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The Relationship between Time Perspective and Self-Monitoring of Blood Glucose among people with Type 1 Diabetes

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Abstract

Background. Self-monitoring of blood glucose helps people with type 1 diabetes to maintain glycaemic control and reduce the risk of complications. However, adherence to blood glucose monitoring is often suboptimal. **Purpose.** Like many health behaviours, self-monitoring of blood glucose involves exerting effort in the present in order to achieve future benefits. As such, the present research explored whether individual differences in time perspective – specifically, the extent to which people have a balanced time perspective – are associated with the frequency with which people with type 1 diabetes monitor their blood glucose and, thus, maintain glycaemic control. **Methods.** Adults with type 1 diabetes completed measures of time perspective, feelings associated with monitoring, attitudes toward monitoring, and trait self-control. Objective data regarding the frequency with which participants monitored their blood glucose levels and their long-term glycaemic control was extracted from their medical records. **Results.** Hierarchical regression analyses and tests of indirect effects (N = 129) indicated that having a more balanced time perspective was associated with more frequent monitoring of blood glucose, and as a result, better glycaemic control. Further analyses (N =158) also indicated that there was an indirect relationship between balanced time perspective and monitoring of blood glucose via the feelings that participants associated with monitoring and their subsequent attitudes toward monitoring. **Conclusions.** These findings point to the importance and relevance of time perspective for understanding health-related behaviour and may help to inform interventions designed to promote self-monitoring of blood glucose in people with type 1 diabetes.

Keywords: Type 1 diabetes, balanced time perspective, self-monitoring of blood glucose, glycaemic control, HbA_{1c} levels

The Relationship between Time Perspective and Self-Monitoring of Blood Glucose among people with Type 1 Diabetes

Diabetes Mellitus is a group of metabolic disorders that are characterised by an excess of glucose circulating in the blood stream, known as hyperglycaemia. Type 1 diabetes accounts for approximately 5 to 10% of cases of diabetes [1] and occurs due to the destruction of insulin-producing cells that impairs the body's ability to metabolise glucose. The management of type 1 diabetes is directed toward maintaining healthy blood glucose levels in order to reduce the risk of microvascular complications (e.g., damage to the eyes, kidneys, and nervous system) and macrovascular complications (e.g., heart attack, heart failure, and strokes), that can have serious and life-debilitating consequences, including loss of vision, limb amputation, and premature death [2, 3].

Self-monitoring of blood glucose has been identified as a key strategy in maintaining glycaemic control [4]. Obtaining reliable information about glycaemic variations enables the individual and their healthcare providers to make informed adjustments to their therapeutic regime (e.g., diet, exercise, insulin dosage [5]). Indeed, numerous studies have shown that frequent monitoring of blood glucose (i.e., three to four times daily) is associated with reductions in glycated haemoglobin (HbA_{1c}; a measure of long-term glycaemic control) and improved health outcomes [6, 7]. However, despite clear recommendations and the potential benefits, adherence to blood glucose monitoring is often suboptimal, with studies suggesting that 21% of adults never engage in glucose monitoring [8] and 60% monitor less frequently than recommended [9]. As such, identifying factors that are associated with adherence to glucose monitoring has become a focal point of research [10].

Factors associated with Self-Monitoring of Blood Glucose

Previous research has demonstrated that demographic factors (e.g., older age, male gender, ethnic minority, low socioeconomic status, and lower levels of education) and biomedical factors (e.g., longer time since diabetes diagnosis and less intensive treatment regimens) are associated with less frequent monitoring of blood glucose [9, 10]. However, researchers have recently highlighted the importance of identifying psychological factors (e.g., locus of control and compensatory beliefs [11]) that can help to understand self-management behaviours in diabetes, especially as such research could inform health education and interventions designed to promote adherence [12].

Many psychological models of health behaviour suggest that the extent to which a person values future benefits over more immediate benefits or costs is an important determinant of health behaviour [13]. For example, the possible benefits of regularly monitoring blood glucose (e.g., lower likelihood of kidney failure, stroke, and heart attack) may not come to fruition for many years, while at the same time monitoring blood glucose may involve short-term costs (e.g., inconvenience, discomfort, difficulty, or fear of a “bad” monitoring result). Furthermore, it has been suggested that some people are motivated to avoid monitoring their blood glucose as it serves as a reminder of their diabetes diagnosis [14]. Thus, while some individuals may value their future health and will take steps to ensure it, others may discount their future health in favour of more immediate benefits or to avoid short-term costs. The present research therefore suggests that time perspective may be associated with the extent to which people monitor their blood glucose.

Time Perspective

Time perspective refers to cognitive and affective biases that people have for the past, present, and / or future, and has been found to motivate and influence behaviour [15]. According to Zimbardo and Boyd [15], there are five time perspectives: (i) Past-negative, reflecting an adverse view of the past, (ii) past-positive, reflecting a warm and sentimental view of the past, (iii) present-hedonistic, reflecting a pleasure-seeking attitude toward life, (iv) present-fatalistic, reflecting the belief that much of life is determined by fate, and (v) future time perspective, reflecting a greater consideration of the effects of current actions on future outcomes. Previous research has indicated that specific time perspectives are associated with specific health behaviours (for a review, see [16]), including the health behaviours of people with diabetes. For example, studies have shown that a future time perspective is associated with more adaptive behaviours, such as medication adherence [17], weight management behaviours (e.g., eating less fatty foods and engaging in more physical activity [18]), and stronger intentions to attend a diabetes screening appointment [19].

Although this evidence seems to suggest that having a future time perspective is beneficial for engaging in health-protective behaviours, researchers have also argued that focusing on one time perspective, while excluding others, can be detrimental [20]. For example, while having a future time perspective may encourage people to set goals for the future (e.g., to achieve long-term glycaemic control), it would be difficult for an individual to form plans in order to achieve these goals without using information from the past (e.g., past knowledge of how certain foods influence their blood glucose levels) or the present (e.g., information obtained from monitoring their blood glucose). As such, it has been suggested that having a balanced time perspective is most beneficial, where people are able to draw from multiple timeframes and switch flexibly between them in order to meet situational demands and achieve their goals [21, 22]. Interestingly, however, although differences in a balanced time perspective have been explored in relation to psychological well-being (e.g., happiness and life satisfaction [23]), very little research has explored the relationship between balanced time perspective and specific health behaviours. Given the importance of blood glucose monitoring for managing the symptoms of type 1 diabetes and promoting future health, the present research explored whether individual differences in a balanced time perspective was associated with the frequency with which participants monitored their blood glucose, and thus, achieved long-term glycaemic control.

Why might a Balanced Time Perspective be associated with Blood Glucose Monitoring?

