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Research Article Treatment

Prospective memory slips are associated with forgetting to take glucose-lowering therapies among adults with diabetes: results from the second Diabetes MILES – Australia (MILES-2) survey

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What's new?

- Medication forgetting among adults with diabetes is common and impacts on glycaemic control. Nearly a quarter of adults with diabetes report forgetting medication recently.
- Medication forgetting was similar for adults with Type 1 or Type 2 diabetes, and was associated with younger age and higher HbA_{1c}.
- Prospective memory slips were associated with medication forgetting among adults with Type 1 or Type 2 diabetes.
- Forgetting to take medication was associated with higher self-reported HbA_{1c} (+7 mmol/mol; +0.6%) among respondents with Type 1 diabetes, which is both statistically and clinically significant.
- There is potential for prospective memory-based interventions to support diabetes self-care.

Abstract

Aims Prospective memory has been long considered a fundamental cognitive ability for optimal medication taking, but the role of prospective memory errors (termed 'slips') in diabetes self-care is unclear. Our aim was to examine associations between prospective memory and medication taking in adults with Type 1 and Type 2 diabetes mellitus.

Methods Some 901 adults with Type 1 diabetes and 927 with Type 2 diabetes completed a cross-sectional survey focused on the psychological and behavioural aspects of living with diabetes. Respondents reported whether they had forgotten to take their diabetes medication over the previous 14 days.

Results Twenty-four per cent ($n = 220$) of adults with Type 1 diabetes and 23% ($n = 211$) with Type 2 diabetes reported that they had forgotten their medication at least once over the previous 14 days. This was associated with more prospective memory slips in adults with Type 1 diabetes [odds ratio (OR) 1.09, 95% confidence interval (CI) 1.05 to 1.13; $P < 0.001$] and Type 2 diabetes (OR 1.10, 95% CI 1.05 to 1.15; $P < 0.001$); and with younger age (both

groups), insulin pump use (Type 1 diabetes), insulin treatment (Type 2 diabetes), less frequent blood glucose checks (Type 1 diabetes) and higher HbA_{1c} (Type 1 diabetes).

Conclusions These findings suggest that forgetting medication is relatively common among adults with Type 1 or Type 2 diabetes, and provide preliminary evidence for its relationship with self-reported prospective memory slips.

<H1>Introduction

For people with diabetes, an important aspect of self-management is taking medication(s) as needed/recommended, as indicated by worse clinical outcomes observed among those with suboptimal medication-taking behaviours [1]. Although medication taking is a complex behaviour, involving both personal and contextual factors, forgetfulness is often cited as the main reason for not taking medications as recommended. For example, 59% [2] and 49% of adults [3] with Type 2 diabetes have reported that they have forgotten to take their medication [4].

Several studies have shown the importance of cognition for effective diabetes self-management [5]. However, the type of cognitive function that specifically relates to remembering to take medication, commonly referred to as prospective memory [6], is rarely mentioned in the diabetes research literature. By contrast, memory research among people with diabetes is focused on retrospective memory performance, which is the ability to recall information from the past [7]. To our knowledge, only one published study has examined the role of prospective memory functioning in diabetes medication taking [8]. In 2004, using electronic dose-event monitors over a 10-day period, Vedhara *et al.* [9] found a positive relationship between the number of prospective memory slips and medication taking among 48 older adults with Type 2 diabetes. This result was expected, given that prospective memory has been considered a fundamental cognitive ability for optimal medication taking [10], and has been associated with medication taking in a range of health conditions and situations [11]. However, whether the relationship between prospective memory and medication taking holds in a larger population sample of adults with Type 1 and Type 2 diabetes is unknown.

The aim of this study was three-fold. First, to assess self-reported medication forgetting frequency in a large cross-sectional sample of adults with Type 1 diabetes, and insulin-treated and non-insulin-treated Type 2 diabetes. Second, to gain a better understanding of the relationship between prospective memory slips and forgetting medication. We hypothesized

that prospective and retrospective memory performance would have differential sensitivity for predicting medication forgetting, with prospective, not retrospective, memory performance showing a relationship with medication forgetting. Finally, we aimed to assess frustration with memory performance, hypothesizing that prospective memory failures would be considered more frustrating than retrospective memory failures among people with diabetes.

