Comprehensive Psychoneuroendocrinology 7 (2021) 100065

Contents lists available at ScienceDirect

Comprehensive Psychoneuroendocrinology

journal homepage: www.sciencedirect.com/journal/comprehensive-psychoneuroendocrinology

Selective attention to threat, anxiety and glycaemic management in adolescents with type 1 diabetes☆

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ARTICLE INFO

Keywords:
Diabetes
Anxiety
Attentional bias
Selective attention
Glycaemic control

ABSTRACT

Objective: Previous research has established that adolescents with type 1 diabetes (T1D) experience more anxiety symptoms than their healthy peers and are also more likely to develop an anxiety disorder. Research in cognitive psychology has found that selective attention favouring the processing of threatening information causally contributes to elevated levels of anxiety; however, this process has not been investigated in the context of T1D. The current study examined whether selective attention for threatening information contributes to the association between anxiety and glycaemic management in adolescents with T1D.
Methods: Participants completed a dot-probe task to assess selective attention for diabetes-related threatening information and general non-diabetes-related threatening information and we examined the associations between these measures and measures of HbA1c and anxiety.
Results: Findings suggest that individual differences in anxiety vulnerability do not predict HbA1c alongside the attentional bias for threatening information.
Conclusions: The attentional bias for threatening information makes a contribution to the relationship between anxiety and glycaemic management and may represent a target for therapeutic intervention to both reduce anxiety and improve glycaemic management

1. Introduction

Children and adolescents with type 1 diabetes (T1D) are at greater risk for experiencing anxiety than young people without diabetes [1]. Besides the known association between living with a chronic disease and increased incidence of psychological disorders, young people with T1D have the added psychological stressor of having to frequently check and manage their blood glucose levels (BGL). In a large sample of adolescents with T1D, as many as 17% were identified as needing clinical care for their anxiety [2].

Experiencing frequent anxiety impacts quality of life and psychosocial functioning [3]. Excessive anxiety may in turn compromise effective T1D management and longer-term health outcomes. Associations have been found between elevated levels of anxiety and a range of poor diabetes-related outcomes, including higher haemoglobin A1c (HbA1c) levels [4], less frequent BGL monitoring [2] and more poorler diabetes management [5,6]. State anxiety is also predictive of poor glycaemic management as far as 12 months into the future [4].

We still lack a clear understanding of the mechanisms that underlie the association between anxiety and glycemic management in T1D. One such mechanism that has not been examined in this population is attentional selectivity for threatening information. Individuals who fail to effectively monitor their BGL or do not selectively attend to diabetes-related threatening information (e.g. feeling lightheaded or faint) run the risk of hypo- or hyperglycemia. Given the importance of attending to such information, it is worth considering how this cognitive process may

☆ This study was funded by a grant from the Princess Margaret Hospital Foundation. Daniel Rudaizky and Colin MacLeod are supported by an ARC Laureate Fellowship FL170100167. Ashleigh Lin is funded by a NHMRC Career Development Fellowship (#1148793).

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https://doi.org/10.1016/j.cpnec.2021.100065
Received 30 November 2020; Received in revised form 13 April 2021; Accepted 3 June 2021
Available online 6 June 2021

contribute to the association between anxiety and glycaemic management.

1.1. Attentional bias for threatening information and anxiety vulnerability

Investigations into the cognitive processes that underlie anxiety have demonstrated that variation in the tendency to selectively attend to threatening information is related to variation in the tendency to experience anxious symptomatology [7]. This selective processing of threatening information is also known as an anxiety-linked attentional bias for threat.

The most widely used method to assess anxiety-linked attentional bias under controlled conditions is the dot-probe task [8]. In this task, participants are briefly exposed to a pair of words on a computer screen that differ in emotional tone, typically one is threatening and the other is non-emotional. After 500 ms the words disappear and a small visual probe (e.g. a small line) then appears in the locus of either word. The participants are required to discriminate the orientation of the line (either horizontal or vertical) as quickly and accurately as possible.

