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The Relationship between Attentional Bias to Food and Disordered Eating in Females with Type 1 Diabetes

Melanie M. Broadley\textsuperscript{a}, Tenile Bishop\textsuperscript{a}, Melanie J. White\textsuperscript{a}, Brooke Andrew\textsuperscript{a}

\textsuperscript{a}Queensland University of Technology School of Psychology and Counselling, 170 Victoria Park Rd, Kelvin Grove, QLD, Australia, 4059; Institute of Health and Biomedical Innovation, 60 Musk Avenue, Kelvin Grove, QLD, Australia, 4059.

Corresponding Author: Melanie Broadley
Ph: +45 6550 9462
Email: mbroadley@health.sdu.dk

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Ethical approval: All procedures performed in studies involving human participants were in accordance with ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards

Informed consent: Informed consent was obtained from all individual participants included in the study.
Abstract

Objective: Factors which may render females with type 1 diabetes mellitus (T1DM) vulnerable to disordered eating behavior or difficulties with dietary management require further investigation. Given prior associations observed between food-related attentional biases and eating behavior in groups without diabetes, this study explored the relationships between attentional bias to healthy and unhealthy pictorial food cues and disordered eating in young adult females with and without T1DM, aged 18-40 yrs. Methods: 97 participants (41 with T1DM, 56 without) completed an initial online survey assessing demographic and clinical information, and disordered eating via the Eating Disorders Examination-Questionnaire (EDE-Q). They subsequently attended an in-person session to complete a computer-based visual probe task to assess attentional bias to pictorial food cues. Results: Analyses of Variance (ANOVAs) adjusting for age and body mass index showed a unique significant relationship in the group with T1DM whereby greater attentional bias scores away from unhealthy foods was associated with greater disordered eating. No relationship was observed in the group without diabetes. Discussion: This study suggests that early attentional disengagement from food-related cues may be uniquely associated with eating-related outcomes for females with T1DM relative to those without diabetes. This should be further explored in future research with an aim to develop novel strategies for prevention and treatment of disordered eating behaviour in this vulnerable group.

Keywords: Type 1 Diabetes, Diabetes, Attentional Bias, Disordered Eating, Cognition, Young Adult, Dot-probe
The Relationship between Attentional Bias to Food and Disordered Eating in Females with Type 1 Diabetes

Effective management of type 1 diabetes mellitus (T1DM) requires a complex self-care program of daily dietary management, blood glucose monitoring, exercise, and insulin treatment, in order to maintain optimum glycaemic control (Austin, Senecal, Guay, & Nouwen, 2011; Rassart, Luyckx, Moons, & Weets, 2014b). These characteristics of T1DM and its management have been proposed to increase the risk of both clinical and subclinical disordered eating behaviors, particularly in young adult females (Colton et al., 2015; Wisting, Frøisland, Skrivarhaug, Dahl-Jørgensen, & Rø, 2013; Young et al., 2013). Disordered eating behavior in this group may include dietary restriction, intense exercise, binge eating, and compensatory purging behaviors such as self-induced vomiting, abuse of laxatives and diuretics, and insulin manipulation, which is a compensatory weight loss behavior that is uniquely available to individuals with T1DM (Colton, Olmsted, Daneman, Rydall, & Rodin, 2007; Custal et al., 2014). Disordered eating behaviour in those with T1DM is associated with reduced glycaemic control, and consequently, significant morbidity and mortality such as macro- and micro-vascular complications and diabetic ketoacidosis (Goebel-Fabbri et al., 2008; Hanlan, Griffith, Patel, & Jaser, 2013; Ismail, 2008; Peveler et al., 2005; Young et al., 2013). The unique and serious consequences of disordered eating behavior for females with T1DM highlight the importance of better understanding the factors which may contribute to these difficulties, so that prevention and intervention strategies may be developed.

Cognitive theories of disordered eating posit that maladaptive schemata trigger biased cognitive processing of eating/weight-related information, causing concerns about food, body weight, and shape to become engrained (Brooks, Prince, Stahl, Campbell, & Treasure, 2011; Shafran, Lee, Cooper, Palmer, & Fairburn, 2007; Smeets, Roefs, van Furth, & Jansen, 2008). This results in a range of biases in attention, memory, and judgment of eating-related stimuli
and contributes to the development and maintenance of disordered eating behavior (Johansson, Ghaderi, & Andersson, 2005; Smeets et al., 2008). Attentional bias can be inferred when an individual preferentially attends to or avoids a particular environmental stimulus, providing a measure of the motivational salience of that stimulus (Mobbs, Van der Linden, d'Acremont, & Perroud, 2008; Voon, 2015). The visual dot probe task is one task which provides a measurement of visual attention distribution (MacLeod, Mathews, & Tata, 1986). This is a reaction time task that was developed based on the assumption that individuals respond more quickly to a probe appearing in the same spatial location as the stimulus to which they were attending (Shafran et al., 2007). By requiring participants to simultaneously attend to two separate stimuli, this task can detect differences between attention directed towards or away from a particular stimulus relative to the paired stimulus, providing an indirect measure of attentional bias (Smeets et al., 2008; Wolz, Fagundo, Treasure, & Fernández-Aranda, 2015). Attentional bias scores using target stimuli presented for 500ms (the most commonly applied duration) are taken to reflect automatic early attentional processes.

