TESTING A MODEL OF DIABETES SELF-CARE MANAGEMENT
A Causal Model Analysis With LISREL

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The daily management of diabetes involves a complex interaction of metabolic variables, self-care behaviors, and psychological and social adjustments to having the disease. Diabetes patient-education programs usually focus on the self-care aspects of managing the disease with emphasis on specific cognitive knowledge and performance of daily diet, medication and exercise routines. This study presents a model of diabetes management which includes an attitudinal element—the personal meaning of having diabetes. This expanded model allows for testing of hypothesized relationships between all elements, rather than a single linear cause and effect model. Data were obtained from 115 Type I and 105 type II people from three states who had had diabetes for at least one year. The data were analyzed using a structural equation analysis (LISREL VI). While the results showed that the data did not fit the proposed model well enough to allow for definitive conclusions, the results are generally supportive of the original hypothesis that the personal meaning of diabetes is an important element in the daily management of diabetes and the psychosocial adjustment to the disease.

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There has been an increased use of a data analysis technique called the maximum-likelihood analysis of structural equations to investigate the plausibility of specific theoretical models (for example, Chen & Land, 1986). This technique allows for analysis of nonexperimental data to determine if the observed data exhibit patterns of relationships which fit patterns expected from the theoretical model. This study used the LISREL computer program (Jöreskog & Sörbom, 1986) to investigate the plausibility of a model relating three aspects of an individual's daily management of diabetes. The first part of this article presents the components of diabetes daily management and how they interrelate, followed by a description of the parameters estimated by the LISREL program. A description of the diagrammatic representation of the model and the specific measures, a presentation of the sample and its characteristics, and a discussion of the results and analysis make up the final section.

MODEL OF MANAGING DIABETES

Diabetes research is complex at the clinical level, involving several domains of variables. There are metabolic variables, such as blood glucose, glycosylated hemoglobin, weight, circulating insulin, C-peptides, as well as a great number of biologic indicators related to the complications of diabetes. Some of the variables from the self-care behavior domain include patient knowledge of diabetes, consumption of food, level of physical activity, monitoring of blood glucose, administration of medication, self-treatment of hypoglycemia and hyperglycemia, and psychological and social adjustment to diabetes. Finally, some of the relevant demographic variables include age, sex, socioeconomic status, and ethnic group.

There are many important variables from different domains and interactions among these variables that affect the course of the disease. For example, in some instances, stress raises blood glucose and in other instances stress lowers glucose levels (Horton, 1988). The same is true of the impact of exercise on blood glucose (Carter, Gonder-Frederick, Cox, Clarke, & Scott, 1985). Also, what can be a symptom of hypoglycemia for one patient can be a symptom of hyperglycemia

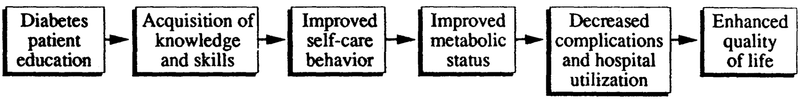

Figure 1: Linear Model of Diabetes Patient Education

for another patient (Cox et al., 1985). Furthermore, in some situations causal relationships are reciprocal; for example, psychological states can alter the level of blood glucose, and changes in blood glucose levels can affect psychological states (Gonder-Frederick, Cox, Babbitt, & Pennebaker, 1989).

Diabetes patient education usually focuses on the self-care domains by improving skills (Graber, Christensen, Alogna, & Davidson, 1977; Lawrence & Cheely, 1980; Whitehouse, Whitehouse, Smith & Hohl, 1979), which contribute to better self-care behavior (Mazzuca, 1982; Webb et al., 1984), resulting in improved blood glucose levels (Karlander & Kinderstedt, 1983; Korhonern et al., 1983), decreased complications (Muhlhouser et al., 1986), and reduced use of health care services (Kaplan & Davis, 1986). This process is expected to result in an improved quality of life for the patient, as depicted in Figure 1, which is a linear model often used to describe the logic of diabetes-education programs.