<H1>Material and methods

<H2>Survey respondents and procedures

The second Diabetes MILES (Management and Impact for Long-term Empowerment and Success)—Australia study (MILES-2) was a national, online cross-sectional survey of the psychological, behavioural and social aspects of diabetes, the full details of which are reported elsewhere [12]. The primary recruitment strategy relied on accessing the National Diabetes Services Scheme (NDSS) database to contact potential respondents (similar to previous MILES surveys) [13]. Eligible respondents could access the survey from 23 March to 11 May 2015. A hard copy of the survey was available for those who requested it. The survey had a final sample of 2342 respondents (Type 1 diabetes $n = 1078$, 46%; Type 2 diabetes $n = 1264$, 54%). The current report focuses on the subset of respondents who completed the questions on medication forgetting and memory performance (Type 1 diabetes $n = 901$; Type 2 diabetes $n = 927$).

Respondents with Type 1 diabetes were excluded for the following reasons: self-reported diagnosis of cognitive impairment ($n = 7$) or diabetes diagnosed within the previous 12 months ($n = 25$); they did not complete the questions relating to memory performance ($n = 17$) or medication forgetting ($n = 50$). Respondents with Type 2 diabetes were excluded for the following reasons: self-reported diagnosis of cognitive impairment ($n = 16$) or a diabetes diagnosis within the previous 12 months ($n = 20$); they did not complete the general health section ($n = 71$); they were not using glucose-lowering medication to manage their diabetes ($n = 161$); they did not respond to the questions relating to memory performance ($n = 23$) or medication forgetting ($n = 46$).

<H2>Measures

The MILES-2 study included a wide range of self-report measures, which have been described in detail elsewhere [12]. Measures relevant to the current study are described below. A study-specific question (tailored to the respondent's treatment regimen) asked respondents if they had forgotten their medication over the previous 14 days, e.g. 'In the

PAST 14 DAYS (2 weeks), on how many days have you forgotten to take an insulin injection or bolus?'. Five response options were available: no (0) days, 1–3 days, 4–7 days, 8–11 days and 12–14 days. Because of the small proportion of responses greater than '1–3 days', scores were collapsed into two categories ('did not forget medication' and 'forgot medication at least once' over the previous 14 days). All analyses were conducted using this dichotomous indicator of medication forgetting. To avoid confounding forgetting with other reasons for missing medications, participants were asked another study-specific question (tailored to their treatment regimen), e.g. 'In the PAST 14 DAYS (2 weeks), on how many days have you not taken your diabetes tablets on purpose?'. The same five response options were available. As before, because of the low frequency of responses greater than '1–3 days' scores were collapsed into 'medication never skipped' or 'medication skipped at least once'.

Subjective memory performance was measured by the Prospective and Retrospective Memory Questionnaire (PRMQ) [14]. The PRMQ consists of two 8-item subscales that ask questions regarding prospective and retrospective memory functioning. Each question provides an example of a memory complaint and asks the respondent to estimate the frequency on a five-point scale ranging from 1 = never to 5 = very often, providing a total maximum scale score of 80, with 40 as the maximum for each subscale. Higher scores indicate higher self-reported incidence of memory errors or problems. Consistent with the term used by the PRMQ developers, prospective memory errors are referred to as 'memory slips'. The term 'memory performance' is used in a more general context where appropriate. This enables consideration of outcome measures not specifically related to completing the intention, such as compensatory reduction in other concurrent tasks [15]. Internal consistency of the PRMQ in this sample was excellent for both the respondents with Type 1 diabetes (Cronbach's alpha; total scale $\alpha = 0.93$, prospective memory subscale $\alpha = 0.89$ and retrospective memory subscale $\alpha = 0.84$) and those with Type 2 diabetes (Cronbach's alpha; total scale $\alpha = 0.94$, prospective memory subscale $\alpha = 0.90$ and retrospective memory subscale $\alpha = 0.87$).

Frustration with memory failures was assessed with two additional PRMQ items, which ask respondents to indicate how frustrating they find 'forgetting things from the past' (retrospective memory) and 'forgetting to do things' (prospective memory) on a four-point scale ranging from 1 = not at all frustrating to 4 = very frustrating. For analysis, these variables were dichotomized into high frustration ('quite frustrating' and 'very frustrating') and low frustration ('slightly frustrating' and 'not at all frustrating'). These two items were not used in the overall scoring.