There are several reasons to think that differences in the extent to which people have a balanced time perspective may be associated with the frequency with which they monitor their blood glucose levels. First, empirical research has indicated that having a more balanced time perspective is associated with higher levels of positive affect (e.g., the extent to which people tend to feel excited and determined) and lower levels of negative affect (e.g., the extent to which people tend to feel scared and ashamed [23]). Therefore, individuals with a more balanced time perspective may associate more positive feelings with monitoring (e.g., monitoring their blood glucose makes them feel relaxed and reassured) and so monitor more frequently as a result. Second, having a more balanced time perspective may be associated with people's attitudes toward monitoring their blood glucose. Specifically, individuals with a more balanced time perspective may consider monitoring to be more beneficial and worthwhile for their future health (i.e., they have more positive attitudes toward monitoring) and so monitor more frequently as a result. Additionally, given that past research has highlighted that people's feelings toward a particular behaviour (or the emotions that they associate with performing the behaviour) can influence their subsequent attitudes toward that behaviour (for a review, see [24]), it also seems likely that feelings and attitudes are related, such that positive feelings toward monitoring promote positive attitudes toward monitoring (i.e., these mediators may occur sequentially).

Finally, previous research has demonstrated that having a more balanced time perspective is associated with greater self-control ability [25]. Furthermore, greater self-control ability has been found to be associated with better glycaemic control in adolescents with type 1 diabetes [26]. Therefore, there may be an indirect relationship between balanced time perspective and blood glucose monitoring via self-control ability. In light of these considerations, the present research will explore three possible mediators of the relationship between a balanced time perspective and the frequency of blood glucose monitoring: (i) The feelings that people associate with monitoring, (ii) people's attitudes toward monitoring, and (iii) self-control ability.

The Present Research

People with type 1 diabetes need to self-monitor their blood glucose in order to maintain glycaemic control and reduce the risk of future health complications. The present research proposes that differences in people's time perspective and, specifically, differences in the extent to which people hold a balanced time perspective, may be associated with the frequency with which people with type 1 diabetes monitor their blood glucose, and thus, achieve long-term glycaemic control. A second aim of the present research was to explore potential reasons why balanced time perspective may be associated with self-monitoring. Specifically, the following hypotheses were tested:

Hypothesis 1: A more balanced time perspective will be associated with more frequent self-monitoring of blood glucose and, as a consequence, lower HbA_{1c} levels, indicating better long-term glycaemic control.

Hypothesis 2: The feelings that people associate with monitoring, their attitudes toward monitoring, and their self-control ability, will mediate the relationship between the extent to which people hold a balanced time perspective and the frequency with which people self-monitor their blood glucose levels.

Method

Study Setting and Recruitment

The study was conducted in collaboration with the Adult Diabetes Outpatient Clinics at Sheffield Teaching Hospitals NHS Foundation Trust in the UK. This Trust has two diabetes centres, based at the Royal Hallamshire Hospital and the Northern General Hospital. Potential participants were identified by nurse specialists, clinicians, and research coordinators at these diabetes centres. To be eligible to participate, individuals needed to be aged 18 or over, have had a diagnosis of type 1 diabetes for at least 12 months (as assessed by the date on which they were clinically diagnosed), and have access to an electronic glucose meter to monitor their blood glucose.

Eligible participants were provided with a recruitment pack that contained a letter of invite, an information sheet, a consent form, a questionnaire, and a stamped addressed envelope. This information was either sent to eligible participants via post, or it was given to them when they attended an appointment at the clinic. Participants were able to decide whether they would like to complete a paper copy of the consent form and questionnaire, or whether they would prefer to provide this information online via the survey software, Qualtrics (https://www.qualtrics.com/). Participants who chose to complete a paper copy of the questionnaire were asked to return this, along with their consent form, using the envelope provided. Participants did not receive any incentives for taking part in this research.

Between April 2016 and January 2017, 779 postal questionnaires were distributed. Of those contacted, 165 (21%) agreed to participate. A further 74 participants were approached at the diabetes outpatient clinics and 22 (30%) agreed to take part. Four participants (2%) were removed from the analyses because they did not meet the inclusion criteria (i.e., they did not have a diagnosis of type 1 diabetes), resulting in a final sample of 183 participants.

Participant Characteristics

Table 1 displays the demographic and biomedical characteristics of the sample. Participants were aged between 18 and 88 years ($M = 49.95$; $SD = 17.18$). Approximately one half of the sample were female (49%) and the majority were White British (97%). An Index of Multiple Deprivation (IMD) score was calculated using postcode data. The English IMD ranks every postcode area in England from the most deprived area (ranked 1) to the least deprived area (ranked 32,844). Due to this wide range, ranks were divided by 1,000 for ease of comprehension. The mean IMD for the present sample was 18.01 (*SD* = 98.00) which is slightly higher than the overall mean rank for England (16.42), suggesting that the sample was, on average, marginally more deprived than the population of England as a whole. Participants were, on average, 21 years post diagnosis at the time that they completed the study (*SD* = 15.99; range: 1 to 73 years). The mean HbA_{1c} for the sample was 63 mmol/mol (*SD* = 14.71), which is higher than the recommended value (≤ 48 mmol/mol; [27]), indicating that the sample tended to have difficulties controlling their blood glucose levels. The mean HbA_{1c} level for the current sample was also compared to the mean HbA_{1c} level for other patients with Type 1 diabetes under the care of Sheffield Teaching Hospitals. Research co-ordinators at these diabetes centres identified 1,437 patients who matched our inclusion criteria (i.e., had Type 1 diabetes for longer than 12 months and were aged 18 or over). The average HbA_{1c} level for this patient group was 68.4 mmol/mol, which is slightly higher (*d* = 0.37) than the average HbA_{1c} level for our sample (i.e., 62.99 mmol/mol). Although this suggests that our sample tended to have difficulties controlling their blood glucose, they had slightly better glycaemic control than the average patient under the care of Sheffield Teaching Hospitals.

Design and Procedure

The study employed a cross-sectional design in which participants were asked to complete measures of time perspective, the feelings that they associate with monitoring their blood glucose levels, their attitudes toward monitoring their blood glucose, and their ability to exert self-control. Permission was also obtained for the research team to access participants' Diasend database and medical records in order to extract information regarding the frequency with which they monitored their blood glucose levels and their long-term glycaemic control (i.e., their HbA_{1c} level). The study was presented to participants as an investigation into the factors that influence blood glucose monitoring and glycaemic control;

however, no details were provided on the specific factors of interest or how they might relate to these outcomes.

Measures

Demographics. The following demographic information was collected from participants: Date of birth, gender, ethnicity, country of birth, postcode, occupation, employment status, and level of education. Participants were also asked to indicate whether they had participated in the Dose Adjustment for Normal Eating (DAFNE) training course. This course is offered to adults with type 1 diabetes across the UK and provides formal training on how to adjust insulin doses according to diet (e.g., carbohydrate intake) and lifestyle (e.g., amount of exercise). The course trains attendees to monitor their blood glucose levels before each meal in order to guide the calculation of their insulin dose.