Research using this linear model (Beggan, Cregan, & Drury, 1982; Korhonern et al., 1983) has demonstrated that knowledge and skills are not good predictors of self-care behavior, psychosocial adaptation, or metabolic control. These studies indicated that it was necessary to develop a more comprehensive understanding of the relationship between what patients know about diabetes and how they care for it and adapt to it. Preliminary studies (Anderson, Nowacek, & Richards, 1985; Anderson, Nowacek, & Richards, 1986; Nowacek, Anderson & Richards, 1985; Nowacek, Anderson, Richards, & O'Malley, 1986) suggested that it would be useful to examine the role of the personal meaning (attitudes) of having and treating diabetes in influencing self-care behavior and psychosocial adaptation to diabetes, as shown in an expanded model of diabetes patient education (Figure 2). This expanded model hypothesizes that changes in self-care behaviors and

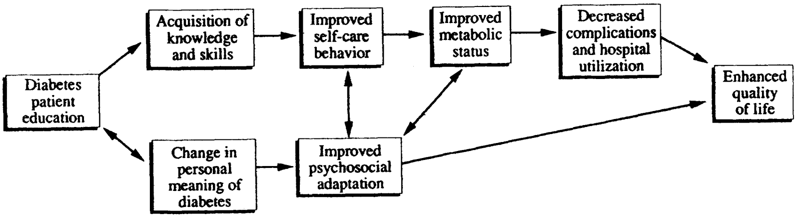

Figure 2: Expanded Model of Diabetes Patient Education

metabolic control require not only adequate knowledge and skill, but also a positive "attitude" or a personal meaning of diabetes which underlies psychosocial adjustment.

INVESTIGATION OF THE MODEL

To investigate the expanded model in Figure 2, we chose structural equation analysis because it allows the analysis of multiple indicators of key theoretical constructs (the measurement model), and an analysis of the relationships among those key theoretical constructs (the structural model). There are other advantages to the LISREL approach, in particular the ability to model relationships among errors in observed variables. These relationships are often due to methodological sources—for example, shared variances due to particular methods of measurement. Another advantage of structural equation analysis is its ability to evaluate both the measurement and the structural model.

ESTIMATING THE PARAMETERS OF THE MODEL

The parameters of the model were estimated using the SPSS-X version of LISREL VI. The measurement model is:

$$y = \Lambda_y \eta + \varepsilon$$
$$x = \Lambda_x \xi + \delta$$

where y is a vector of observed indicators of the latent endogenous variables, Λ_y is a matrix of regression coefficients of y on η, and ε is a vector of errors of measurement in y, and similarly, x is a vector of observed indicators of the latent exogenous variables, Λ_x is a matrix of regression coefficients of x on ξ, and δ is a vector of errors of measurement in x.

The basic structural model is:

$$\eta = \beta\eta + \Gamma\xi + \zeta$$

where β is a matrix of coefficients representing direct causal effects of η-variables (latent endogenous variables) on other η-variables, Γ is a matrix of coefficients representing direct causal effects of ξ-variables (latent exogenous variables) on η-variables, and ζ is a vector of residuals (that is, random disturbance terms, or errors in equations).

With appropriate assumptions, this series of equations can be solved for estimates of parameters for both the measurement and structural equation models. The program uses a maximum-likelihood full-information procedure to determine estimates, making use of all information in the data about each parameter in determining estimates.

DESCRIPTION OF MODEL TO TEST

Using the organization of information in structural equation analysis, the expanded model of diabetes education (Figure 2) can be diagrammed as shown in Figure 3, which includes both the measurement and structural models. The diagrammatic representation of the expanded model[1] is important for several reasons. The primary use of an analysis of structural equation program such as LISREL assumes the investigator wants to confirm whether observed data fit a theoretical model. The specification of the model in diagrammatic form, therefore, requires explicit statement of the constructs and the expected relationships among these constructs.

In the diagram, the constructs are represented by circles; they are variables that are not measured directly (these are sometimes called unmeasured or latent variables) and are analogous to the first factor of a principal component analysis. There are two general types of constructs: exogenous, whose causes are not of interest or unknown (Ability and SES); and endogenous, which are construct variables