Theory and empirical evidence suggest that individuals with disordered eating behavior differ from individuals without disordered eating behavior in terms of how food stimuli are processed (Faunce, 2002; Wolz et al., 2015). Incentive-sensitization theory has been used to explain observed altered patterns of attention for food cues, particularly those high in sugar or fat (Doolan, Breslin, Hanna, & Gallagher, 2015; Nijs & Franken, 2012). This theory proposes that repeated exposure to the rewarding properties of highly palatable food results in modification of the brain’s dopaminergic reward systems, enhancing attentional awareness for visual cues in the environment related to these foods. This is theorised to alter subsequent food-seeking and eating behaviors, often resulting in disordered patterns and obesity (Doolan et al., 2015).
Previous research has explored the role of early attentional processing in eating contexts, finding significant relationships with disordered eating behavior including clinical eating disorder status (Brooks et al., 2011), binge-eating (Lyu, Zheng, & Jackson, 2016), obesity (Wolz, Fagundo, Treasure, & Fernandez-Aranda, 2015), and trait eating styles such as external and restrained eating (Hepworth, Mogg, Brignell, & Bradley, 2010). In line with incentive-sensitization theory, a recent review describes evidence for attentional biases to unhealthy food cues in obese samples and samples with binge-eating symptoms (Kakoschke, Aarts, & Verdejo-Garcia, 2018). In a more heterogeneous sample of females with clinical eating disorders (3 with anorexia nervosa, 6 with bulimia nervosa, and 14 with eating disorders not otherwise specified) versus those without, a significant attentional bias to food stimuli was also found, as participants with disordered eating responding more quickly to images of high-calorie foods (such as pizza) and more slowly to images of low-calorie foods (such as celery) relative to control images (animals) (Shafran et al., 2007).

In contrast, a study by Giel et al. (2011) revealed that individuals with anorexia nervosa showed attentional disengagement from food images (versus images of household items). Moreover, Veenstra and de Jong (2012) found that following exposure to food images (versus household items), both patients with restrictive anorexia-like symptoms and healthy controls demonstrated attentional avoidance of high-calorie foods, and yet the patients with relatively severe anorexia-like eating pathology showed strong attentional engagement with low-calorie foods. These studies demonstrate that eating-related ABs may manifest either toward or away from the threat-related or target stimulus category (Zvielli, Bernstein, & Koster, 2014). The Hypervigilance-Avoidance Hypothesis posits that threat-related ABs may manifest as an initial (automatic) attention orientation towards the threatening stimulus, followed by an attentional avoidance of these stimuli once top-down processes are recruited (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van, 2007; Mogg, Bradley, De Bono, & Painter,
1997). However, this pattern of attentional bias has not been shown consistently across studies (Nijs & Franken, 2012), which may reflect sample-specific patterns of early attentional processing.

In comparison to individuals without diabetes, individuals with T1DM are required to be far more cognizant of the food choices they make, and they must continually plan ahead in terms of balancing food intake and insulin dosage. Management of T1DM can also leave individuals feeling deprived as a result of rigid dietary restrictions (Merwin et al., 2014). This persistent focus on food intake, portion sizes, and meal planning required to manage their condition explains why individuals with T1DM are particularly vulnerable to eating disturbances (Hanlan et al., 2013). Given the vulnerability of individuals with T1DM to disordered eating behavior (e.g., Colton et al., 2015), and the mechanisms proposed to contribute to attentional bias in groups without diabetes, it follows that individuals with T1DM may exhibit unique patterns of attention regarding food stimuli, as this category has particular salience for this group. However, it is unlikely that pathways proposed by existing theory (e.g., incentive-sensitization theory or the hypervigilance-avoidance hypothesis) fully capture the experiences of people with T1DM, due to enhanced conflict between reward and threat characteristics of food cues (and their unique relationship to diabetes management and overall health status).

