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Testing a Self-Determination Theory Process Model for Promoting Glycemic Control Through Diabetes Self-Management

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A longitudinal study tested the self-determination theory (SDT) process model of health behavior change for glycemic control within a randomized trial of patient activation versus passive education. Glycosylated hemoglobin for patients with Type 2 diabetes ($n = 159$) was assessed at baseline, 6 months, and 12 months. Autonomous motivation and perceived competence were assessed at baseline and 6 months, and the autonomy supportiveness of clinical practitioners was assessed at 3 months. Perceptions of autonomy and competence were promoted by perceived autonomy support, and changes in perceptions of autonomy and competence, in turn, predicted change in glycemic control. Self-management behaviors mediated the relation between change in perceived competence and change in glycemic control. The self-determination process model fit the data well.

Key words: diabetes self-management, autonomous motivation, perceived competence, self-determination theory, maintenance of behavior change

Because improved glycemic control has been shown to reduce long-term diabetes complications for patients with Type 2 diabetes (UK Prospective Diabetes Study Group, 1998), research is needed to understand how patients can be motivated to manage their diabetes more effectively. Prior research has demonstrated that interventions providing diabetes self-management education improved glycemic control (Brown, 1999), but little is known about the processes by which it has its effects on patients' behavior and health (Peyrot, 1999; Williams & Zeldman, 2002).

Research on self-determination theory (SDT; Deci & Ryan, 1985; Sheldon, Williams, & Joiner, 2003) has indicated that autonomous and competence motivations are correlated with improved glycemic control (Senecal, Nouwen, & White 2000; Williams, Freedman, & Deci, 1998), suggesting that perceptions of autonomy and competence may underlie effective diabetes self-management and thus better glycemic control. Central to SDT are the concepts of autonomous versus controlled motivations and perceived competence versus incompetence. People are autonomously motivated when they experience volition and choice while behaving; they are controlled when they experience pressure or coercion. Patients following a diabetes diet would be autonomous if they freely chose to limit their calories because they believed it would help with glucose control and they were personally committed to improving their health. In contrast, patients would be controlled if they followed their diet because a doctor, nurse educator, dietician, or family member pressured them to do so.

Further, people perceive themselves to be competent when they feel able to control important outcomes such as their glucose levels, and they perceive themselves to be incompetent when they feel unable to control those outcomes. Studies have shown that as people become more autonomously motivated, they feel more competent to attain relevant outcomes (Williams & Deci, 1996; Williams, Freedman, & Deci, 1998). This is consistent with SDT because autonomy concerns the experience of initiating behaviors, whereas perceived competence concerns the feelings about achieving the outcome. One could thus expect that patients' being self-initiating would promote the development of perceived competence for managing their diabetes. SDT predicts that people will be most effective in long-term glycemic control when they are autonomous and feel competent with respect to critical self-management behaviors.

According to the SDT model, when practitioners are autonomy supportive, patients will tend to become more autonomous and to

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feel more competent. Autonomy support refers to the extent to which providers elicit and acknowledge patients' perspectives, support patients' initiatives, offer choice about treatment options, and provide relevant information while minimizing pressure and control. Studies have shown that autonomy support by health care practitioners affected patients' motivation and health-relevant behaviors, including smoking abstinence (Williams, Cox, Kouides, & Deci, 1999; Williams, Gagné, Ryan, & Deci, 2002), weight loss (Williams, Grow, Freedman, Ryan, & Deci, 1996), and medication adherence (Williams, Rodin, Ryan, Grolnick, & Deci, 1998). Of importance to the present research, autonomy support was found to be a significant predictor of change in glycemic control over 12 months in a study of patients with diabetes (Williams, Freedman, & Deci, 1998). In the present study, the degree of autonomy support provided by diabetes center clinicians was expected to predict change in patients' autonomy, perceived competence, and glycemic control.

Research has shown that practitioners can be trained to be more autonomy supportive (Williams & Deci, 2001; Williams et al., 2002). The present study was designed to examine whether using the patient-activation approach introduced in the Expanding Patient Involvement in Care (EPIC) trials (Kaplan, Greenfield, & Ware, 1989) might also prompt providers to be more autonomy supportive. The reasoning was that if patients are taught to take greater initiative during their provider visits, the providers might in turn be more supportive of the patients' autonomy for diabetes management. Thus, patients experiencing the activation intervention may have greater internalization of autonomy and competence. However, intention-to-treat analyses for the trial, which are presented in a separate report (Williams, McGregor, Zeldman, Freedman, & Deci, in press), showed that the activation intervention, relative to passive education, did not significantly affect patients' glycosylated hemoglobin (HbA1c) over the 12 months of the study. The present study examined whether the patient-activation intervention related to patients' perceptions of practitioner autonomy support (assessed at 3 months) and increased both autonomous motivation and perceived competence of the patients (from baseline to 6 months).