Time perspective. Time perspective was measured using Zimbardo's Time Perspective Inventory (ZTPI; [15]). This measure contains 56-items that assess five dimensions of time perspective; (i) past-positive (e.g., "It gives me pleasure to think about my past"), (ii) past-negative (e.g., "I often think of what I should have done differently in my life"), (iii) present-fatalistic (e.g., "It doesn't make sense to worry about the future, since there is nothing I can do about it anyway"), (iv) present-hedonistic (e.g., "I find myself getting swept up in the excitement of the moment"), and (v) future (e.g., "I am able to resist temptations when I know there is work to be done"). Participants are asked to respond to each of the items on a 5-point Likert scale, anchored by 'very untrue of me' to 'very true of me'. Cronbach's alpha suggested that each subscale was internally reliable: Past-positive (α = .75); past-negative (α = .86), present-fatalistic (α = .72), present-hedonistic (α = .80), and future (α = .80). In order to measure a balanced time perspective, we first computed a deviation from a balanced time perspective (DBTP) score [25] by subtracting participants' scores for each subscale from the “optimal” score, as specified by Zimbardo and Boyd [28]. This measure was then reverse-scored so that higher scores indicated a more balanced time perspective.

Affect associated with self-monitoring blood glucose. How participants typically feel when they self-monitor their blood glucose was measured using the stem “Monitoring my blood glucose makes me feel…”, followed by 8 items: Guilty, bad about myself, good about myself, relaxed, disappointed, at ease, anxious, and reassured. These items were devised for the purpose of this study and were informed by the literature and attendance at a DAFNE training course. Items were rated on a 5-point Likert scale ranging from ‘strongly disagree’ to ‘strongly agree’. Negative items were reverse coded so that higher scores indicated that participants associated monitoring with more positive affect ($\alpha = .86$).

Attitudes toward self-monitoring blood glucose. Participants’ attitudes toward monitoring were measured with the stem “I think that monitoring my blood glucose every time that I am supposed to is…” followed by six bipolar adjectives rated on a 5-point scale: ‘Important – unimportant’, ‘easy – difficult’, ‘harmful – beneficial’, ‘worthwhile – pointless’, ‘unpleasant – pleasant’, and ‘wise – foolish’. After reverse coding negative items, the items were averaged such that higher scores indicated that participants held more positive attitudes toward self-monitoring their blood glucose levels ($\alpha = .77$). We also measured the extent to which participants found their current monitoring regime effective, convenient, and intrusive using the Glucose Monitoring Experiences Questionnaire (GME-Q; [29]); however, none of these subscales mediated the relationship between balance time perspective and the frequency with which participants monitored their blood glucose (see Electronic Supplementary Material 1).

Self-control. Trait self-control was assessed using the 13-item Brief Self-Control Scale (BSCS; [30]). Previous studies have demonstrated that the BSCS is a valid measure of self-control [e.g., 30] and it has been found to be associated with glycaemic control in individuals with type 1 diabetes [26]. Example items include: "I am good at resisting temptation" and "I often act without thinking through all the alternatives". Items were rated on a 5-point Likert scale, anchored by 'not at all' to 'very much'. After reverse scoring negative items, items were averaged such that higher scores reflected greater levels of trait self-control (α = .77).

Clinical Outcomes

Biomedical information. The following information was collected from participants' medical records: Time since diabetes diagnosis, name of consultant in charge of care, and current insulin regime (e.g., frequency of injections, insulin types, and doses).

Frequency of blood glucose monitoring. The frequency with which participants monitored their blood glucose was measured using Diasend® software (https://diasend.com//en). Diasend is a system for recording information from electronic blood glucose meters, including the value, date, and time of each measurement. This information is uploaded by patients or their healthcare providers to a secure online database. To account for any effects of participation in the research on the frequency with which participants monitored their blood glucose, this data was extracted for three separate weeks: (i) the week prior to when participants completed the questionnaire (or nearest available date), (ii) the week when participants completed the questionnaire, and (iii) the week after the questionnaire was completed (or nearest available date). A one-way repeated measures ANOVA was conducted to test whether there were differences in the frequency with which participants monitored their blood glucose between these weeks. Mauchly's test of sphericity indicated that the assumption of sphericity had been violated (χ^2 (2) = 9.31, p = .010), and therefore the degrees of freedom were corrected using the Huynh-Feldt estimate of sphericity (ε = .90). There were no differences in the frequency with which participants monitored their blood glucose according to the week that the data was extracted, $F(1.81, 117.44) = 1.68$, p =

.193; Time 1: *M* = 28.55, *SD* = 12.99; Time 2: *M* = 29.71, *SD* = 13.70; Time 3: *M* = 28.35, *SD* = 13.55. This confirms that participating in the study did not influence the frequency with which participants monitored their blood glucose. If no data was available within a year of the date required, then the data was recorded as missing. The number of times that participants monitored their blood glucose in each of these weeks (where available) was averaged to provide an objective measure of the frequency with which participants self-monitored their blood glucose during the study period.

Participants also reported how often they monitored their blood glucose each week using a single item: "On average, how many times a week do you monitor your blood glucose?" If participants provided a range (e.g., 25 to 30), then the median value was recorded. There was a high correlation between the data extracted from the Diasend software and the self-reported frequency with which participants monitored their blood glucose (r = .75; see Table 3). As such, to reduce missing data in these variables ($N_{missing}$ = 45 and 5 for the objective and self-report measures, respectively) and to ensure sufficient power for subsequent analyses, a composite measure was created. That is, when data was available for both of these measures, an average was taken, otherwise scores were based on either the objective or self-reported data depending on which was available.

Long-term glycaemic control. Medical records were reviewed to extract participants' most recent HbA_{1c} level. HbA_{1c} is a measure of glycosylated haemoglobin that reflects overall blood glucose levels over the previous 6 to 8 weeks [31]. Previous research has demonstrated a strong relationship between high levels of HbA_{1c} and complications [2] and, as such, HbA_{1c} is considered to be the 'gold standard' measure of long-term glycaemic control [32]. HbA_{1c} levels are measured in mmol/mol, with levels exceeding 48 mmol/mol reflecting difficulties controlling blood glucose levels [27]. The HbA_{1c} reading that most closely corresponded to the date that the participant completed the questionnaire was extracted from participants' medical records. If a participants' HbA_{1c} level had not been tested within a year of the date that the questionnaire was completed, then it was recorded as missing.

