferred food at longer intervals ($t(55) = 7.71$, $p < .001$).

Hierarchical regression analysis revealed a significant relationship between the slope coefficient and DFS (diet) score, with less healthful diets associated with steeper slopes indicating a more rapid shift to less preferred immediate choices as delay interval increased (see Table 6 for final model details). This effect was not moderated by gender, and the addition of the TFEQ scale scores did not explain any additional variance.

4.0 Discussion

Study 1 indicated a relationship between greater trait impulsivity on the BIS and consumption of a Western-style diet. This effect was independent of BMI and was not moderated by gender. We also found that consumption of sugar sweetened beverages and take-away food was significantly associated with trait impulsivity. In Study 2, using only lean participants, consumption of a Western-style diet was associated with greater trait Urgency on the

UPPS and with more impulsive behaviour on a food DDT. Participants who reported consuming more saturated fat and added sugar in their diet, were more inclined to choose (hypothetically) an immediately available but less preferred food over a more preferred food as delay interval increased. Two gender moderated dietary effects were found for trait Sensation seeking on the UPPS, and performance on the MFFT. We also observed in Study 1 that BMI was related to greater trait impulsivity, and in Study 2, that for the monetary DDT both Disinhibition and Restraint, from the TFEQ, were correlated with this impulsivity measure. Finally, effect sizes tended to be larger in Study 2 than in Study 1, which might reflect the better psychometric properties of the tests included in the former (e.g., the UPPS contains 45 items in contrast to the short-form BIS's 15).

Both Study 1 and 2 suggest that the relationship between consuming a Western-style diet and measures of impulsivity can be observed irrespective of BMI and in lean healthy and young participants. The principal implication of these findings is that if a nutritionally poor diet contributes to weight gain and obesity, and impulsive traits are more frequent among the obese (Schag, 2013) then these traits likely *precede* weight gain. Thus our findings imply that the causal arrow points from impulsivity to weight gain, rather than impulsivity being a consequence of weight gain (a possibility given animal findings discussed further below). The suggestion then that impulsivity may be a risk factor for weight gain is also consistent with the finding that impulsivity may be partially heritable and thus present from an early age (e.g., Bezdjian, Baker & Tuvblad, 2011; de Castro & Lilenfeld, 2005). Moreover, it is also consistent with the observation that the most successful weight control strategies involve minimal self-control (i.e., medication, bariatric surgery; Levitsky & Pacanowski, 2011).

Study 1 had sufficient power to examine for correlations between food items on the DFS and the BIS trait impulsivity measure. Of the four sugar-sweetened beverage items included on the DFS, three of these were significantly associated with greater trait impulsivity. This is of interest because not only has consumption of these beverages increased in many countries over the last two decades (e.g., Bleich et al., 2009), but also because their consumption has been frequently linked to excess weight gain and increased risk of Type-II diabetes (Fardet & Boirie, 2014). To the extent that greater impulsivity is a risk factor for weight gain, then one means by which this risk may be expressed is through excess consumption of these types of drinks. This may be facilitated by their ready availability, high palatability, and low cost. A similar conclusion applies to the trait-impulsivity link observed with take-away and fast foods, as there consumption is also known to be independently associated with weight gain (e.g., Rosenheck, 2008).

In Study 2 the Urgency facet score of the UPPS, which measures tendency to act upon impulse, was associated with consumption of a Western style diet. This relationship was of a similar magnitude in men and women, and parallels the association observed with Motor impulsivity and the BIS in Study 1. Gender mediated relationships on the UPPS were evident for one facet score. Greater sensation seeking in men was associated with a diet richer in saturated fat and added sugar. While sensation seeking has been associated before with ingestion of foods commonly perceived as ‘risky’ such as shellfish and spicy foods (e.g., Terasaki & Imada, 1988), these risks are far more immediate than those associated with a Western-style diet. For women, the reverse relationship between sensation seeking and diet quality was evident. It may be that female sensation-seekers prioritise a more healthful diet and its consequences such as enhanced physical attractiveness.

Study 2 also included a new food DDT, in which participants had to choose (hypothetically) between a less preferred food now versus a more preferred food later over differing time delays. Consistent with expectations, choices were affected by delay length such that in general participants shifted from choosing their delayed more preferred food to the less preferred immediate option as the time delay increased. The slope of this delay interval function was significantly associated with consumption of a Western-style diet, with frequent consumers tending to shift to the immediate less preferred choice at shorter delays. This finding is consistent with others in the literature indicating more impulsive choices on DDTs (financial) in overweight and obese samples (e.g., Davis et al., 2010; Epstein et al., 2014; Francis & Susman, 2009).