Thus, the current study aimed to explore relationships between food attentional bias scores and disordered eating behavior in a young adult female population with T1DM (compared to a control group without diabetes) to examine whether unique attentional biases in this group (to either healthy foods, unhealthy foods, or both) may explain disordered patterns of eating-related thoughts and behaviors. A female-only sample was chosen as this is the established high-risk group for disordered eating in populations with type 1 diabetes (e.g., Colton et al., 2015; Wisting et al., 2013). It was expected that the relationship between
disordered eating behaviour and food attentional bias scores would be stronger in the T1DM sample versus a sample without diabetes. No directional hypotheses were made regarding this relationship. A secondary aim was to establish if rates of disordered eating behavior were significantly different between the groups with versus without type 1 diabetes. It was expected that disordered eating behaviour would be more prevalent in the diabetes versus the control group. To the authors’ knowledge, this is the first study to explore attentional bias to food cues in a sample with T1DM; thus, hypotheses are exploratory. The relationships explored in this study are important, because if altered attentional processing can be reliably implicated in disordered eating patterns in populations with T1DM, these attentional components may become the focus of screening, prevention, or intervention strategies in the future.

**Methods**

**Participants**

Participants were 97 females aged 18-40 years ($M = 26.15$, $SD = 7.00$) who were either diagnosed with T1DM for more than a year ($n = 41$) or without any form of diabetes (control: $n = 56$). No participants had a current diagnosis of an eating disorder. Two participants were pregnant at the time of participation, and one participant reported retinopathy. Main analyses were therefore conducted with and without these participants, with no changes in the pattern or statistical significance of the results; thus, the full sample was retained. Participants were recruited via a register of participants from a previous study (Broadley, White, & Andrew, 2018), University advertising, a targeted mail-out organised through the Australian National Diabetes Services Scheme, and paid social media advertising. The T1DM group were on average 4 years (or less than 1 $SD$) ($M = 28.57$, $SD = 6.74$) older than the control group ($M = 24.64$, $SD = 7.12$), $p = .008$. The T1DM group also had an average body mass index (BMI) 2 points higher than the control group (T1DM group
$M = 25.91, SD = 4.29$; control group $M = 23.18, SD = 5.21), p = .001$. No outliers were identified on age or BMI, thus the full sample was retained for analysis. Further participant characteristics are reported in Table 1.
Table 1

Participants Demographic and Clinical Information

<table>
<thead>
<tr>
<th></th>
<th>T1DM (N = 41)</th>
<th>Controls (N = 56)</th>
<th>All (N = 97)</th>
<th>T-test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>M (SD)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (yrs)*</td>
<td>28.34 (6.24)</td>
<td>24.55 (7.15)</td>
<td>26.15 (7.00)</td>
<td>t (95) = 2.72, p = .008</td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>15.94 (2.66)</td>
<td>15.00 (2.89)</td>
<td>15.40 (2.82)</td>
<td>t (95) = 1.62, p = .109</td>
</tr>
<tr>
<td>BMI* (kg/m²)</td>
<td>25.52 (4.42)</td>
<td>22.69 (3.89)</td>
<td>23.89 (4.34)</td>
<td>t (95) = 3.35, p = .001</td>
</tr>
<tr>
<td>Age of onset (yrs)</td>
<td>13.77 (8.18)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes duration (yrs)</td>
<td>14.57 (7.74)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>7.80 (1.33)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pump (vs. injections)</td>
<td>27 (65.85%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Retinopathy</td>
<td>1 (2.44%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Hypoglycaemia (ever)</td>
<td>12 (29.27%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetic keto-acidosis history</td>
<td>12 (29.27%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suboptimal HbA1c (&gt;8%)</td>
<td>17 (41.46%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Early onset diabetes (&lt;7yrs)</td>
<td>8 (19.51%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*p < .05; BMI = body mass index; HbA1c = haemoglobin A1C; Demographic and clinical information was collected via self-report. “Poor control” was defined by a self-reported current HbA1c of more than 8%.

Procedure and Measures

Participation involved completion of an initial online survey (completed in the order listed below), followed by an in-person laboratory session to undertake a computer-based visual probe task. One hundred and sixty participants initially completed the online survey, and 102 (63.75%) were available to then attend an in-person session. On average, participants attended their in-person session 9.4 (SD = 14.08) days after completing the
survey. Upon completion of both parts, participants were given either course credit or a $10 shopping voucher. The university’s Human Research Ethics Committee approved the procedures for this study and all participants provided written informed consent.

Online Survey.

**Demographics and validity checks.** All participants answered a range of items pertaining to demographics (e.g., gender, age, height, weight) and participants with diabetes provided clinical information (e.g., age at diagnosis, insulin management method (injection or pump), current HbA1c level, and experience of any T1DM-related complications). An additional 2 validity items were interspersed amongst other items in the survey battery to check for invalid participant responses (e.g., “please answer ‘sometimes’ to this question.”).