Previous research has demonstrated that individuals who are high in trait anxiety reliably demonstrate a speeding to process probes that appear in the spatial locus of threatening words [8]. This finding is interpreted to support the proposal that these individuals selectively allocate visual attention towards the locus of threatening information.

1.2. Attentional bias for threatening information, anxiety and glycaemic management in T1D

In order for an adolescent to maintain optimal glycaemic levels they need to adhere to a complex treatment regimen. One of the key components of this regimen is to actively and frequently monitor many different pieces of diabetes-related information, such as BGL or food intake. This information may be considered threatening to an adolescent with T1D given the negative consequences that could arise from failing to attend to it. Actively monitoring these various pieces of information requires appropriate selective attentional processing in order to register the necessary information before executing an appropriate behavioural response. Previous research has reliably demonstrated a causal relationship between selective attention for threatening information and elevations in anxiety vulnerability [9]. As such, it may be the case that being required to frequently engage in monitoring of diabetes-related threatening information leads to elevations in anxiety in children and adolescents with T1D. Indeed this assertion is supported by previous research demonstrating an increased tendency for children and adolescents with T1D to experience elevations in anxiety [10].

While previous bodies of research have separately shown that elevated anxiety is associated with poorer glycemic management in adolescents with T1D and also that an attentional bias for threatening information is causally related to elevated levels of anxiety, it remains to be determined if anxiety is impacting glycaemic management independent of the selective attentional processing of threatening information. If selective attention for threatening information does contribute to the association between anxiety and glycaemic management, then this cognitive process may represent a potential therapeutic target to both improve emotional functioning and maintain optimal glycaemic levels in adolescents with T1D.

Previous research has shown that individuals' typically show an attentional bias towards stimuli that are concern relevant, for example, people with social phobia show an attentional bias towards socially relevant stimuli [11]. In light of this research it may be important to assess selective attention for both diabetes-related threatening information as well as general threat-related information in order to uncover evidence of concern-relevant attentional biases. By examining the relationship between measures of attentional bias that account for both of these categories of information, and measures of glycaemic levels and trait anxiety, we could then determine whether either or both of these attentional biases are associated with glycaemic levels and/or anxiety in young people with T1D.

1.3. The current study

In the current study we recruited a cross-sectional sample of adolescents with T1D to complete a dot-probe task designed to provide an assessment of attentional bias for general threat information and diabetes-related threat information. In addition, we assessed individual differences in the experience of anxiety and individual glycaemic levels over the preceding 12 months. This design enabled us to address the following three aims: 1) to replicate the finding that elevated levels of anxiety are associated with poorer glycaemic management; 2) to determine if glycaemic management was associated with a measure of attentional bias for threatening information; and 3) to determine if anxiety continues to predict glycaemic management alongside the attentional bias for threatening information.

2. Method

2.1. Participants

A cross-section of adolescents with T1D aged between 12 and 18 years participated in this study. Participants were recruited from the Diabetes Service at Princess Margaret Hospital, between September 2015 and March 2016. The only exclusion criterion was a lack of English or cognitive capacity to provide informed consent and complete the tasks and questionnaires. The present study was approved by the Human Ethics Research Committee. A total of 62 adolescents (29 males) were recruited into the study. Mean age at time of assessment was 15.62 (SD = 1.63, range 12.17–18.42 years). Sample demographics are presented in Table 1. A power analysis determined that a sample size of 48 was needed to detect a medium effect ($R^2 = 0.2$) in our regression analysis with alpha level .05 and power of .8 indicating that our recruited sample would be sufficient.

Table 1
Characteristics of the study sample.

Variable	Value
N, (% female)	62 (53% female)
Age, M (SD)	15.62 (1.63)
Age of diagnosis of T1D in years, M (SD)	9.16 (4.29)
Time since diagnosis of T1D in years, M(SD)	6.46 (4.54)
STAI-T, M (SD)	39.77 (10.62)
HbA1c over past year in %, M (SD)	7.96 (1.44)
BGL prior to assessment in mmol/L, M (SD)[a]	11.11 (5.75)
N treatment regimen – daily injections	32
N treatment regimen - pump	30

[a] BGL prior to assessment was not available for 16 participants.