Demographic data included age, sex, employment status, highest level of education and socio-economic status (SES), which was determined from the respondents' postcode and based on the Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD), one of the Socioeconomic Indexes for Areas (SEIFA) [16]. Deciles of the IRSAD were used, where lower deciles indicate more disadvantage and less advantage. For the purposes of this study, these deciles were collapsed into three SES groups; low (1–3), middle (4–7) and high (8–10). Self-reported clinical characteristics included diabetes duration (years), daily frequency of self-monitoring of blood glucose (SMBG), number of severe hypoglycaemic events in the past 6 months (defined as 'where you needed help or were unable to treat yourself'), impaired awareness of hypoglycaemia (using the Gold score single item, 'Do you know when your hypos are commencing?' scored on a seven-point scale, with scores ≥ 4 indicating impaired awareness) [17] and HbA_{1c} (in the past 3 months). HbA_{1c} was dichotomized into optimal or suboptimal based on the current recommendation that < 53 mmol/mol (7%) is a reasonable goal [18]. Hence, the percentage of respondents reporting suboptimal HbA_{1c}, ≥ 53 mmol/mol (7%), was reported here. To assess depressive symptoms, respondents completed the 8-item Patient Health Questionnaire (PHQ-8) [19]. Internal consistency, measured by Cronbach's alpha, in this sample was good for both respondents with Type 1 diabetes ($\alpha = 0.89$) and those with Type 2 diabetes ($\alpha = 0.90$). For a measurement of anxiety symptoms, respondents completed the 7-item Generalized Anxiety Disorder Scale (GAD-7) [20]. Internal consistency, measured by Cronbach's alpha, in this sample was excellent for both respondents with Type 1 diabetes ($\alpha = 0.92$) and those with Type 2 diabetes ($\alpha = 0.93$).

<H2>Statistical analysis

The responses of participants with Type 1 and Type 2 diabetes were examined separately. Descriptive statistics were used to report medication forgetting. Owing to the non-normal distribution of age in both groups and the use of nominal data, non-parametric tests were used to compare demographic characteristics between participants with Type 1 and Type 2 diabetes (Mann–Whitney *U* and chi-squared tests). Demographic, clinical and psychosocial characteristics were split by those who did and did not report forgetting their medication at least once over the previous 2 weeks and examined using odds ratios (ORs) with 95% confidence intervals (CIs).

Logistic regression analysis was used to determine the relationships between several demographic and clinical variables and medication forgetting for both the Type 1 and Type 2

diabetes groups. Univariate relationships significant at the 25% level were considered in the model [21], and multicollinearity among these variables was checked using the variance inflation factor before running the regression analysis [22]. The highest variance inflation factor values for Type 1 diabetes and Type 2 diabetes variables were 3.3 and 3.7, respectively, which are below the traditional cut-off of 10 [23]. Variables that were not statistically significant ($P < 0.05$) or did not improve the model were removed and the model was re-run, following the purposeful covariate selection technique described by Hosmer and Lemeshow [21]. Results are reported as ORs with 95% CIs. To avoid overfitting the regression model, the event per variable (EPV) was calculated. The EPV is taken as the ratio of outcome events to the number of predictor variables and is expected to be at least 10 [24]. The Hosmer–Lemeshow test was used to assess model fit [21]. All statistical analyses were conducted using R, version 3.4.2 [25].

<H1>Results

<H2>Respondent characteristics

Of the 1828 eligible respondents, 901 had Type 1 diabetes and 927 had Type 2 diabetes. Sample characteristics are shown in Tables 1 and 2. Respondents with Type 2 diabetes were significantly older than those with Type 1 diabetes (63, IQR 55 to 68 years vs. 44, IQR 32 to 57 years; $U = 161050$, $P < 0.001$) and, relatedly, were more likely to be retired (46% vs. 15%; $\chi^2 = 241.05$, $df = 2$, $P < 0.001$). Respondents with Type 2 diabetes also reported a lower level of education, with 27% having a primary level or less compared with 12% of those with Type 1 diabetes ($\chi^2 = 79.92$, $df = 2$, $P < 0.001$), and a larger number of respondents with Type 2 diabetes reported residential postcodes from a lower SES area than those with Type 1 diabetes (26% vs. 16%; $\chi^2 = 31.69$, $df = 2$, $P < 0.001$).

<H2>Medication forgetting among adults with Type 1 diabetes

Among respondents with Type 1 diabetes, 20% ($n = 176$) reported forgetting their medication during the previous 14-day period on between 1 and 3 days, 2% ($n = 19$) between 4 and 7 days, 1% ($n = 7$) between 8 and 11 days, and < 1% ($n = 4$) between 12 and 14 days. Overall, 23% ($n = 206$) of respondents indicated that they had forgotten, and 12% ($n = 106$) had intentionally skipped, their medication at least once over the past 14 days. There was a significant relationship between not taking medication and whether it was intentional (skipped; 12%, $n = 106$) or not (forgotten; 20%, $n = 176$), $\chi^2 = 31.3$, $df = 1$, $P < 0.001$. More problems were reported with prospective memory on the PRMQ subscale (19.2 ± 5.9) than retrospective memory (16.1 ± 5.2); $t(900) = 29.3$, $P < 0.001$. Prospective memory

slips were considered more frustrating (42%; $n = 378$) than retrospective memory errors (35%; $n = 314$), $\chi^2 = 9.56$, $df = 1$, $P = 0.002$.