The present study also tested four hypotheses derived from the SDT process model. The primary outcome for the hypothesized relations was change in HbA1c maintained over the 12 months of the study, which was indexed as the residual of 12-month HbA1c after controlling for baseline HbA1c. Although not hypothesized, additional analyses also examined maintenance of HbA1c after change had occurred, which was indexed as the residual of 12-month HbA1c after controlling for 6-month HbA1c.

The first hypothesis was that autonomy support would predict change in autonomous motivation and perceived competence from baseline to 6 months and change in glycemic control from baseline to 12 months. The second hypothesis was that changes in autonomous motivation and perceived competence would predict change in HbA1c maintained over the 12-month period. The third hypothesis was that change in perceived competence would mediate the relation between change in autonomous motivation and change in HbA1c, as was found in a previous study (Williams, Freedman, & Deci, 1998). The fourth hypothesis was that diabetes self-management behaviors (e.g., diet, exercise, and glucose monitoring) would mediate the relation between perceived competence and improvement in HbA1c over the 12 months.

Method

Participants

Participants were recruited from a diabetes care center at a university-affiliated community hospital between 1996 and 1999. The center has more than 4,000 visits per year from about 1,300 patients. Eligibility criteria for the study included having Type 2 diabetes that was poorly controlled (HbA1c elevated more than 1 point above the upper end of the lab reference range), being responsible for self-management of the diabetes, having a life expectancy greater than 1 year, and being able to speak and read English. We recruited participants by placing a sign in the waiting room, and front-office staff often mentioned the study to patients when they checked in. Patients who expressed interest were referred to a research assistant who had an office at the center. The research assistant described the study and, if patients were still interested, obtained informed consent. Of 232 patients who met the criteria and gave informed consent, 159 (69%) provided complete data and were used in the analyses.

Procedure

At baseline (Time 1; T1), patients completed questionnaires concerning demographics, their disease and treatment, autonomous motivation, and perceived competence. At 3 months (Time 2; T2), patients reported on their perceptions of practitioner autonomy support. This was measured at 3 months so the measurement would be done after patients had had enough experience with practitioners to make informed ratings but at a time that was not concomitant with the assessment of their own motivation. At 6 months (Time 3; T3), patients again completed questionnaires about autonomous motivation and perceived competence. At 12 months (Time 4; T4), patients completed a questionnaire about diabetes self-management behaviors. In addition, at T1, T3, and T4, patients had blood drawn to check their HbA1c. Patients received $50 for completing the questionnaires and lab work. Patients saw three providers: an endocrinologist, a nurse educator, and a registered dietician. When completing the perceived autonomy-support questionnaire, patients were reporting on the general interpersonal climate provided by their three practitioners.

Measures

Modified Health Care Climate Questionnaire (HCCQ). The HCCQ (Williams et al., 1996) assesses patients' perceptions of the degree to which their providers were autonomy supportive (versus controlling) in consulting with them at the diabetes center. Patients responded to six items on a 7-point Likert-type scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). The original HCCQ has 15 items and has been used in several studies (e.g., Williams et al., 1996), with alphas ranging from .92 to .96. On the basis of a factor analysis of data across previous studies ($n = 638$), we selected six items to use in this study as indicators of the latent variable autonomy support. The alpha for the six items in the cross-study sample was .82. A sample item is "I feel that my health care practitioners provided me with choices and options about handling my diabetes."

Treatment Self-Regulation Questionnaire (TSRQ). The TSRQ for diabetes, which uses an assessment approach introduced by Ryan and Connell (1989), was used in an earlier study of patients with diabetes (Williams, Freedman, & Deci, 1998). Autonomous motivation and controlled motivation for following a diabetes diet and exercising regularly were assessed with a set of six items, and autonomous motivation and controlled motivation for taking diabetes medications and checking glucose were assessed with an additional set of eight items. Summary scores for autonomous motivation and controlled motivation were created within each of the two sets of items and were used in structural equation modeling (SEM) analyses as indicators of latent variables.

In the TSRQ, patients were presented two stems: first, "The reason I follow my diet and exercise regularly is that," and second, "The reason I

Table 1
Means, Standard Deviations, Ranges, and Reliabilities for Study Variables