2.2. Measures

2.2.1. Spielberger trait anxiety inventory (STAI-T; [12])

Individual differences in anxiety vulnerability were assessed with the STAI-T. The STAI-T has been used extensively as a standard measurement tool for assessing anxiety in adolescents [13] and consists of 20 items that ask the participant to rate the frequency with which they generally experience particular symptoms associated with anxiety on a Likert scale ranging from 1 = Never to 4 = Almost Always. Scores can range from 0 to 80 with higher scores reflecting higher levels of trait anxiety. The STAI-T has been shown to have good reliability ($\alpha = 0.93$) and validity [14].

2.2.2. Glycaemic management

Mean glycated haemoglobin (HbA1c) over the past year was employed as a measure of glycaemic management. HbA1c data is obtained at each three-monthly visit to the Diabetes Clinic. HbA1c is widely regarded as the gold standard for assessing glycaemic management. The measure reflects the average blood glucose over the lifespan of the red blood cells containing it but does not capture variations in blood glucose, for example, discrete episodes of hypo or hyperglycaemia [15]. HbA1c levels are reported as a percentage and a target HbA1c of <7% is recommended for all age groups. However, each child should typically have their targets individually determined to maintain as close to normal functioning as possible [16,17].

2.2.3. Stimulus word/letter string pairs

Two stimulus sets were created, one to assess attentional bias towards diabetes-related threat and one to assess attentional bias towards general (non-diabetes-related) threat. Each stimulus set consisted of 120 words, half of which were threatening in emotional tone, the other half of which were non-threatening. Diabetes-related threat words were chosen on the basis that they represented the potential harmful consequences of diabetes-related complications (e.g. coma, hypoglycaemia), non-threatening diabetes-related words were chosen on the basis that they were of particular relevance to someone with type 1 diabetes but did not represent something threatening in and of themselves (e.g. camps, exercise). A pool of general threat and non-threat words were selected from a study previously conducted by Ref. [18]. Each word was paired with a random letter string of the same number of characters as the word. For example, the word “HYPOGLYCAEMIA” was paired with the random letter string “AHBWJVBNXWZEH”. All word stimuli were rated by two adolescents with T1D prior to the study for both valence and diabetes-relevance to ensure that they met the requirements of the task design.

Word pairs were presented on the screen in all uppercase letters in Courier font. A full list of stimulus word pairs can be found in Table 5 in Appendix 1 along with more details describing the process of stimulus set creation and selection.

2.3. Dot-probe task

The dot-probe task was employed to measure attentional bias for diabetes-related threat and general threat. The task has been effectively employed in adolescent samples in previous research (e.g. Ref. [19]. Each dot-probe trial began with the presentation of a white fixation cross in the middle of the screen for 500 msec. Immediately following, a stimulus word pair appeared on the screen in white letters. One stimulus of the pair was presented just above the location where the fixation cross had previously appeared and one just below. The vertical distance between the stimuli was 4 cm, subtending a 2° angle of separation. The position of the word was randomized, appearing with equal frequency either in the upper or lower screen locus. The stimulus pair remained onscreen for 500 msec, whereupon the words disappeared and a small visual probe appeared on the screen in one of the two locations previously occupied by the stimuli. The probe was a small red line, either horizontal or vertical, appearing with equal frequency in either the location of the word or the location of the letter string. The participant was required to identify the orientation of the probe and respond using the left and right arrows on the keyboard. The left arrow was used to indicate a horizontal probe and the right arrow was used to indicate a vertical probe. The time from probe presentation until response was recorded. The probe remained onscreen until a response was recorded. Once the participant had made a response, the trial was over. There was a short inter-trial interval of 500 msec until the next trial began.