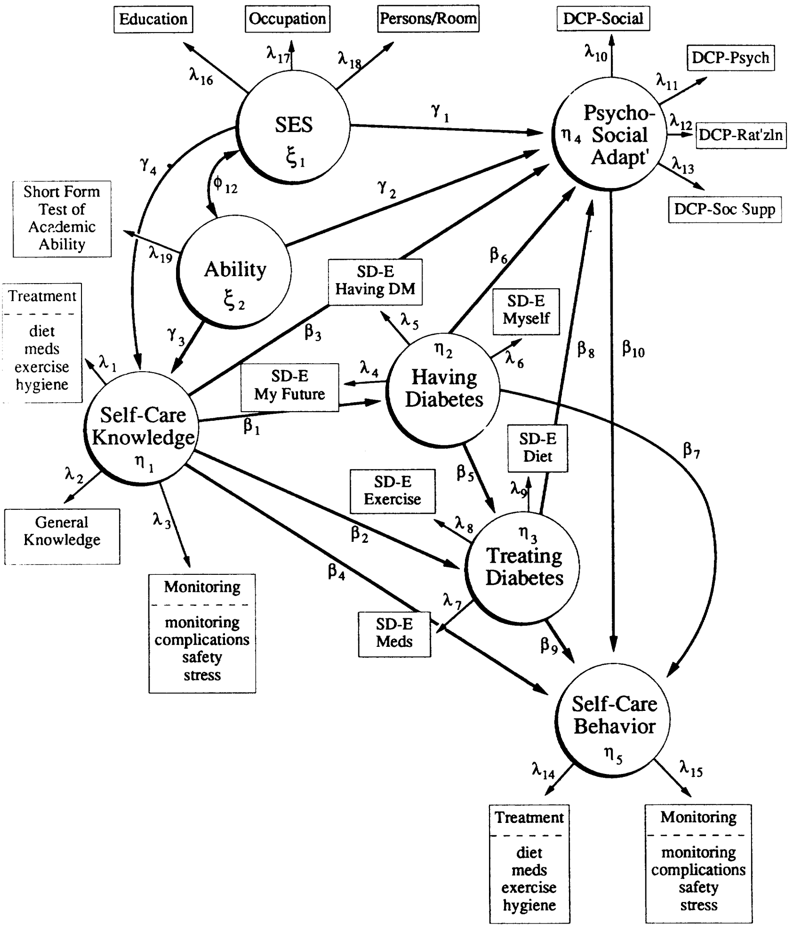

Figure 3: Measurement and Structural Models of Expanded Model of Diabetes Self-Care Management

whose relationships and causative factors are to be identified (Self-Care Knowledge, Having Diabetes, Treating Diabetes, Psychosocial Adaptation, and Self-Care Behavior).

The boxes in the diagram represent the actual data elements that are collected to measure the constructs. These measures represent a sampling of the universe of all the measures that could be chosen to measure that particular construct. In this analysis, these measures are fixed to be estimates only of the construct to which they belong.[2] In the specification of a model, the arrows are statements of the expected relationships between the constructs. In addition, the head of the arrow indicates the direction of the effect. When there is one arrow going from one construct to another, this relationship is called recursive. It is possible to specify a reciprocal effect with two arrows between two constructs; this relationship is called nonrecursive. The two-headed curved arrow between SES and Ability specifies correlated exogenous variables.

The model in Figure 3 includes five constructs. The first, Knowledge, represents the cognitive knowledge of diabetes management. This is the basic knowledge that is needed for daily management; it does not include the highly technical and scientific aspects of diabetes treatment. There are nine areas in the content structure which are organized into 3 indicators of diabetes knowledge. These content areas are the focus of most diabetes-education programs and form the basics of the treatment regimen. The second and third constructs are included in the model as the affective component of having diabetes. The second construct, Having Diabetes, estimates the present and future affects of the disease on the person, or as described earlier, the personal meaning of having diabetes. The third construct, Treating Diabetes, represents the affective component of the daily management routines of treating diabetes.

The fourth construct, Psychosocial Adaptation, is an estimate of the overall psychosocial adjustment of the person to diabetes. It focuses on the impact that the illness has on daily living. The measures used to estimate this construct were taken from work at the University of Michigan in the development of the Diabetes Care Profile (DCP) (Davis, Hess, Van Harrison, & Hiss, 1987). The last construct, Self-Care Behavior, is an estimate of the degree to which the daily treatment regimen is followed. While the measure of this construct is based on self-report data, it does include a statement of the expected treatment regimen and the extent to which that particular regimen is followed.

The boxes in Figure 3 represent the specific measures that were chosen to estimate the constructs and collectively are the measurement model. The measurement of the Knowledge construct consisted of a

30-item multiple choice test covering nine construct areas. The scoring of the test produced three category subscores that estimated the different components: general diabetes knowledge, knowledge of the treatment parameters, and knowledge of monitoring techniques and complications. The Having Diabetes construct was measured using the semantic differential technique. Because this construct represents an affective element, only the evaluation dimension of the semantic differential was used. There were three concepts presented in semantic differential format which in preliminary analyses were shown to relate to the construct of Having Diabetes: myself, my future, and me having diabetes.