Table 1 also details the demographic and clinical characteristics for respondents with Type 1 diabetes in terms of medication forgetting status. Univariate analysis identified several variables associated with self-reported forgetting of medication, including female gender, younger age, higher level of education, employment (employed) and relationship status (single), insulin pump treatment, recent severe hypoglycaemic event, higher HbA_{1c}, shorter diabetes duration, greater diabetes distress, depressive and anxious symptomatology, and increased prospective slips and retrospective memory errors and frustrations.

The 16 variables that were significant at trend level ($P \leq 0.25$) in the univariate analysis were further analysed in a multivariate logistic regression model (Table 3). Squared and cubed age terms had no significant effect in the model ($P = 0.90$ and 0.73 , respectively) suggesting a linear relationship with medication forgetting. The final regression model included six variables that were associated significantly with self-reported medication forgetting: younger age, insulin pump treatment, less frequent daily blood glucose checks, higher HbA_{1c}, recent history of severe hypoglycaemia and greater prospective memory slips. The Hosmer–Lemeshow test was non-significant ($\chi^2 = 4.05$, $df = 8$, $P = 0.85$), indicating that the model fit the data well. The EPV was > 10 ($115/6$) indicating that the model could be estimated accurately.

<H2>Medication forgetting among adults with Type 2 diabetes

For respondents with Type 2 diabetes, during the previous 14-day period, 21% ($n = 190$) reported forgetting on between 1 and 3 days, 2% ($n = 105$) between 4 and 7 days, $< 1\%$ ($n = 1$) between 8 and 11 days, and 1% ($n = 5$) between 12 and 14 days. Overall, 23% ($n = 211$) of respondents indicated that they had forgotten, and 7% ($n = 68$) had intentionally skipped, their medication at least once over the past 14 days. There was a significant relationship between not taking medication and whether it was intentional (skipped; 7%, $n = 68$) or not (forgotten; 21%, $n = 190$), $\chi^2 = 38.0$, $df = 1$, $P < 0.001$. There was no difference in frustration ratings between prospective memory slips (35%; $n = 323$) and retrospective memory errors (31%; $n = 290$), $\chi^2 = 2.49$, $df = 1$, $P = 0.114$.

Table 2 details the demographic and clinical characteristics for respondents with Type 2 diabetes in terms of medication forgetting status. Univariate analysis identified several variables related with self-reported forgetting of medication; female gender, younger age, higher level of education, employment (employed), insulin treated, higher HbA_{1c}, greater

diabetes distress, depressive and anxious symptomatology, prospective and retrospective memory complaints and frustrations. The 13 variables that were significant at trend level ($P \leq 0.25$) in the univariate analysis were further analysed in a multivariate logistic regression model (see Table 3). Squared and cubed age terms had no significant effect in the model ($P = 0.47$ and 0.74 , respectively) suggesting a linear relationship with medication forgetting. The final regression model included three variables that were associated significantly with self-reported medication forgetting: younger age, insulin treatment and greater prospective memory slips. The Hosmer–Lemeshow test was non-significant ($\chi^2 = 7.4$, $df = 8$, $P = 0.494$), indicating that the model fit the data well. The EPV was > 10 ($102/3$) indicating that the model could be estimated accurately.

<H1>Discussion

Almost a quarter of those surveyed had forgotten their medication at least once over the previous 14 days. This was associated with younger age, treatment type (Type 1 diabetes, insulin pump; Type 2, diabetes insulin-treated) and prospective memory; and, in those with Type 1 diabetes, with less frequent daily glucose checking and increased HbA_{1c}. Prospective memory slips were reported as more frustrating than retrospective memory slips for adults with Type 1 diabetes.

The medication forgetting rates observed here are within the range reported previously among adults with diabetes [4]. This finding is of clinical interest and relevance both because of the potential impact on glycaemic control [26] and the equivalent (and sizeable) prevalence of medication forgetting between respondents with Type 1 and Type 2 diabetes. Not taking diabetes medication was more likely to be due to forgetting than intentionally skipping it for adults with Type 1 and Type 2 diabetes.

In the final regression model, treatment regimen was associated with medication forgetting for both respondents with Type 1 diabetes and those with Type 2 diabetes. Insulin-treated respondents with Type 2 diabetes were more likely to report forgetting their medication than those using oral hypoglycaemic agents. Among respondents with Type 1 diabetes, those using an insulin pump were more likely to report medication forgetting than those using injections. The reasons why different treatment regimens influence forgetting in this way is unclear and needs further exploration. No interactions were found between these and other demographic variables, such as age or diabetes duration. In the current data set, we do not have information about dosing frequency, regimen complexity or recent changes in

medication, all of which have been associated previously with suboptimal medication taking in a range of chronic conditions, including diabetes [27].