In addition to the Money DDT, where we found no relationship with consumption of a Western-style diet, a further behavioral measure of impulsivity that was not related to food was also included - the MFFT picture matching task. The relationship between Western-style diet and performance on the MFFT was moderated by gender. Women demonstrated the expected pattern, with those reporting a poorer diet quality performing worse on the overall iScore (i.e., more errors on the MFFT task and taking less time to complete them). There was no relationship evident in males. It has been suggested that greater male visuospatial ability may underpin some of the observed gender-related differences on this task (Cross, Copping & Campbell, 2011), which could explain the failure to observe a relationship in males (i.e. a greater buffering against decline in ability).

In the Introduction we described the link between impulsivity and obesity, and above we suggested that our data are consistent with impulsive behavior then shaping dietary choices. However, it is possible that the causal chain may be far more complex. Eating highly palatable and nutritionally poor quality foods may act to weaken dietary self-control (see, Daniel, Stanton & Epstein, 2013, for a similar argument). One reason this might happen is because diet can affect the brain as indicated by the animal studies described in the Introduction (e.g., Kanoski & Davidson, 2010; Kanoski et al., 2007). It is plausible that habitually consuming a highly palatable diet, irrespective of BMI, may then come to impair self-control and thus increase intake of such foods. An important way to address this issue would be to see if a shift towards a more healthful diet could produce improvements in self-control, above and beyond any benefits of simply learning to exercise more control over what is being eaten. This is an intriguing possibility, especially in children, where it might also lead to improved educational outcomes if any gains in self-control generalised outside of the food domain. The finding here that diet quality is associated with impulsivity, independent of BMI, certainly suggests that impaired self-control *may* assist weight gain. It also leaves open the very interesting possibility that self-control is actively undermined by a Western-style diet.

5.0 References

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Figure legend

Figure 1: Histogram of the diet quality scores from the DFS (maximum range, 26 to 130) for the participants in Study 1.

Figure 2: Histogram of the diet quality scores from the DFS (maximum range, 26 to 130) obtained on the day of testing in Study 2.

Table 1: Hierarchical regression analyses for Study 1 (n = 571), with the final and simplest significant model indicated in bold

Hierarchical regression	Short-form Barratt Impulsiveness Scale score			
	Total	Motor	Non-planning	Inattention
Step 1 – Dietary Fat and Sugar Scale (DFS)				
$F(1,569)_{inc}$, R^2_{change}	12.80, .02*	25.14, .04*	0.36, .00	**6.58, .01***
DFS Zero order r	.15*	.21*	.03	.11*
Step 2 – Adding in DFS x Gender				
$F(1,568)_{inc}$, R^2_{change}	0.00, .00	0.00, .00	0.77, .00	0.56, .00
DFS x Gender Zero order r	.00	.00	-.04	.03
DFS Sr	.15*	.21*	.03	.11*
DFS x Gender Sr	.00	.00	-.04	.03
Step 3 – Adding in Body Mass Index (BMI)				
$F(1,567)_{inc}$, R^2_{change}	**4.82, .01***	**4.86, .01***	1.76, .00	2.15, .00
BMI Zero order r	.09*	.08*	.06	.05
DFS Sr	.15*	.21*	.03	.11*
DFS x Gender Sr	.01	.01	-.03	.04
BMI Sr	.09*	.09*	.06	.06

* $p < .05$

Table 2: Correlations (Pearson r) between self-control scores and individual food and beverage items on the Dietary Fat and Sugar Scale (DFS) in Study 1 (n = 571)

