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Accuracy of Subjective Blood Glucose Estimation by Patients with Insulin-Dependent Diabetes[1]

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A between-groups design using a baseline, treatment, follow-up procedure was used to investigate the accuracy of 20 patients with insulin-dependent diabetes when subjectively estimating their blood glucose levels. Patients were encouraged to attend to their mood for cues when making estimates of their blood glucose. Their capacity for reducing estimation errors when given immediate or delayed feedback of actual blood glucose was examined. The results showed that neither delayed nor immediate feedback produced a significant improvement in the mean estimation accuracy of these groups of patients or in their ability to predict whether their blood glucose was in the acceptable or unacceptable range. Patients were particularly inaccurate in detecting Low [< 4.0 mmol/L (< 72.0 mg/dl)] and Very High [> 16.0 mmol/L (> 288.0 mg/dl)] blood glucose levels. Examination of mood-blood glucose relationships revealed consistent patterns for individual subjects and considerable differences between subjects.

DESCRIPTOR KEY WORDS: blood glucose; diabetes; estimation accuracy; feedback; mood.

A number of recent reports have considered the possibility that blood glucose levels may be included among the visceral events that have been shown to be discriminable (Bradley & Jefferies, 1980; Cameron & Curtis, 1980;

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Cameron, Buzan, & Matherly, 1984; Gross et al., 1983, 1984; Wing et al., 1984). The study by Cameron and Curtis (1980) found that two of a group of three healthy subjects who were given intravenous glucose solutions of two different concentrations learned, with the help of feedback, to discriminate between high and normal levels of blood glucose within 17 trials. The majority of reports, however, have been of clinical studies with patients who have diabetes.

The goal of diabetes treatment is to maintain blood glucose levels within the normoglycemic range. Fluctuations in blood glucose are the result of interactions among a large number of influences, including diet, exercise, and stress as well as insulin levels. If the balance among these factors is disturbed, blood glucose may either fall into the hypoglycemic range or rise to produce hyperglycemia. If left untreated, both extremes of blood glucose concentration can have life-threatening consequences. Hypoglycemia and hyperglycemia are associated with well-defined symptom patterns, such as sweating and confusion when blood glucose is low and thirst when blood glucose is very high. Mild and moderate levels of hyperglycemia are less acutely threatening and commonly have been regarded as asymptomatic. However, the importance of avoidance of hyperglycemia has become increasingly recognized with the accumulation of evidence for an association between chronic hyperglycemia and an increased risk of developing the microvascular complications of diabetes (Pirart, 1978; Tchobroutsky, 1978).

The ability to recognize changes in blood glucose level is therefore of central importance in the management of diabetes. Many patients with diabetes regularly self-monitor their blood glucose levels. However, the requirement that patients perform numerous daily tests on which to base adjustments to their treatment regimen may place unacceptable demands on the individual. Alternative procedures such as preprandial blood glucose testing have been suggested as a workable compromise (Danowski & Sunder, 1978; Tattersall, 1978; Tattersall, Walford, Peacock, Gale, & Allison, 1980), but even with regular preprandial blood glucose testing, hypoglycemia may still be difficult to predict and episodes of hyperglycemia may go undetected. If patients could learn to discriminate blood glucose levels outside the normoglycemic range, then blood glucose testing equipment might be more effectively and economically used. Initially, the equipment would provide feedback about the accuracy of patients' estimates of blood glucose level and subsequently would confirm subjective estimates when unacceptable fluctuations in blood glucose occur so that patients could make appropriate readjustments to their treatment.