Variable	*M*	*SD*	Range	Reliability
Demographic variables				
Age (years)	55.99	10.95	24.23–79.77	
Education level (%)				
Through grade 8	4.40			
Through grade 11	4.40			
High school diploma/GED	34.60			
Some college	30.80			
Four-year college degree	10.10			
Graduate school	15.70			
Household income (%)				
Under $5,000	1.90			
$5,000–$9,999	8.20			
$10,000–$14,999	4.40			
$15,000–$24,999	13.80			
$25,000–$34,999	16.40			
$35,000–$44,999	10.10			
$45,000–$54,999	9.40			
$55,000–$64,999	8.80			
$65,000 and over	24.50			
Refused to report	2.50			
Marital status (%)				
Married	66.00			
Living as married	1.90			
Widowed	7.50			
Legally divorced	9.40			
Separated	3.80			
Never married	10.70			
Not reported	0.60			
Gender (%)				
Female	50.30			
Male	48.40			
Not reported	1.30			
Race (%)				
African American	16.40			
Asian American	1.90			
European American	67.90			
Hispanic American	3.10			
Native American	2.50			
Other	4.40			
Not reported	3.80			
Diabetes variables				
Age of onset (years)	45.54	11.08	14.68–72.62	
Duration (years)	10.80	7.82	0.00–35.00	
Complications[a]	0.87	0.98	0.00–3.00	
No. of visits to diabetes center during study	9.36	2.56	3.00–15.00	
No. of months treated at diabetes center prior to study	28.39	36.56	0.00–151.00	
Treatment type (%)				
Diet and exercise	1.90			
Oral medication	56.20			
Insulin	16.70			
Insulin and oral medication	25.20			
Motivation variables				
Autonomy support				
3 months	5.94	1.06	1.33–7.00	.86
Autonomous motivation for medication and glucose testing				
Baseline	5.97	1.01	2.38–7.00	.86
6 months	6.30	0.80	2.75–7.00	.84
Autonomous motivation for diet and exercise				
Baseline	5.90	1.08	1.29–7.00	.88
6 months	6.13	0.90	3.57–7.00	.87
Perceived competence				
Baseline	4.84	1.46	1.00–7.00	.83
6 months	5.62	1.17	1.50–7.00	.86

Table 1 (*continued*)

Variable	*M*	*SD*	Range	Reliability
Outcome variable				
Relative HbA1c				
Baseline	1.74	0.34	1.05–3.15	
6 months	1.48	0.23	1.06–2.49	
12 months	1.47	0.28	0.94–2.78	

Note. GED = general equivalency diploma; HbA1c = glycosylated hemoglobin.
[a] Defined as neuropathy, nephropathy, retinopathy.

take my medications as prescribed and check my glucose regularly is that." Each stem was followed by items that represent either autonomous or controlled motivation. An example of autonomous motivation is, "I've carefully thought about my diet and exercise and believe they are the right things to do." An example of controlled motivation is, "Other people would be upset with me if I didn't exercise and diet." Participants responded to each item on 6-point Likert-type scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

Items reflecting autonomous reasons for following a diabetes diet and exercising regularly exhibited good internal consistency at T1 (α = .88) and T3 (α = .87) of the present study. Items reflecting autonomous reasons for taking diabetes medications as prescribed and for checking glucose levels were also highly reliable at T1 (α = .86) and T3 (α = .84). Internal consistency for the two controlled subscales were adequate. Alphas for diet and exercise at T1 were .73 and .67, respectively, and for medication and glucose monitoring at T3 were .75 and .70, respectively.

Perceived Competence for Diabetes Scale. The Perceived Competence for Diabetes Scale contains four items representing the degree to which patients feel they can manage daily aspects of diabetes care. Participants indicated their level of agreement with each item on a 1–7 scale. Each item was used as an indicator of the latent variable. Alphas in this study were .83 at T1 and .86 at T3.

Diabetes self-management. Toobert and Glasgow's (1994) Summary of Diabetes Self-Care Activities questionnaire measured diabetes self-management. It assesses four aspects of diabetes self-care (diet, exercise, glucose testing, and medication taking) across the 7 days prior to completion of the questionnaire, although Toobert and Glasgow reported that compliance to medication prescriptions tends to be so high that there is no variance. Participants reported on each regimen activity both in terms of frequencies and percentage of the time they did a behavior as prescribed (e.g., "On how many of the last 7 days did you participate in at least 20 minutes of physical exercise?" and "What percentage of the time in the last 7 days did you successfully limit your calories as recommended in healthy eating for diabetes control?"). The number of items for the four behaviors ranged from 2 to 5, and the items within a behavior were summed to form the score for that behavior. Medication taking in the present sample also showed very high compliance, so it was not included in the analyses. Participants completed the Summary of Diabetes Self-Care Activities at T4.