**Disordered eating behavior.** The 28-item Eating Disorder Examination Questionnaire (EDE-Q) measured disordered eating behavior, thoughts, and attitudes across four subscales: restraint, eating concern, shape concern, and weight concern, which combine into a global scale score (Fairburn & Beglin, 1994). Participants respond either on Likert scales (0-6), or by specifying the frequency of specific behaviors (e.g., episodes of binge-eating or purging) over the past 28 days. The EDE-Q yields mean scores (0-6) across 4 subscales (restraint, eating concern, weight concern, and shape concern) and a total mean “global” score across these subscales. Higher scores indicate greater disordered eating, and cut-off scores indicate those at high risk for a clinical eating disorder (Mond, Hay, Rodgers, Owen, & Beumont, 2004). Classification into the ‘clinical risk’ category for the EDE-Q requires participants to score >2.3 on the EDE-Q Global subscale and to have reported either one or both of the following behaviors: an ‘objective’ binge episode or use of exercise as a compensatory weight control behavior (Mond et al., 2004). Objective binge episodes are defined by two features (corresponding to items 13 and 14 of the EDE-Q): a loss of control over eating at the time of the episode, and consumption of an ‘objectively large’ amount of food. The scale also allows
for classification of ‘regular’ disordered eating behaviors, defining regular objective binge eating and driven exercise episodes as occurring at least once per week over the preceding 4 weeks (Mond et al., 2004). This measure has been validated in non-clinical samples (e.g., Luce, Crowther, & Pole, 2008) and administered in both Australian and T1DM populations (d’Emden et al., 2013; Mond et al., 2004). Internal consistency for the EDE-Q Global scale in the present sample was high ($\alpha = .947$).

**Visual probe task.** The visual probe task was used to assess attentional bias to food stimuli (Posner & Rothbart, 2007; Zucker, Moskvich, & Soo, 2011). For the present study, the task stimuli and presentation parameters were adapted from Castellanos et al. (2009).

**Materials.** This study used twenty food images selected from a larger database (Castellanos et al., 2009), comprising 10 ‘healthy’ low-calorie foods (e.g., strawberries, carrots) and 10 ‘unhealthy’ high-calorie foods (e.g., hot chips, chocolate cake). Each food image was paired with a non-food image (either stationery (e.g., pencils), a household item (e.g., clothes pegs, as in Figure 1), or a nature item (e.g., pine cones)), based on matching criteria of colour, complexity and brightness. Twenty distractor neutral images of nature scenes were used as filler pairs to reduce monotony during the task (Castellanos et al., 2009). Images were 24-bit with maximum dimensions of 300 pixels x 400 pixels, and a minimum visual angle of 2° corresponding to the distance between the inner edges of the image pairs.

**Procedure.** The visual probe task was performed on laboratory computers (screen width = 48 cm, height = 27 cm, resolution = 1920 $\times$ 1080) using E-Prime 2.0 software, with participants seated approximately 60 cm from the screen. The visual probe task was the final task administered following a battery of executive function assessments (taking approximately 30mins). Each trial began with a fixation cross (+) in the centre of the screen for 500ms, followed by a pair of images to the left and right sides of the screen for 500ms. A visual probe (*) then briefly appeared in the location of one of the previous images, and the
participant was required to indicate its location as quickly and accurately as possible, by pressing ‘1’ (left) or ‘2’ (right) on their keyboard. The visual probe disappeared after response or after a maximum of 1500ms (see Figure 1 for a schematic description of a typical trial). The distractor images were presented twice, and the critical food images were presented 4 times each. In total, the task commenced with 8 practice trials (using images of simple shapes), followed by a block of 40 control trials and 80 critical trials in randomised order. All probe and image location combinations were counterbalanced.

<table>
<thead>
<tr>
<th>Fixation</th>
<th>Image</th>
<th>Probe</th>
</tr>
</thead>
<tbody>
<tr>
<td>(500ms)</td>
<td>(500ms)</td>
<td>(Maximum of 1500ms)</td>
</tr>
</tbody>
</table>

*Figure 1. Schematic example of a trial in the visual probe task.*

**Statistical Analyses & Preliminary Checks**

Consistent with Castellanos et al. (2009), critical trial reaction time data which were less than 200ms or greater than 1500ms were considered outliers and excluded from calculations of attentional bias scores. Task performance was high overall, with 96% of the sample achieving >93% accuracy ($M = 97.5\%, SD = 3.77\%$). Attentional bias scores for healthy food and unhealthy food cues were each calculated by subtracting the mean reaction time of correct responses to critical trials when the probe replaced the respective food image from the mean reaction time for critical trials when the probe replaced the paired neutral image. Positive reaction time scores indicated a tendency to direct attention towards food, and negative scores indicated a tendency to direct attention away from food.
Statistical analyses were conducted using IBM’s Statistical Package for the Social Sciences (SPSS) Version 25. Data were screened for invalid responses, and overall, 5 participants were excluded from further analyses on this basis, resulting in a total sample of 97 participants. A missing values analysis showed that overall rates of missing data were very low (< 5%) with non-significant Little’s MCAR tests, indicating that missing data were missing completely at random. Thus, an Estimation Maximisation (EM) imputation was used for questionnaire data to ensure a complete dataset (Tabachnick & Fidell, 2007). The data were checked for multivariate outliers via consultation of Mahalanobis and Cook’s distance values, and no influential outliers were identified, with all Cook’s distance values below the accepted cut-off value of 1 (largest = 0.33) (Weisberg, 1983). Assumption checks of residual scores revealed no significant breaches of normality, linearity, or homoscedasticity in the dataset. No multicollinearity was noted between predictor variables; thus, all key multivariate assumptions were met and analyses proceeded. Due to the exploratory nature of the research questions (i.e., the aim to explore potential relationships between key variables), we did not adjust for multiple comparisons (Bender & Lange, 2001).