The association between the odds of medication forgetting and younger age is inconsistent with previous research showing differences in prospective memory performance between younger and older participants [28]. For instance, a large-scale national survey in the UK has shown that prospective memory functioning begins to deteriorate between the third and fifth decades of life [29]. However, some medication forgetting studies have found a similar relationship between forgetting and younger age, while also highlighting the impact a busy lifestyle has on memory performance [30].

Forgetting to take medication in the previous 14 days was associated with a self-reported $HbA_{1c} \sim 7$ mmol/mol (0.6%) higher among respondents with Type 1 diabetes, which is both statistically and clinically significant [26]. The relationship between lower frequency of SMBG and medication forgetting among respondents with Type 1 diabetes is also noteworthy. Although it might suggest that those with a higher daily frequency of SMBG are less likely to forget their medication, performing a blood glucose check is, arguably, a prospective memory task in itself. As such, it would be expected that increased frequency of SMBG would also be associated with a reduction in medication forgetting. Conversely, if an individual's SMBG checks are not optimal, then they might also be forgetting their medication. This knowledge may be helpful for clinicians, prompting them to also enquire about medication forgetting if the individual is not checking their glucose as frequently as recommended.

As anticipated, only prospective memory slips were associated with medication forgetting in the final regression models for both Type 1 and Type 2 diabetes. This highlights the clinical relevance of prospective memory functioning among adults with diabetes, which has previously gone unrecognized as research has focused primarily on retrospective memory functioning. Consequently, medication reminders (auditory and/or visual) may be important in improving medication adherence in people with diabetes [11]. Importantly, the fact that respondents with Type 1 diabetes found prospective memory slips more frustrating than retrospective memory slips implies that they consider prospective memory slips to be more significant. Whether such frustration over medication forgetting is related to the potential health costs or an impact on social status is unclear.

Although this study has several strengths (noted above and reported elsewhere) [12], some limitations must be acknowledged. First, because the data are cross-sectional it is not possible to make any causal inferences, although it should be noted that the theoretical background

linking prospective memory performance to medication forgetting is robust. Second, the study did not use a validated measure of medication taking, such as the Morisky Medication Adherence Scale [2]. Whether subjective prospective memory performance among adults with diabetes would be associated with such a scale is unknown because the two variables have never been included together in a diabetes study. However, the outcome measure reported here, with its specific emphasis on forgetting medication, has clear face validity for the behaviour in question. It should also be acknowledged that verification of medication use (via medical records or objective, electronic monitoring) would have been ideal. Future research needs to include objective measures of both prospective memory performance and medication taking to validate these findings. The issue of sample size is also noteworthy, especially with regard to the reduced subset of respondents with Type 1 diabetes assessed in the regression model. Incorporating assessments of medication forgetting and prospective memory performance into larger, national studies such as the ongoing Australian Diabetes, Obesity, and Lifestyle Study [31] would be of significant benefit. With regards to generalizability, the relationship between medication forgetting and prospective memory performance needs to be examined in other populations.

A further limitation is the absence of data on polypharmacy. The survey did not collect the prescribed number, timing and frequency of medication(s) taken, including both diabetes-specific and other (e.g. hypertension) treatments. This information would be helpful when considering whether medication forgetting is more likely if the individual needs to remember to take several medications. From a theoretical perspective, this question is well founded. Polypharmacy would result in a greater number of delayed intentions associated with the same, or a larger number of prospective memory reminder cues (e.g. after breakfast and dinner). A well-established finding in retrospective memory research is that memory retrieval can deteriorate when the number of similar, competing memories increases [32]. This phenomenon, known as the 'fan effect', has also been shown to disrupt prospective memory performance [33]. However, research specific to people with diabetes does not show any relationship between medication taking and polypharmacy [34]. Nevertheless, this is an important area to explore in future work, as it may highlight an additional burden of managing multiple medications.

In conclusion, this national study has highlighted that nearly a quarter of adults with diabetes report forgetting their medication at least once over the previous 2 weeks, and this was associated with several demographic and clinical characteristics. Furthermore, for the first time, this study highlights the relationship between prospective memory function and self-

reported medication forgetting among adults with diabetes. Continued investigation into the prevalence of diabetes medication forgetting, the role of prospective memory and their associations with glycaemic control is likely to be beneficial in identifying individuals who need more support with remembering to take their diabetes medication.

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Competing interests

None declared.