Relative HbA1c. The HbA1c tests were analyzed by four different laboratories, on five different instruments, using two different techniques. Thus, test results from the five instruments reported five different reference ranges for HbA1c. Each lab with the type of instrument and its reference range is as follows: The Genesee Hospital's high-performance liquid chromatography (Variant Analyzer, Bio-Rad, Hercules, CA), reference range was 4.1%–6.5%; Strong Lab's high-performance liquid chromatography (Variant Analyzer, Bio-Rad, Hercules, CA), reference range was less than 6.0%; Rochester General's lab analyzed HbA1c using boronate affinity chromatography (models 330 and 385, Primus, Kansas City, MO), reference range was 4.2%–5.5%; ACM lab's high-performance liquid chromatography (Variant Analyzer, Bio-Rad, and A1c 2.2, Tosoh Bioscience, Shunan City, Yamaguchi-kem, Japan), reference ranges were 3.8%–6.7% and 4.6%–6.5%, respectively. Each result was corrected by calculating a relative HbA1c, consistent with the method used by Muller et al. (1999) to compare change in HbA1c across sites and across time. Relative HbA1c was calculated by dividing the patient's HbA1c by the median of the instrument reference range. In this article, all HbA1c data are reported as relative HbA1c, and all analyses were conducted using relative HbA1c.

Results

Preliminary Analyses

Patients who completed the study had a mean age of 56 years; 50% were female and 50% were male. A comparison of patients who completed the study (n = 159) with those who dropped out (n = 73) indicated that those who dropped out of the study were younger, $t(225) = 2.68$, $p < .01$, and had higher HbA1c levels at baseline, $t(229) = -1.98$, $p < .05$. In addition, patients on oral and insulin medications were more likely to complete the study, $t(230) = 2.50$, $p < .05$. The differences in dropout by age and glycemic control are typical in studies of patients with diabetes. Older patients typically have more time to participate in longitudinal studies, and patients who have poorer control are less likely to attend treatment.

Using three regression analyses, we predicted change in relative HbA1c over the year (from T1 to T4) from the (a) demographic variables, (b) disease variables, and (c) treatment variables shown in Table 1. None of the variables were significantly related to change in relative HbA1c, so they were not included in the tests of the SDT model.

We then examined whether the intervention (activation versus education) affected any of the motivation variables. A repeated measures multivariate analysis of variance, followed by two repeated measures analyses of variance, with autonomous motivation and perceived competence at T1 and T3 revealed that there was not a significant change for either autonomous motivation, $F(1, 157) = 1.64$, $p = .20$, or perceived competence, $F(1, 157) = 1.64$, $p = .20$, nor did either interact with condition. Further, a t test indicated that the intervention did not affect perceptions of autonomy support from the practitioners at T2, $t(157) = 0.40$, $p = .80$.

A repeated measures analysis of variance on HbA1c at T1, T3, and T4 revealed a significant effect for time across the 12 months, $F(2, 306) = 33.39$, $p < .01$. Table 1 shows that the means for relative HbA1c were 1.76 at T1, 1.48 at T3, and 1.50 at T4. In other words, the significant drop in the average hemoglobin score

occurred during the first 6 months, when patients were receiving intensive treatment. Because the significant group-level change in HbA1c occurred wholly during the first 6 months, it gave us the opportunity to do additional analyses examining maintenance (from 6 months to 12 months) rather than maintained change (from baseline to 12 months).

Testing the Hypotheses and the SDT Model for Diabetes Self-Management

The SDT model was tested with a series of SEM analyses. Table 2 presents correlations among all the study variables, which provided the basis for the SEM analyses. First, we conducted a confirmatory factor analysis (Anderson & Gerbing, 1988; Bollen, 1989) to determine whether the item indicators of autonomous motivation, autonomy support, and perceived competence demonstrated adequate loadings on the latent variables and to test the overall fit of the measurement model (Anderson & Gerbing, 1988; Bollen, 1989). The test of the measurement model revealed good loadings for the indicators on the latent variables, and the overall model had an excellent fit, $\chi^2(121, n = 159) = 171.94$, $p < .01$ (incremental fit index [IFI] = .96, comparative fit index [CFI] = .96, root-mean-square error of approximation [RMSEA] = .05), thus justifying testing the proposed relations among the latent variables in the second step.

Before testing the actual process models, we tested the first three hypotheses, which are integral to the SDT models. Results relevant to testing the first two hypotheses and part of the third can be found in Table 3, which shows the correlations among perceived autonomy support at T2, the residual of autonomy at T3 controlling for T1, the residual of perceived competence at T3 controlling for T1, and the residual of relative HbA1c at T4 controlling for T1.

Hypothesis 1 stated that perceived autonomy support at T2 would predict change in HbA1c from T1 to T4 and change in autonomous motivation and perceived competence from T1 to T3. As can be seen in Table 3, perceived autonomy support did not relate to change in HbA1c from baseline to 12 months ($r = .02$, $p = .82$). Thus, participants' perceptions of practitioner autonomy support did not predict change in participants' glycemic control. However, perceived autonomy support at T2 did relate to change from baseline to 6 months in both autonomous motivation ($r = .27$, $p < .01$) and perceived competence ($r = .29$, $p < .01$).

Hypothesis 2 stated that changes in both autonomous motivation and perceived competence from T1 to T3 would relate to change in relative HbA1c from T1 to T4. As shown in Table 3, this hypothesis was supported ($r = -.24$, $p < .01$, and $r = -.26$, $p < .01$, respectively).