The task consisted of 240 trials, half of which were employed to assess attentional bias for diabetes-related threat and the other half for general threat. The order of the trials was random. However, it was ensured that across each block of 60 trials there was an equal ratio of diabetes-related and general threat bias assessment trials.

The primary behavioural measures obtained from the dot-probe task were the attentional bias index (ABI) scores. If a person selectively attends to threat then the reaction times (RT) to respond to probes that are presented in the locus of threat stimuli will be faster than the RT to process probes in the location of the letter string. As such, we subtract the mean RT for trials on which the probe appears in the locus of the threat word from the mean RT on trials on which the probe appears in the locus of the letter string:

i. Threat trials: (mean RT when probe in location of letter string – mean RT when probe in location of threat word)

The same computation is then undertaken for trials on which a non-threatening stimulus word is presented.

ii. Non-threat trials: (mean RT when probe in location of letter string – mean RT when probe in location of non-threat word)

The score from non-threat trials is then subtracted from threat trials.

iii. Attentional Bias Index Score = Non-threat trials – Threat trials

Two ABI scores were calculated; one ABI that reflects individual differences in attentional selectivity towards diabetes-related threatening information only and another ABI that reflects individual differences in attentional selectivity towards general threat information only. For both of these indices, a higher score reflects a greater attentional preference for threatening relative to non-threatening information, i.e. the individual tends to selectively attend to threat rather than non-threat information.

2.4. Procedure

The experiment was conducted in a dedicated testing room when the adolescent attended their regular clinic appointment. Questionnaires assessing emotional functioning and psychological symptoms were completed on a laptop. After completing these questionnaires, participants were provided with instructions on how to complete the dot probe task and given the opportunity to complete a block of practice trials. They were permitted to repeat this block of practice trials as many times as needed until they felt that they properly understood the task. The participants then completed the assessment version of the dot-probe task.

2.5. Analyses plan

The analyses conducted in this study were designed to test each of the three aims reported earlier. Firstly, to test whether elevated levels of

anxiety are associated with poorer glycaemic management a bivariate correlation was conducted between STAI-T scores and HbA1c. If findings from previous research are replicated, then we would expect to find a significant correlation between these measures such that higher STAI-T scores are associated with higher HbA1c levels. Secondly, to determine if glycaemic levels were associated with either attentional bias for diabetes-related threatening information or attentional bias for general threat information a bivariate correlation was conducted between HbA1c levels and each of the attentional bias scores. Lastly, to test the hypothesis that attentional bias for either or both diabetes-related threat and general threat contribute to the relationship between anxiety and HbA1c levels, a stepwise regression was conducted with HbA1c levels as the DV, STAI-T scores were entered at the first step and both attentional bias scores were entered at the second step. If anxiety does indeed continue to predict HbA1c levels at the second step of the regression then this will suggest that attentional bias for threat does not contribute to the relationship between anxiety and HbA1c.

3. Results

Two participants were identified as having specific language difficulties and were excluded from analyses. A further two participants did not complete the dot-probe task in its entirety and one participant was missing HbA1c data. Sample demographics are presented in Table 1. All available data was included in the final analyses.

The mean response latencies observed under the differing task conditions were used to calculate the ABI for diabetes-related information and the ABI for general threat information for each participant. In computing these indices, response latencies from trials on which participants made an incorrect response were excluded. On average, accuracy rates were very high across the sample at 97.28% ($SD = 2.28$). In addition, outliers were identified using a 99% confidence level, meaning that scores greater than 2.58 standard deviations from participant's mean latency for the experimental condition were excluded. A total of 1609 trials (5.88%) across all participants were excluded from the analysis. The mean response latencies obtained under each condition in the dot-probe task are shown in Table 3 along with the resulting ABIs.

In order to determine whether participants' HbA1c (average over last year) was associated with individual differences in trait anxiety we ran a bivariate correlation between STAI-T scores and HbA1c levels. This correlation was significant $r = 0.302$, $N = 58$, $p = .021$, indicating that higher HbA1c was associated with higher trait anxiety.