Analytic Strategy

The aim of the present research was to investigate whether individual differences in a balanced time perspective are associated with the frequency with which people with type 1 diabetes monitor their blood glucose levels and, as a result, maintain glycaemic control. To address these questions, the data was analysed in three stages. First, the relationships between the demographic factors (e.g., age, gender, ethnicity) and biomedical factors (e.g., time since diagnosis) and the outcome variables (i.e., frequency of self-monitoring of blood glucose and HbA_{1c} levels) were explored using correlations, *t*-tests, and ANOVAs as appropriate. When significant relationships between these factors and the outcome variables were found, the relevant factors were controlled for in subsequent analyses. Second, hierarchical regression analyses were conducted, with balanced time perspective as the independent variable (entered in Step 2) and the frequency of blood glucose monitoring or HbA_{1c} level as the dependent variables, controlling for any covariates identified in the first step of the analyses (entered in Step 1). These analyses were conducted using SPSS version 23 [33]. Finally, a series of mediation models were conducted using PROCESS [34]. These models explored (i) whether the relationship between balanced time perspective and long-term glycaemic control was mediated by the frequency with which participants monitored their blood glucose and (ii) whether the relationship between balanced time perspective and self-monitoring of blood glucose was mediated by the feelings that participants' associated with monitoring, their attitudes towards monitoring, and/or their self-control ability. In all of the mediation models, the indirect effect was tested using a bootstrap estimation approach with 10,000 resamples. Confidence intervals excluding zero were considered statistically significant at the $p < 0.05$

level. All of the analyses used the composite measure of the frequency with which participants monitored their blood glucose to reduce missing data and increase the statistical power of these analyses.

Additional analyses were also conducted to explore the relationship between the individual dimensions of time perspective and the outcome variables (i.e., frequency of self-monitoring of blood glucose and HbA_{1c} levels), to permit comparison with previous studies that have focused on these variables. These analyses are not reported here, but can be found in Electronic Supplementary Material 2.

Results

Preliminary analyses

Preliminary analyses were conducted to establish whether the data met the statistical assumptions for the analyses outlined above. These analyses revealed the presence of outliers. Specifically, an analysis of standardised residuals indicated that four participants had outlying values (i.e., z-scores greater than +/- 3.29 standard deviations from the mean) on the measure of the frequency of self-monitoring of blood glucose and one participant had an outlying HbA_{1c} value. As such, these participants were removed from subsequent analyses involving these variables. The means, standard deviations, and range for the key study variables (excluding the outliers identified above) are presented in Table 2.

Identification of covariates

We measured a number of demographic and biomedical factors that have previously been found to be associated with the frequency with which people monitor their blood glucose levels. However, to avoid reducing the statistical power of our main analyses, our decision as to which of the covariates to include in our analyses was determined by identifying the demographic and biomedical factors that have significant relationships with the outcome variables in the current sample. The correlations between the study variables are presented in Table 3. Neither age, time since diabetes diagnosis, nor index of multiple deprivation scores were significantly associated with the frequency with which participants self-monitored their blood glucose or HbA_{1c} levels (*p*s > .05). Thus, these factors were not controlled for in later analyses. Independent t-tests indicated that gender was not significantly associated with either the frequency of blood glucose monitoring or HbA_{1c} values (*p's* > .05). However, there was a significant difference in the frequency of monitoring blood glucose between participants who had attended a DAFNE course and those who had not, $t(174) = -3.49$, $p = .001$. As might be expected, participants who had attended a DAFNE course tended to monitor their blood glucose levels more frequently ($M = 30.91$; $SD = 12.70$) than those who had not attended ($M = 23.75$; $SD = 12.21$). Thus, whether participants had attended a DAFNE course was controlled for in analyses exploring the relationship between time perspective and the frequency with which participants monitored their blood glucose levels. There was no difference in HbA_{1c} levels as a function of DAFNE attendance, $t(46.24) = -0.10$, $p = .925$, and so DAFNE attendance was not controlled in the analyses focusing on $HbA1_c$ levels.

Two ANOVAs were conducted to examine whether participants' level of education or employment status influenced the outcome variables. Given that some levels of these variables contained just a small number of participants (e.g., only 3 participants reported having no formal education, see Table 1), some of the groups were combined in order to reduce unequal group sizes and to ensure that post hoc tests could be conducted if required. Specifically, for level of education, the lowest two levels (i.e., 'no formal education' and 'primary education') were combined, as were the upper two levels (i.e., 'postgraduate degree' and 'PhD/ doctorate'). For employment status, the groups 'unemployed' and 'unable to work' were combined, and the group 'other', which only contained three observations, was excluded. The analyses indicated that there were no differences in HbA_{1c} levels according to level of education or employment status (*p's* > .05). Similarly, there was no difference in the frequency with which participants self-monitored their blood glucose levels according to employment status, $F(4,151) = 1.78$, $p = .136$. There was, however, a significant difference in the frequency with which participants monitored their blood glucose according to their level of education, $F(4, 151) = 3.42$, $p = .010$. Post hoc tests revealed that participants who had completed secondary education (i.e., up to GCSE level) monitored their blood glucose more frequently ($M = 33.15$, $SE = 2.19$) than those who had completed college/ sixth form (i.e., up to A-level; $M = 24.37$, $SE = 2.16$, $p = .038$). Thus, level of education was controlled for in analyses exploring the relationship between balanced time perspective and the frequency with which participants monitored their blood glucose. As the sample in this study were predominantly White British (97.3%) and from the UK (90.7%), differences in ethnicity and country of birth could not be explored. Finally, given that our sample was recruited using two different methods (i.e., via postal questionnaires or approached in clinic) independent t-tests and chi-squared tests were conducted to explore whether the demographics, biomedical factors, or the outcome measures varied according to how participants were recruited. These analyses revealed that none of the variables differed according to how the sample was recruited (*p*s > .05), and therefore, the method of recruitment was not considered further.

Is a balanced time perspective associated with (i) the frequency of blood glucose monitoring and (ii) long-term glycaemic control?

The correlation between balanced time perspective and the frequency of blood glucose monitoring was small and not statistically significant ($r = 0.14$; $p = .066$); as was the correlation between balanced time perspective and HbA_{1c} levels ($r = -0.08$; $p = .365$; see Table 3). However, given that our earlier analyses indicated that whether participants had attended a DAFNE course and their level of education were significantly associated with the frequency with which they monitored their blood glucose, further tests of these relationships were conducted as planned, using hierarchical regression and mediation analyses. These analyses provide a better estimate of the relationship between balanced time perspective and the frequency with which people with Type 1 diabetes monitor their blood glucose and HbA_{1c} levels as they enable us to control for these confounding factors.