There is evidence from clinical observation and patients' reports to suggest that some diabetic individuals are able to perceive changes in their blood glucose concentrations, and that they can, in particular, recognize the symp-

tom patterns associated with moderate degrees of hypoglycemia and hyperglycemia. Pennebaker et al. (1981) examined the relationship between physical symptoms and changes in blood glucose level. They found that 80% of the 30 diabetic patients in their study could identify at least one physical symptom that correlated highly with either high or low levels of blood glucose. There were, however, considerable individual differences in the types of symptoms associated with high and low blood glucose levels. The same research group, Cox, Gonder-Frederick, Pohl, & Pennebaker, (1983), went on to examine the stability of symptom-blood glucose relationships over time. Their finding that 70% of patients had at least one significant reliability coefficienct (>/= .49) suggested that subjective symptoms may be reliable endogenous indicators of blood glucose fluctuations. The accuracy of diabetic patients' perception of blood glucose levels has been assessed by Cameron et al. (1984) and Wing et al. (1984). Both studies suggested that the correlation between patients' estimated and measured blood glucose level was high (the Pearson Correlation coefficient was $r = +.75$ in both studies, and rose to $r = +.85$ when Wing et al. (1984) excluded the outlying results of one patient). Wing et al. (1984) found that patients could predict a change in their blood glucose level and that 65% of patients were able to estimate their blood glucose to within 20% of the measured value.

The effectiveness of feedback in improving the accuracy of patients' estimates of blood glucose levels has been examined by Bradley and Jefferies (1980) and by Gross et al. (1983, 1984). Wing et al. (1984) had shown in their study that a history of blood glucose monitoring was not sufficient to improve blood glucose estimation accuracy beyond that exhibited by patients who had not previously measured their blood glucose regularly. Bradley and Jefferies (1980) reported that the accuracy of patients' estimates improved after they used a Glucocheck meter for 7 days to provide feedback. Gross et al. (1983, 1984) found that patients' blood glucose estimation accuracy improved when they were provided with feedback but returned to baseline levels when feedback was withdrawn.

While the findings of these studies suggest that patients can estimate their blood glucose levels accurately and that this ability improves with the provision of feedback, these results are based on data from small numbers of patients (Bradley & Jefferies, 1980; Gross et al., 1983, 1984) or on a few data points from each patient (Cameron et al., 1984; Wing et al., 1984). With the exception of Bradley and Jefferies (1980), none have instructed subjects about the cues to which they should attend when making estimates of blood glucose and each has been conducted under artificial laboratory conditions.

In learning to discriminate between different levels of blood glucose, the work of Pennebaker et al. (1981) and Cox et al. (1983) suggests that it

may be useful to instruct patients to attend to their physical symptoms when estimating blood glucose. Among the cues that may be salient when blood glucose is estimated are mood states. One of the aims of the present study was to examine the consistency of mood-blood glucose relationships both within and between subjects. The work of Bradley and Jefferies (1980) was replicated and extended by this study. It also examined (a) the accuracy of subjective blood glucose estimation in patients with no previous history of self-monitoring of blood glucose, (b) the efficacy of feedback of objective blood glucose determination in improving the accuracy of subjective blood glucose estimation, including a comparison of the effects of immediate versus delayed feedback, and (c) the extent of individual differences in accuracy of blood glucose estimation.

METHOD

Subjects

Twenty patients with insulin-dependent diabetes, 10 men and 10 women, were recruited from the Outpatient Clinic of the Royal Hallamshire Hospital, Sheffield. Patients selected had previous experience of urine glucose testing only and were interested in using blood glucose testing. The study was described in detail to each patient before informed consent was sought. Five men and five women were assigned to each group. Groups were structured for age and duration of diabetes.Mean ages were 35.2 years in Group 1 (range 23 to 49 years) and 37.6 years in Group 2 (range 20 to 57 years). Mean duration of insulin-dependent diabetes and mean insulin requirements were 11.3 years and 50.6 units in Group 1, and 12.8 years and 50.8 units in Group 2. Mean blood glucose levels during the baseline phase were 10.3 mmol/L (185 mg/dl) for Group 1 and 8.8 mmol/L (158 mg/dl) for Group 2; this difference was not significant on a *t* test.