The construct, Treating Diabetes, was also measured with semantic differential evaluation dimension. The three concepts chosen for the measurement model of this construct were based on the practical importance of the three elements of diabetes management: me following a diabetic diet, me exercising, and me taking medications. The Self-Care Behavior construct was measured with two general components of treatment behaviors and monitoring behaviors. Four measures in each of the two components estimated the completion of daily management behaviors with 59 questions which were self-reports of whether expected treatment-regimen behaviors were followed. The specific instrument used was the self-care management behavior sections from the Diabetes Care Profile.

The fifth construct, Psychosocial Adaptation, was a measure of psychosocial adjustment and focused primarily on the impact of diabetes on daily living. Various measures were investigated, but sections from the Diabetes Care Profile were chosen because they were most directly relevant to the potential impact of diabetes on the individual. Four independent components from the profile were chosen as the measurement for the Psychosocial Adaptation: social problems, psychological problems, rationalization, and social support.

SAMPLE

The sample for this study included 220 people with diabetes who were recruited through diabetes clinics in several states: 193 in Vir-

TABLE 1
Descriptive Statistics of Sample of Type I and Type II Diabetes

	Total	*Type I Diabetes*	*Type II Diabetes*
Location			
Virginia [N]	193	104	89
Maine [N]	12	5	7
Nebraska [N]	10	3	7
Other [N]	5	3	2
Age [X,(SD)]	51.0	43.9	59.0
	(15.2)	(15.1)	(10.6)
Sex			
Male [%]	36.8%	36.0%	37.9%
Female [%]	63.2%	64.0%	62.1%
Duration of disease [X, (SD)]	12.5	15.3	9.3
	(10.4)	(11.8)	(7.1)

ginia; 12 in Maine; 10 in Nebraska; and 5 from other locations. Participation in the study was voluntary, and all volunteers who met the criteria of having diabetes for at least one year and were at least 18 years old were accepted. The sample included 115 people with Type I diabetes (insulin dependent) and 105 people with Type II diabetes (non-insulin dependent). The data were initially analyzed separately for Type I and Type II, but the results were similar; therefore, all reported analyses included both Type I and Type II diabetes. The data collection instruments and the administration procedures were field-tested during a six-month period in Virginia. A detailed administration manual was developed to standardize the data collection procedures for the primary data collection. The demographic characteristics of the sample are shown on Table 1.

RESULTS

The correlation matrix with means and standard deviations used in the analysis is shown in Table 2 for all variables. Table 3 shows the

TABLE 2
Correlation Matrix of Observed Measures

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	Treat	Gen	Mont .	Futr	Have	Me	Meds	Exrc	Diet	Soc	Psych	Ratn	Supp	Treat	Mont	Educ	Occup	R/P	Ablty
1 Knowledge: Treatment		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 Knowledge: General	627[1]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3 Knowledge: Monitoring	588	477	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4 SD-E: My Future	-017	-043	-057	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5 SD-E: Me Having Diabetes	-071	-025	-126	214	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6 SD-E: Me (Myself)	061	143	088	472	257	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7 SD-E: Me Taking Meds	066	179	109	308	313	172	-	-	-	-	-	-	-	-	-	-	-	-	-
8 SD-E: Me Exercising	-042	-091	027	221	-023	102	238	-	-	-	-	-	-	-	-	-	-	-	-
9 SD-E: Me Following Diet	-146	-133	-057	386	247	220	385	428	-	-	-	-	-	-	-	-	-	-	-
10 Adapt: Social Problems	112	105	-005	271	220	214	048	220	251	-	-	-	-	-	-	-	-	-	-
11 Adapt: Psychological Problems	178	215	160	426	384	307	277	213	345	562	-	-	-	-	-	-	-	-	-
12 Adapt: Rationalization	165	202	181	268	325	234	264	213	346	331	586	-	-	-	-	-	-	-	-
13 Adapt: Social Support	027	031	-071	281	227	236	-004	090	227	310	350	176	-	-	-	-	-	-	-
14 Behavior: Treatment	247	147	245	096	-031	143	056	347	183	064	206	334	106	-	-	-	-	-	-
15 Behavior: Monitoring	142	172	112	074	119	178	075	101	138	115	142	353	088	421	-	-	-	-	-

