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Many apples a day keep the blues away – Daily experiences of negative and positive affect and food consumption in young adults

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Objectives. Prior research has focused on the association between negative affect and eating behaviour, often utilizing laboratory or cross-sectional study designs. These studies have inherent limitations, and the association between positive affect and eating behaviour remains relatively unexplored. Therefore, the objective of this study was to investigate the bidirectional relationships between daily negative and positive affective experiences and food consumption in a naturalistic setting among healthy young adults.

Design. Daily diary study across 21 days (microlongitudinal, correlational design).

Methods. A total of 281 young adults with a mean age of 19.9 (±1.2) years completed an Internet-based daily diary for 21 consecutive days. Each day they reported their negative and positive affect, and their consumption of five specific foods. Hierarchical linear modelling was used to test same-day associations between daily affect and food consumption, and next-day (lagged) associations to determine directionality. Moderating effects of BMI and gender were also examined in exploratory analyses.

Results. Analyses of same-day within-person associations revealed that on days when young adults experienced greater positive affect, they reported eating more servings of fruit ($p = .002$) and vegetables ($p < .001$). Results of lagged analysis showed that fruits and vegetables predicted improvements in positive affect the next day, suggesting that healthy foods were driving affective experiences and not vice versa. Meaningful changes in positive affect were observed with the daily consumption of approximately 7–8 servings of fruit or vegetables.

Conclusions. Eating fruit and vegetables may promote emotional well-being among healthy young adults.

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Statement of contribution

What is already known on this subject? Laboratory and cross-sectional studies have found a strong link between experiences of negative affect and food consumption. These studies generally show that people eat more food and less healthy food when experiencing negative affect; however, there is less evidence of this association in a natural setting. Moreover, the association between positive affect and eating remains relatively unexplored. Some studies have found stronger links between negative affect and unhealthy food consumption among women and individuals with higher BMI. Conversely, the foods people eat may influence their affective experiences. Cross-sectional research has shown that a diet high in fruits and vegetables is associated with a lower lifetime prevalence of depression and anxiety, but it is not known whether healthy food consumption may also influence affective experiences on a day-to-day basis.

What does this study add? Using online daily diaries for three weeks, we found strong relationships between daily positive affect and fruit and vegetable consumption. Lagged analyses showed that fruit and vegetable consumption predicted improvements in positive affect the next day, and not vice versa. Gender and BMI were not major factors in these associations. Fruit and vegetable consumption may promote feelings of well-being among healthy young adults.

How do emotions influence the foods people eat? And, how do the foods people eat influence their emotions? It is generally acknowledged that negative emotions can act as triggers to food intake and overeating (Christensen, 1993; Gibson, 2006; Hepworth, Mogg, Brignell, & Bradley, 2010; Kenardy, Butler, Carter, & Moor, 2003; Macht, 2008; Macht, Haupt, & Ellgring, 2005; Macht, Roth, & Ellgring, 2002; Macht & Simons, 2000; O'Connor, Jones, Connor, McMillan, & Ferguson, 2008; Yeomans & Coughlan, 2009). For example, a range of laboratory studies have found that experimentally induced negative affect can trigger an increased consumption of high fat and sugar snacks (Greeno & Wing, 1994; Macht, 2008; O'Connor *et al.*, 2008; Sieber, 2007), a preference for snacks over meals (Lowe & Fisher, 1983; Macht, 2008; O'Connor *et al.*, 2008; Oliver, Wardle, & Gibson, 2000; Sieber, 2007), and a decreased consumption of vegetables (Greeno & Wing, 1994; O'Connor *et al.*, 2008; Torres & Nowson, 2007).

Similarly, cross-sectional surveys also show that individuals perceive themselves to eat more servings of foods high in sugar and fat, and fewer servings of fruits and vegetables when experiencing negative affect (Anschutz, Van Strien, Van De Ven, & Engels, 2009; Laitinen, Ek, & Sovio, 2002; Loth, van den Berg, Eisenberg, & Neumark-Sztainer, 2008; Mikolajczyk, Ansari, & Maxwell, 2009; Ng & Jeffery, 2003; Oliver & Wardle, 1999; Rose, Soperski, & Golomb, 2010). Associations between stress and eating behaviour are similar to those between negative affect and eating behaviour (Greeno & Wing, 1994), and have been more extensively studied (O'Connor *et al.*, 2008). However, relatively few studies have investigated the relationship between positive affect and food consumption (Ioakimidis *et al.*, 2011; Macht & Dettmer, 2006), or the potential bidirectionality of relationships between food intake and emotions. For example, biochemical evidence suggests that foods high in carbohydrates may boost brain serotonin levels (Blundell, Lawton, & Halford, 1995) and that certain micronutrients found in fruits and vegetables (e.g., folate) might ameliorate symptoms of depression in as little as 10 weeks when used in conjunction with conventional antidepressant medication (Coppen & Bailey, 2000; Coppen & Bolander-Gouaille, 2005). Likewise, cross-sectional research has shown that a 'western' diet characterized by high-sugar and refined carbohydrates is associated with depression among adult women (Jacka *et al.*, 2010); however, it is not known whether consumption of certain