We next ran a correlation between ABIs and STAI-T scores. Both the ABI for diabetes-related information, $r = -0.301$, $N = 58$, $p = .022$, and the ABI for general threat information, $r = -0.389$, $N = 58$, $p = .003$, were found to be negatively correlated with STAI-T scores. This suggests that higher levels of anxiety were associated with an attentional avoidance of threat-related information. This same inverse relationship was found between HbA1c and the ABI for general threat information only, $r = -0.263$, $N = 57$, $p = .048$, whereby higher HbA1c was associated with lower ABI scores for general threat information, indicating an attentional avoidance of general threat information. No significant correlation was found between HbA1c and the ABI for diabetes-related threat ($r = -0.112$, $N = 57$, $p = .41$) (see Table 2).

In order to determine whether anxiety continued to predict HbA1c independent of the attentional bias for general threat information we ran a stepwise regression with HbA1c as the dependent variable, reported in Table 3. In the first step we entered STAI-T anxiety scores and the regression model was significant $F(1, 55) = 5.97$, $p = .018$. STAI-T scores were found to predict independent variance in HbA1c ($t(55) = 2.44$, $p = .018$). In the second step we added both ABIs (diabetes-related and general threat); the regression model was no longer significant, $F(3,53) = 2.43$, $p = .078$, and none of the predictor variables were found to predict independent variance in HbA1c (all p's > 0.08). These findings suggest that individual differences in anxiety vulnerability do not independently predict glycaemic management alongside the attentional bias for general threat information (see Table 4).

Table 2
Correlations between study variables.

Variable	HbA1c	STAI-T	ABI - diabetes related threat	ABI - general threat	Age
HbA1c	1				
STAI-T	.302[a]	1			
ABI - diabetes related threat	-.112	-.301[a]	1		
ABI - general threat	-.263[a]	-.389[b]	.324[a]	1	
Age	.116	.100	-.095	-.013	1

[a] $p < .05$.

[b] $p < .005$.

Table 3
Mean response latencies in milliseconds obtained under each experimental condition on the dot-probe task.

	Probe in locus of word		Probe in locus of Non-word		
Trial type	Threat/Non-word pair, M (SD)	Non-threat/Non-word pair, M (SD)	Threat/Non-word pair, M (SD)	Non-Threat/Non-word pair, M (SD)	Bias Index, M (SD)
Diabetes-related trials	626.93 (129.50)	626.63 (138.35)	637.90 (140.71)	635.84 (142.11)	−1.76 (49.53)
General threat trials	627.22 (131.57)	617.48 (130.71)	631.96 (137.24)	634.09 (136.58)	11.87 (53.37)

Table 4
Summary of step-wise regression.

Variables	B	SE_B	β	t	P	R	R^2	F	p
Step 1									
STAI-T	.05	.02	.31	2.44	.02[a]	.31	.10	5.97	.02[a]
Step 2									
STAI-T	.04	.02	.25	1.75	.09	.35	.12	2.43	.08
Diabetes-related ABI	.00	.00	.02	.13	.90				
General threat ABI	-.01	.00	-.17	−1.16	.25				

[a] $p < .05$.

4. Discussion

The aims of the current study were threefold: 1) to replicate the finding that elevated levels of anxiety are associated with poorer glycaemic management; 2) to determine if glycaemic management was associated with a measure of attentional bias for threatening information; and 3) to determine if anxiety continues to predict glycaemic management alongside the attentional bias for threatening information. The current findings lend further support to previous research by demonstrating an association between elevated levels of anxiety and poorer glycaemic management in youth with T1D. We also found an association between our measure of attentional bias for general threat and glycaemic management, indicating that attentional avoidance of general threat information is associated with poorer glycaemic management. Furthermore, we found evidence to suggest that this attentional avoidance of threatening information makes a significant contribution to the association between anxiety and glycaemic management. Specifically, we found that trait anxiety did not continue to predict variance in glycaemic management after accounting for the measures of attentional bias. To our knowledge this is the first study to demonstrate that an attentional avoidance of threat may contribute to the association between anxiety and glycaemic management. There are several important implications of this finding for clinical practice and future research.