Frequency of self-monitoring blood glucose levels. Participants' level of education and whether they had attended a DAFNE course were entered into Step 1 of a hierarchical regression and explained 8% of the variance in the frequency with which participants monitored their blood glucose levels (R^2 = .08, adj.R^2 = .07, F(2, 159) = 6.66, p = .002). Inspection of the beta weights revealed that, while attendance on a DAFNE course was a significant predictor (β = 0.28, p < .001), level of education was not (β = -0.07, p = .391). The addition of the variable representing a balanced time perspective in Step 2 led to a significant increase in the variance explained in the frequency with which participants self-monitored their blood glucose levels (R^2_{change} = .03, F_{change}(1, 158) = 4.97, p = .027). The beta weight indicated that balanced time perspective was positively associated with monitoring (β = 0.18, p = .027). This suggests that the more balanced a participant's time perspective, the more frequently they monitored their blood glucose levels. In the final model, the variables explained 11% of the variance in the frequency with which participants self-monitored their blood glucose levels, F(3, 158) = 6.21, p = .001, with DAFNE course attendance and a balanced time perspective both emerging as significant, independent predictors.

Long-term glycaemic control. In order to explore whether a balanced time perspective predicted long-term glycaemic control, a second regression analysis was conducted with participants' HbA_{1c} levels as the dependent variable and balanced time perspective as the independent variable. We did not control for DAFNE course attendance or level of education, as our initial analyses suggested that these factors were not associated with HbA_{1c} levels. This regression analysis indicated that a balanced time perspective was not a significant, direct predictor of participants' long-term glycaemic control, $F(1, 134) = 1.01$, $p = .317$, $\beta = -0.09$, $p = .317$.

Does self-monitoring of blood glucose mediate the relationship between balanced time perspective and long-term glycaemic control?

A mediation analysis was conducted to explore whether there was an indirect relationship between balanced time perspective and HbA_{1c} levels, via the frequency with which participants monitored their blood glucose. As before, we controlled for whether participants had attended a DAFNE course and their level of education. As can be seen in Figure 1, a balanced time perspective was positively associated with the frequency with which participants monitored their blood glucose ($a = 5.119$, $p = .004$), and more frequent monitoring was negatively associated with HbA_{1c} levels ($b = -0.204$, $p = .034$), indicating that more frequent monitoring led to better glycaemic control. There was also a significant indirect effect of balanced time perspective on HbA_{1c} levels via the frequency of blood glucose monitoring (indirect effect = -1.045, *95% CI*: [-2.696, -0.018]). Taken together, these findings suggest that participants with a more balanced time perspective monitored their blood glucose more frequently, which resulted in lower (and therefore healthier) HbA_{1c} levels. In support of the regression analysis, there was not a direct relationship between balanced time perspective and HbA_{1c} levels ($c' = -0.870$, $p = .657$).

Which factors mediate the relationship between a balanced time perspective and the frequency of blood glucose monitoring?

The final set of analyses explored whether the relationship between a balanced time perspective and the frequency with which participants monitored their blood glucose was explained by the feelings that they associate with monitoring, their attitudes towards monitoring, and / or their self-control ability. Two different predictions can be made regarding the ordering of these variables. On the one hand, it is possible that these variables mediate the relationship independently (i.e., parallel mediation). On the other hand, it is possible that the feelings that participants associate with monitoring are related to their attitudes towards monitoring that, in turn, influence the frequency with which they monitor their blood glucose (i.e., serial mediation). In order to test these predictions, two mediation models were tested: (i) A parallel mediation model (containing all of the potential mediators), and (ii) a serial mediation model (containing feelings and attitudes associated with monitoring in series).

The findings from the parallel mediation model are presented in Figure 2. Balanced time perspective was significantly related to the feelings that participants associated with monitoring their blood glucose levels ($a^1 = 0.343$, $p < .001$) and their attitudes towards monitoring ($a^2 = 0.152$, $p = .021$), but not participants' self-control ability ($a^3 = 0.133$, $p = 0.067$). The only significant predictor of the frequency with which participants monitored their blood glucose levels was their attitudes towards monitoring ($b^2 = 6.293$, $p = .004$). However, tests of the indirect effects indicated that none of these factors independently mediated the relationship between balanced time perspective and the frequency with which participants monitored their blood glucose levels (see Table 3). The direct effect was also not significant ($c' = 1.594$, $p = .321$).

The findings from the serial mediation model are presented in Figure 3. When feelings associated with monitoring and attitudes towards monitoring were placed in series, balanced time perspective significantly related to feelings associated with monitoring ($a^1 = 0.343$, $p < .001$), but not attitudes towards monitoring ($a^2 = 0.022$, $p = .694$). In turn, the feelings that participants' associated with monitoring did not significantly predict the frequency with which they monitored their blood glucose levels ($b^1 = 1.635$, $p = .265$), but attitudes towards monitoring did ($b^2 = 6.183$, $p = .004$). Clarifying these findings, there was a significant indirect effect of balanced time perspective on the frequency with which participants monitored their blood glucose levels through the feelings that they associated with monitoring and then their attitudes towards monitoring (indirect effect = 0.800, *95% CI:* [0.25, 1.86]). Furthermore, after controlling for the feelings that participants associated with monitoring and their attitudes towards monitoring, the direct effect was not significant (c' = 1.579, p = .324). This provides support for a serial mediation model in which a balanced time perspective influences the feelings that participants associate with monitoring that, in turn, influences their attitudes toward monitoring and so the frequency with which they do so.

Discussion

The aim of the present research was to test whether time perspective was associated with the frequency with which people with type 1 diabetes monitored their blood glucose levels, and as a result, achieved long-term glycaemic control. Consistent with our initial hypotheses, we found that, after controlling for participants' level of education and whether they had attended a DAFNE course, a more balanced time perspective was associated with more frequent self-monitoring of blood glucose. Furthermore, the findings indicated that, although there was not a direct relationship between the extent to which participants had a balanced time perspective and long-term glycaemic control, there was a significant indirect effect, suggesting that a more balanced time perspective is associated with better long-term glycaemic control via its relationship with the frequency of blood glucose monitoring.

A second aim of the present research was to identify factors that explain why the extent to which participants had a balanced time perspective was associated with self-monitoring of blood glucose. Our findings suggested that the feelings that participants associated with monitoring their blood glucose (e.g., the extent to which doing so made them feel reassured) and participants' subsequent attitudes towards monitoring (e.g., the extent to which they believed that monitoring their blood glucose is worthwhile) mediated the relationship between a balanced time perspective and the frequency with which participants monitored their blood glucose levels. Specifically, participants with a more balanced time perspective tended to associate more positive affect with monitoring their blood glucose levels. This, in turn, was associated with more positive attitudes toward monitoring, which were associated with more frequent monitoring.