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Author contributions

ST researched data and wrote the manuscript. JS, SB and FP reviewed and edited the manuscript. FP and JS conceived the Diabetes MILES Study International Collaborative. All authors approved the final version. ST is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Table 1 Characteristics of total sample with Type 1 diabetes and by self-reported ‘medication forgetting’ status over the past 14 days

	Total Type 1 diabetes sample	Did not forget medication in past 14 days	Forgot medication in past 14 days	Univariate analysis Odds ratio (95% CI)	P-value
N (%)	901	681 (76)	220 (24)		
Gender					0.03
Women	537 of 899 (60)	392 of 680 (58)	145 of 219 (66)	–	
Men	362 of 899 (40)	288 of 680 (42)	74 of 219 (34)	0.69 (0.5 to 0.95)	0.03
Age, years	44 (32, 57)	48 (34, 59)	35.5 (27, 49)	0.96 (0.95 to 0.97)	< 0.001
Education					
Primary or less	110 of 898 (12)	93 of 679 (14)	17 of 219 (8)	–	
Secondary or trade	353 of 898 (39)	259 of 679 (38)	94 of 219 (43)	1.99 (1.15 to 3.6)	0.02
Tertiary	435 of 898 (48)	327 of 679 (48)	108 of 219 (59)	1.81 (1.05 to 3.26)	0.04
Socio-economic status					
High	447 of 893 (50)	339 of 675 (50)	108 of 218 (50)	–	
Medium	301 of 893 (34)	226 of 675 (33)	75 of 218 (34)	1.04 (0.74 to 1.46)	0.81
Low	145 of 893 (16)	110 of 675 (16)	35 of 218 (16)	1.00 (0.64 to 1.54)	>0.99
Employment status					
Currently employed	635 of 901 (70)	472 of 681 (69)	163 of 220 (74)	–	
Retired	132 of 901 (15)	115 of 681 (17)	17 of 220 (8)	0.42 (0.24 to 0.71)	0.002
Other	134 of 901 (15)	94 of 681 (14)	40 of 220 (18)	1.23 (0.81 to 1.85)	0.32
Relationship status					
Single	257 of 898 (29)	181 of 679 (27)	76 of 219 (35)	–	
In a relationship	641 of 898 (71)	498 of 679 (73)	143 of 219 (65)	0.68 (0.49 to 0.95)	0.02
Diabetes duration, years	15 (9, 29)	16 (9, 32)	14 (9, 23)	0.98 (0.96 to 0.99)	< 0.001
Blood glucose checks, per day					

	Total Type 1 diabetes sample	Did not forget medication in past 14 days	Forgot medication in past 14 days	Univariate analysis Odds ratio (95% CI)	P- value
≤ 3	248 of 900 (28)	168 of 680 (25)	80 of 220 (36)	–	
4–6	462 of 900 (51)	351 of 680 (52)	111 of 220 (50)	1.16 (0.73 to 1.79)	0.51
≥ 7	190 of 900 (21)	161 of 680 (24)	29 of 220 (13)	0.98 (0.14 to 4.11)	0.98
Primary diabetes treatment					
Insulin pump	330 of 901 (37)	226 of 681 (33)	104 of 220 (47)	–	
Insulin injections	571 of 901 (63)	455 of 681 (67)	116 of 220 (53)	0.65 (0.53 to 0.82)	< 0.001
Severe hypoglycaemia: ≥ 1 event in past 6 months	144 of 873 (16)	102 of 659 (15)	42 of 214 (20)	1.33 (0.89 to 1.97)	0.16
Self-reported HbA _{1c} in past 3 months, mmol/mol (%)	57 ± 15 (7.3 ± 1.3)	56 ± 13 (7.2 ± 1.2)	62 ± 17 (7.8 ± 1.6)	1.41 (1.22 to 1.65)	< 0.001
Suboptimal HbA _{1c} (≥ 53 mmol/mol, ≥7%)	348 of 568 (61)	246 of 432 (60)	102 of 136 (75)	2.27 (1.49 to 3.53)	< 0.001
Diabetes-specific distress: PAID total score	24.8 ± 21.3	23.0 ± 20.3	30.3 ± 23.3	1.02 (1.01 to 1.02)	< 0.001
PAID >40	171 of 778 (22)	112 of 582 (19)	59 of 196 (30)	1.81 (1.25 to 2.60)	0.002
Anxiety symptoms: GAD-7 total score	4.7 ± 4.9	4.4 ± 4.8	5.7 ± 5.1	1.05 (1.02 to 1.08)	< 0.001
GAD-7 >10	117 of 900 (13)	75 of 680 (11)	42 of 220 (19)	1.90 (1.25 to 2.87)	0.002
Depressive symptoms: PHQ-8 total score	5.9 ± 5.3	5.4 ± 5.1	7.3 ± 5.6	1.07 (1.04 to 1.10)	< 0.001
PHQ-8 >10	163 of 899 (18)	103 of 680 (15)	60 of 219 (27)	2.11 (1.46 to 3.03)	< 0.001
PRMQ: Total score	35.3 ± 10.6	34.2 ± 10.1	38.7 ± 11.5	1.03 (1.02 to 1.05)	< 0.001
Prospective memory subscale	19.2 ± 5.9	18.6 ± 5.6	21.1 ± 6.2	1.07 (1.05 to 1.10)	< 0.001
Retrospective memory subscale	16.1 ± 5.2	15.7 ± 5.0	17.5 ± 5.6	1.07 (1.03 to 1.10)	< 0.001
Prospective memory high frustration	378 of 897 (42)	270 of 678 (40)	108 of 219 (49)	1.47 (1.08 to 2.00)	0.014
Retrospective memory high frustration	314 of 899 (35)	220 of 679 (32)	94 of 220 (43)	1.56 (1.14 to 2.12)	0.005