Preliminary analyses were conducted to determine the prevalence of clinically significant disordered eating behavior, as well as specific disordered eating behaviors, across the sample. Logistic regression analyses were used to determine whether the prevalence of disordered eating behaviors differed according to T1DM status. Independent samples t-tests (bootstrapped, bias-corrected and accelerated, 1000 samples) were then conducted to determine any differences across EDE-Q subscales and total scores and attentional bias scores according to T1DM status. To explore the main research questions, regarding the interactive relationships between T1DM status and attentional bias scores on disordered eating behavior (EDE-Q global scores), two split-plot, customised ANOVAs; (allowing for both continuous and categorical independent variables (IVs), using the general linear model)
were conducted, following procedures outlined by Decoster (2004). T1DM status (dummy coded as 0 = no diabetes and 1 = T1DM diagnosis) was entered as a categorical IV, and attentional bias scores were entered as a continuous IV via the covariate step. The interaction term between these two IVs was specified using a custom model (Decoster, 2004). Age and BMI were entered as control variables (covariates) in these analyses, due to the significant differences observed between samples with versus without T1DM. Separate ANOVAs were run for healthy food attentional bias scores and unhealthy food attentional bias scores. The interaction between the two key IVs (T1DM status and attentional bias scores) was the key focus of the ANOVA analyses. An a priori power analysis using G*Power (Faul, Erdfelder, Buchner & Lang, 2009) was conducted to calculate the sample size required to detect a medium effect ($F = 0.3$) with statistical power of 0.8 in these models, yielding an estimate of $N = 90$.

**Results**

**Descriptive Data and Preliminary Analyses**

Regarding disordered eating behavior, Table 2 shows the number of participants who engaged in regular binge-eating episodes, self-induced vomiting, laxative use, and regular driven exercise over the preceding 28 days. It also shows the number of participants who scored above the clinical cut-off for the EDE-Q. Logistic regression analyses showed that individuals with T1DM were significantly more likely than control participants to engage in regular binge-eating episodes (i.e., at least once per week for the preceding 4 weeks, as defined by Mond et al., 2004), and were significantly more likely to score above the clinical cut-off on the EDE-Q relative to those without diabetes (26.83% vs. 7.14%, respectively). However, these differences did not reach statistical significance when adjusted for age and BMI, likely reflecting statistical power issues, given the comparable odds ratios across the two analyses (see Table 2). Table 3 provides means and SDs for key variables across EDE-Q
sub-scales and attentional bias scores according to T1DM status, as well as Cronbach’s alphas for the whole sample.

Table 2

Prevalence of T1DM and Control Participants Engaging in Disordered Eating Behavior Across the Past 28 Days

<table>
<thead>
<tr>
<th></th>
<th>T1DM</th>
<th>Controls</th>
<th>Total</th>
<th>Logistic regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (%)</td>
<td>OR</td>
<td>p</td>
<td>OR^ p^</td>
</tr>
<tr>
<td>Regular† objective binge‡</td>
<td>14 (34.25%)</td>
<td>9 (16.07%)</td>
<td>23 (23.71%)</td>
<td>2.812 .036* 2.750 .075</td>
</tr>
<tr>
<td>Vomiting</td>
<td>2 (4.88%)</td>
<td>2 (3.57%)</td>
<td>4 (4.12%)</td>
<td>1.385 .750 1.561 .693</td>
</tr>
<tr>
<td>Laxatives</td>
<td>0</td>
<td>2 (3.57%)</td>
<td>2 (2.06%)</td>
<td>&lt;.001 .998 &lt;.001 .998</td>
</tr>
<tr>
<td>Regular† driven exercise</td>
<td>8 (19.51%)</td>
<td>8 (14.29%)</td>
<td>16 (16.49%)</td>
<td>1.455 .495 1.396 .580</td>
</tr>
<tr>
<td>EDE-Q clinical</td>
<td>11 (26.83%)</td>
<td>4 (7.14%)</td>
<td>15 (15.46%)</td>
<td>4.767 .013* 4.661 .053</td>
</tr>
</tbody>
</table>

* p <.05; N = 97 (41 with T1DM, 56 control participants). EDE-Q = Eating Disorders Examination – questionnaire, OR = odds ratio. †“regular” refers to a frequency of at least 1 episode per week over the preceding 4 weeks. ‡objective binge episodes are defined by responses to items 13 and 14 on the EDE-Q. This definition takes into account both a) eating what other people would consider an “unusual” amount of food and b) feeling a sense of loss of control over their eating (Mond et al., 2004). ^adjusted for age and BMI.