These findings are important from both a theoretical and practical perspective. From a theoretical perspective, the findings are consistent with theories and past research that points to the importance of time perspective for understanding health behaviour (e.g., [16]), including the self-management behaviours of people with diabetes (e.g., [17-19]), and research that has demonstrated the importance of self-monitoring of blood-glucose for maintaining glycaemic control (e.g., [6, 7]). Furthermore, and in light of the findings from our serial mediation analysis, the present research also indicates that how people typically feel when they monitor their blood glucose is related to their attitudes toward monitoring. This is important because, although attitudes are commonly featured in models of health behaviour (e.g., the Theory of Planned behaviour [35]), a common criticism of these models is that they assume that behaviour is rational and, as such, they fail to acknowledge the role of other non-cognitive determinants, such as emotions [36]. Thus, our findings provide empirical support for these criticisms and for past research that has highlighted the role of (anticipated and experienced) emotions in shaping people's attitudes toward various behaviours [24].

The present findings also extend previous investigations in two ways. First, while previous research has highlighted the benefits of a future time perspective, the present research demonstrates the efficacy of having a balanced time perspective in promoting the performance of health-protective behaviours. This is significant as it suggests that the optimal time perspective is more nuanced than simply a focus on the future and that other dimensions of time perspective should not be ignored. Second, while previous research has explored the relationship between balanced time perspective and psychological well-being (e.g., [23]), the present research is the first study, to our knowledge, that has explored the relationship between having a more balanced time perspective and a specific health behaviour – namely, the extent to which people with type 1 diabetes monitor their blood glucose levels.

In contrast to previous research, the present research did not find a relationship between a balanced time perspective and self-control ability [25]. Similarly, we did not find a relationship between participants' self-control ability and the extent to which they self-monitored their blood glucose levels. This is perhaps surprising as previous research has found that self-control is associated with a wide range of behaviours [37], including better glycaemic control in adolescents with type 1 diabetes [26]. One possible explanation for the lack of relationship in the present research is that a core component of self-control is the ability to resist immediate temptation (i.e., an inhibitory response [38]), whereas self-monitoring of blood glucose is considered an active and deliberate behaviour that does not necessarily require the person to overcome or resist an alternative course of action. As such, the self-regulatory challenges involved in blood glucose monitoring are likely motivational (e.g., is this something that I want to do?) rather than volitional (e.g., I want to do this, but struggle to do so). Self-control may be more strongly associated with self-management behaviours that involve inhibiting impulses (e.g., resisting fatty foods), rather than self-management behaviours that involve deciding whether to take proactive steps to benefit future health (e.g., checking blood glucose levels). Nonetheless, the present research further highlights the need to explore psychological factors for understanding self-management behaviours in diabetes [12].

The present findings also have a number of practical implications; not least for interventions designed to promote self-monitoring of blood glucose levels. Specifically, future research could explore whether it is possible to facilitate a balanced time perspective in order to promote self-monitoring of blood glucose. For example, previous research with individuals with Post Traumatic Stress Disorder has developed a therapy that involves identifying and modifying time perspective [39]. During this therapy, deviations from a balanced time perspective are identified (e.g., a high score on the past-negative subscale) and efforts are made to enhance neglected dimensions of time perspective in order to promote balance (e.g., by asking the individual to think about all the positive things in their past that they have previously ignored). It would be interesting to investigate if a similar intervention could also increase the frequency with which participants with type 1 diabetes monitor their blood glucose levels. Such studies would not only be practically important, but would also represent the first experimental tests of the relation between balanced time perspective and health outcomes.

Strengths and limitations

Although the present research provides support for the significance of time perspective for understanding how frequently people with type 1 diabetes self-monitor their blood glucose levels, we acknowledge that the size of the effects found were relatively small. That is, after controlling for whether participants had attended a DAFNE course and their level of education (which together explained 8% of the variance in the frequency with which participants monitored their blood glucose), differences in time perspective only explained an additional 3% of the variance. These effects are, however, comparable to other studies exploring psychological correlates of health behaviour (e.g., [40]), and variables explaining a similar percentage of variance are often included in models of health behaviour (e.g., [41]). Furthermore, even small effects can have substantive implications for public health [42, 43]. However, in order to provide stronger support for interventions designed to modify time perspective, future research could consider context-specific measures of time perspective. For example, previous studies have demonstrated that using a measure of time perspective that is specific to the health condition being studied (e.g., using the Hypertension Temporal Orientation Scale [44]), to assess differences in time perspective in individual with hypertension), can explain a larger amount of the variance in subsequent behaviour (e.g., [45]). This suggests that a diabetes-specific measure of time perspective may increase the size of the effects found, therefore providing greater support for the development of interventions designed to modify time perspective. It may also be easier to modify time perspective with respect to a specific issue, than more general perspectives.

A strength of the present research was the use of an objective measure of glycaemic control and the frequency with which participants self-monitored their blood glucose levels. Although this is not the first study to use HbA1c levels to measure glycaemic control, it is one of the first studies to use Diasend software for research purposes. The promising findings reported here suggest that the software may be a useful way to investigate other research questions (e.g., exploring habits associated with blood glucose monitoring). The present research found a high correlation between participants' self-reported frequency of monitoring and the objective data extracted from participants' electronic blood glucose meters, and so these measures were combined to reduce missing data and to ensure that the analyses were sufficiently powered. While this suggests that people are fairly accurate in reporting their blood glucose monitoring practices, future studies that use data provided by Diasend software may want to recruit larger samples in order to compensate for data that may not have been uploaded onto the system.

There are; however, some further limitations to the present research that warrant discussion. One limitation is the cross-sectional nature of this research which means that any inferences about the causal nature of these relationships are based on theoretical considerations that cannot be empirically verified using the present data. Although it seems reasonable to assume that time perspective (being a relatively stable individual difference

[14]) is a precursor to the frequency with which people monitor their blood glucose and, in turn, outcomes such as glycaemic control, future studies could and should utilise a longitudinal design – or better still, an experimental design as suggested above – in order to provide empirical support for these ideas.

A second limitation of the present research was the relatively low response rate (22% of those invited to take part agreed to do so). Low response rates can introduce self-selection bias and, as a result, our sample may not be representative of individuals with type 1 diabetes. For example, given that we told participants that we were interested in blood glucose monitoring and glycaemic control, it is possible that individuals who monitored their blood glucose more frequently and had better glycaemic control were more likely to take part. That said, the average HbA_{1c} level for the current sample was only slightly lower than the average HbA_{1c} level for the 1,437 patients at Sheffield Teaching Hospitals who matched our inclusion criteria (63 mmol/mol compared to 68 mmol/mol), and the size of this effect was estimated to be small ($d = 0.37$). This suggests that, although the current sample had slightly better glycaemic control, there was not a substantial difference between those participants who took part in this study and the larger population pool. Our sample did, however, lack ethnic diversity as 97% of the sample was White British. Given that previous research has indicated that ethnic minority groups are less likely to monitor their blood glucose [9], future studies with more ethnically diverse samples are important in order to ensure that the findings can be generalised.

Finally, given the limited population from which participants could be recruited (i.e., adults with type 1 diabetes attending the outpatient clinics at Sheffield Teaching Hospitals) and due to missing data, the size of the sample obtained to test our hypotheses was smaller than anticipated. Therefore, it is possible that our analyses failed to detect some potentially significant associations (i.e., there was an increased chance of making a type 11 error).