Finally, to test Hypothesis 3, which stated that change in perceived competence (from T1 to T3) would mediate the relation between change in autonomy (from T1 to T3) and change in relative HbA1c (from T1 to T4), we used SEM. The direct path between change in autonomy and change in HbA1c has been established, as just mentioned (see Table 3). When the change in autonomous motivation, change in perceived competence, and change in HbA1c were entered into SEM analyses for the purpose of testing the mediation hypothesis, the path between change in perceived competence and change in relative HbA1c was significant ($\beta = -.25$, $p = .01$), and the path from change in autonomy to change in perceived competence was also significant ($\beta = -.53$, $p = .01$); however, the relation of change in autonomous motivation to change in relative HbA1c became nonsignificant ($\beta = -.08$, $p > .10$). The model fit the data well (IFI = .96, CFI = .96, RMSEA = .06). Thus, the analyses indicate that change in perceived competence did mediate the relation between change in autonomous motivation and change in relative HbA1c.

In summary, the first three hypotheses were supported except that there was not a direct relation between perceived autonomy support and change in HbA1c. Each of the confirmed relations is contained within the hypothesized process models, so we turn now to the models.

The change models (from T1 to T4). We tested two SDT process models of 12-month change in HbA1c. The first, which is the basic form of the model, states that perceived autonomy support (T2) would predict change in autonomous motivation and perceived competence (from T1 to T3), that change in autonomous motivation would predict change in perceived competence, and that change in perceived competence would predict change in HbA1c (from T1 to T4). This model is wholly contained within the second model, which simply places the diabetes self-management

Table 2
Correlations Among Motivation Variables, Relative HbA1c Variables, and Diabetes Self-Management Behaviors

Measure (and time)	1	2	3	4	5	6	7	8	9	10	11
1. Autonomous motivation (T1)	—										
2. Perceived competence (T1)	.36**	—									
3. Relative HbA1c (T1)	−.10	−.21**	—								
4. Autonomy support (T2)	.33**	.26**	.03	—							
5. Autonomous motivation (T3)	.70**	.29**	.09**	.42**	—						
6. Perceived competence (T3)	.38**	.31**	.06	.36**	.51**	—					
7. Relative HbA1c (T3)	−.08	−.07	.40**	−.05	−.14	−.17*	—				
8. SDSCA diet (T4)	−.15†	−.04	−.08	−.12	−.03	−.06	−.07	—			
9. SDSCA exercise (T4)	.22*	.09	−.14	.06	.21*	.17†	−.25**	.11	—		
10. SCSCA glucose testing (T4)	.15	.10	−.04	.03	.01	.19*	−.11	.04	.08	—	
11. Relative HbA1c (T4)	−.08	−.05	.37**	.01	−.15*	−.24**	.68**	−.14	−.31**	−.13	—

Note. HbA1c = glycosylated hemoglobin; T1 = baseline; T2 = 3 months; T3 = 6 months; T4 = 12 months; SDSCA = Summary of Diabetes Self-Care Activities questionnaire.
†$p < .10$. *$p < .05$. **$p < .01$.

Table 3
Correlations Among Change in Motivation, Change in Relative HbA1c, Perceived Autonomy Support, and Diabetes Self-Management

Measure (and time)	1	2	3	4	5	6	7
1. Change in autonomous motivation (T1–T3)	—						
2. Change in perceived competence (T1–T3)	.35**	—					
3. Change in relative HbA1c (T1–T4)	−.24**	−.26**	—				
4. Autonomy support (T2)	.27**	.29**	.02	—			
5. SDSCA diet (T4)	.11	−.05	−.11	−.12	—		
6. SDSCA exercise (T4)	.08	.15	−.27**	.06	.11	—	
7. SCSCA glucose testing (T4)	.12	.16†	−.12	.03	.04	.08	—

Note. HbA1c = glycosylated hemoglobin; T1 = baseline; T2 = 3 months; T3 = 6 months; T4 = 12 months; SDSCA = Summary of Diabetes Self-Care Activities questionnaire.
†$p < .10$. **$p < .01$.

behaviors between change in perceived competence and change in HbA1c. The second model is shown in Figure 1. We tested the model using SEM done with AMOS 4.0.