foods may influence emotions felt on a day-to-day basis. Thus, our aim was to use a daily diary design (Gunthert & Wenze, 2012) to examine the natural covariation between day-to-day affective experiences and food consumption and to clarify the directionality of these relationships – that is, the extent to which affective experiences influence the foods people eat, and the extent to which the foods people eat influence their affective experiences.

The few studies that have applied daily diary designs to the affect–food relationship have revealed a more complex picture than is found using laboratory studies. To date, daily diary studies have found negative affect to be associated with consuming more food than usual (as measured using 2-week food diaries; Patel & Schlundt, 2001), larger meals (Macht, Haupt, & Salewsky, 2004) and more frequent snacking (Patel & Schlundt, 2001; Wolff, Crosby, Roberts, & Wittrock, 2000). Daily diary studies have not yet investigated how the experience of negative affect is related to the consumption of specific foods such as unhealthy foods like crisps, chips or sweets, or healthy foods like fruits and vegetables.

Even less is known about the role of positive affect and food consumption. When induced in laboratory studies, positive affect has been shown to increase the consumption of foods such as crackers (Kenardy *et al.*, 2003), popcorn and raisins (Yeomans & Coughlan, 2009) and chocolate chip cookies (Turner, Luszczynska, Warner, & Schwarzer, 2010), suggesting that positive affect increases consumption of a variety of foods. In a recent analysis of several large cross-sectional surveys, adults who reported greater well-being (i.e., life satisfaction, happiness, etc.) also reported consuming more fruits and vegetables (Blanchflower, Oswald, & Stewart-Brown, 2012). However, as these data are correlational, it is unknown whether greater emotional well-being drives people to eat healthfully or whether eating healthfully improves well-being. Moreover, the day-to-day associations between positive affect and food consumption in natural settings remain relatively unexplored. In one daily diary study, greater self-reported elation averaged across a 9-day period was associated with consuming more carbohydrates and less fat during that time period (De Castro, 1987). However, affect was rated on bipolar scales ('elation depression'), so positive states could not be isolated from negative states. Another study using daily diary methods showed that eating itself was a pleasurable experience, as it was more likely to co-occur with positive affect than with negative affect or neutral affect (Macht *et al.*, 2004), but the authors did not track the actual types and amounts of food consumed. Lastly, there is some evidence to suggest that certain macronutrients may improve positive affect in daily life. For example, a study of 30 secondary students found that increased consumption of carbohydrates in response to a naturalistic stressor predicted increases in subsequent positive affect (Kubiak & Krog, 2012); however, this association was only found among emotional eaters and does not distinguish between healthy or unhealthy sources of carbohydrates.

To our knowledge, no published daily diary studies have investigated the potential bidirectional associations between both negative and positive affect and specific food consumption. Thus, the aim of this study was to use a daily diary approach to test the hypotheses that negative and positive affect have different associations with the consumption of healthy and unhealthy foods, and that the associations between affect and eating may be bidirectional. We investigated these associations in a sample of normal young adults, ages 18–25, the age range when emotional tendencies from childhood begin to stabilize (Watson & Walker, 1996). This is also a time when young adults have moved away from home and are developing their own eating habits.

The study also aimed in secondary analyses to determine whether BMI or gender moderated the affect–eating associations. Many laboratory and cross-sectional studies have found that individuals with high BMI and women tend to eat more food, particularly

foods high in sugar and fat, when experiencing negative affect (Baucom & Aiken, 1981; Wallis & Hetherington, 2009; Yeomans & Coughlan, 2009). However, there is little evidence of this linkage in a natural setting. O'Connor *et al.* (2008) used daily diaries to investigate the relationship between specific stressors and between-meal snacking, but the affect–eating relationship has not been as closely examined. Similar to findings from many laboratory and cross-sectional studies (Grunberg & Straub, 1992; Ng & Jeffery, 2003; Oliver *et al.*, 2000), O'Connor *et al.* (2008) found the association to be stronger in overweight individuals and women. However, a recent review (Macht, 2008) has suggested that the role of obesity in the affect–eating behaviour relationship may not be as straightforward as previously thought (Lowe & Fisher, 1983). Furthermore, the vast majority of studies have only examined the affect–eating behaviour relationship in women. Therefore, our goal was to determine whether BMI or gender moderated the affect–eating relationship in this mixed-gender healthy young adult population.