Although our sample size is comparable to similar studies conducted within this population (e.g., [26]), the findings should be interpreted with caution.

Conclusion

The present research found that a more balanced time perspective was associated with more frequent self-monitoring of blood glucose among adults with type 1 diabetes and, as a consequence, better long-term glycaemic control. The present research also sheds light on why a balanced time perspective is associated with blood glucose monitoring. Specifically, the findings suggest that people with a more balanced time perspective monitor their blood glucose more frequently because they associate more positive feelings with monitoring and thus have more positive attitudes towards monitoring. From a theoretical standpoint, these findings suggest that future research should consider whether and how balanced time perspective influences the performance of other health behaviours. From a practical standpoint, the research suggests that a promising intervention for people with type 1 diabetes might be to try to promote a balanced time perspective in order to increase the frequency with which people monitor their blood glucose and thus improve glycaemic control.

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Table 1. Demographic and biomedical characteristics of the sample.

Characteristic	*n (missing)*	%	*Mean (SD)*
Sex	177 (6)		
Male	87	47.5	
Female	90	49.2	
Age (years)	177 (6)		49.95 (17.17)
Ethnicity	182 (1)		
White British	178	97.3	
Non-white	4	2.2	
Country of birth	170 (13)		
UK	166	90.7	
Other	4	2.2	
Education Level	180 (3)		
No formal education	3	1.6	
Primary education	7	3.8	
Secondary education	45	24.6	
College/ sixth form	48	26.2	
Undergraduate degree	46	25.1	
Postgraduate degree	22	12.0	
PhD/ Doctorate	9	4.9	
Employment Status	182 (1)		
Full-time	84	45.9	
Part-time	24	13.1	
Unemployed	8	4.4	
Student	8	4.4	
Retired	43	23.5	
Unable to work	12	6.6	
Other	3	1.6	
Index of Multiple Deprivation score	177 (6)		18.01 (98.00)
Attended a DAFNE course	181 (2)		
Yes	125	68.3	
No	56	30.6	
Time since diabetes diagnosis (years)	172 (11)		21.34 (15.99)
HbA_{1c} value	147 (36)		62.99 (14.71)

Table 2. Means, standard deviations, and range for key study variables

Variable	Sample Size *(N)*	Mean *(SD)*	Range
Balanced time perspective	164	2.80 (0.66)	3.98
Affect associated with monitoring	175	3.55 (0.82)	4.00
Attitudes towards monitoring	174	4.22 (0.59)	3.67
Self-control	178	3.23 (0.60)	3.15
Self-reported SMBG frequency	173	30.01 (13.91)	74.00
Objective SMBG frequency	136	27.85 (13.53)	72.00
Combined SMBG frequency	177	28.61 (13.00)	73.00
HbA_{1c} level	142	62.94 (13.62)	82.00

Notes. SMBG = Self-monitoring of blood glucose, HbA_{1c} = glycated haemoglobin. Outliers have been excluded.

Table 3. Descriptive statistics and Pearson's bivariate correlations between study variables

Variables	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Age	.07	.44**	-.02	.29**	.28**	.35**	.06	-.05	.05	-.13
N	172	167	159	169	169	172	167	136	171	142
2. Index of multiple deprivation		.04	.12	-.02	.06	.09	.03	-.00	.04	-.14
N		167	159	169	169	172	167	136	171	142
3. Time since diagnosis (in years)			-.08	.18*	.07	.04	.13	.14	.13	.01
N			157	165	164	167	162	134	166	142
4. Balanced Time Perspective				.26**	.18*	.13	.15	.19*	.14	-.08
N				162	162	164	160	126	164	132
5. Affect associated with monitoring					.53**	.34**	.25**	.20*	.24**	-.37**
N					171	175	170	134	174	141
6. Attitudes towards monitoring						.29**	.35**	.16	.31**	-.20*
N						174	170	134	174	139
7. Self-control ability							.08**	.01	.07	-.31**
N							173	136	177	142
8. Self-reported SMBG frequency								.75**	.95**	-.18*
N								132	173	137
9. Objective SMBG frequency									.93**	-.15
N									136	122
10. Combined SMBG frequency										-.20*
N										141
11. HbA_{1c} value										-

Notes. ZTPI = Zimbardo Time Perspective Inventory, SMBG = Self-monitoring of blood glucose, HbA_{1c} = glycated haemoglobin. *N* = sample size for each correlation.

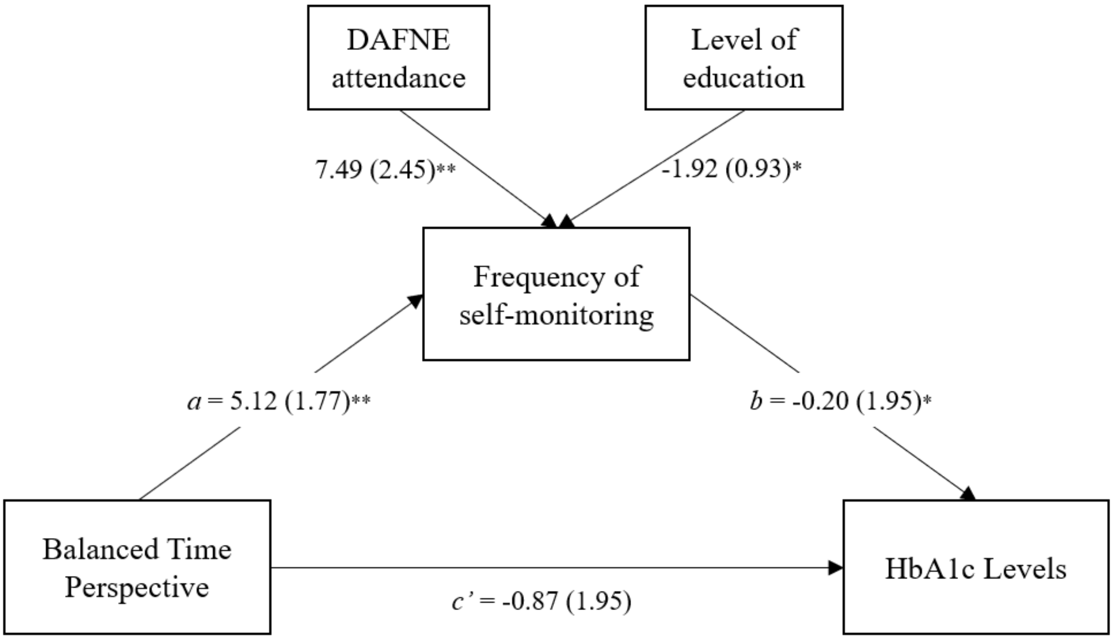
* $p < .05$, ** $p < .01$, *** $p < .001$

Table 3. Summary of indirect effects (*N* = 158) for the parallel mediation model depicted in Figur e 3

Variable	Indirect effect			
	Effect	*SE*	Lower *95% CI*	Upper *95% CI*
Affect associated with SMBG	0.591	0.503	-0.221	1.809
Attitudes towards SMBG	0.955	0.632	-0.027	2.570
Self-control ability	-0.075	0.230	-0.677	0.304
Total indirect effect	1.471	0.815	0.001	3.215

Notes. Effect = Unstandardized indirect effect, *SE* = Standard error, *CI* = Confidence interval, SMBG = Self-monitoring of blood glucose. Confidence intervals for indirect effects are based on 10,000 bootstrapped samples. Confidence intervals excluding zero are considered statistically significant at the $p < 0.05$ level.