Design and Procedure

The baseline, treatment, and follow-up procedure included the following: Phase 1, Baseline—5 days; Phase 2, Feedback—14 days; Phase 3, Immediate follow-up—5 days; Phase 4, 3-month follow-up—5 days.

Patients in Group 1 completed all four phases while patients in Group 2 received no feedback of blood glucose level in Phase 2. In Phases 1, 3, and 4 all patients completed a Mood Adjective Checklist (MACL), made an estimate of their blood glucose level, and then provided a filter-paper blood sample (Wakelin, Goldie, Hartog, & Robinson, 1978; West, Marsland, &

Bradshaw, 1979). Filter-paper blood spots were a convenient method of obtaining blood samples for later analysis during the phases when the experimental design demanded that patients should receive no feedback about their blood glucose levels. Patients were instructed to follow this procedure three times each day. To ensure that each estimate would be independent of the preceding blood glucose measure, patients varied their times of estimation and sampling, spreading them throughout the day.

Mood Assessment

A 30-item MACL, developed by Mackay, Cox, Burrows, and Lazzerini (1978), was used by the patients to rate their mood. Mackay's factor analysis of the checklist had indicated that the items loaded highly on one of two factors, labeled Stress and Arousal. Each of the 30 items was rated on 4-point unipolar scale. Three versions of the checklist were prepared, with the adjectives presented in different random order. The daily order of presentation of each version was also random.

Blood Glucose Estimation

Scales, labeled in units of 1 mmol/L, were constructed to show blood glucose levels from 0 to 22 + mmol/L, (396 mg/dl). This was the range of measurement of the Hypocount-B meter, which was used to measure blood glucose in Phase 2. The scales were provided with four descriptive labels: Low [0 to 3 mmol/L (54 mg/dl)], Acceptable [4 to 10 mmol/L (72 to 180 mg/dl)], High [11 to 16 mmol/L (198 to 288 mg/dl)], and Very High [17 to 22+ mmol/L (306 to 396 mg/dl)]. Labels were assigned to ranges of blood glucose so that they corresponded to labels used by the referring physicians in clinical practice. Patients indicated their estimate of blood glucose level, on each occasion, by circling the appropriate unit on the 0–22 + mmol/L scale.

On completion of Phases 1, 3, and 4, the MACLs, estimate sheets, and filter papers were collected and analyzed. All patients received feedback at the end of these phases in the form of a graph showing their estimated and actual blood glucose levels and a table summarizing their results and indicating the accuracy of their estimation.

Before beginning Phase 2, patients in Group 1 received detailed instruction in the use of the Hypocount-B meter. Three times daily, during this phase, Group 1 patients completed the MACL, estimated their blood glucose level, and then used the Hypocount-B meter to provide immediate feedback about the accuracy of their estimate. Each patient performed between 35 and 42

blood glucose tests. At the completion of Phase 2, the Hypocount-B meter was collected and patients returned to filter-paper blood sampling. Patients in Group 2 received no immediate feedback of blood glucose level and took no blood samples during Phase 2. Thus, all patients received delayed feedback of blood glucose levels during the baseline and follow-up phases but only Group 1 patients received immediate feedback of blood glucose level in the feedback phase, Phase 2.

On completion of Phase 3, all patients were introduced to the visually read Boehringer-Mannheim 20–800 Test Glycemia strips. Eighteen patients used this method of blood glucose monitoring for the 3-months period intervening between Phases 3 and 4. Two patients did not fill their prescriptions for blood test strips. Two patients began to use a continuous subcutaneous insulin infusion pump in the period between Phases 3 and 4 and were using it to control their diabetes during Phase 4 of the study.