Interestingly, only the measure of attentional bias for general threat information (and not the measure of attentional bias for diabetes-related threat information) was found to be associated with glycaemic management. That is, a higher degree of selective attention away from threatening information is associated with poorer glycaemic management but only for general threat and not when the threat was diabetes specific. One possible explanation for this is emotion regulation. One of the ways in which adolescents with T1D can reduce the experience of anxiety is to reduce selective attentional processing for threatening information (i.e. paying less attention to diabetes-related threating information; [20]. Engaging in this kind of emotion regulation would have negative consequences for the effective monitoring of their diabetes symptoms. Previous research has shown that adolescents with elevated trait anxiety tend to misattribute non-diabetes related (neutral sensations) symptoms to fluctuations in blood glucose levels [21].

It stands to reason that avoiding these types of diabetes-related threat signals would in turn be helpful for down regulating one's experience of anxiety. In our sample of adolescents we found an inverse association between attentional bias for threat and trait anxiety such that an increased levels of trait anxiety were associated with a reduction in attentional bias for threatening information. Much like previous research in samples with low to moderate trait anxiety [20,22], emotion regulation could also explain the nature of this association. Although this is beyond the scope of the current study, future research could test this hypothesis by examining the patterns of attentional bias and emotional functioning in people with T1D that demonstrate good glycaemic management and compare them to youth with T1D who demonstrate poor glycaemic management. Any observable differences between these two cohorts would provide valuable information about the patterns of cognition that underpin healthy emotional functioning and good glycaemic management. In particular, future research could usefully explore whether or not a sample of high functioning adolescents who maintain optimal HbA1c levels perceive diabetes-related threats (as assessed on questionnaire measures such as the Diabetes Distress Scale ([23]) in a different manner to adolescents with suboptimal HbA1c levels).

Of course, these results must be interpreted with some caution as the regression reported here included the attentional bias score for diabetes-related threat as a predictor in the second step despite no evidence of an association between this bias score and HbA1c levels. Although this approach was adopted due to our a priori hypothesis, which made no predictions that either biases for diabetes-related or general threat would differentially contribute to HbA1c levels, it should also be recognized that the regression model reported here demonstrated relatively poor fit ($R^2 = 0.12$). When taking a post-hoc approach to the regression analysis and only including the attentional bias score for general threat in the second step of the regression, the regression model remained significant ($F(2, 54) = 3.69$, $p = .031$) at this second step, however, it was also the case that trait anxiety scores no longer predicted independent variance in HbA1c alongside attentional bias scores for general threat alone ($p = .08$). While these results provide complementary support for the idea that attentional bias for threat may contribute to the relationship between anxiety and HbA1c, again, this model had relatively poor fit ($R^2 = 0.12$) and these conclusions should be considered preliminary.

Having now demonstrated that glycaemic management in youth with T1D is associated with selective attention to threatening information, specifically that HbA1c levels were negatively correlated with attentional bias scores for general threat, an important next step for future research is to investigate whether this attentional bias is causally related to glycaemic management. Previous research has established that attentional bias can be manipulated by exposing participants to training versions of the dot-probe task used in this study [24]. In these training versions of the dot-probe the position of the probe is constrained to always appear in the locus of one particular type of stimulus, either threat or non-threat. Such training versions of these tasks can induce changes in attentional biases consistent with the direction of training. Importantly, researchers have found that this change in attentional bias is associated with a concomitant change in emotional functioning (e.g. training selective attention away from threatening information leads to a decrease in anxious symptomatology; [25]. In our sample we found a negative association between trait anxiety scores and the attentional bias indices such that elevated levels of trait anxiety were associated with attentional avoidance of threatening information. By delivering attentional bias modification to adolescents with T1D designed to induce attentional processing of threatening information (i.e. training attention towards threat), it is possible that this may reduce anxiety which may in turn increase monitoring of relevant diabetes-related information and consequently increase glycaemic management in this population. Such research would not only potentially deliver therapeutic benefits for young people with T1D but would also enrich our understanding of the relationship between glycaemic management and anxiety.