Method

Participants

Two hundred and eighty-one undergraduate students were recruited into the study through an on-campus student employment agency (26%) or through undergraduate psychology courses (74%), which were heavily subscribed by non-Psychology majors and representative of the wider university population. Table 1 shows the participant characteristics. We excluded anyone with an eating disorder or a history of eating disorders from participating (an additional three women excluded). Participants were recruited across four academic semesters between April 2008 and August 2009, and ethical approval was obtained from the University of Otago Ethics Committee. Participants were remunerated with payment up to NZ$70 if recruited through the employment agency or, through course credit awarded by filling out a worksheet if recruited through Psychology classes.

Table 1. Participant characteristics

Characteristics (n = 281)	Mean ± *SD*	*n* (%)
Male		128 (45.6)
Female		153 (55.4)
Age (years)	19.9 (1.2)	
Height (cm)	172.8 (9.7)	
Weight (kg)	71.3 (13.5)	
Body mass index (BMI; kg/m^2)	23.8 (3.5)	
BMI classification		
Underweight (<18.5)		10 (3.6)
Normal range (18.5–24.9)		196 (69.8)
Overweight (25.0–29.9)		58 (20.6)
Obese ($\geq$ 30)		17 (6.0)
Prioritized ethnicity		
European		220 (78.3)
Asian		19 (6.7)
Māori		9 (3.2)
Pacific Islander		2 (0.7)
Other		31 (11.0)

Procedure

Participants attended an initial laboratory session in the week prior to the start of the daily diaries. In this session, following informed consent procedures, they completed a computer-based, self-administered questionnaire that included demographic measures of age, gender and ethnicity, as well as self-reported height and weight. A scale was provided, and participants could measure their own weight if required. After completing the questionnaire, participants received training for how to complete the daily survey.

The 21-day Internet-based daily diary procedure began on the first Monday following the initial laboratory session. Each day participants accessed an online survey between 3.00 pm and 8.00 pm. This time was chosen to coincide with participants' naturally occurring end of day, before any night-time activity. The survey contained a range of questions related to daily experiences, took approximately 5 min to complete, and could only be accessed during the designated time window. An automated e-mail reminder was sent to participants if they had not completed the daily survey by 6 pm. After the 21 days, participants returned to the laboratory for debriefing.

Daily diary measures

Negative and positive affect

Participants rated how they felt 'that day' using 18 adjectives, each a scale from 1 'not at all' to 5 'extremely'. The nine negative affect adjectives were depressed, sad, unhappy, anxious, nervous, tense, angry, hostile and short-tempered. The nine positive affect adjectives were calm, content, relaxed, cheerful, happy, pleased, energetic, enthusiastic and excited. These were chosen to capture a range of low- to high-intensity negative and positive states (Barrett & Russell, 1999). We averaged the nine negative and the nine positive affect adjectives rated each day for separate measures of daily negative affect (α = .768) and daily positive affect (α = .831; multilevel reliability procedures based on Nezlek, 2012).

Food consumption

In the daily diary, participants were asked a set of five questions regarding their food consumption during the previous night (i.e., 'In the time between completing yesterday's survey and going to bed'), and separately, for that day (i.e., 'From the time you woke up until now'). The five food consumption questions were modified from standard questions in the New Zealand National Nutrition Survey 1997 (NNS'97; Russell *et al.*, 1999). Specifically, participants were asked to report the number of servings eaten per day (either last night or today) of (1) *fruit* (*excluding fruit juice and dried fruit*); (2) *vegetables* (*excluding juices*); (3) *chocolate-coated and/or cream-filled biscuits*; (4) *potato crisps*, *corn snacks or corn chips*; and (5) *cake*, *muffins or buns*. Possible response options ranged from 0 'no servings' to 3 'three or more servings' for all items except 'servings of potato crisps or corn snacks or corn chips' where the option 4 'four or more servings' was also included. Examples were provided of what constituted one serving size, as specified in the NNS'97 (Russell *et al.*, 1999).