Data Preparation

Evaluation of the filter-paper blood spot and Hypocount reflectance meter blood glucose results revealed that there was a systematic difference between the measurements provided by each method (Moses & Bradley, 1984; Bradley & Moses, 1986). Blood glucose measures for Group 1 patients had been obtained using both methods. Adjustments to the filter-paper measures for this group were made using appropriate regression equations so that the results from Phases 1, 3, and 4 were made comparable with those of Phase 2, in which subjects received immediate feedback. Results for 3 patients who returned fewer than 10 usable filter-paper blood spots in Phase 1 were excluded from the analyses. The analyses reported are based on data from the remaining 17 patients.

The patients' accuracy of estimation was defined as the absolute difference between their estimated blood glucose level and their measured blood glucose level. A second measure of the patients' accuracy in recognizing different levels of blood glucose was obtained by defining the number of correct classifications of blood glucose as Acceptable [4 to 10 mmol/L (72 to 180 mg/dl)], Unacceptably Low [less than 4 mmol/L (72 mg/dl)], or Unacceptably High [greater than 10 mmol/L (180 mg/dl). For the purpose of comparison, each frequency was expressed as the percentage correct. Summing the percentage correct in the acceptable and in the two unacceptable ranges provided an index of patients' accuracy in predicting the classification of each blood glucose measure obtained.

RESULTS

In order to establish that there were no changes in glycemic control that might have influenced estimation accuracy, an analysis of variance was carried out that used range of blood glucose levels as the dependent variable. This demonstrated that there were no differences between the Groups ($F(1, 15) = .36$, n.s.) in the range of blood glucose levels experienced and no significant interaction between Groups and Phases ($F(2, 30) = .07$, n.s.).

There were large individual differences in patients' accuracy of estimation. Mean errors of estimation ranged from 9.71 to 2.11 mmol/L (174.78 to 37.98 mg/dl) during Phase 1, 6.42 to 1.87 mmol/L (115.56 to 33.6 mg/dl) in Phase 3, and 4.99 to 1.84 mmol/L (89.82 to 33.12 mg/dl) in Phase 4 (see Table I). During Phase 2 the Feedback group's mean error of estimation ranged from 4.86 to 2.29 mmol/L (87.48 to 41.22 mg/dl). While the majority of patients showed little change in their estimation accuracy across phases, some patients were remarkably accurate in all three phases. Six patients were accurate to within a mean of 4 mmol/L (72 mg/dl) on each of Phases 1, 3, and 4, and two of these patients were accurate to within 3 mmol/L (54 mg/dl). A repeated-measures analysis of variance using each patient's mean absolute errors of estimate in Phases 1, 3, and 4 showed no significant difference between the groups ($F(1, 15) = 2.41$, n.s.) and no significant change in estimation accuracy from baseline to the immediate or 3-month follow-up phases ($F(2, 30) = 1.87$, n.s.). Group 2 patients tended to be more accurate than Group 1 patients during baseline ($t(15) = 1.99$, $p < .07$).

As the groups appeared to differ in initial levels of accuracy, which in turn appeared to influence capacity for improvement in estimation accuracy, analysis of covariance was employed to assess change in accuracy across phases using initial levels of accuracy as the covariate. Repeated-measures analysis of covariance using changes in each patient's mean absolute errors of estimate from Phase 1 to Phase 3 and from Phase 1 to Phase 4 showed no significant difference between the groups ($F(1, 14) = .16$, n.s.). There was a tendency for greater improvement to be shown between Phases 1 and 4 than between Phases 1 and 3, although this difference did not reach significance ($F(1, 15) = 3.43$, $p < .09$). A tendency for Group 1 to show improvement in accuracy from Phase 1 to 3 (adjusted mean .63), which was maintained at Phase 4 (adjusted mean .65) while Group 2 showed little improvement in accuracy from Phase 1 to 3 (adjusted mean .31) followed by a greater improvement to Phase 4 (adjusted mean 1.42), did not reach significance ($F(1, 15) = 3.18$, $p < 0.1$).