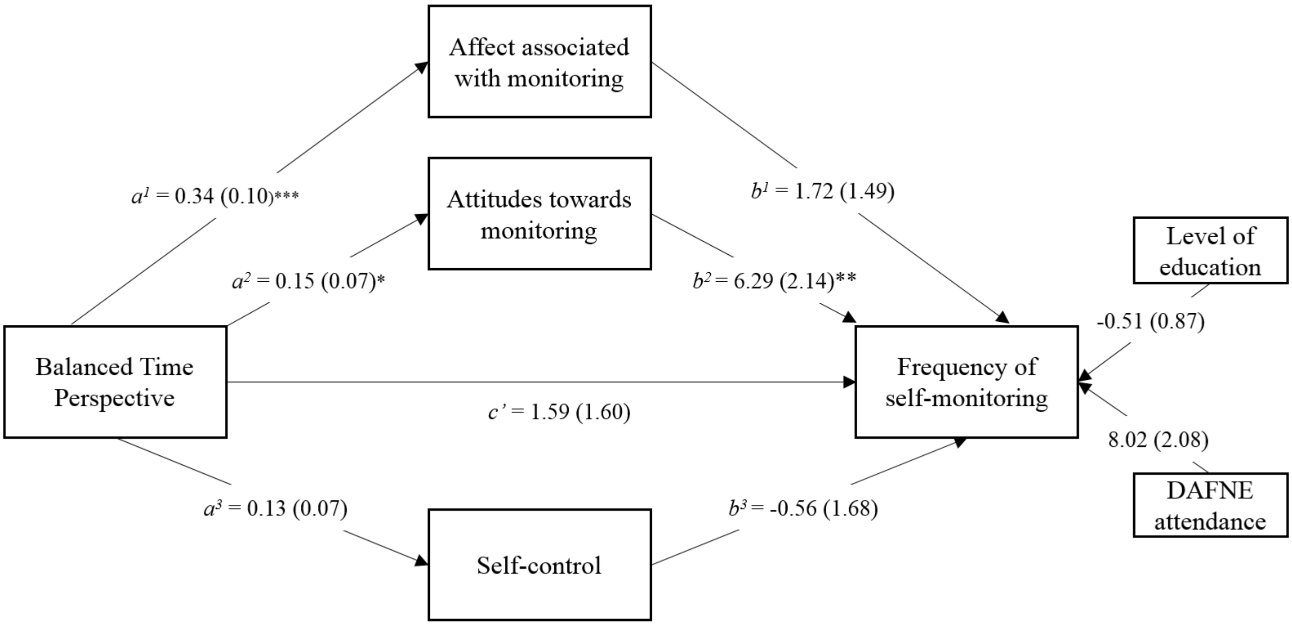
Figure 1. Mediation model of the relationship between a balanced time perspective and long-term glycaemic control (i.e., HbA1c levels) via the frequency with which participants self-monitor their blood glucose levels (*N* = 129).



Notes. As recommended by Hayes (2013), values represent unstandardized beta coefficients with the standard error (*SE*) shown in parentheses.

* $p < .05$, ** $p < .01$, *** $p < .001$.

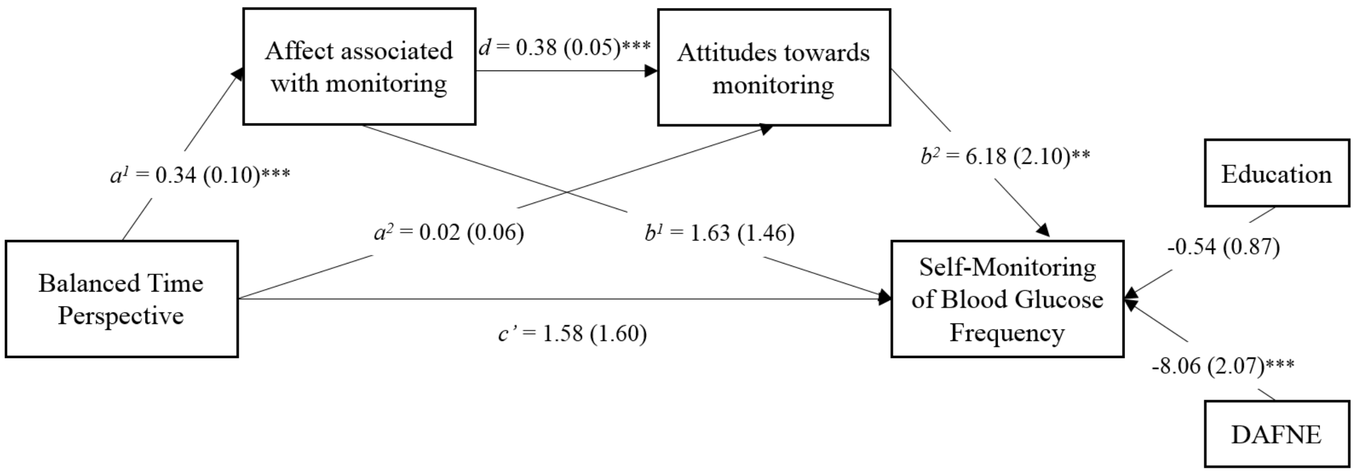
Figure 2. Parallel mediation model of the relationship between a balanced time perspective and the frequency of blood glucose monitoring via the feelings that participants associate with monitoring, their attitudes towards monitoring, and self-control ability (N = 158).



Notes. As recommended by Hayes (2013), values represent unstandardized beta coefficients with standard error (*SE*) shown in parentheses.

* $p < .05$, ** $p < .01$, *** $p < .001$

Figure 3. Sequential mediation model of the relationship between a balanced time perspective and the frequency of blood glucose monitoring via the feelings that participants associate with monitoring and their subsequent attitudes towards monitoring (N = 158).



Notes. As recommended by Hayes (2013), values represent unstandardized beta coefficients with standard error (*SE*) shown in parentheses.

* $p < .05$, ** $p < .01$, *** $p < .001$