DFS item	Short-form Barratt Impulsiveness Scale score			
	Total	Motor	Non-planning	Inattention
Mince, beef or lamb	0.00	0.04	-0.04	0.00
Beef or pork	-0.03	0.03	-0.05	-0.05
Fried chicken/burger	0.10	0.16*	-0.02	0.07
Sausages, frankfurts or salami	0.06	0.08	0.04	0.02
Bacon	0.10	0.17*	0.04	0.02
Salad dressings (not low fat)	0.09	0.10	0.05	0.07
Margarine, butter or oil in cooking	0.01	0.02	0.01	-0.07
Eggs (not egg whites alone)	-0.04	0.02	-0.03	-0.07
Pizza	0.18*	0.22*	0.09	0.10
Cheese or cheese spread (not low fat)	0.07	0.09	0.04	0.04
French fries, fried potatoes	0.18*	0.21*	0.08	0.12
Corn/potato chips, popcorn with butter	0.15*	0.16*	0.05	0.14*
Doughnuts, pastries, croissants	0.06	0.14*	-0.03	0.01
Cakes, cookies	-0.02	0.06	-0.05	-0.06
Ice cream (not sorbet or low fat)	0.02	0.03	-0.06	0.07
Chocolate	-0.04	0.02	-0.09	-0.01
Lollies	0.07	0.14*	-0.03	0.06
Spreads	0.00	0.01	-0.01	0.00
Pancakes or French toast	0.03	0.06	-0.02	0.03
Sports/energy drinks	0.14*	0.14*	0.09	0.10
Soft drink (not including diet)	0.17*	0.16*	0.10	0.13*
Milk (full fat only)	0.03	0.03	0.01	0.04
Other sweetened beverages	0.20*	0.19*	0.10	0.17*
White bread	0.05	0.05	-0.01	0.08
Takeaway or fast food restaurant	0.15*	0.19*	0.01	0.14*
Added sugar to food/drink	0.09	0.13	0.00	0.09

* $p < 0.002$

Table 3: Trial types for the Food Delayed Discounting Task in Study 2

Trial	Immediate choice	Interval (mins)	Delayed choice
28	Least preferred food 1	0	Moderately preferred food 1
20	Least preferred food 1	1	Moderately preferred food 1
6	Least preferred food 1	10	Moderately preferred food 1
26	Least preferred food 1	30	Moderately preferred food 1
11	Least preferred food 1	60	Moderately preferred food 1
1	Least preferred food 1	120	Moderately preferred food 1
3	Least preferred food 1	0	Most preferred food 1
24	Least preferred food 1	1	Most preferred food 1
27	Least preferred food 1	10	Most preferred food 1
32	Least preferred food 1	30	Most preferred food 1
30	Least preferred food 1	60	Most preferred food 1
15	Least preferred food 1	120	Most preferred food 1
2	Least preferred food 2	0	Moderately preferred food 2
36	Least preferred food 2	1	Moderately preferred food 2
35	Least preferred food 2	10	Moderately preferred food 2
5	Least preferred food 2	30	Moderately preferred food 2
16	Least preferred food 2	60	Moderately preferred food 2
31	Least preferred food 2	120	Moderately preferred food 2
34	Least preferred food 2	0	Most preferred food 2
13	Least preferred food 2	1	Most preferred food 2
25	Least preferred food 2	10	Most preferred food 2
10	Least preferred food 2	30	Most preferred food 2
14	Least preferred food 2	60	Most preferred food 2
9	Least preferred food 2	120	Most preferred food 2
29	Moderately preferred food 1	0	Most preferred food 1
8	Moderately preferred food 1	1	Most preferred food 1
23	Moderately preferred food 1	10	Most preferred food 1
17	Moderately preferred food 1	30	Most preferred food 1
22	Moderately preferred food 1	60	Most preferred food 1
18	Moderately preferred food 1	120	Most preferred food 1
21	Moderately preferred food 2	0	Most preferred food 2
33	Moderately preferred food 2	1	Most preferred food 2
4	Moderately preferred food 2	10	Most preferred food 2
19	Moderately preferred food 2	30	Most preferred food 2
12	Moderately preferred food 2	60	Most preferred food 2
7	Moderately preferred food 2	120	Most preferred food 2

Table 4: Foods available for selection on the Preference task in Study 2

Food as described to participants
A scoop of vanilla ice-cream
A slither of apple pie
A slither of chocolate mud cake
A mini-packet of Malteser’s
A slither of pavlova
A lamington (a cream filled coconut covered sponge)
A slither of brownie
Four marshmallows
A slither of stick-date pudding
A mini packet of M&Ms
Four Allen’s snakes
A slither of cheese cake
A small container of chocolate mousse
A white chocolate Lindt ball
A milk chocolate Lindt ball
A choc-chip cookie
A Ferrero Rocher
A small portion of hot chips
A slither of Krispy cream donut
A slither of your favourite pizza
A small portion of onion rings
A small handful of salted cashews
Four starburst chews
A small handful of original Pringles
A small handful of Doritos
A handful of buttered popcorn
A handful of salt and vinegar chips
A handful of plant salt chips
A slither of lemon tart
A mini Mars bar
A mini Milky way
A mini Crunchie
Two mini chocolate Easter eggs
A mini Turkish delight