Table I. Mean Estimation Errors[a]

Subjects	Mean error Phase 1 (mmol/L)		Mean error Phase 2 (mmol/L)		Mean error Phase 3 (mmol/L)		Mean error Phase 4 (mmol/L)	
Group 1 (n = 9)								
1	8.17		3.88		4.21		4.64	
2	6.18		3.89		2.57		3.21	
3	3.17		3.38		3.42		3.30	
4	3.38		2.48		1.87		2.48	
5	3.83		4.38		3.03		3.99	
7	2.13		2.29		6.42		4.82	
8	9.71		4.86		3.03		1.84	
9	4.58		4.14		3.90		1.94	
10	4.54		4.43		2.95		4.99	
Group 2 (n = 8)	5.08	(2.37)	3.75	(.88)	3.49	(1.30)	3.47	(1.22)
13	2.56		–		4.51		2.65	
14	2.75		–		2.55		2.90	
15	3.75		–		2.84		2.43	
16	2.55		–		2.91		2.50	
17	4.18		–		5.01		2.22	
18	2.11		–		5.44		2.72	
19	3.98		–		5.73		4.88	
20	4.01		–		3.05		2.83	
	3.24	(.82)	–		4.01	(1.30)	2.89	(.83)

[a]The table shows the mean error in blood glucose estimates for subjects in the immediate feedback (Group 1) and delayed feedback groups. Figures in brackets are the standard deviation of errors in each phase.

Table II. Percentage of Correct Classifications of Blood Glucose as Unacceptably Low, Acceptable, or Unacceptably High

	Phase 1	Phase 2	Phase 3	Phase 4
Group 1 (n = 9)	52%	65%	68%	60%
Group 2 (n = 8)	59%	–	58%	59%

The accuracy of patients' recognition of blood glucose level as Unacceptably Low, Acceptable, or Unacceptably High was investigated by calculating each subject's change in percentage correct classification of blood glucose (Table II), and analysis of covariance was used to control for initial differences in classification accuracy.

There was no significant difference between the groups ($F(1, 14) = .61$, n.s.) in their ability to estimate correctly whether their blood glucose was acceptable or in one of the two unacceptable ranges, and there were no significant differences between improvements found between Phases 1 and 3 and those obtained between Phases 1 and 4 ($F(1, 15) = .49$, n.s.). The interaction between the main effects of Group and Phase were not significant ($F(1, 15) = .68$, n.s.). Together with the analysis of the mean errors of estimation these results showed that immediate feedback of blood glucose levels compared with delayed feedback did not produce significantly different levels of estimation accuracy either for fine or coarse discrimination of blood glucose level.

The results from all patients were combined on each of the subsequent analyses. During Phases 1, 3, and 4, patients' blood glucose levels were below 4 mmol/L (72 mg/dl) on 80 occasions and above 16 mmol/L (288 mg/dl) on 103 occasions, which, when combined, represented 25% of the total number of occasions on which blood glucose was measured. Accuracy in detecting these extreme levels of blood glucose was found to be low. Patients made 13 and 38 estimates within the Low and Very High ranges, respectively, but on only 6 and 19 occasions were these estimates correct.

Mood Predictors of Blood Glucose Level

Pearson correlations were used to identify those mood adjectives that patients associated with their experience of different levels of blood glucose. Neither the Stress nor the Arousal scale of the MACL was found to predict reliably either high or low levels of blood glucose across all patients. One subject had statistically significant negative correlations between both stress and arousal factors and blood glucose level. In this case, the greater the reported stress or arousal, the lower the blood glucose level. Two subjects

had significant negative correlations between the stress factor and blood glucose level and showed a significant positive relationship between arousal and blood glucose level. All these subjects were from Group 1 (the correlations were based on a minimum of 83 sample pairs). None of the remaining subjects had correlations that reached a probability of .05 on a two-tailed test between stress or arousal and blood glucose level.