Table 3

Questionnaire Data according to T1DM status: Means (SDs), T-tests, and Cronbach’s Alpha

<table>
<thead>
<tr>
<th></th>
<th>T1DM</th>
<th>Controls</th>
<th>Total</th>
<th>T-test</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>Range</td>
<td>M (SD)</td>
<td>Range</td>
<td>p value</td>
</tr>
<tr>
<td>EDE-Q Restraint</td>
<td>1.69 (1.44)</td>
<td>0 - 5.00</td>
<td>0.94 (1.02)</td>
<td>0-3.80</td>
<td>†.009**</td>
</tr>
<tr>
<td></td>
<td>EDE-Q Eating Concern</td>
<td>1.15 (1.25)</td>
<td>0 - 4.20</td>
<td>0.74 (0.93)</td>
<td>0-5.80</td>
</tr>
<tr>
<td></td>
<td>EDE-Q Shape Concern</td>
<td>2.80 (1.80)</td>
<td>0 - 5.75</td>
<td>2.06 (1.35)</td>
<td>0-6.00</td>
</tr>
<tr>
<td></td>
<td>EDE-Q Weight Concern</td>
<td>2.42 (1.66)</td>
<td>0 - 5.80</td>
<td>1.64 (1.37)</td>
<td>0-5.80</td>
</tr>
<tr>
<td></td>
<td>EDE-Q Global</td>
<td>2.01 (1.37)</td>
<td>0 - 4.94</td>
<td>1.34 (1.03)</td>
<td>0-5.05</td>
</tr>
<tr>
<td>AB Healthy (ms)</td>
<td>4.16 (25.67)</td>
<td>-37.45 – 3.46</td>
<td>65.42 –</td>
<td>3.75</td>
<td>.892</td>
</tr>
<tr>
<td>AB Unhealthy (ms)</td>
<td>0.41 (22.86)</td>
<td>-78.72 – 4.97</td>
<td>55.37 –</td>
<td>3.07</td>
<td>.339</td>
</tr>
</tbody>
</table>
Main Analyses

Table 4 presents the ANOVA results for the effect of attentional processing of healthy food and unhealthy food, respectively, on EDE-Q global scores. Results showed a significant and large ($\eta^2_p = 0.31$, $p < 0.001$) main effect of BMI, such that higher BMI was associated with higher disordered eating scores. No significant main effect of attentional bias scores for healthy food, or interaction between T1DM status and attentional bias scores for healthy food was shown. However, a significant interaction was found between T1DM status and attentional bias scores for unhealthy food, showing a small to medium effect size ($\eta^2_p = 0.05$, $p = .030$). Follow-up analyses of this interaction were performed using separate linear regression models for the groups with and without T1DM, with age and BMI entered in step 1 as control variables, attentional bias scores for unhealthy food added in step 2, and EDE-Q global scores as the dependant variable. These follow-up analyses revealed a moderate negative relationship between attentional bias scores and EDE-Q scores in the group with T1DM, such that a tendency to direct attention away from unhealthy food was associated with greater disordered eating ($r = -.319$, $p = .032$). In contrast, for the control group, there was no significant relationship between attentional bias scores and EDE-Q global scores ($r = -.047$, $p = .642$). This significant interaction between T1DM status and attentional bias scores for unhealthy food was additionally inspected visually using the regression approach recommended by DeCoster (2004)¹ (see Figure 2).

¹Please note: These plots provide a visual representation of the bivariate relationship between attentional bias to unhealthy food scores and EDE-Q global scores separately for those with vs. without T1DM. However, these plots are not adjusted for age and BMI.
Table 4

ANOVA Summary for the Effects of Attentional Bias to Food Scores on Disordered Eating

(EDE-Q Global scores)