(Continued)

TABLE 2 Continued

	1 Treat	2 Gen	3 Mont	4 Futr	5 Have	6 Me	7 Meds	8 Exrc	9 Diet	10 Soc	11 Psych	12 Ratn	13 Supp	14 Treat	15 Mont	16 Educ	17 Occup	18 R/P	19 Ablty
16 Education[2]	488	369	360	006	026	143	220	016	-089	018	124	186	-036	147	117	-	-	-	-
17 Occupation[2]	274	323	243	-085	012	102	125	-090	-138	-076	068	073	-016	166	125	404	-	-	-
18 Rooms/Person	218	103	113	-011	-065	022	020	-021	-086	-058	044	183	082	101	071	269	147	-	-
19 Ability	581	565	477	-137	-080	-005	051	-066	-169	028	099	125	038	207	128	514	301	275	-
Mean	74.1	80.4	74.4	5.1	2.7	5.0	3.7	5.2	4.2	3.6	3.7	3.1	4.0	48.1	49.5	30.4	10.2	2.7	19.2
Standard Deviation	19.5	24.6	20.5	1.7	1.3	1.6	1.5	1.4	1.6	.8	1.0	.8	.8	4.3	6.2	16.3	4.8	1.5	5.5

1. Decimal point omitted for clarity.
2. Ordinal variable scaled to approximate interval variable.

coefficients for both the measurement model and the structural model for the primary analysis of the data.

MEASUREMENT MODEL

The measurement model results (Λ_y and Λ_x) show the constructs to be sufficiently estimated by the measures. The measurement errors in the observed indicators appeared to be relatively independent of each other, and the results reflected no correlated errors. However, approximately 15% of the modification indices (not shown) relating measure to constructs other than those shown in the measurement model were greater than 5.0 (indicating that the measure would load significantly on that construct). The highest indices suggest that the measures for the construct Treating Diabetes also would load moderately well on Knowledge and Self-Care Behavior. One measure of the construct Psychosocial Adaptation would load on Self-Care Behavior. These indices imply that the measurement model may need to be revised and supplemented with new measures for future studies. A particular problem might be the semantic differential measures; the modification indices suggest that five of six would have significant loadings on at least one other construct. A refinement of meaning constructs (Having Diabetes and Treating Diabetes) is needed and additional indicators should be included in future studies.

STRUCTURAL MODEL

The coefficients in the structural model show that the addition of the meaning constructs—Having Diabetes and Treating Diabetes—adds to the understanding of the relationships between the traditional constructs—Knowledge and Self-Care Behavior—that are the focus of most diabetes education efforts. While the results suggest that Knowledge affects Psychosocial Adaptation ($\beta_3 = .333$), Having Diabetes has the strongest effect on Psychosocial Adaptation ($\beta_6 = .592$). Likewise, while Knowledge affects Self-Care Behavior ($\beta_4 = .393$), Treating Diabetes also has a strong effect on Self-Care Behavior ($\beta_9 = .409$). Other relationships of interest could not be investigated

TABLE 3
Measurement and Structural Coefficients for Figure 3

		Unstandardized	*Standardized*	*Residual*	*Variance*
			Measurement Model		
Knowledge:Treatment	λ_1	1.259	.873	ε_1	.281
Knowledge:General	λ_2	1.100	.763	ε_2	.451
Knowledge:Monitoring	λ_3	1.000	.693	ε_3	.547
SDE:My Future	λ_4	1.587	.713	ε_4	.491
SDE:Having Diabetes	λ_5	1.000	.450	ε_5	.798
SDE:Myself	λ_6	1.200	.562	ε_6	.684
SDE:Medications	λ_7	.873	.460	ε_7	.789
SDE:Exercise	λ_8	1.000	.527	ε_8	.723
SDE:Diet	λ_9	1.562	.823	ε_9	.324
DCP:Social Problems	λ_{10}	.675	.608	ε_{10}	.634
DCP:Psycho. Problems	λ_{11}	1.000	.901	ε_{11}	.195
DCP:Rationalization	λ_{12}	.724	.652	ε_{12}	.578
DCP:Social Support	λ_{13}	.446	.401	ε_{13}	.840
Behavior:Treatment	λ_{14}	1.000	.796	ε_{14}	.371
Behavior:Monitoring	λ_{15}	.670	.533	ε_{15}	.718
Education	λ_{16}	1.000	1.000	δ_1	.187
Occupation	λ_{17}	.496	.496	δ_2	.787
Persons/Room	λ_{18}	.337	.337	δ_3	.902
Sht.Frm.Test Academic	λ_{19}	1.000	1.000	δ_4	.053
		Structural Model			
	Φ_{12}	.625	.625	ζ_1	.389
	γ_1	–.070	–.078	ζ_2	.999
	γ_2	.013	.015	ζ_3	.601
	γ_3	.390	.563	ζ_4	.412
	γ_4	.204	.294	ζ_5	.705
	β_1	–.018	–.028		
	β_2	–.100	–.131		
	β_3	.433	.333		
	β_4	.451	.393		
	β_5	.720	.614		
	β_6	1.185	.592		
	β_7	–.208	–.118		
	β_8	.325	.190		
	β_9	.617	.409		
	β_{10}	.101	.114		