When specific mood adjectives were examined, statistically significant correlations ($p < .025$) relating to either high or low blood glucose levels could be identified for 12 of the 17 patients. The 12 patients who had significant mood-blood glucose correlations did not demonstrate greater estimation accuracy or greater improvement in estimation accuracy across phases than patients who had no significant correlations. The mean number of mood adjectives that were found to correlate significantly with blood glucose for these 12 patients was four. Table III lists, for each subject, the mood adjective that was found to correlate most strongly with blood glucose level.

The associations were highly individualistic. Adjectives describing subjective feelings associated with high and low blood glucose levels, although predictive for the individual, showed no consistent pattern of association for the group. Different patients associated the same items from the MACL with both high and low blood glucose levels; for example, "comfortable" was one patient's best predictor of high blood glucose while, for another patient, "comfortable" was their best predictor of low blood glucose.

DISCUSSION

Estimation accuracy was not significantly improved by providing patients with either immediate or delayed feedback. Across Phases 1, 3, and

Table III. Correlations of Mood Adjectives with Blood Glucose Level

Subject	Mood adjective	Correlation	N	Predictor
1	Tired	.43 $p < .001$	83	Low blood glucose
2	Drowsy	.34 $p < .001$	84	Low blood glucose
3	Jittery	.37 $p < .001$	87	Low blood glucose
4	Calm	.33 $p < .001$	83	High blood glucose
5	Relaxed	.30 $p < .01$	83	High blood glucose
7	Stimulated	.39 $p < .001$	82	High blood glucose
8	Lively	.28 $p < .01$	85	Low blood glucose
10	Comfortable	.23 $p < .025$	77	Low blood glucose
16	Sluggish	.38 $p < .01$	44	Low blood glucose
17	Drowsy	.40 $p < .01$	45	Low blood glucose
19	Dejected	.33 $p < .025$	39	High blood glucose
20	Comfortable	.36 $p < .01$	45	High blood glucose

4, both groups of patients performed similarly and did not demonstrate significant differences either in their ability to make fine discriminations of blood glucose levels or in their ability to predict whether their blood glucose was in the acceptable or unacceptable range. Furthermore, Group 1 patients' ability to make fine or coarse discriminations of blood glucose level did not improve when they received immediate feedback of their estimation accuracy. Although no significant differences were observed between the groups, when differences in baseline accuracy were controlled for using analysis of covariance, there was a tendency for subjects who received immediate feedback to show a greater improvement in accuracy from Phase 1 to Phase 3 than did the delayed feedback group, although by Phase 4, after most subjects had experienced 3 months of routine blood glucose monitoring, the accuracy of Group 2 had also improved. These findings are not in agreement with those of Gross et al. (1983), who reported that their patients' accuracy of estimation improved only during those periods in which they received immediate feedback and returned to baseline levels when that feedback was withdrawn. There were fundamental methodological differences, however, between the two studies. The Gross et al. report was a set of three case studies for patients whose blood glucose variability was low, [their daily mean blood glucose levels were less than 200 mg/dl (11 mmol/L) throughout the study] and for whom the time difference between their blood glucose tests was relatively constant. Not only did estimation accuracy of Gross and colleagues' patients improve with feedback but their glycemic control was also improved during feedback phases. Gross et al. recognized that improved glycemic control, resulting in a reduced range of blood glucose, could decrease the difficulty of the estimation task and discussed the possibility that their patients' improvements in estimation accuracy might be attributed either to the direct effects of feedback or to the indirect effects of improvements in control.

In the present study, times of estimation were varied in order to reduce the influence of the preceding blood glucose measures on blood glucose estimates and to assess the degree to which patients could accurately predict changes in their blood glucose levels throughout the day. Levels of blood glucose recorded by patients varied substantially within each phase, as did their estimates. There were no significant differences between the groups in the range of blood glucose experienced or in the range of blood glucose estimated in each phase.