Concerning the first model, there was a significant path from perceived autonomy support (T2) to change in autonomous motivation from T1 to T3 ($\beta = .19$, $p < .01$). The path from perceived autonomy support to change in perceived competence from T1 to T3 was marginal ($\beta = .16$, $p < .10$). The path from change in autonomous motivation to change in perceived competence was significant ($\beta = .48$, $p < .01$), and the path from change in perceived competence to reduction in relative HbA1c (from T1 to T4) was also significant ($\beta = -.25$, $p < .01$). The overall model fit the data well, $\chi^2(153) = 212.14$, $p < .01$ (IFI = .96, CFI = .96, RMSEA = .05). Thus, the analyses provide a good fit of the model to the data.[1]

As we noted above, perceived autonomy support did not have a direct effect on change in HbA1c. Therefore, the fit of the model just tested, which contained both perceived autonomy support and change in HbA1c, could imply only that the effect is indirect, with autonomy support predicting changes in autonomous motivation and perceived competence, with they in turn predicting change in HbA1c. To examine whether there was a significant indirect effect of autonomy support on change in HbA1c, we used a bootstrapping procedure involving bias-corrected confidence intervals as recommended by Efron and Tibshirani (1993). The indirect relation was significant ($\beta = -.06$, $p < .02$), indicating that perceived autonomy support relates to change in HbA1c (from T1 to T4) indirectly through changes in autonomous motivation and perceived competence.

We next tested the second model, in which the three self-management behaviors were placed between change in perceived competence and HbA1c at T4 to investigate whether change in perceived competence had its effect on change in HbA1c by affecting the diabetes-management behaviors of improved diet, exercise, and glucose monitoring. The model is shown in Figure 1.

The paths that also appeared in the first model tested had parameters in this model that were virtually identical to those in the first model. The paths that were new to this model, namely, the paths from change in perceived competence to the behaviors were to diet ($\beta = .49$, $p < .01$), to exercise ($\beta = .26$, $p < .01$), and to glucose monitoring ($\beta = .37$, $p < .01$). Finally, paths from the behaviors to change in HbA1c from baseline to 12 months were from diet ($\beta = -.21$, $p < .05$), from exercise ($\beta = -.15$, $p < .10$), and from glucose monitoring ($\beta = -.21$, $p < .05$). The overall model fit the data well, $\chi^2(383) = 590.26$, $p < .01$ (IFI = .99, CFI = .99, RMSEA = .06).

The maintenance model. Because most of the improvement in glucose control occurred during the first 6 months of the study, when patients were receiving intensive treatment in the diabetes center, the significant decrease in HbA1c occurred concomitant with the increase in autonomous motivation and perceived competence. Accordingly, it is impossible to determine whether the increases in autonomous motivation and perceived competence caused the decrease in HbA1c, or vice versa. However, it is possible to test whether the increases in autonomous motivation and perceived competence had a causal long-term effect on main-

[1] First, because the model was run with data that had been collapsed across experimental conditions, we reran the model controlling for condition and found that the fit of the model was virtually the same. The path coefficients were slightly higher, including that the path from autonomy support to change in perceived competence became significant ($\beta = .16$, $p < .05$).

Second, in the test of the model, both when condition was controlled for and when it was not, we used the items from the autonomous motivation subscale of the TSRQ as the indicators or the latent variable autonomous motivation. We reran the first model using the residual of autonomous motivation after controlling for controlled motivation to examine the unique effects of autonomy, over and above the effects of the variance it shared with controlled motivation. The fit indices were virtually unchanged, and, as when we controlled for condition, each path coefficient was either the same or higher, including that the path from autonomy support to change in perceived competence became significant ($\beta = .17$, $p = .050$).

Third, because patients in this study were engaged in diabetes self-monitoring, they checked their own glucose levels regularly. It is possible, therefore, that their levels of autonomy and perceived competence may have been affected by their glucose readings rather than the other way around, as we hypothesized. Thus, we repeated the test of the T1–T4 model controlling for the number of times people checked their glucose. In other words, any variance in HbA1c accounted for by patients' reports of how frequently they took glucose readings was removed before we examined the effects of the motivation variables on hemoglobin. The fit of the model to the data was excellent (IFI = .99, CFI = .99, and RMSEA = .05).