Data analysis

Data preparation

The 281 participants completed on average 19 of 21 daily diaries (*SD* = 2, min = 11, max = 21; 91% compliance). An additional seven people failed to complete the minimum

number of diaries (≥ 11 diaries) and were excluded from analysis. From the 281 participants, a total of 5,320 daily records were collected. To represent food consumption for a complete day, day and night food consumption data were added. Missing either day or night data resulted in a listwise deletion of that record. This reduced the number of complete diary records to 4,593. Although combining the data in this way resulted in a loss of 2 days of sampling per person, there was still an average of 16 of 21 daily diaries per person (76%) available for analyses involving complete daytime and night-time sampling of food consumption. Lagged data were also prepared (negative affect, positive affect and foods consumed from the next day, $t + 1$) and subjected only to pairwise deletion within the multilevel modelling programme.

Multilevel modelling analysis

Multilevel modelling was conducted using the hierarchical linear modelling programme (HLM 6.08; Raudenbush & Bryk, 2002) to accommodate the specialized data structure with repeated daily observations nested within individuals (Raudenbush, Bryk, & Congdon, 2005).

HLM was used to determine the within-person relationship between daily reported negative affect (or positive affect) as the level-1 predictor, and food consumption on that same day (i.e., the number of servings of each specific foods consumed across the entire day) as the level-1 outcome. This model enabled us to determine how affect and food consumption covaried within a given individual over time. The level-1 predictor (negative or positive affect) was group-mean centred. Separate models were run for negative and positive affect for each of the five specific foods – a total of 10 multilevel models. The alpha level for statistical significance was set at .005 to account for multiple testing (using the Bonferroni correction method), $p = .05/10$ tests $= .005$. From these models, we determined the average within-person relationship between affect and food consumption for the sample overall as indicated by the level-2 G_{10} coefficient. A significant G_{10} coefficient would indicate that, on average, when people experienced changes in their mood, their food consumption changed in a corresponding way on that same day.

Next-day lagged analyses were conducted for all significant affect–eating associations in an attempt to clarify the direction of causality. These analyses tested, for example, whether experiencing positive affect on 1 day (level-1 predictor) predicted next-day vegetable consumption (level-1 $t + 1$ outcome), while controlling for previous-day vegetable consumption (level-1 covariate; evidence for affective experiences influencing food consumption); or alternately, whether consuming vegetables on 1 day (level-1 predictor) predicted next-day positive affect (level-1 $t + 1$ outcome), while controlling for previous-day positive affect (level-1 covariate; evidence for food consumption influencing affective experiences). All level-1 predictors were group-mean centred.

Next, exploratory analyses were conducted to determine whether the affect and food relationships (same day and next day) varied as a function of BMI and gender. BMI (grand-mean centred) and gender (coded 0 for men, 1 for women) were added as simultaneous level-2 predictors to determine whether the association between negative affect (or positive affect) and food consumption was moderated by the BMI or gender of the participants.

Lastly, for all significant affect–eating associations, a final set of models were run in which we treated food consumption as the predictor of affect rather than as the outcome of affect. This provided a different G_{10} coefficient that revealed the changes in affect for each serving increase in a specific food. This was performed to derive recommended guidelines for how many servings of food corresponded to meaningful changes in affect.

Results

Daily affect and food consumption

As shown in Table 2, left-side columns, experiences of negative affect were associated with some unhealthy eating patterns. On days when individuals experienced more negative affect, they consumed 0.085 fewer servings of fruit and 0.069 more servings of crisps, corn snacks or corn chips. However, these patterns did not exceed the adjusted significance threshold of $p < .005$.

By contrast, as shown in Table 2, right-side columns, higher positive affect was associated with healthy eating patterns. On days when individuals reported experiencing greater positive affect, they also reported consuming 0.112 more servings of fruit and 0.147 more servings of vegetables. These associations exceeded the adjusted significance threshold of $p < .005$.

Directionality

Lagged analyses were conducted for the two significant associations bolded in Table 2. Both sets of lagged analyses showed that fruit and vegetable consumption predicted changes in next-day positive affect, but positive affect did not predict changes in next-day fruit and vegetable consumption. Specifically, on days when individuals consumed more servings of fruit and/or vegetables, they reported experiencing greater positive affect the following day, while controlling for current-day fruit or vegetable consumption (servings of fruit $G_{20\ \text{lagged}}\ \beta$ [*SE*] = .019 [.009], $p = .029$; servings of vegetables $G_{20\ \text{lagged}}\ \beta$ [*SE*] = .017 [.007], $p = .015$). The reverse pattern (i.e., current-day positive affect predicting next-day fruit or vegetable consumption) was not significant (servings of fruit $G_{10\ \text{lagged}}\ \beta$ [*SE*] = .003 [.033], $p = .935$; servings of vegetables $G_{10\ \text{lagged}}\ \beta$ [*SE*] = .018 [.041], $p = .666$).