Table 5: Hierarchical regressions for the four facets of the Urgency, Premeditation, Perseverance and Sensation seeking (UPPS) scale in Study 2, with the final and simplest model in bold

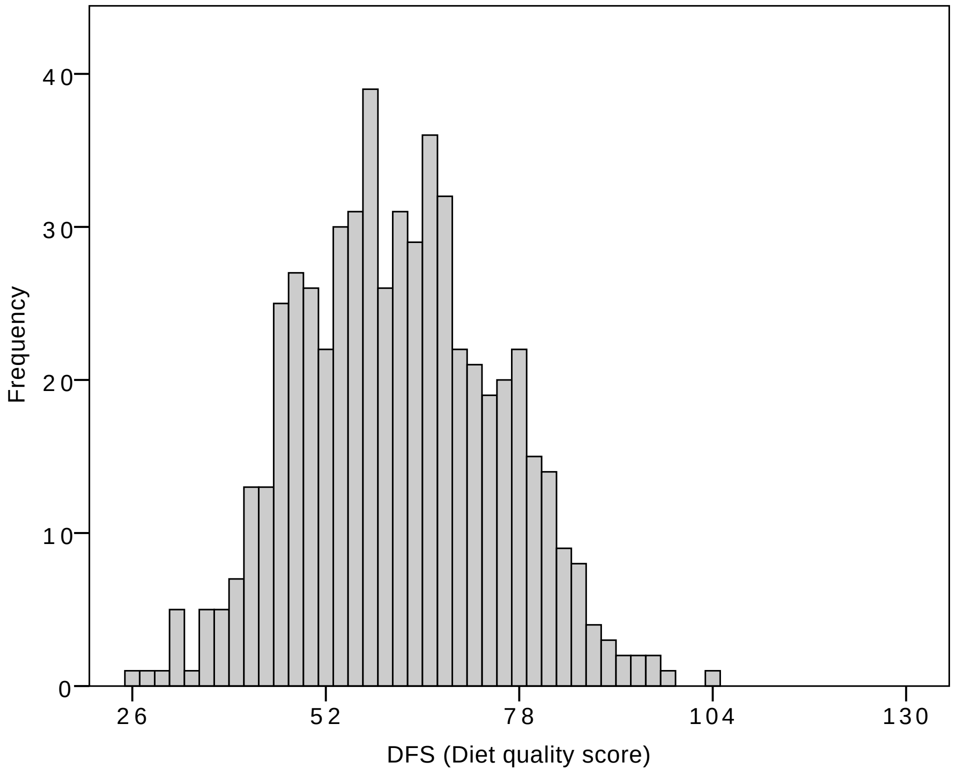
Hierarchical regression	Pre-meditation	Urgency	Sensation seeking	Perseverance
Step 1 – Dietary Fat and Sugar Scale (DFS)				
$F(1,54)_{inc}$, R^2_{change}	1.79, .03	8.88, .14*	0.32, .01	0.07, .00
DFS Zero order r	.18	-.38*	.08	.04
Step 2 – Adding in DFS x Gender				
$F(1,53)_{inc}$, R^2_{change}	0.25, .01	0.94, .02	**11.28, .17***	2.94, .05
DFS x Gender Zero order r	-.04	-.17	.42*	-.22
DFS Sr	.19	-.36*	.02	.07
DFS x Gender Sr	-.07	-.12	.42*	-.23
Step 3 – Adding in Three Factor Eating Questionnaire (TFEQ): Restraint, Disinhib. & Hunger				
$F(3,50)_{inc}$, R^2_{change}	0.07, .00	**3.39, .14***	0.67, .03	0.35, .02
TFEQ Restraint Zero order r	-.09	.20	-.19	-.02
TFEQ Disinhib. Zero order r	-.03	-.33*	.02	.08
TFEQ Hunger Zero order r	.08	-.38*	.05	.01
DFS Sr	.16	-.28*	-.11	.06
DFS x Gender Sr	-.06	-.11	.41*	-.25
TFEQ Restraint Sr	.06	-.09	-.16	-.04
TFEQ Disinhib. Sr	-.03	-.21	-.02	.14
TFEQ Hunger Sr	.04	-.15	.03	-.09