Descriptive statistics reported either as n (%), mean ± SD or median (interquartile range). Denominators may vary due to missing data. Outcome variable is the proportion of respondents who forgot their medication in past 14 days.

PAID, Problem Areas in Diabetes questionnaire; GAD-7, Generalized Anxiety Disorder 7-item scale; PHQ-8, Patient Health Questionnaire Depression Scale; PRMQ, Prospective and Retrospective Memory Questionnaire.

Table 2 Characteristics of total sample with Type 2 diabetes and by self-reported ‘medication forgetting’ status over the past 14 days

	Total Type 2 diabetes sample	Did not forget medication in past 14 days	Forgot medication in past 14 days	Univariate analysis Odds ratio (95% CI)	P-value
N (%)	927	716 (77)	211 (23)		
Gender					
Women	390 of 926 (42)	287 of 716 (40)	103 of 210 (49)	–	
Men	536 of 926 (58)	429 of 716 (60)	107 of 210 (51)	0.69 (0.51 to 0.95)	0.02
Age, years	63 (55, 68)	64 (57, 69)	58 (52, 65)	0.95 (0.93 to 0.97)	< 0.001
Education					
Primary or less	248 of 927 (27)	199 of 716 (27)	49 of 211 (23)	-	
Secondary or trade	382 of 927 (41)	294 of 716 (41)	88 of 211 (42)	1.22 (0.82 to 1.81)	0.02
Tertiary	297 of 927 (32)	223 of 716 (31)	74 of 211 (35)	1.35 (0.90 to 2.04)	0.04
Socio-economic status					
High	355 of 912 (39)	276 of 708 (39)	79 of 204 (39)	-	
Medium	324 of 912 (36)	246 of 708 (35)	78 of 204 (38)	1.10 (0.77 to 1.58)	0.57
Low	233 of 912 (26)	186 of 708 (26)	47 of 204 (23)	0.88 (0.59 to 1.32)	0.55
Employment status					
Currently employed	344 of 927 (37)	472 of 716 (34)	163 of 211 (48)	–	
Retired	423 of 927 (46)	115 of 716 (51)	17 of 211 (27)	0.38 (0.26 to 0.54)	< 0.001
Other	160 of 927 (17)	94 of 716 (15)	40 of 211 (24)	1.11 (0.74 to 1.66)	0.61