Table 2. Within-person relationships between daily affect and food consumption

		Negative affect			Positive affect		
Food category outcome	G_{00}	G_{10}	*SE*	*p*	G_{10}	*SE*	*p*
Fruit	1.703	−0.085	.040	.036	**0.112**	**.034**	**.002**
Vegetables	2.515	−0.033	.051	.521	**0.147**	**.038**	**<.001**
Chocolate-coated and/or cream-filled biscuits	0.399	0.019	.029	.499	0.002	.021	.943
Crisps, corn snacks or corn chips	0.449	0.069	.030	.020	0.002	.026	.954
Cake, muffins or sweet buns	2.515	−0.024	.030	.432	0.028	.026	.276

Notes. G_{00} = average number of food servings/day at average levels of negative or positive affect. The G_{00} coefficients were the same regardless of whether negative or positive affect was entered as a level-1 predictor; therefore, only one column of G_{00} coefficients is presented.

G_{10} = change in food servings/day for each point increase in negative or positive affect (i.e., average within-person slope) computed with robust standard errors (*SE*) and df = 280. Bolded coefficients were significant below the Bonferroni adjusted *p*-value of .005.

Negative affect = mean of total daytime negative affect (depressed, sad, unhappy, anxious, nervous, tense, angry, hostile, short-tempered).

Positive affect = mean of total daytime positive affect (calm, content, relaxed, cheerful, happy, pleased, energetic, enthusiastic, excited).

Exploratory analyses: moderators of the daily affect and food consumption relationships

BMI moderated only one relationship between affect and food – the relationship between negative affect and consumption of crisps, corn snacks, and corn chips (G_{11} β [*SE*] = .017 [.007], p = .015). Whereas high BMI individuals ate more servings of these unhealthy foods when experiencing negative affect (β [*SE*] = .143 [.036], $p < .001$), low BMI individuals did not (β [*SE*] = .025 [.042], p = .561). Gender moderated the relationship between fruit and positive affect only (G_{12} β [*SE*] = −.130 [.062], p = .036). Whereas men ate more fruit when experiencing positive affect (β [*SE*] = .201 [.055], $p < .001$), women did not (β [*SE*] = .055 [.044], p = .206).

Lagged analyses for the two associations moderated by BMI and gender also suggested that food consumption was driving affect and not vice versa. High BMI individuals who consumed crisps, corn snacks and corn chips experienced greater negative affect than low BMI individuals the following day (controlling for previous-day negative affect; β $[SE]_{\text{lagged}}$ = .031 [.014], p = .029), while the reverse pattern (i.e., current-day negative affect predicting next-day crisp consumption) was not significant (β $[SE]_{\text{lagged}}$ = .043 [.047], p = .361). And, men who consumed fruit experienced greater positive affect the following day (controlling for previous-day positive affect; β $[SE]_{\text{lagged}}$ = .041 [.014], p = .003), while the reverse pattern (i.e., current-day positive affect predicting next-day fruit consumption) was not significant (β $[SE]_{\text{lagged}}$ = −.032 [.054], p = .554).

Recommended healthy food guidelines for improving positive affect

The final set of models treated food consumption as the predictor of affect rather than as the outcome of affect to understand how many servings of fruit or vegetables may be required to evidence meaningful changes in daily affect. Reanalysing the two significant associations from Table 2 showed that for every one serving increase in fruit or vegetables (above participants' usual consumption), positive affect increased by 0.029 or 0.028 points, respectively (average positive affect G_{00} = 2.59; effect of fruit G_{10} β [*SE*] = .029 [.008], p = .001; effect of vegetables G_{10} β [*SE*] = .028 [.007], $p < .001$).

Based on these G_{10} coefficients, we estimated that participants who consumed approximately 5.5 (or 5.7) additional servings of fruits (or vegetables) above their typical daily consumption achieved small but meaningful improvements in their daily positive affect.[1] Because the typical daily consumption in our sample was 1.7 servings of fruit and 2.5 servings of vegetables, our data suggest that young adults would need to consume approximately 7.2 daily servings of fruit or 8.2 servings of vegetables to notice a meaningful change in positive affect.