It was somewhat surprising that no association was found between the measure of attentional bias for diabetes-related threat information and glycaemic management given that this information is of particular relevance for our cohort. It may be that individuals with T1D are unable to distinguish between threatening and non-threatening diabetes-related information, or that such a distinction may be too artificial, as all diabetes-related information would be pertinent to their health status and thus require attentional processing. As a result it would be difficult to pick up any potential individual differences in attentional bias to diabetes-related threat information with our measure from the dot-probe task and this may explain why we were unable to find a relationship with glycaemic management. As a preliminary investigation into this potential explanation in our sample we calculated a composite bias score collapsing across both threat and non-threat stimuli for diabetes-related information and compared this to our measure of attentional bias for general non-threat information.[1] The resulting attentional bias score reflects the attentional bias for diabetes related information relative to general neutral information. However, the correlation between this new composite diabetes attentional bias score showed no significant correlations with either HbA1c measures or trait anxiety scores. This finding suggests that it was not the case that participants in this study had an attentional bias for diabetes-related

[1] We thank an anonymous reviewer for this helpful suggestion.

information relative to non-threat general information. However, it could still be the case that the words employed in this study were simply not personally relevant enough for each of the participants in the study. The fact that the mean ABI score for diabetes-related threat was so close to zero (0.27) lends some support to this idea; as, on average, across the sample, participants showed neither a bias towards, or an avoidance of, this particular type of stimuli. Future research could usefully explore the possibility of employing more tailored stimuli for each participant whereby prior to attentional assessment, each participant rates a set of diabetes-related words for threat value. Subsequently, only the words rated as being highly threatening by that participant would be used for that participant. It is possible that selecting stimuli in such a personalized manner may render the task more effective at uncovering attentional biases for diabetes-related threat.

It is also worth noting that the sample employed in the study all demonstrated reasonably good glycaemic management (mean HbA1c was <8), as such, absence of an attentional bias for diabetes-related threatening information observed in this study may simply reflect adaptive attentional processing in those adolescents with appropriate glycaemic management. For example, a recent study by Ref. [26]; found that in a sample of youth with T1D with poor glycaemic management, reductions in attentional bias to diabetes-related information were associated with improved self-management behaviours. However, it should also be noted that in light of the reasonably good glycaemic management demonstrated by the participants in the recruited sample, it is difficult to know whether these findings would generalize to other samples of adolescents with T1D that may have higher HbA1c levels or higher levels of anxiety. Furthermore, the sample in this study was not assessed in terms of whether or not they experienced anxiety specifically in relation to performing diabetes-specific tasks, as such, we have no information pertaining to whether or not this sample of adolescents experienced any perceptions of diabetes as threatening and this may be an important factor to consider in future research investigating the relationship between attentional processing, anxiety and glycaemic management.

Of more general importance, this research highlights the need to further investigate the mechanisms that contribute to the association between anxiety and glycaemic management. From the current study, we conclude that trait anxiety does not independently predict glycaemic management alongside selective attention to threatening information. However, future research could usefully seek to determine the particular nature of this relationship and whether anxiety-linked attentional bias causally contributes to the association between anxiety and glycaemic management and therefore represents a potential therapeutic target to improve glycaemic management in youth with T1D.