Patients were inaccurate in detecting blood glucose levels outside the acceptable or high blood glucose ranges, tending to overestimate their blood glucose level when it was low and underestimate it when it was very high. It would be tempting to conclude that these differences in estimation accuracy

were due to differences in patients' sensitivity to blood glucose within each range. However, it could equally be that, independent of sensitivity, patients were overoptimistic about the acceptability of their blood glucose levels; wishful thinking may have led them to estimate their blood glucose to be in the middle rather than at the extremes of the 0 to 22 mmol/L (0 to 396 mg/dl) range. Whatever the explanation, the tendency for patients to be inaccurate in identifying very high or low levels of blood glucose was disturbing since the detection and correction of extreme levels is necessary to ensure satisfactory glycemic control.

The finding that mood correlates of blood glucose differed for individuals and that no one mood state was associated with blood glucose for all patients complements the finding of Pennebaker and his colleagues (1981), who found that there were substantial individual differences in the physical symptoms patients associated with different blood glucose levels. While data demonstrated significant mood–blood glucose relationships, the usefulness of these relationships to patients when they estimated their blood glucose appeared to be low. Those patients who had significant mood–blood glucose correlations showed neither greater estimation accuracy nor greater improvement in accuracy across phases than patients who had no significant correlations. The Pearson correlations demonstrated that there was an average of four significant mood–blood glucose correlations per patient. Thus, there was a large number of adjectives on the MACL which had little or no predictive value for the patient but which they were nevertheless required to consider before making an estimate of their blood glucose. If the amount of noise in the MACL were reduced by compiling, for each patient, lists of mood descriptors that included only those adjectives found to correlate highly with their individual blood glucose levels, the predictive value of mood as a cue to blood glucose level might be improved. For some subjects, however, none of the mood adjectives correlated highly and, for them, focusing on mood may have served to hinder rather than help their estimation accuracy.

Within these more general findings, some individuals' blood glucose estimates were accurate to within an average of 3 mmol/L (54 mg/dl) during each phase of the study. For these more accurate patients, subjective estimates of blood glucose provided a useful guide to their actual blood glucose levels. Blood glucose monitoring equipment could, therefore, be used by these patients not simply to provide a record of glycemic control but to confirm their subjective estimates of their blood glucose level. This use would be particularly recommended when they judged their blood glucose to be outside the acceptable range. Other patients, however, could be misled if they relied on their subjective estimates. Where patients' estimation accuracy is low or unknown, it would be advisable for them to test their blood

glucose frequently and be instructed not to rely on feelings of well-being as indicative of acceptable levels of blood glucose. These patients may also benefit by exploring the relationship between their food intake, exercise, insulin regimen, or daily activities and changes in their blood glucose level. The use of self-monitoring to provide feedback about relationships between internal sensations, external factors, and blood glucose levels, might not only improve patients' estimation accuracy and ability to detect unacceptable levels of blood glucose but might also help to improve each individual's understanding of the factors that cause disruptions to their blood glucose control.

In summary, this study examined patients' accuracy in estimating their blood glucose level and the relationship between mood and blood glucose. A baseline, treatment, follow-up procedure was used to compare the performance of a group of patients provided with delayed feedback of their estimation accuracy from filter-paper blood spot analyses with that of a group of patients who not only received delayed feedback but during treatment were provided with 14 days of immediate feedback from a Hypocount meter. Differences between the estimation accuracy of these two groups did not reach significance, and there was no significant change in patients' estimation accuracy when baseline performance was compared with performance after the treatment phase. Accuracy in detecting extreme levels of blood glucose was found to be low. There were considerable individual differences in patients' estimation accuracy. Individual differences in the nature of the mood–blood glucose relationships were also apparent. Adjectives describing moods that were significantly associated with high and low blood glucose levels for individual patients were not predictive of blood glucose levels across patients. There findings, together with those of other researchers, have led us to suggest (Cox et al., 1985) that clinicians should not expect to be able to inform patients of the feelings they will experience with extreme blood glucose levels. They might, however, encourage patients to identify their own idiosyncratic predictors of blood glucose levels.

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