Discussion

On days when people ate more fruits and vegetables, they reported feeling calmer, happier and more energetic than they normally do. They also felt more positive the next day. These associations held regardless of the BMI of individuals, although the association

[1] *A meaningful change in positive affect was defined as an increase in 0.16 points (i.e., increasing from the mean of 2.59–2.75 points on the positive affect scale). A change of 0.16 points reflects a Cohen's* d *of 0.20, a small effect, which was computed by the formula 0.20 = (2.75–2.59)/0.80, where 0.80 equals the average within-person standard deviation in positive affect.*

for fruit consumption was stronger in men than women. Both men and women benefitted equally from vegetable consumption.

These results add to the small but growing literature on the potential role of diet in emotional outcomes (Jacka *et al.*, 2010; Sachdev *et al.*, 2005; Sanchez-Villegas, Henriquez, Bes-Rastrollo, & Doreste, 2006). For example, a recent cross-sectional study found that a 'western diet' characterized by higher consumption of fried or sugary foods, more refined grains and fewer fruits and vegetables was associated with a higher prevalence of clinical depression and anxiety in adult women, compared with a diet characterized by fruit, vegetables, fresh meat, fish and whole grains (Jacka *et al.*, 2010). Likewise, another recent investigation found that a higher fruit and vegetable consumption was correlated with greater well-being across several large cross-sectional data sets (Blanchflower *et al.*, 2012). Our study extends this work by showing that fruit and vegetable consumption is associated with and may influence emotional processes on a day-to-day basis. While the emotional changes were small, we found meaningful shifts in positive affect when participants consumed an additional 5.5 servings of fruit or 5.7 vegetables above their usual daily intakes of 1.7 and 2.5 servings, respectively. Therefore, our data suggest that a daily intake of approximately 7–8 combined servings of fruits or vegetables is associated with a meaningful increase in daily positive affect. These estimates also support the findings of Blanchflower *et al.* (2012) who found that well-being peaked at seven daily servings of fruit or vegetables.

Of course, inferences about causality should be considered tentative until replicated with an experiment. Although our design allowed us to conduct lagged analyses, and these analyses suggested that fruit and vegetable consumption might be influencing positive affect, we agree that future research needs to include randomized controlled trials (RCTs) evaluating the influence of high fruit and vegetable intake on affect and well-being (Blanchflower *et al.*, 2012). We also recommend that researchers incorporate daily diaries as an effective method of tracking affective changes in response to dietary intervention (Conner & Barrett, 2012).

In terms of mechanism, it is possible that eating behaviour may influence affect simply through psychological mechanisms. Perceptions of the health value of certain foods may lead a person to feel more positive following consumption of 'healthy' foods (Hayes, D'Anci, & Kanarek, 2011; Macht & Dettmer, 2006; Ogden & Wardle, 1991). However, physiological mechanisms are also possible (Gomez-Pinilla, 2008). For example, brain-derived neurotrophic factor (BDNF), a protein responsible for promoting neurogenesis (Duman, Heninger, & Nestler, 1997), is believed to play a central role in mood states and depression (Hashimoto, Shimizu, & Iyo, 2004). Diets high in fat and refined sugar, and low in fresh fruits and vegetables have been found to reduce BDNF, independent of obesity (Molteni, Barnard, Ying, Roberts, & Gomez-Pinilla, 2002). Therefore, it is possible that changes in BDNF may mediate the observed emotional changes. Visceral signals derived from diet can also affect mood through vagal nerve stimulation (VNS) and gut hormones; however, the mechanisms of these pathways are not yet well understood (Clark, Naritoku, Smith, Browning, & Jensen, 1999; Nahas *et al.*, 2005). One randomised controlled trial found VNS to reduce craving ratings for sweet foods in adults with depression (Bodenlos *et al.*, 2007). Changes could also be due to increased carbohydrate intake, as carbohydrate-rich foods increase concentrations of brain serotonin (Blundell *et al.*, 1995; Takeda *et al.*, 2004) and may be related to improved positive affect (Kubiak & Krog, 2012). However, it is possible that not all carbohydrates act equally. There is some evidence to suggest that complex carbohydrates found in fruits, vegetables and whole grain breads may improve mood, while refined sucrose may worsen mood (Christensen & Burrows,

1990; Reid, Hammersley, & Duffy, 2010). Results from our study are consistent with these findings.