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix. Word stimuli

The word stimuli that were employed in the task were selected through a three step process. First, an initial pool of words was collected after consultation with diabetes clinicians and the attentional bias literature to reflect words across four different categories 1) diabetes-related threatening 2) diabetes-related non-threatening 3) general (non-diabetes related) threatening and 4) general (non-diabetes related) non-threatening. We then selected 60 words that best reflected each of these four categories, resulting in a pool of 240 words. In order to ensure that these words did indeed reflect the intended categories and were suitable for the experiment, two adolescents with Type 1 Diabetes were then asked to rate each word in terms of its valence and its relevance to diabetes. These ratings were averaged across the two raters and checked against the intended categories for each selected word. The final set of 240 words employed in the dot-probe task are shown below.

Table 5
List of word stimuli used in the dot-probe task.

	Diabetes-related Threatening	Diabetes-related Non-Threatening	General Threatening	General Non-Threatening
1	Coma	Hot	Nag	Hug
2	Pain	Diet	Hate	Sit
3	Risk	Fits	Decay	Bow
4	Sick	Food	Choke	Help
5	Alarm	Pump	Drown	Chat
6	Death	Meal	Vomit	Hold
7	Dizzy	HbA1c	Punch	Kiss
8	Fever	Sleep	Guilt	Rest
9	Itchy	Sport	Annoy	Wipe
10	Moody	Sugar	Punish	Bend
11	Prick	Bread	Beaten	Lick
12	Tired	Fruit	Cancer	Turn
13	Weary	Camps	Tumour	Teach
14	Virus	Doctor	Bashed	Thank
15	Clinic	Eating	Mangle	Loyal
16	Denial	Hungry	Mauled	Touch
17	Drowsy	Lantus	Damage	Taste
18	Cramps	Levels	Murder	Clean
19	Nausea	School	Detest	Brush
20	Needle	Travel	Ignore	Stand
21	Stress	Lancet	Reject	Swing
22	Unwell	Active	Betray	Kneel
23	Wobbly	Habits	Insult	Strum
24	Disease	Alcohol	Accuse	Humour
25	Fatigue	Glucose	Pester	Invite
26	Parched	Control	Destroy	Praise
27	Seizure	Fitness	Stabbed	Reward
28	Shaking	Humalog	Assault	Please

(*continued on next page*)

Table 5 (*continued*)

	Diabetes-related Threatening	Diabetes-related Non-Threatening	General Threatening	General Non-Threatening
29	Smoking	Insulin	Damaged	Admire
30	Thirsty	Ketones	Torture	Caress
31	Illness	Lollies	Punched	Cuddle
32	Surgery	Parties	Condemn	Juggle
33	Lancing	Testing	Despise	Pulsed
34	Bullying	Tablets	Jealous	Petted
35	Headache	Chemist	Snubbed	Include
36	Inflamed	Fasting	Hassled	Impress
37	Injuries	Routine	Bleeding	Inspire
38	Numbness	Drinking	Strangle	Respect
39	Restless	Educator	Crippled	Cherish
40	Scratchy	Exercise	Collapse	Popular
41	Sweating	Hospital	Detested	Involve
42	Symptoms	Intimacy	Disgrace	Forgive
43	Vomiting	Research	Inferior	Embrace
44	Weakness	Tingling	Offended	Commute
45	Blindness	Pharmacy	Bothered	Stretch
46	Confusion	Holidays	Mutilated	Applause
47	Exhausted	Chocolate	Destroyed	Honoured
48	Infection	Sleepover	Disfigure	Faithful
49	Irritable	Dietician	Execution	Motivate
50	Lethargic	Novorapid	Neglected	Chatting
51	Injections	Urination	Rejection	Massaged
52	Amputations	Procedure	Unpopular	Muscular
53	Convulsions	Breathless	Upsetting	Pregnant
54	Nervousness	Monitoring	Dishonour	Squeezed
55	Palpitations	Compliance	Intolerant	Encourage
56	Complications	Transplant	Unfriendly	Gratitude
57	Embarrassment	Medication	Complained	Appreciate
58	Hypoglycaemia	Lightheaded	Suffocating	Permission
59	Disorientation	Carbohydrates	Electrocute	Appreciated
60	Hyperglycaemia	Responsibility	Threatening	Congratulate

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