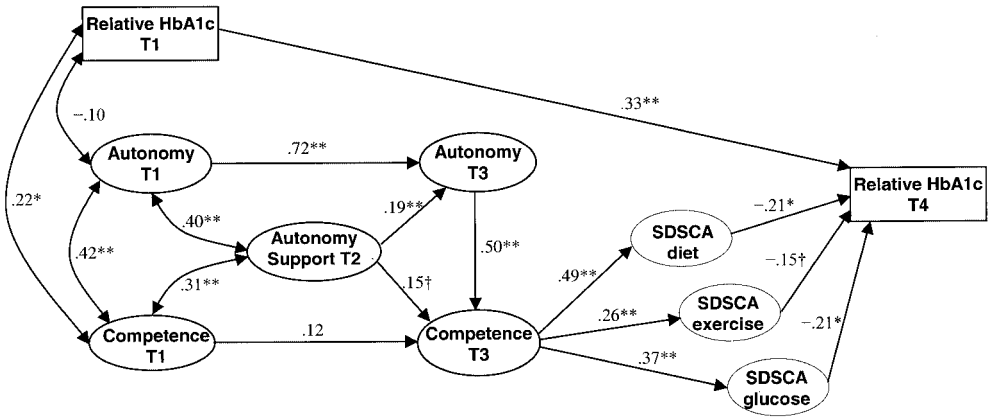

Figure 1. The change model, with diabetes self-management behaviors mediating the relation between change in perceived competence and change in glycosylated hemoglobin (HbA1c). T1 = baseline; T2 = 3 months; T3 = 6 months; T4 = 12 months; SDSCA = Summary of Diabetes Self-Care Activities. $\chi^2(383, N = 159) = 590.26$, $p < .01$; incremental fit index = .99, comparative fit index = .99, root-mean-square error of approximation = .06. †$p < .10$. *$p < .05$. **$p < .01$.

tenance of HbA1c. To do this, we reran the first SDT process model; however, we predicted HbA1c at T4, controlling for HbA1c at T3 (rather than at T1). Because all change in HbA1c in this model occurred after the changes in autonomous motivation and perceived competence, significant paths would be consistent with a causal interpretation. The model appears as Figure 2.

As shown in Figure 2, there was a significant path from perceived autonomy support (T2) to change in autonomous motivation from T1 to T3 ($\beta = .19$, $p < .01$) and a marginally significant path from perceived autonomy support (T2) to change in perceived competence from T1 to T3 ($\beta = .16$, $p < .10$). The path from change in autonomous motivation to change in perceived competence was significant ($\beta = .49$, $p < .01$), and the path from change in perceived competence to change in relative HbA1c (from T3 to T4) was significant ($\beta = -.15$, $p < .01$). Furthermore, the indirect effect from autonomy support to the change in HbA1c (from T3 to T4) was also significant ($\beta = -.03$, $p = .05$), suggesting that the motivation variables were responsible for maintenance of the improvement in HbA1c. The process model had a good overall fit to the data, $\chi^2(156) = 201.21$, $p < .01$ (IFI = .99, CFI = .99, RMSEA = .04).

Thus, the self-determination model for maintenance was supported, with autonomy support predicting change in autonomous motivation and change in perceived competence (although the path to perceived competence was weaker), with change in autonomous motivation strongly predicting change in perceived competence, and with change in perceived competence predicting maintenance in relative HbA1c.

Discussion

SDT suggests that long-term psychological energy for making and maintaining a healthy change emanates, in part, from people's perceptions of being the initiator of their behavior and of having mastered the skills necessary to make and maintain the change. In this study, the SDT model received substantial support in that the overall model fit the data very well in each analysis. Further, both change in autonomous motivation and change in perceived com-

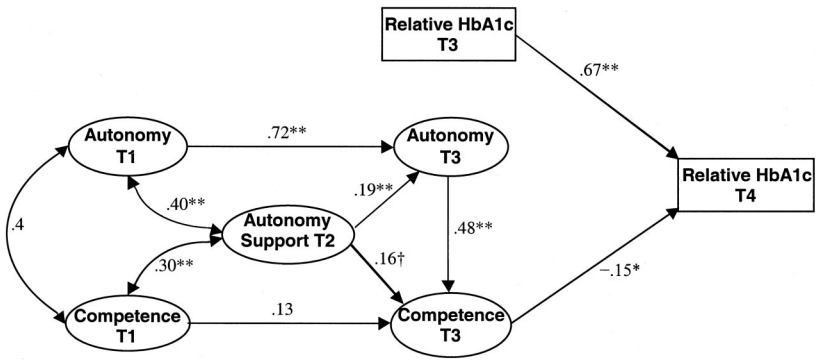

Figure 2. The maintenance model in which autonomy support predicts change in autonomous motivation and perceived competence, which in turn predict maintenance in glycosylated hemoglobin (HbA1c). T1 = baseline; T2 = 3 months; T3 = 6 months; T4 = 12 months. $\chi^2(383, N = 159) = 204.24$, $p < .01$; incremental fit index = .99, comparative fit index = .99, root-mean-square error of approximation = .04. †$p < .10$. *$p < .05$. **$p < .01$.

petence were found to predict improvement in glycemic control over a 12-month period. Change in perceived competence was found to predict diabetes self-care behaviors and maintenance of change in glycemic control over the period from 6 months to 12 months. In addition, perceived autonomy support predicted change in autonomous motivation in each of the models, and it was a marginal predictor of change in perceived competence in each model. The SDT model was not supported to the extent that autonomy support did not directly predict improved glycemic control as it had previously (Williams, Freedman, & Deci, 1998), although analyses showed that it did indirectly predict improvements in HbA1c by influencing autonomous motivation and perceived competence.