Single nutrients may also play a role in the food–mood relationship. Folate intake and folate status have been inversely associated with prevalence of depression after adjusting for anthropometric and psychological factors (Sachdev *et al.*, 2005; Sanchez-Villegas *et al.*, 2006), and folate supplementation has been found to potentiate the effects of antidepressants (Coppen & Bolander-Gouaille, 2005; Fava *et al.*, 1997). Other nutrients such as flavonols (found in fruits; van Praag *et al.*, 2007) and the omega-3 fatty acid docosahexaenoic acid (DHA; Adams, Lawson, Sanigorski, & Sinclair, 1996; Freeman *et al.*, 2006; Hibbeln, 1998) have been found to improve cognitive function, which may improve mood. There is also evidence that micronutrient formulas may have therapeutic benefits for children with mood disorders such as paediatric bipolar disorder and attention-deficit/hyperactivity disorder (Rucklidge, Gately, & Kaplan, 2010). Conversely, foods with high contents of trans or saturated fat have been shown to adversely affect cognition (Greenwood & Winocur, 2005).

It is notable that our results did not support the idea that positive affect might precede healthy eating. Current theories of positive emotion such as the broaden-and-build Theory (Fredrickson, 2001) suggest that positive emotions might trigger an upward spiral that could reinforce positive behavioural patterns such as healthy eating. Thus, it is somewhat surprising that the data did not support a bidirectional association when examining next-day patterns. Of course, it is still possible that positive affect might precede healthy eating – it just may do so within a given day. For example, waking up 'feeling good' or having a relaxing morning might promote healthier food choices that day, which in turn may promote positive feelings the next day. Future research using multiple assessments across the day rather than once-a-day reporting is needed to understand the potential within-day bidirectional relationships.

Contrary to most previous research, we found few associations between negative affect and eating behaviour. The marginally significant finding for higher crisp consumption and lower vegetable consumption was consistent with previous research showing that when experiencing negative affect, individuals crave foods high in fat and salt (i.e., potato crisps; Connor, Fitter, & Fletcher, 1999; Gibson, 2006; Macht, 2008) and make more 'unhealthy' food choices (Macht & Simons, 2000; Macht *et al.*, 2005). However, these associations were far weaker than those found for positive affect and healthy food consumption. This could be due to slightly lower reliability of our negative affect scale ($\alpha = .768$) compared with the positive affect scale ($\alpha = .831$). It is possible that analysis of specific emotional states (e.g., sadness) might have yielded different results. It is also possible that our findings differ from prior research because other work has not made direct comparisons between negative and positive affect. Also, our analyses modelled changes in eating around a person's own average level of negative affect (within-person analyses), and negative affect is typically less variable than positive affect (Watson, 2000). It is also possible that the links between negative affect and poor eating behaviour only manifest in more clinical populations such as binge eaters or emotional eaters, and our study population was relatively 'normal' in these respects.

Our analyses of BMI showed few moderating effects. Although many laboratory and cross-sectional studies have found BMI to play an important role in moderating the affect and eating behaviour relationships (Anschutz *et al.*, 2009; Baucom & Aiken, 1981; Geliebter & Aversa, 2003; Habhab, Sheldon, & Loeb, 2009; Haynes, Lee, & Yeomans, 2003; Heatherton, Striepe, & Wittenberg, 1998; Laitinen *et al.*, 2002; Lattimore & Maxwell, 2004; Rotenberg & Flood, 1999; Shapiro & Anderson, 2005; Tanofsky-Kraff, Wilfley, &

Spurrell, 2000; Wallis & Hetherington, 2004, 2009; Yeomans & Coughlan, 2009), there is less evidence of this moderating effect in a natural setting (O'Connor *et al.*, 2008). Indeed, our study found that BMI moderated only one association, such that higher BMI was associated with consuming more servings of crisps, corn snacks, or corn chips on days with greater negative affect. This finding is consistent with previous literature, which has found overweight individuals to eat more food and less healthy food than normal weight individuals under these conditions (Arnow, Kenardy, & Agras, 1992; Baucom & Aiken, 1981; Chua, Touyz, & Hill, 2004; Geliebter & Aversa, 2003; Lowe & Fisher, 1983; Patel & Schlundt, 2001; Rose *et al.*, 2010). However, given prior evidence for BMI as a key factor, it is perhaps surprising that BMI did not moderate more of the affect–eating associations.