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Effect</th>
<th>F</th>
<th>p</th>
<th>$\eta^2_p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB Healthy Food</td>
<td>T1DM</td>
<td>1.80</td>
<td>.183</td>
<td>.020</td>
</tr>
<tr>
<td></td>
<td>AB</td>
<td>0.15</td>
<td>.708</td>
<td>.002</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>1.44</td>
<td>.233</td>
<td>.016</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>33.38</td>
<td>&lt;.001*</td>
<td>.271</td>
</tr>
<tr>
<td></td>
<td>AB x T1DM</td>
<td>0.15</td>
<td>.903</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>AB Unhealthy Food</td>
<td>T1DM</td>
<td>1.65</td>
<td>.202</td>
<td>.018</td>
</tr>
<tr>
<td></td>
<td>AB</td>
<td>5.61</td>
<td>.020*</td>
<td>.059</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>1.66</td>
<td>.201</td>
<td>.018</td>
</tr>
<tr>
<td></td>
<td>BMI</td>
<td>40.42</td>
<td>&lt;.001**</td>
<td>.310</td>
</tr>
<tr>
<td></td>
<td>AB x T1DM</td>
<td>4.88</td>
<td>.030*</td>
<td>.051</td>
</tr>
</tbody>
</table>

Note. $\eta^2_p$ = partial eta squared. $N = 96$ (T1DM $n = 40$, control $n = 56$). $df = 1$. AB = attentional bias, BMI = body mass index.

*p < .05, **p < .001.

Figure 2. Scatterplots of the relationship between attentional bias scores for unhealthy food cues and Eating Disorder Examination- Questionnaire (EDE-Q) scores plotted against the least-squares regression line in the T1DM group (left panel) and the control group (right panel).

Discussion

This study demonstrated that young adult females with T1DM were approximately 4.7 times more likely than a control group without diabetes to score above the clinical cut-off on
the EDE-Q, and approximately 2.7 times more likely to report engagement in regular binge-eating episodes. However, the statistical significance of these differences was not retained after adjusting for age and BMI, likely due to reduced statistical power in a sample of this size. The higher rates of disordered eating in the group with diabetes confirms various reports from other studies that young adult females with T1DM are vulnerable to eating-related disturbances (e.g., Colton et al., 2015; Wisting et al., 2013; Young et al., 2013) which can have significant negative impacts on their physical and psychological wellbeing. This was the first investigation into the relationship between early attentional processing of unhealthy and healthy food cues and disordered eating behavior in a population with T1DM. There were no overall differences in attentional bias scores for food images between groups with and without T1DM. This may indicate that attentional processing needs to be considered in the context of how it relates with disordered eating thoughts, attitudes, and behaviors, and with BMI/weight status. Indeed, results provided partial support for the prediction that the relationship between attentional bias scores and disordered eating behaviour would be more pronounced for young adult females with T1DM versus those without diabetes. In this sample, evidence of a significant relationship between greater attentional bias scores away from unhealthy food cues and greater disordered eating behavior (adjusting for age and BMI) was demonstrated for the participants with diabetes only. No significant relationships between attentional bias scores for healthy food cues and disordered eating behavior were found in either group.

The noted direction of attention away from unhealthy food aligns with some studies in populations without diabetes who exhibit disordered eating behavior (e.g., Giel et al., 2011; Veenstra & de Jong, 2012), but do not align with similar studies which have shown an attentional bias towards food/weight-related stimuli (e.g., Castellanos et al., 2009; Shafran, Lee, Cooper, Palmer, & Fairburn, 2007). A key difference between the Giel et al. (2011),
Veenstra and de Jong (2012) and Shafran et al. (2007) studies was that the former two focused on restrictive-type disordered eating behaviour only, whereas the latter examined a broader sample with clinical eating disorders (including only 3 participants diagnosed with anorexia). It may be the case that attentional bias scores away from unhealthy food cues are associated with a more restrictive presentation, and that these restrictive tendencies align more with the T1DM context, which would explain the similar pattern of results in the current study and Giel et al. Additionally, the incentive-sensitization theory and additional empirical evidence suggests that attentional bias towards food is associated with obesity (which is often associated with a more disinhibited eating style) (Castellanos et al., 2009b; Nijs & Franken, 2012), and thus, disordered eating behavior such as restraint and eating/shape/weight concern may be associated with the opposite pattern of attention orientation. Developing restrictive attentional tendencies would be theoretically consistent with the sometimes-restrictive nature of the T1DM treatment context.

In this sample, attentional differences were only exhibited in the context of unhealthy, threatening (i.e., to emotional and physical health) food cues; not to food cues generally. This finding may align with threat-related theories of attentional bias which suggest that selective attention to threatening information is implicated in disordered behavior (e.g., Bar-Haim et al., 2007; Harrison, Sullivan, Tchanturia, & Treasure, 2010). The Hypervigilance-Avoidance Hypothesis proposes that attentional bias towards threat-related cues is demonstrated in very early stages of attention (100-300ms) and is followed by attentional bias away from these stimuli after some top-down processing has occurred (Bar-Haim et al., 2007; Wolz et al., 2015; Zucker et al., 2011). The dot-probe task does not allow for the differentiation between attentional components required to confirm this pattern, thus, this hypothesis should be explored in future research in people with T1DM.
As would be expected, the current study showed that weight status (i.e., BMI) was significantly related to global scores on the EDE-Q. Previous studies exploring attentional biases to food cues and their relationship with disordered eating (e.g., binge-eating) have also confirmed the relevance of weight status, noting significant differences between obese versus normal weight participants on measures of attentional processing (Castellanos et al., 2009; Kakoschke et al., 2018). Weight status was not a key focus of the present investigation, and key relationships could not be explored separately in normal weight versus overweight or obese participants due to limited statistical power. However, the emergence of BMI as a strong and significant predictor in our models provides a basis to further explore the role of BMI in the relationship between attentional biases and disordered eating in populations with versus without T1DM.