NOTE: SDE = Semantic differential evaluation; DCP = Diabetes care profile; Sht.Frm.Test Academic = Short form test of academic ability.

because the addition of reciprocal relationships resulted in models that were under identified or failed to converge.

OVERALL FIT OF MODEL

The criteria used to evaluate the fit of the model to the observed data are not universally accepted. There are three indicators readily available from the SPSS-X LISREL output to judge good fit of the data to the model: (a) chi-square/degrees of freedom ratio (for example, Carmines & McIver, 1981); (b) adjusted goodness of fit (AGFI); and (c) root mean squared residual. For the model shown in Figure 1, the chi-square/*df* ratio is 1.88, the adjusted goodness of fit is .846, and the root mean square residual is .074. There is currently still considerable discussion about what constitutes a good fit (see, for example, Bollen, 1986; Marsh, Balla, & McDonald, 1987; Wheaton, 1987). Wheaton, Muthen, Alwin, and Summers (1977) suggested that a chi-square/*df* ratio of less than 5 might be a good fit; Boruch and Wolins (1970) suggested the ratio should be less than 3; and Carmines and McIver (1981) suggested that a ratio in the range of 2-3 might constitute a reasonable fit. By this standard, the current model provides a reasonable fit. By the two other standards, however, the indicators suggest that the fit leaves something to be desired. For example the AGFI should be better than .9 in a good fitting model (Bentler & Bonett, 1980). And root mean square residuals less than .05 are ordinarily seen as desirable in models that fit well. Thus we may conclude that while these indicators suggest a moderately good fit, there is still a sufficient amount of variance not accounted for, which implies that refinements of the model are needed. The squared multiple correlations for the five constructs were .61 for Knowledge, .001 for Having Diabetes, .40 for Treating Diabetes, .59 for Psychosocial Adaptation, and .30 for Self-Care Behavior.

CONCLUSIONS

Because the observed data do not meet all the criteria for model fit, the results of the study are only suggestive. The results showing strong relationships between the personal meaning variables and psychosocial adaptation are generally supportive of the original hypothesis that the affective component of diabetes is important in the daily management of diabetes. The results suggest that diabetes-education programs should include structured experiences to promote positive attitudes toward diabetes in addition to teaching the knowledge and skill of daily management. The results also suggest there might exist a diabetes self-concept which is separate from a global self-concept. This finding emerged from preliminary analysis of the semantic differential data and evolved as our understanding of the relationships among the constructs were identified through the structural equation analysis.

There are four suggestions for future research which emerged from this study. The first is to identify other constructs and include them in the models; one such construct is a diabetes self-concept which would replace the Having Diabetes construct in the current model. A second change would be additional measurement of the construct, Treating Diabetes. The semantic differential was used in this study; an additional measure which scaled the affective component of treating diabetes in relation to other daily activities would be desirable. A third change would be different or additional measures of Psychosocial Adaptation. It was recognized early in this study that this was an important outcome variable in the model and required more extensive measurement than the resources of this study could provide. The last change for future research would be to incorporate a longitudinal study design to overcome the limitation of the cross-sectional design used in this study. A longitudinal study would help establish the validity of the model and provide further insight into the causal relationships identified by the model.

NOTES

1. The model in Figure 2 was abridged and modified because of the limitations of the clinical setting and the study resources. Figure 3 describes the actual model tested.
2. Note that this restriction to only one construct is not required by the LISREL model.

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