It is probable that the failure to find a direct relation between practitioner autonomy support and improvements in HbA1c, as well as the failure to find an effect for the experimental manipulation on any of the motivation variables or on glycemic control, was a result of the setting where the study was conducted. Specifically, patients made several visits to a diabetes center where they received intensive treatment during the first 6 months of the study, averaging about eight visits during that period, so the medical aspects of their diabetes were carefully monitored by the multispecialty team of practitioners. Further, most of the practitioners had had training in patient empowerment, so the psychosocial as well as the medical conditions that facilitate healthy change were present. As such, the activation intervention may have been relatively nonsalient to the patients compared with the other activities going on for them in the center, and the variation in the autonomy support from the providers may not have been great enough to impact the physiologic measure directly. Indeed, the fact that there was significant improvement in glycemic control of comparable magnitude for patients in the activation condition and those in the passive education condition attests to the quality of care being provided to the patients. In contrast, the study by Greenfield, Kaplan, Ware, Yano, and Frank (1988), in which patients with diabetes were activated with an intervention involving somewhat less time than ours (40 min for theirs vs. 60 min for ours), showed an improvement in HbA1c in the activation group that was comparable in magnitude with the improvement for both groups in our study, but they found no improvement in the education group.

The fact that the intensive treatment led to significant change in glycemic control during the first 6 months meant that we could not conclude that changes in perceptions of autonomy and competence led to the change in glycemic control, because changes in the motivation variables were occurring at the same time as the improvements in hemoglobin scores. In other words, improvement in HbA1c could have produced the change in motivation, or the relations could have been bidirectional. However, the fact that the overall improvement occurred during the first 6 months opened up an important opportunity, namely, examining the causal relations of changes in autonomy and competence during the first 6 months to maintenance of improved glycemic control from 6 to 12 months. Indeed, the model shown in Figure 2 indicated that improvements in motivation did yield better maintenance in the subsequent 6 months. This is a very important finding for chronic diseases such as diabetes because the maintenance of healthy behaviors and physiologic indicators is crucial for minimizing long-term complications, which for diabetes includes reductions in blindness, kidney failure, and neuropathy (UK Prospective Diabetes Study Group, 1998). As such, the present study solidifies the evidence that autonomous motivation and perceived competence for diabetes self-management are important predictors of long-term glycemic control and exert their effects through diabetes self-care behaviors.

Perceived autonomy support from providers accounted for change in the experiences of autonomy and, to a lesser extent, competence, so autonomy support facilitated the internalization of autonomous motivation and perceived competence, as predicted. Further, change in perceived competence mediated the relation between change in autonomous motivation and change in HbA1c. This is an important demonstration of a complex set of relations. The finding that autonomous motivation had its effect on HbA1c through mediation by perceived competence supported our prediction and provides additional evidence for a finding that has emerged in previous studies. It appears then that people will more likely feel able to control important health outcomes when they are self-initiating of the behavior. It is thus important for clinicians to support, in a nonjudgmental manner, patients' initial attempts to master a new technique in order for the patients to internalize the regulation of the behavior—that is, to become more autonomous and competent in making healthy changes and then sustaining the changes over time.

Diabetes self-management requires that multiple complex behaviors be performed on a long-term basis and thus is an excellent model for understanding chronic disease management. We believe the SDT model for health behavior is useful in explaining a variety of chronic disease outcomes, and we believe it will be helpful in informing health care policy makers in how to structure systems of care to improve outcomes. Results from this study, like those of related studies (e.g., Williams et al., 1996, 2002; Williams, Rodin, et al., 1998), suggest that it would be important for health care systems and practitioners to provide care that facilitates patients' experience of autonomy and competence.

This study leads to several conclusions. First, the EPIC activation intervention was not related to the self-determined process of internalization. Second, the self-determination model for health behavior was supported, although perceived autonomy support did not have a direct effect on glycemic control. Third, autonomy support enhanced both autonomous motivation and perceived competence. Fourth, enhanced autonomous motivation and perceived competence promoted better glycemic control, although the relation from autonomous motivation to glycemic control was mediated by perceived competence. Fifth, the relation between autonomy support and HbA1c was indirect through the motivation variables. Finally, the influence of the motivation variables on improved glycemic control was through self-management behaviors. Thus, autonomy support facilitated internalization of autonomous and competence motivation for diabetes self-management. These motivation variables led directly to maintained change in glycemic control, and an indirect relation between autonomy support and glycemic control through perceived autonomy and competence was found to be significant. It remains unclear whether the motivation variables accounted for initial improvement in glycemic control or this relation was bidirectional. However, analyses did show that the motivation variables accounted for maintenance of glycemic control after initial control was attained.

Additional research is called for to develop and test self-determination interventions that would enhance patients' autonomous and competence motivations. Presumably, these interventions would include ways to improve health care practitioner autonomy supportiveness, but they could also include changes in the health care system that encourage patients to take more responsibility for their health outcomes as health care systems orient more toward chronic disease management and away from acute care models.

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