Gender also showed few moderating effects. Although some reviews have reported differences in mood–eating associations between genders (Gibson, 2006; Macht, 2008), on closer inspection, few studies of affect and eating have included both genders (Baucom & Aiken, 1981; Kenardy *et al.*, 2003; Mikolajczyk *et al.*, 2009). Of these studies, only one cross-sectional study has found any difference between genders in food consumed in response to negative affect (Mikolajczyk *et al.*, 2009) –women (but not men) perceived that their depressive symptoms were associated with consuming fewer servings of meat, fruit and vegetables. We did not find this effect. The only gender difference we found was that fruit consumption was associated with increased same-day and next-day positive affect among men but not women. Thus, the present study found more gender similarities than differences.

There were several strengths of this study. We used an intensive computerized daily diary study across 21 days to simultaneously measure real-time experiences of negative and positive affect and food consumption. And, unlike other daily diary studies on this topic, we measured consumption of specific foods as opposed to only measuring the total amount of food, which allowed us to pinpoint food groups that covaried with affect. We also recruited a relatively large representative sample of healthy young adults and excluded those individuals with a history of eating disorders.

There were also several limitations to our study in additional to the correlational nature of our design. Foremost, our study relied on self-reports of food intake. While we provided guidelines for estimating serving sizes, and these questions were validated previously, there may still be bias in these reports. Foods high in fat and sugar, which may have a negative health image, might have been under-reported, whereas those with a positive health image such as fruits and vegetables might have been over-reported (Bingham *et al.*, 1995; Macdiarmid & Blundel, 1998; Pryer, Vrijheid, Nichols, Kiggins, & Elliot, 1997). Our daily diary reports also relied on some memory recall across that day and the previous night. However, daily diary reports are less reliant on memory than questionnaires pertaining to the previous week or month, and memory recall over the previous day is reasonably accurate (Conner, Barrett, Tugade, & Tennen, 2007). A further limitation was the limited number of foods investigated. Space considerations and respondent burden precluded use of a daily food frequency questionnaire. Inclusion of fatty foods (e.g., deep-fried foods), chocolate, sweets and sugary drinks would also have been useful (Oliver & Wardle, 1999; Parker, Parker, & Brotchie, 2006; Rose *et al.*, 2010). Our results pertain mainly to the association between eating and the broad dimensions of negative and positive affect. Research on specific emotional states (e.g., sadness, anger, happiness) in the context of dietary behaviour might yield different results. Our sample was also limited to young adults. Day-to-day behaviours and responsibilities depend on life stage, thus it is not known whether older populations would show similar associations as seen with this younger adult population.

The public health implications of this study depend on clarification of the mechanisms involved. Healthy food choices were found to be associated with (and possibly intensify) feelings of positive affect, including calmness, happiness and energy. Improved mood may be the result of the perception that by eating fruit and vegetables one is doing something positive for one's health. In this case, improved mood may only occur in those who perceive eating fruit and vegetables to be healthy, *and* who value eating healthy foods. However, if the mechanism is confirmed to be a direct influence of fruit and vegetables on physiological processes (e.g., vis-à-vis improved micronutrient status) rather than their perceived healthiness, public health strategies to promote fruit and vegetable consumption may be strengthened by emphasizing short-term outcomes, such as feeling better emotionally. Long-term health outcomes of fruit and vegetable consumption such as cancer prevention are less motivating because the benefits are perceived as too distant (Ammerman *et al.*, 2000). If prospective and intervention studies confirm that consuming fruit and vegetables can make individuals feel better *right now*, adherence to recommendations may be more successful.

The success of proximal motivating factors has been established in the field of exercise and mood. Not only are the long-term psychological benefits of exercise on mood states well documented (Weyerer & Kupfer, 1994), but a systematic review reported that even single bouts of exercise can alleviate negative mood, enhance positive mood and promote long-term exercise adherence (Yeung, 1996). It is not unreasonable that such a link exists with food. The public health implications are that if people understand that short-term diet changes can improve mood in the short term, this may improve people's adherence to healthy diet recommendations. Adherence to diet recommendations in the long term could reduce the risk of chronic diseases (WHO/FAO, 2002).

Research is also needed to determine whether increased fruit and vegetable consumption could act as a prevention strategy for early or mild cases of depression. Healthy eating may not be a substitution for traditional therapies, but could be used in conjunction to therapy where the clinician believes the addition of a holistic and healthful strategy may be appropriate (Beck, Rush, Shaw, & Emery, 1979). Nonetheless, the current findings suggest that many apples a day is part of a balanced approach to keep the blues away.

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