	Total Type 2 diabetes sample	Did not forget medication in past 14 days	Forgot medication in past 14 days	Univariate analysis Odds ratio (95% CI)	P- value
Relationship status					
Single	250 of 925 (27)	197 of 716 (28)	53 of 209 (25)	–	
In a relationship	675 of 925 (72)	519 of 716 (72)	156 of 209 (75)	1.11 (0.79 to 1.60)	0.54
Diabetes duration, years	12 (7, 16)	12 (7, 16)	11 (6, 15)	0.99 (0.97 to 1.00)	0.27
Blood glucose checks, per day					
≤ 3	795 of 923 (86)	616 of 712 (87)	179 of 211 (85)	–	
4–6	128 of 923 (14)	96 of 712 (13)	32 of 211 (15)	1.14 (0.73 to 1.75)	0.54
≥ 7	0 of 923 (0)	0 of 712 (0)	0 of 211 (0)	–	
Primary diabetes treatment					
Oral hypoglycaemic agents	461 of 927 (50)	383 of 716 (53)	83 of 211 (39)	–	
Insulin	466 of 927 (50)	333 of 716 (47)	128 of 211 (60)	1.77 (1.30 to 2.43)	< 0.001
Severe hypoglycaemia: ≥ 1 event in past 6 months	37 of 530 (7)	30 of 399 (8)	7 of 131 (5)	0.69 (0.27 to 1.53)	0.40
Self-reported HbA _{1c} in past 3 months, mmol/mol (%)	56 ± 18 (7.3 ± 1.7)	54 ± 16 (7.1 ± 1.4)	61 ± 23 (7.7 ± 2.1)	1.21 (1.08 to 1.37)	0.001
Suboptimal HbA _{1c} (≥ 53 mmol/mol; ≥ 7%,)	262 of 512 (51)	191 of 392 (49)	71 of 120 (59)	1.52 (1.01 to 2.32)	0.001
Diabetes-specific distress: PAID total score	20.1 ± 19.7	17.8 ± 18.5	27.8 ± 21.4	1.02 (1.01 to 1.02)	< 0.001
PAID >40	122 of 800 (15)	75 of 614 (12)	47 of 186 (25)	2.43 (1.61 to 3.65)	< 0.001
Anxiety symptoms: GAD-7 total score	4.7 ± 5.1	4.2 ± 4.9	6.3 ± 5.2	1.08 (1.05 to 1.10)	< 0.001
GAD-7 >10	138 of 926 (15)	75 of 680 (11)	42 of 220 (19)	1.97 (1.32 to 2.90)	< 0.001
Depressive symptoms: PHQ-8 total score	6.7 ± 5.7	6.1 ± 5.5	8.9 ± 5.8	1.09 (1.06 to 1.11)	< 0.001
PHQ-8 >10	222 of 922 (24)	145 of 712 (20)	77 of 210 (36)	2.26 (1.62 to 3.16)	< 0.001
PRMQ: Total score	35.8 ± 10.4	34.5 ± 9.7	40.0 ± 11.6	1.05 (1.04 to 1.06)	< 0.001
Prospective memory subscale	19.1 ± 5.7	18.4 ± 5.3	21.4 ± 6.3	1.10 (1.07 to 1.13)	< 0.001
Retrospective memory subscale	16.7 ± 5.2	16.1 ± 4.9	18.6 ± 5.7	1.09 (1.06 to 1.13)	< 0.001

	Total Type 2 diabetes sample	Did not forget medication in past 14 days	Forgot medication in past 14 days	Univariate analysis Odds ratio (95% CI)	P-value
Prospective memory high frustration	323 of 926 (35)	223 of 715 (31)	108 of 211 (47)	1.98 (1.45 to 2.72)	< 0.001
Retrospective memory high frustration	290 of 926 (31)	201 of 715 (28)	89 of 220 (42)	1.87 (1.35 to 2.56)	< 0.001

Descriptive statistics reported either as n (%), mean \pm SD or median (interquartile range). Denominators may vary due to missing data. Outcome variable is the proportion of respondents who forgot their medication in past 14 days.

PAID, Problem Areas in Diabetes questionnaire; GAD-7, Generalized Anxiety Disorder 7-item scale; PHQ-8, Patient Health Questionnaire Depression Scale; PRMQ, Prospective and Retrospective Memory Questionnaire.

Table 3 Adjusted odds ratios (OR) for factors associated with medication forgetting among respondents with Type 1 and 2 diabetes

Forgetting medication in previous 14 days	Type 1 diabetes (N = 567)*		Type 2 diabetes (N = 927)	
	Adjusted OR (95% CI)	P value	Adjusted OR (95% CI)	P-value
Age, years	0.97 (0.96 to 0.99)	< 0.001	0.95 (0.93 to 0.97)	< 0.001
Primary diabetes treatment (type 1 diabetes / type 2 diabetes):				
Insulin pump/oral hypoglycaemic agents	-			
Insulin injections/insulin	0.65 (0.46 to 0.92)	0.016	1.86 (1.34 to 2.60)	< 0.001
Blood glucose checks, per day:				

≤ 3	-			
4-6	0.51 (0.29 to 0.88)	0.016		
≥ 7	0.32 (0.15 to 0.66)	0.002		
Self-reported HbA _{1c} in past 3 months	1.33 (1.12 to 1.58)	0.001		
PRMQ: Prospective memory subscale	1.09 (1.05 to 1.13)	< 0.001	1.09 (1.06 to 1.12)	< 0.001

*Owing to missing data, the number of respondents with Type 1 diabetes included in the logistic regression analysis was reduced compared with Table 1. In total, 334 respondents were removed from the model; 333 because of a lack of HbA_{1c} data and one because of primary treatment omission (N = 901 – 334 = 567).

95% CI, 95% confidence intervals; PRMQ, Prospective and Retrospective Memory Questionnaire.