* $p < .05$

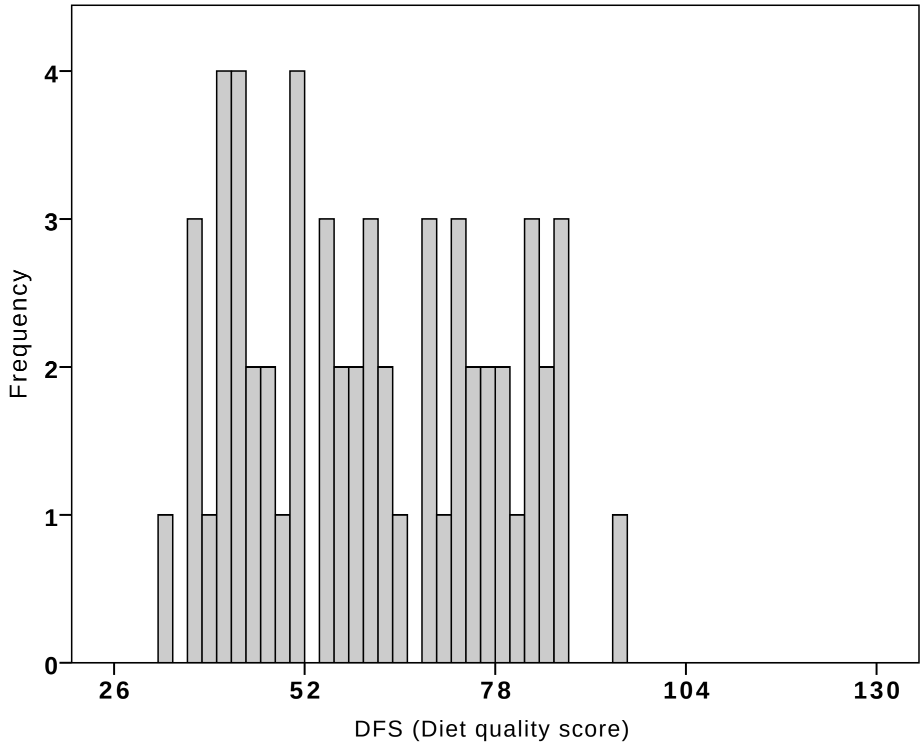
Table 6: Hierarchical regression analyses for the Matching Familiar Figures Task (MFFT) iScore, the monetary delayed discounting immediate choices score (DDTi-Money) and the food delayed discounting time interval slope score (DDTs-Food) in Study 2, with the final model in bold.

Hierarchical regression	MFFT iScore	DDTi-Money	DDTs-Food
Step 1 – Dietary Fat and Sugar Scale (DFS)			
$F(1,54)_{inc}$, R^2_{change}	0.15, .00	1.89, .03	**5.70, .10***
DFS Zero order r	-.05	.18	.31*
Step 2 – Adding in DFS x Gender			
$F(1,53)_{inc}$, R^2_{change}	**9.00, .15***	0.30, .00	0.10, .00
DFS x Gender Zero order r	-.38*	.10	.08
DFS Sr	.00	.17	.31*
DFS x Gender Sr	-.38*	.08	.08
Step 3 – Adding in Three Factor Eating Questionnaire (TFEQ): Restraint, Disinhib. & Hunger			
$F(3,50)_{inc}$, R^2_{change}	1.39, .07	**3.51, .17***	0.47, .03
TFEQ Restraint Zero order r	-.09	-.26	-.21
TFEQ Disinhib. Zero order r	-.17	.31*	-.15
TFEQ Hunger Zero order r	.10	.13	.09
DFS Sr	-.15	.01	.21
DFS x Gender Sr	-.35*	.00	.07
TFEQ Restraint Sr	-.13	-.25	.04
TFEQ Disinhib. Sr	-.16	.37*	-.16
TFEQ Hunger Sr	.14	-.14	.08

* p < .05



Frequency
40
30
20
10
0
26
52
78
104
130
DFS (Diet quality score)


4
3
2
1
0
Frequency
26
52
78
104
130
DFS (Diet quality score)