**Strengths, Limitations, and Future Research**

This study had some notable strengths and limitations; and overall provides an initial basis for further research investigation, pending replication in larger independent samples. A strength of the current study was the use of previously validated image pairs from the study by Castellanos et al. (2009), which had been closely matched in terms of potentially confounding visual variables such as image complexity, colour, and brightness. While this yielded very high internal validity, the external validity could be debated. In real life, food approach and avoid decisions are likely not triggered by highly similar competing visual cues of food versus stationery, but rather by competing types of foods and associated cognitions. It would therefore be interesting to explore how these findings compare with a study employing different food-related image sets. Extending on this, future research should also explore other stimulus categories related to disordered eating, such as weight/shape related stimuli.

A second key strength was the separate examination of attentional bias scores for healthy and unhealthy food cues, given that biases of attention have been shown to vary
depending on this criterion (Freijy, Mullan, & Sharpe, 2014). This more fine-grained analysis is particularly important given the T1DM population of interest, for whom maintaining a healthy diet is crucial, and for whom avoidance or approach of different foods may be embedded into their treatment regimens (Hanlan et al., 2013). While the focus on ‘healthy’ and ‘unhealthy’ foods was useful, it would be interesting for future studies to extend upon these findings with food cues selected and analysed on the basis of carbohydrate content or glycaemic index, which may be more salient distinctions for diabetes populations, and may represent categories that are more robustly associated with disordered eating behavior (with less variability around the mean). It is possible, for example, that individuals with T1DM may respond differently to images of foods with high carbohydrate content than people without diabetes, given their need to continuously balance carbohydrate intake with insulin dosage (Austin et al., 2011; Corr, DeYoung, & McNaughton, 2013). A limitation of this study was that post-rating of images by participants in terms of “healthiness” or positive/negative valence were not included. Future studies should include these measures to ensure that stimuli categories are meaningful for populations with diabetes. Similarly, it would also be useful for future studies to assess state hunger, satiety, and blood glucose levels at the time of attentional bias assessment, as these factors may also influence aspects of attention (Gailliot & Baumeister, 2007; Nijs, Muris, Euser, & Franken, 2010).

Another limitation of the current study is the sensitivity and accuracy of the measures employed. Future studies should consider assessing disordered eating behaviour via interview and weight status via objective measures. The employment of ocular-tracking technology and/or electroencephalographic event-related potentials as complementary measures would also be useful in future studies, to examine more comprehensively the time course of attention in relation to food stimuli (Wolz et al., 2015; Zucker et al., 2011). The Hypervigilance-Avoidance hypothesis suggests that perhaps earlier components of attention
(within the 100-300ms time frame) would reveal a bias towards unhealthy food in individuals with T1DM and greater disordered eating behavior, followed by the slightly later behavioral avoidance. As previous studies have shown inconsistent results regarding this early hypervigilance (e.g., Giel et al., 2011), this hypothesis should be explored in future research in groups with T1DM.

Finally, while the results of this study are consistent with evidence that has shown attentional avoidance of high calorie images in females with eating disorders (e.g., Brooks et al., 2011); the current study did not show these relationships in the control sample without diabetes. It is possible that this is due to the very low rates of disordered eating behavior exhibited in the control group sample in this study. Further research should examine if attentional bias relationships are similar in samples with and without T1DM who exhibit comparable rates of disordered eating behavior, or if the findings in the current study reflect diabetes-specific mechanisms.

**Conclusion**

Overall, this study showed a high risk for disordered eating behavior in a sample of young females with T1DM. Additionally, this was the first study to explore early attentional processing of healthy and unhealthy food cues in females with T1DM (relative to a sample of females without diabetes). This is an important avenue for future research, as young females with T1DM have been shown to be particularly vulnerable to disordered eating behavior and difficulties managing the dietary aspects of their treatment regimens. This study showed that vulnerability to disordered eating behavior in this clinical group may be uniquely related to cognitive associations between unhealthy foods and threat or negative emotion. Future research should explore these relationships further in a larger sample, to confirm that these associations are robust. Subject to future replications, extending knowledge in this area may
ascertain whether preventative or treatment strategies aimed at addressing emotional salience of food cues or modifying attention orientation, may be developed for this vulnerable group.
References


